

Significance and Research Standards for Prehistoric Archaeological Sites at Fort Bliss: A Design for the Evaluation, Management, and Treatment of Cultural Resources

Edited by Myles R. Miller, Nancy A. Kenmotsu, and Melinda R. Landreth

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Geo-Marine, Inc.,
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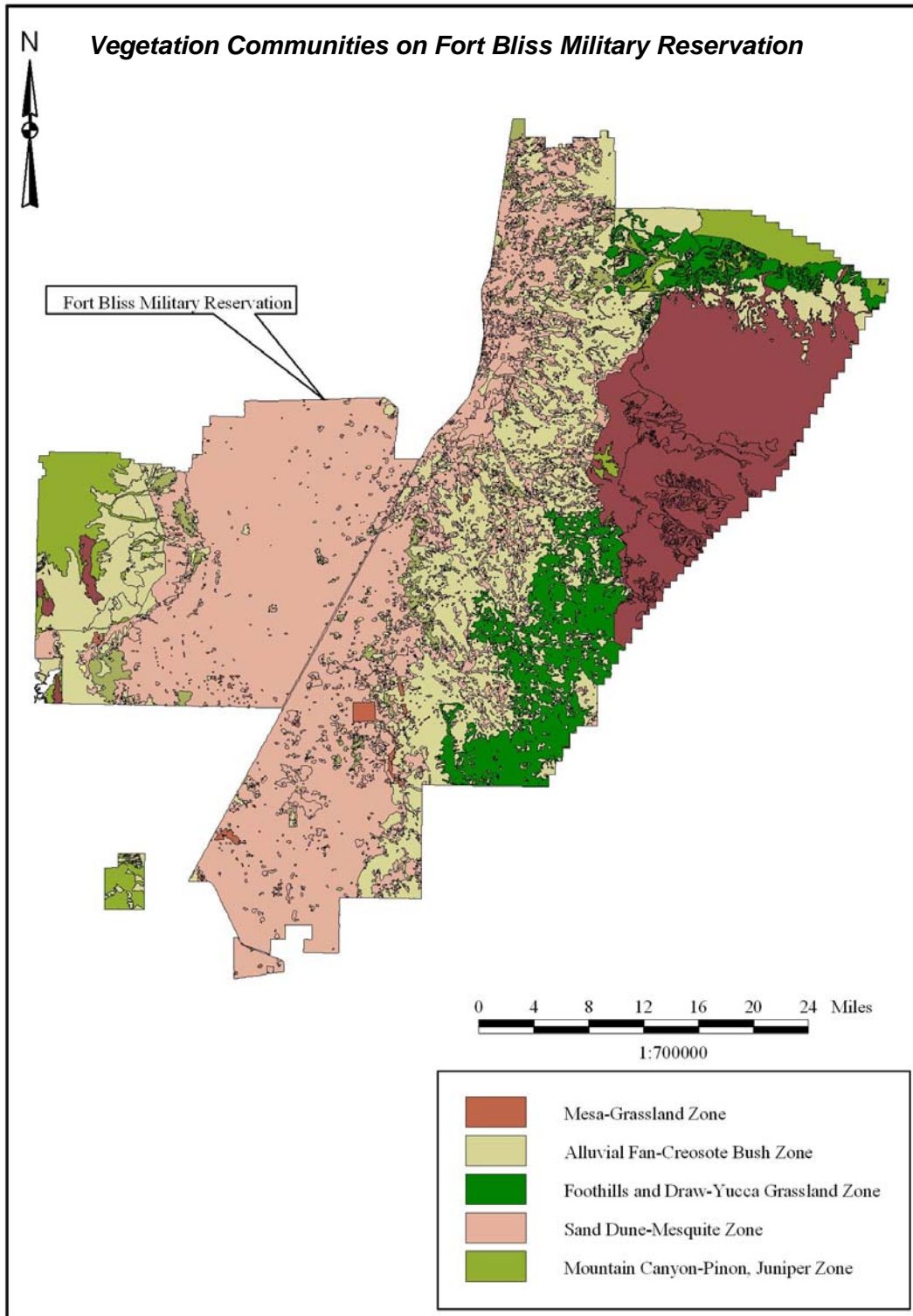
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PART 1. RESEARCH CONTEXT



CHAPTER 1. INTRODUCTION AND OVERVIEW OF THE REVISED FORT BLISS SIGNIFICANCE AND RESEARCH STANDARDS

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In 1996, a document entitled *Significance Standards for Prehistoric Archeological Sites at Fort Bliss: A Design for Further Research and the Management of Cultural Resources* (Abbott et al. 1996) was published. The document was intended to be a design for prehistoric archaeological research at Fort Bliss, including the anticipated National Register of Historic Places (NRHP) eligibility evaluation of thousands of prehistoric archaeological sites recorded during the previous 20 years of survey projects. In the years since its publication, the document has indeed served its purpose in guiding the evaluation of several thousand prehistoric sites at Fort Bliss. Moreover, the document established several research domains for consideration during the design of data recovery excavations. While originally designed and intended for the cultural resources management program at Fort Bliss, it is noteworthy that the document is often cited in reports describing projects outside the military installation and throughout the greater Jornada Mogollon region. In many ways, the original Fort Bliss *Significance Standards* document established a benchmark for synthetic overviews of Jornada Mogollon archaeology and several sections of the document still stand as fundamental references for research and management.

Yet, as all manner of things tend to age and fade with time, some aspects of the *Significance Standards* have naturally become outdated, outmoded, or in need of a contemporary review. The increasing pace and quantity of Section 106 and Section 110 compliance projects conducted at Fort Bliss over the ensuing decade has resulted in the production of numerous reports and has generated an immense amount of new and corroborative information on prehistoric settlements and technologies. Furthermore, these and other regional studies have been conducted under a broader range of theoretical perspectives, including human behavioral ecology and optimal foraging theory (Church 2006; Church and Sale 2003; Condon et al. 2005; Dering et al. 2001) and perspectives derived from anthropological social theory such as social boundary maintenance, group identity, and dual processual theory (McBrinn 2005; Miller 2004a; 2005a, 2005b; Railey and Holmes 2002). An impressive number of cultural resources identification, evaluation, and data recovery investigations have taken place at Fort Bliss during the past decade and it is prudent to review this work and identify problem areas and suggest refinements that will further streamline the process.

Considering the volume of information that has become available over the past decade, it is apparent that some sections of the standards are in need of updating and revision. The current document is an update and expansion of the 1996 volume, offering revisions based on the findings from the past decade of work both at Fort Bliss and in the surrounding regions. Like the 1996 volume, the present document reviews previous and ongoing work, assesses the current body of archaeological knowledge, and develops avenues for further inquiry. The *Significance and Research Standards* serves to identify and frame the types of scientific research that are needed to further our knowledge of regional prehistory, and suggests methods and analyses that are useful for filling in the “gaps” and reconciling the ambiguities in the database.

Some sections of the 1996 *Significance Standards* have been retained largely or completely intact. Other sections have been significantly revised or even eliminated due to changes in regional data bases, changes in management strategies and the nature and extent of anticipated

undertakings at Fort Bliss, or changes in research orientation and perspective that accompany the diverse and continually changing group of cultural resource managers and researchers working in the region. As a result, one of the more notable changes is the expansion of the theoretical approaches to the study and interpretation of the archaeological record at Fort Bliss. The 1996 *Significance Standards* were developed using theoretical approaches that were primarily derived from cultural ecology and systems theory. While these approaches have been a productive avenue of inquiry during the past three decades, they will no longer be the sole perspective. Moreover, the focus on research domains and analytical methods has been expanded to reflect the increasing number of data recovery investigations anticipated over the coming years.

It is also important to recognize that the *Significance Standards* document is referenced throughout Section 4.4.2 and in Section 7.4.3.3 of the *Fort Bliss Programmatic Agreement for the Management of Historic Properties on Fort Bliss Under Sections 106 and 110 of the National Historic Preservation Act of 1966 (as amended)*, the formal agreement document between the Fort Bliss Garrison Command, New Mexico State Historic Preservation Officer (New Mexico SHPO), Texas SHPO, and the Advisory Council on Historic Preservation (ACHP). As such, it now serves as a reference document within the statutory framework for programmatic agreements as set forth under 36 CFR 800.13. In other words, the *Significance and Research Standards* is now a formal component of an agreement document that Fort Bliss uses to make decisions about its cultural resources and through which it will conduct its consultations with review agencies and interested parties (State Historic Preservation Officers, Tribes, Advisory Council on Historic Preservation) as required by federal law and regulations.

OVERVIEW OF FORT BLISS MILITARY RESERVATION

Fort Bliss Military Reservation is located north of the city of El Paso in extreme west Texas and south-central New Mexico (Figure 1.1). As one of the nation's largest military installations, Fort Bliss covers over 4,500 square kilometers (km), or nearly 1.1 million acres or 1,700 square miles, and is larger than the state of Rhode Island. Most of the maneuver and training areas and guided missile ranges are located in New Mexico, although the main cantonment is situated in El Paso, Texas, across the border from Ciudad Juárez, Mexico.

History of Fort Bliss

Fort Bliss was established in 1849, when units of the 3rd Infantry commanded by Brevet Major Jefferson Van Horne were first garrisoned in El Paso at the newly formed "Post of El Paso." Abandoned in 1851, the post was re-formed three years later with units of the 8th Infantry in a new location near the intersection of modern Willow and Magoffin streets. The post was named Fort Bliss, for William Wallace Smith Bliss, a distinguished veteran of the Mexican War (Metz 1988:38-40). The fort was a key link in the chain of forts between Santa Fe, New Mexico, and San Antonio, Texas, which were intended to protect the western frontier against Indians. The post participated in several Indian campaigns prior to the Civil War. In 1861, the post was abandoned by the then commander, Colonel Isaac Reeve, and was vacant for three months before being reoccupied by the 2nd Regiment of Texas Mounted Rifles of the Confederacy. Fort Bliss was abandoned again after the defeat of Brigadier General Henry Sibley at the Battle of Glorieta Pass in 1862. It was reoccupied several months later by troops from Carelton's California Column of the Union Army, who kept the Union flag flying at Fort Bliss through the end of the Civil War.

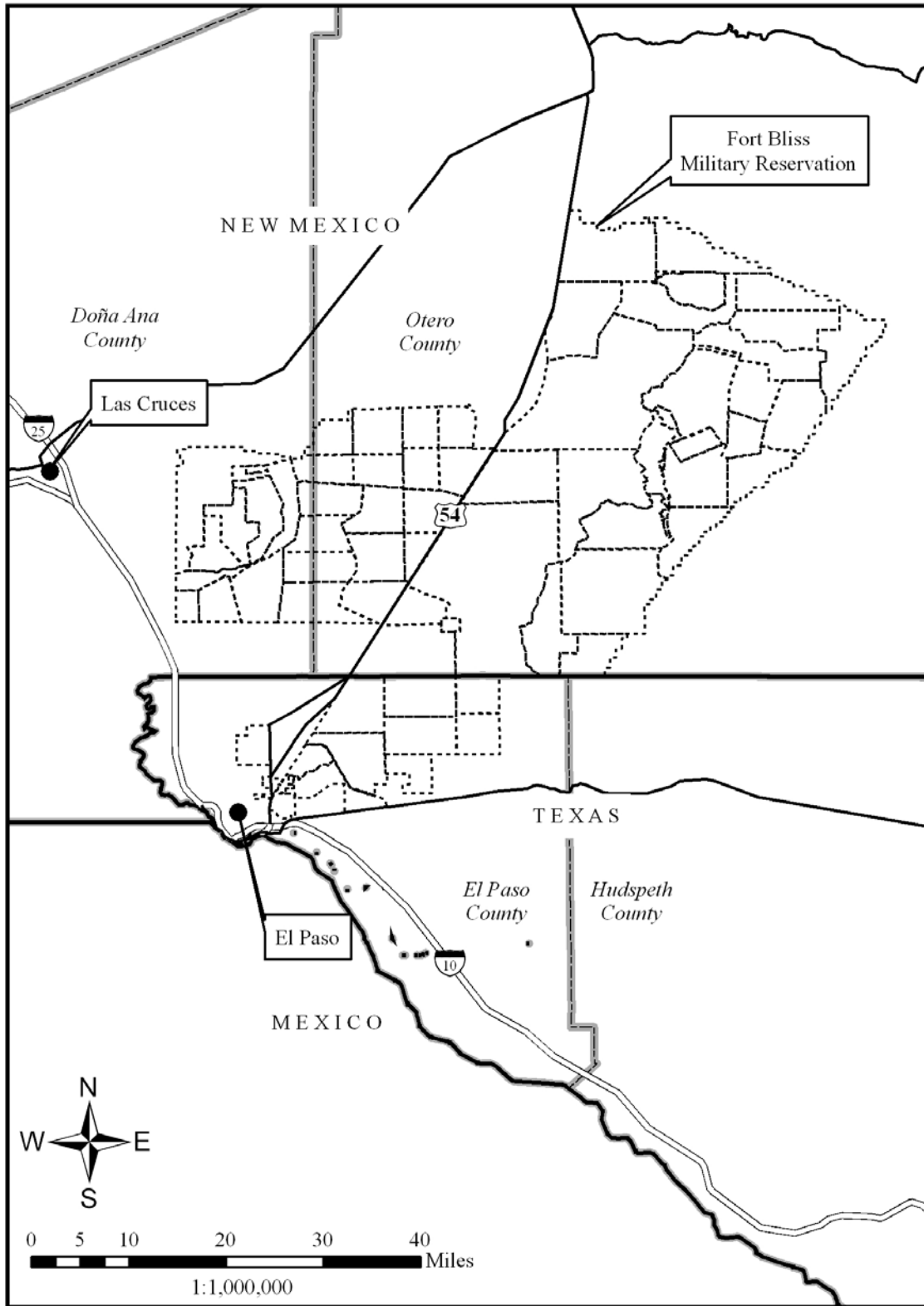


Figure 1.1. Location of Fort Bliss.

In 1865, the U.S. Army 5th Infantry replaced troops from the California Column who were being mustered out of the Army. A new location farther away from the Rio Grande floodplain was chosen in 1868 near the intersection of modern Interstate Highway 10 and US 54, which was temporarily named Camp Concordia (Metz 1988: 52-54). The post was abandoned in 1877. In 1878, units of the 9th Cavalry and 15th Infantry were again posted to Fort Bliss, thus establishing the fourth location for the fort in 1879 in downtown El Paso (Metz 1988: 60). A newly granted railroad right-of-way through the post forced the fifth and final relocation to its present site in northeast El Paso in 1893.

During the Spanish American War in 1898, both the 18th Infantry and 5th Cavalry at Fort Bliss were active, and beginning in the early 1900s, the fort and El Paso began to grow in size and importance. Following Pancho Villa's raid in 1916 of Columbus, New Mexico, General John J. Pershing led the 5th, 7th, and 10th Cavalry, the 6th and 16th Infantry, and the 4th and 6th Field Artillery across the Mexican border on a series of punitive raids.

During World War I, the 15th Cavalry was garrisoned at Fort Bliss and the fort served a key role in training units bound for the European Theater. After the war, Fort Bliss units participated in additional actions across the Mexican border between 1919 and 1921. Biggs Army Airfield was established in 1919 near the intersection of Forrest and Pleasonton Roads, and moved to its present location in 1926. After this, Fort Bliss became the last bastion of the horse cavalry. The end of the horse era came in 1943, when the 1st Cavalry Division was mechanized and sent overseas.

In 1940, the Army established the first Anti-aircraft Training Center at Fort Bliss; by the end of WWII Fort Bliss began its new incarnation with the establishment of the Army's first guided missile unit in late 1945. Research at Fort Bliss quickly led to development of the Nike Ajax guided missile system. During the Cold War, Fort Bliss was a center for the testing and training of increasingly sophisticated air defense weapons systems, including the HAWK and Patriot missile systems. By the end of the Cold War, Fort Bliss was one of the U.S. Army's premier centers for air defense training. During the Gulf War of 1990-1991, many Air Defense Artillery (ADA) troops trained at Fort Bliss were deployed overseas. These ADA personnel were central in defeating the Iraqi Scud missile attacks, and the 3rd Armored Cavalry regiment played a key role in the sweeping and successful ground assault against the armored Iraqi Republican Guard.

Assigned to the United States Army Training and Doctrine Command (TRADOC), the mission of the post at present continues to be move forward and expand. Until 2006, the post was home to the ADA Center and the U.S. Army ADA School. The ADA and the ADA School are being relocated to Fort Sill in Oklahoma and the 108th ADA Brigade to Fort Bragg, North Carolina. This relocation is part of a national re-structuring of the Army from a division-oriented force to a brigade-based modular force where units are self-contained and capable of rapid deployment (US Army 2006: 1-1).

Under this new mission, which was authorized by federal law in 2005, Fort Bliss will become the home of four heavy brigade combat teams, one of which arrived in 2006; the other three will arrive between 2007 and 2011. In these years, Fort Bliss will be transformed to a training installation for heavy mounted maneuvers. As a result of this change, an additional estimated 20,000 troops will be stationed at Fort Bliss. Fort Bliss will continue to be home to the William Beaumont Army Medical Center, one of the largest such facilities in the Army, as well as several non-Department of Defense agencies such as Joint Task Force 6 and the Drug Enforcement Agency El Paso Intelligence Center. Fort Bliss is also headquarters for the German Air Force Air Defense School, which trains thousands of German airmen each year.

HISTORY OF CULTURAL RESOURCE MANAGEMENT PROGRAMS

The initial archaeological investigations on Fort Bliss were not mandated by federal or state historic preservation laws. Rather, they were carried out by early explorers (Bandelier 1890) and anthropologists (e.g., Fewkes 1902; Lehmer 1948; Moore and Wheat 1951; Sayles 1935) seeking to describe prehistoric and vanishing lifeways. Later, in the 1960s and 1970s, considerable work was carried out by the El Paso Archeological Society (EPAS), a local society of avocational and professional archaeologists interested in the history and prehistory of the region.

Soon after the passage of the National Historic Preservation Act (NHPA) in 1966, Fort Bliss began to undertake archaeological surveys to identify and document archaeological sites on its lands (Aten 1972; Beckes et al. 1977; Carmichael 1986a; Skelton et al. 1981; Whalen 1977, 1978). Archaeological fieldwork has continued at Fort Bliss over the subsequent forty years. Currently the Fort Bliss site files contain over 18,000 archaeological and architectural properties (an expansion of 5,000 sites over the size of the database in 1996).

In 1981 the ACHP, the SHPO of New Mexico and Texas, Fort Bliss, TRADOC, and the Department of the Army signed a Memorandum of Agreement (MOA) for evaluation and treatment of cultural resource and in 1982 a Cultural Resources Management Plan (CRMP) for Fort Bliss was ratified by these agencies. By 1992, noncompliance with Section 106 of the NHPA had become an issue with the Fort Bliss cultural resources management program, and a revision of the CRMP was mandated as a solution.

The SHPO from New Mexico and Texas and the Advisory Council met with Fort Bliss and agreed to develop both a Programmatic Agreement (PA) and a new CRMP. In January of 1994, the new PA was signed by all parties. During the drafting of that PA, TRC Mariah was issued a delivery order by the Army Corps of Engineers, Fort Worth District, to develop a draft CRMP for Fort Bliss. Subsequent restructuring within the Fort Bliss Environmental Directorate led to a modification of the delivery order.

The revised delivery order called for TRC Mariah to develop a detailed research design specifically for the evaluation and study of prehistoric archaeological resources. Assessment of historic structures was not included in this research design as they were dealt with in a series of historic contexts (Holmes 1999), as were recommendations for policies and procedures, which were more properly contained in an Integrated Cultural Resource Management Plan (ICRMP). The Fort Bliss Environmental Directorate developed the more broadly focused ICRMP.

Although the Department of the Army has its Army Counterpart Regulation to 36 CFR 800, Fort Bliss has a very large, complex mission. Therefore, the Fort Bliss Environmental Directorate developed a PA in 2006 that will meet the Army's internal standards and other Federal regulations under 36 CFR 800. This agreement document is titled *Programmatic Agreement among the Fort Bliss Garrison Command and the New Mexico State Historic Preservation Officer and the Texas State Historic Preservation Officer and for the Advisory Council on Historic Preservation for the Management of Historic Properties on Fort Bliss, Texas Under Sections 106 and 110 of the National Historic Preservation Act of 1966 (as amended)*.

This document sets forth the formal procedures by which Fort Bliss and its archaeological contractors shall conduct inventory, evaluation, and treatment of archaeological historic properties on the post. The PA significantly streamlines the process for consultation by allowing routine undertakings to be reviewed in-house at Fort Bliss rather than submitted to the appropriate SHPO on a case-by-case basis. This streamlining is based on the fact that the SHPOs believe that Fort Bliss has a model program and has consistently met the standards of 36 CFR 800. Moreover, the base maintains a staff of archaeologists, historians, and architectural historians who meet the Secretary of Interior's standards for professionals. Annually, a list of the routine

undertakings is to be submitted to each SHPO. Under the PA, all determinations of eligibility and research designs for archaeological data recovery programs are submitted to the SHPO. The net result of these stipulations is to enhance the efficiency of the review process. A copy of this document and supporting documentation is provided in Appendix A of this document.

PURPOSE AND SCOPE OF THE SIGNIFICANCE AND RESEARCH STANDARDS

Requirements

The NHPA of 1966 (16 U.S.C. 470)(f) and 470h-2-(f)] created the NRHP to preserve and protect important aspects of our nation's cultural and historic heritage. The NHPA also created the ACHP to have oversight of federal agency compliance with Section 106 of the act, as an implementing agency, and further mandated that each state appoint a SHPO. Under Section 106 of the NHPA and its implementing regulations set forth under 36 CFR 800, federal agencies must take into account the effect of any undertaking on any district, site, building, structure, or object (a "historic property") that is included or eligible for inclusion in the NRHP.

Section 110 of the NHPA further requires that federal agencies assume responsibility for the preservation of historic properties located on their land or controlled by them. The agency must provide the ACHP an opportunity to comment on the undertaking's effect on historic properties. To comply with these requirements, the responsible federal agency must inventory and evaluate cultural resources using the NRHP criteria set forth in 36 CFR 60.

As a federal agency, the U.S. Army is required to undertake a program to locate, inventory, and identify all properties owned or under the control of the Army that are eligible for inclusion on the NRHP. Chapter 6 of Army Regulation (AR) 200-1 outlines Army policy, procedure, and responsibilities for carrying out the NHPA, as amended, and for managing the preservation requirements at the installation level through development and implementation of an ICRMP. The Regulation also sets forth professional standards for Army preservation personnel and projects, and for accomplishing the historic preservation program in a timely and cost-effective manner.

In order to comply with the NHPA and AR 200-1, the ICRMP must (1) develop explicit procedures that allow for the identification of all cultural resources under the installation's jurisdiction, and (2) develop explicit standards of significance that allow for their evaluation with respect to NRHP eligibility. For archaeological properties, such standards are generally developed in a scientific research design.

Native American Consultation

The *Significance and Research Standards* document does not provide background, guidelines, or procedures for the inventory, identification, evaluation, or treatment of traditional cultural properties to federally-recognized Native American tribes. As established under Executive Order 13084 issued in 1996, consultations with Native American tribes involving Federal laws and regulations are to be conducted on a government-to-government basis as, in the present case, between appropriate representatives of federally-recognized Native American tribes and of Fort Bliss as the lead Federal agency.

Fort Bliss has established and maintained consultations with regional Tribal Historic Preservation Officers (THPO) and tribal officials, including the Mescalero Apache Tribe, Comanche Tribe, and the Ysleta del Sur Pueblo, in accordance with the regulations set forth in the Native American Graves Protection and Repatriation Act (NAGPRA), the American Indian Religious Freedom Act (AIRFA), the National Historic Preservation Act (NHPA) and its implementing regulations as set forth in 36 CFR 800, and other federal laws and guidelines. Several procedures for consultation

with Native American tribes are set forth under sections 4.4.11, 8.3, 10.3.1, 10.3.3, and 11.5.2 of the Fort Bliss Programmatic Agreement. Additional procedures are described in the Integrated Cultural Resources Management Plan.

Development of the Significance and Research Standards

This section offers a brief overview of the process through which scientific research designs are developed and used as mechanisms for assessing the significance of cultural resources on military reservations. The discussion is broadly adapted from a research design developed for Fort Hood Military Reservation in central Texas (Trierweiler 1994).

The Nature of Research Designs

As defined by Section 106 and its implementing regulations, the “significance” of any given archaeological site cannot be determined at random. Significance of a site must be assessed by rigorously comparing the property to currently accepted standards of research value. Developing such standards is one function of the research design. The research design identifies specific topics that should be addressed by future research. Because modern installation boundaries seldom coincide with historically or prehistorically meaningful territories, research designs consider the broader region beyond the boundaries of the installation itself.

Research designs vary tremendously in scope and complexity, depending on the project parameters (e.g., size and configuration of the project and its impacts), but all fundamentally consist of a set of questions and a set of methods needed to obtain reliable answers. Nonscientific research is idiosyncratic and nonreplicable: any conclusions rely on the weight of the researcher’s opinions for credibility. By contrast, scientific research sets up experiments and uses data to reach conclusions. In this regard, research designs are rigorous and replicable, and conclusions may be critically examined by other researchers.

In any scientific research design, the questions must be relevant to current regional research. While some research questions are primarily relevant to local or regional contexts, it is also important to develop research questions and domains that have broader archaeological and anthropological relevance, as required under Criterion D for eligibility for the NRHP. Not all research questions are necessarily equivalent in importance; some may have been adequately answered long ago; other questions remain unanswered and problematic despite active investigation; still other questions arise with each new advance in theory and method. Well-documented topics are not targeted by research questions at Fort Bliss, as further research on well-documented topics would only provide redundant information. Problematic research questions are derived from recognized gaps in a current body of scientific knowledge. In cultural sciences such as archaeology, these bodies of knowledge may be highly regional; gaps in one state, or even county, may be well covered in an adjoining region. These so-called “data gaps” are topics for which there is insufficient information to draw reliable conclusions. Some gaps may be due to a lack of previous research on the topic or because the previous research is considered inadequate or outdated. Data gaps can also result simply from scanty information on the topic despite previous intensive and excellent research efforts.

To be useful, a research design must associate each question with the specific data needed to answer the question. Data requirements must be spelled out so that the fieldwork will be sure to collect these kinds of data (if they are available).

Using Research Designs

Under Section 110 of the NHPA, a cultural resources management program must identify significant archaeological sites, or historic properties, so that they can be managed through avoidance and protection. Broadly, those properties that meet many of the data requirements

stipulated in the research design are judged to be significant, whereas those that meet few of them are judged not significant. In practice, the cultural resource management (CRM) compliance process at military installations is often implemented using four largely sequential steps:

1. *developing* standards of significance
2. *finding and evaluating* the resources, and
3. *preserving and protecting* those judged to be significant, or
4. *mitigation of adverse effects* to those historic properties that cannot be avoided or protected.

These components are sometimes operationalized into discrete work phases, but there is often considerable overlap between the steps. Indeed, the larger the study area (such as Fort Bliss), the greater the number of sites, and the more complicated the process can become.

In cultural resources management, the two sequential and complementary phases of determining a sites' significance are often referred to as the "inventory" phase and the "testing," phase, although other terminologies are sometimes used. Each phase focuses on a prioritized hierarchy of data requirements. In the past, the assessment of significance for sites on Fort Bliss followed this two-step process.

Ideally, sites should be evaluated for significance as soon as possible upon their discovery; determining significance should not necessarily be postponed until a later, formalized testing phase. Indeed, the significance of any site can be determined by means of a single, well-planned field visit. The present practice of the Environmental Division at Fort Bliss has addressed this issue and requires that each site be fully evaluated for its significance when it is first identified. This practice has increased the efficiency of cultural resource management at Fort Bliss. Elsewhere, site recording rarely includes efforts to assess their eligibility for the NRHP. Such practices require another visit to determine if they are significant. Second visits are time consuming. By evaluating sites in the initial visit, Fort Bliss has achieved greater streamlining.

During an inventory phase at Fort Bliss, each site is recorded and is also evaluated for its significance. During this phase on Fort Bliss, observations of a site's data potential are also made to allow for assessment of the site's significance. In addition to noting artifacts and cultural features on the surface of the site during this process, features are tested to determine if they contain datable deposits or have subsurface depth. At times, backhoe trenching augments surface observations by verifying the potential for presence/absence of subsurface deposits.

Based on inventory phase observations, two outcomes are possible in assessing site significance: (1) properties have no potential with which to address the data gaps and are recommended as ineligible for inclusion in the NRHP and no further management action is warranted; or (2) properties have clear research potential and are eligible for inclusion in the NRHP; these sites will be preserved and protected or mitigated. Additional information on the survey methodologies employed by Environmental Division at Fort Bliss (Fort Bliss DPW-E) during the site inventory phase is provided in Chapters 13 and 14.

Limitations of this Research Design

This research design develops a framework for further scientific inquiry regarding cultural resources on Fort Bliss. It reviews existing knowledge, identifies data gaps, and delineates important research questions and their data needs. Within the context of the Fort Bliss PA, these data needs may be applied as standards for site "significance" and, hence, NRHP eligibility. However, the research design itself does not develop policies or procedures for integrating the scientific inquiries within the military mission; this is properly the function of the PA. Further, this *Significance and Research Standard* document does not attempt to suggest, advocate, or

restrict alternative management and treatment strategies such as preservation in place, avoidance, creation of districts or zones, monitoring, or mitigation of adverse effects via data recovery investigations. These are properly the focus of consultations between Fort Bliss DPW-E and various review agencies as set forth in PA in its Attachment A: *Standard Operating Procedures of the Fort Bliss Cultural Resources Management Programmatic Agreement*. These distinctions are further discussed in Chapter 15.

This research design develops contexts only for the evaluation of prehistoric archaeological resources. Historic archaeological resources are not included in its scope, nor are historic architectural resources. Significance standards for these types of resources at Fort Bliss have been developed by other contexts that are available at Fort Bliss DPW-E.

This research design is intended to be a working (i.e., active) structure within which to organize and focus archaeological research in accordance with the Army's requirements under 36 CFR 800 and AR 200-1. Although based on both published and unpublished data currently available as of the year 2007, it is not intended to be static nor permanent. As with the 1996 *Significance Standards* document, as new research is completed it is likely that some research questions posed herein will be satisfactorily answered, and new avenues of research will be identified. Therefore, this research design will need periodic review and revision.

UPDATES AND REVISIONS: THE CONTEXT AND PERSPECTIVE OF THE 2008 SIGNIFICANCE AND RESEARCH STANDARDS

As part of the process of updating and revising the *Significance Standards*, a summary of work conducted over the preceding decade is required, as is a preview of the directions of work and undertakings anticipated for the coming decade. An impressive body of information has been compiled and published during the past ten years. Moreover, some of these findings have prompted local researchers and managers to apply a broader range of theoretical approaches to the study of regional prehistory. Equally important for the design of the coming decade of research is a consideration of the changing and expanding military mission at Fort Bliss.

Archaeological Investigations and Cultural Resource Management Practices since Publication of the 1996 *Significance Standards*

Numerous publications describing the results of archaeological projects, research programs, and data compilations in the Jornada Mogollon region have been produced during the decade elapsed since the 1996 publication of the *Significance Standards* (Abbott et al. 1996). The vast majority of this work has been sponsored by and conducted on Fort Bliss. A complete review of all the survey and NRHP eligibility evaluation publications is beyond the scope of this section, but several of the more notable projects and publications will be reviewed. This discussion serves to establish some of the methodological, data quality, and research issues that prompted many of the revisions to the current *Significance and Research Standards* document.

NRHP Eligibility Evaluations of Previously Recorded Sites

By the late 1990s, it was evident that while thousands of sites had been inventoried across Fort Bliss, few had been evaluated for NRHP eligibility. In order to remedy this problem, Fort Bliss DPW-E has funded over 40 projects to evaluate the NRHP eligibility of previously recorded sites. From 1995 to the present, Fort Bliss contracted for a series of NRHP eligibility evaluations involving sites recorded during the large-scale surveys of the 1970s and 1980s. The efforts often involved the evaluation of several hundred sites under a single delivery order.

One important aspect of this effort was to prompt attempts to apply ranking systems, nominally based on criteria established in the 1996 *Significance Standards*, to enforce uniformity in the

application of the eligibility recommendations. The ranking-system applications were devised to generate a numerical score based on a suite of site attributes (artifact content, feature counts, site condition, and so forth) that could be used to scale the research value and contextual integrity of each property. Review of distributional spread of the resulting scores could then be used to establish a threshold point for the NRHP eligibility recommendations.

While this was a laudable goal, its realization was problematic. Since no standardization for application of the ranking systems was ever established, contractors developed and applied project ranking systems using a variety of data collection methods, evaluation criteria, scoring schemes, and numeric point thresholds to make site NRHP eligibility recommendations. The rankings were designed to identify those properties with the highest contextual integrity and data content, regardless of site size or type (e.g., pueblo village or small camp). However, the ranking systems generally lacked explicit and consistent methodological and theoretical underpinnings. While many previously recorded sites have now been evaluated for NRHP eligibility status, new surveys generally evaluate newly recorded sites using the criteria and data content requirements established within the research themes in the 1996 *Significance Standards*.

The general framework of the ranking system approach has thus been replaced by site-specific evaluation recommendations based on thematic issues that integrate assessment of the multiple research domains of chronology, geomorphology, technology, settlement pattern, subsistence, and regional interaction (cf. Knight and Miller 2003; Knight et al. 2003; Lowry et al. 2003, 2004). These and other issues with significance ranking systems prompted a more useful and archaeologically sound NRHP evaluation process discussed in Part IV of this document.

Mitigation of Adverse Effects to Historic Properties through Data Recovery Excavations

Data recovery programs have been implemented and completed for a variety of archaeological resources deemed as significant since 1996. Efforts were initially directed at groups of sites located within areas of intensive military training, such as those located in the Meyer Small Arms Range and the Hueco Mountain project area of Maneuver Area 2. Mitigation of sites within Red Zone (off-limits) and Green Zone (restricted access) archaeological districts has also occurred. More recently, mitigation programs have been developed in response to the increasing number of specific undertakings associated with the widespread expansion of military housing and training facilities and various ranges planned across the post.

Thirty-three data recovery projects have been initiated on Fort Bliss between 1996 and 2007 and several are still in progress. As of 2007, the archaeological data recovery investigations conducted at over 50 sites investigated during this time have been reported. These include several Mesilla, Doña Ana, and El Paso phase residential settlements (Church and Sale 2003; Church et al. 2007; Lukowski et al. 2006; Miller 2007a) and numerous small sites in the Hueco Bolson (Condon et al 2005; Condon, Hermann et al. 2006; Condon, Hall et al. 2006; Condon et al. 2007; Graves and Ernst 2007; Mauldin et al. 1998; Sitton et al. 2005) and Otero Mesa (Quigg et al. 2002). Details of investigations at the Conejo Site, which has figured prominently in various research studies over the past 20 years (Goldborer 1985; Hard 1983a; Hard et al. 1996) but was never fully described or reported, have been published and provide the first view of site layout and several aspects of material culture for this site (Miller and Burt 2007).

Perhaps one of the most significant projects involves the first professional investigation of a pueblo in over 20 years. Madera Quemada Pueblo (situated within the John A. Hedrick Site) is a 13-room pueblo that was the subject of detailed excavation between 2005 and 2006. The partially burned pueblo was in exceptional condition and is providing significant insights into El Paso phase puebloan social organization and settlement adaptations. These insights are the types that show that Fort Bliss is addressing its requirements under Section 106 and AR 200-1.

Investigations at several sites outside of Fort Bliss have also been reported, including the U.S. Highway 54 project (Railey 2002) and the Eastlake Blockup and Westport developments in El Paso (Willis and Peterson 2002, 2003). The long-delayed reports of past excavations have also been published, most notably the Loop 375 project (Dering et al. 2001), Hot Well Pueblo (Lowry 2005), and a summary article on Firecracker Pueblo (O'Laughlin 2001).

Overall, mitigation programs of the past decade have provided a near exponential increase in the amount of information on settlement adaptations ranging from mobile, low-intensity occupations to sedentary pueblo settlements. The data recovery efforts have involved a variety of site types. Research goals have included the investigation of site structure and community layout within small hunter-gatherer camps, pit house complexes, and pueblo villages, socio-political organization and leadership strategies, and several studies of technology and subsistence.

Thematic Research

Several studies that incorporated broad geographic, thematic, or research frameworks have been reported since 1996. These thematic studies are important in dealing with issues related to long-range planning and management efforts and serve to provide the foundations for the development of new research issues and directions. Some of the studies were in progress during the development of the 1996 *Significance Standards* but had not yet been published. These projects and publications have been incorporated into this updated and revised significance standards document.

Several geomorphic and geoarchaeological studies were completed. Don Johnson (1997) completed an important geoarchaeological study that provides basic information on the surface geomorphology of McGregor Range that is being used by archaeologists when considering issues of site preservation and contextual integrity. In addition to Johnson's overview, Smith (2005) and Hall (2007) conducted several geomorphic studies in the Hueco Bolson that will allow Fort Bliss to better and more efficiently address the eligibility of sites.

The *Chronometric and Relative Chronology Project* (CRCP) report (Miller 1996) provides an informational overview along with a review of what work has been conducted concerning the dating of archaeological resources within Fort Bliss. The report provides summary data and discussion of the merits of the various dating techniques such as radiocarbon dating, obsidian hydration dating, relative dating, and a variety of other major methods. Results of this study were unavailable during the production of the 1996 document but are incorporated into the present research program. The *Lithic Source Project* (Church et al. 1996) was published and has had important implications for the study of raw material procurement and understanding chipped stone technological organization as structured by raw material availability.

While not a specifically archaeological project, a Legacy grant obtained by the Laboratory of Tree-Ring Research in partnership with Fort Bliss funded an important analysis of tree-ring sequences in south-central New Mexico. This study ultimately resulted in the reconstruction of precipitation patterns in the southern Rio Grande basin for the past 1,373 years (Grissino-Mayer et al. 1997).

Regional geochemical and sourcing studies have been conducted on obsidian (Church 2000; Miller and Shackley 1997) and ceramics (Brewington and Shafer 1999; Dering et al. 2001; Miller and Burt 2007; Miller et al. 1997; Miller 2005a, 2007a; Quigg et al. 2002). Lipid and immunological residue analysis have been attempted at several sites on Fort Bliss (Church and Sale 2003; Condon, Hermann et al. 2006; Condon et al. 2007; Quigg et al. 2002).

Several published studies have begun to incorporate the extensive material culture, chronological, and settlement pattern databases available from Fort Bliss. Hard and others (1996) utilized

ground stone, flotation, and isotope data from the Jornada region as part of their study of the relationships between ground stone tool design and subsistence. Miller and Kenmotsu (2004) have synthesized the information from several datasets to provide an up-to-date review of the prehistory of the region. A major revision to the Formative period (A.D. 200-1450) chronological sequence has been proposed (Miller 2005c).

Work focused on specific cultural periods has also included information overviews on the Protohistoric and Early Historic periods (Baugh and Sechrist 2001; Seymour 2002, 2003, 2004; see also Kenmotsu and Miller 2008). These efforts have reviewed the existing ethnographic and archaeological data in an effort to provide baseline criteria for the identification of such sites across Fort Bliss. Sites from this critical period of culture change and transition have proven, in most cases, to be ephemeral, short-term use sites difficult to distinguish from prehistoric camps. An evaluation of known Paleo-Indian sites on Fort Bliss is currently underway. Other projects of the thematic nature projects include NRHP evaluation efforts of Cold War and Historic ranching era properties. Hawthorne-Tagg and others (1998) and Stowe, Ernst and others (2007) have investigated portions of the Spanish Salt Trail and Butterfield Trail on Fort Bliss. Adopting the position that thematic research can and should be conducted as part of ongoing Section 106 compliance and data recovery investigations, Church (2006), Miller (2004b), and Walker and others (2005) developed programmatic research designs that may be applied across multiple projects. This type of broad application will streamline future mitigation of sites by providing ready-made research designs.

McGregor Guided Missile Range and Transect Recording Unit Surveys

Beginning in 1996, Fort Bliss began archaeological survey work to provide baseline data on the cultural resources within the 698,482 acres of McGregor Guided Missile Range. These lands were actually held and administered by the Bureau of Land Management (BLM) but have been used by Fort Bliss for over 50 years. Congress recently agreed to allow Fort Bliss to continue their withdrawal from public use for another 25 years. Two sample surveys totaling more than 102,300 acres were conducted in the late 1990s (Graves et al. 1997; Harlan and Ennes 1999; O'Leary et al. 1997). Beginning in 2005, a new series of surveys were initiated to increase the survey inventory coverage in advance of the anticipated expansion of military training across McGregor Range. As of this writing, at least 14 survey projects have been initiated, encompassing more than 100,000 acres (450 square kilometers) of territory that have been surveyed for cultural resources, and can eventually be cleared for military use.

The scope and extent of the McGregor Range surveys inspired the refinement of the transect recording unit (TRU) survey method that has subsequently been adopted for most surveys across Fort Bliss. This survey method represents one of the more notable innovations for cultural resources management of the past decade (Kludt et al. 2007; Lukowski and Stuart 1996; Mauldin et al. 1997; Stowe et al. 2005). Field crews record and provenience all cultural materials encountered within a 15-m by 15-m area, called a TRU recording unit or cell. Assignment of higher-level provenience units, such as sites, is deferred until the end of the fieldwork. Due to recent technological advancements with hand-held computers or personal digital assistants (PDA) and global positioning system (GPS) units, the accuracy and speed of cultural resource survey using the TRU method has been significantly improved. The TRU method of archaeological survey was established to provide researchers with a consistent and analytically valid method for collecting information on cultural manifestations. The foundations of this new approach shared similarities with certain aspects of non-site archaeology (Camilli et al. 1988). Non-site archaeology is an approach that attempts to record the surface archaeological record using a common base of observation - the artifact. The spatial location and attributes of each surface artifact and feature are recorded. From these basic observations, sites (or spatial aggregates) are

built. Non-site archaeology views the archaeological record as a continuous, rather than a discrete, spatial phenomenon. In other approaches, sites have been the focus of investigation and less attention has been paid to archaeological materials that fall outside sites (i.e. isolated occurrences).

The amount of acreage surveyed at Fort Bliss, combined with the detailed level of resolution and spatial consistency afforded by the TRU method, has resulted in the generation of one of the largest archaeological spatial datasets available in North America. Stipulation V of the Fort Bliss PA requires that 30 percent of all unsurveyed lands on McGregor Range exclusive of Otero Mesa be surveyed prior to the change in land use to off-road maneuver. Accordingly, it is anticipated that large-scale surveys will continue on McGregor Range for several years.

Theoretical Orientation

The goal of archaeology is to understand past human behavior and the process of culture change. A number of theoretical perspectives have been put forward as means to study such behavior and change and a number of these perspectives will be incorporated into this revised version of the *Significance and Research Standards*. The revised research program takes into account the need to substantially broaden and diversify the theoretical basis of the standards. The theoretical perspective used in the 1996 version of the *Significance Standards* was explicitly materialistic with a rational-functional approach to explaining human behavior. Under this perspective, material explanations are sought for human behavior, as opposed to ideational, humanistic, or other nonscientific sources. However, as noted above, no single theory will achieve the goal of understanding prehistoric human behavior. Other productive avenues of inquiry exist and several such as social archaeology and so-called “processual plus” (Hegmon 2003) approaches, human behavioral ecology, and evolutionary or selectionist archaeology have been added to the present version of the *Significance Standards*.

THE PRESENT AND FUTURE CRM PROGRAM AT FORT BLISS

An important consideration for the current revision and update of the *Significance Standards* is that Fort Bliss is approaching a new phase in the management and treatment of prehistoric cultural resources. The NRHP eligibility evaluations have been completed for many of the previously recorded sites in the Texas and New Mexico maneuver areas. Large-scale survey and inventory efforts will continue on McGregor Range and hundreds of newly documented sites will need to be evaluated for NRHP eligibility. Aside from these surveys, the focus of archaeological resource management and research is now turning toward an increasing number of intensive data recovery programs in order to mitigate the adverse effects of military training activities. Many of the current projects are driven by specific military projects and actions in support of the current expansion of the military mission at Fort Bliss and proposed transfer of over 20,000 troops to the post as part of recent decisions guided by the Base Realignment and Closure Act (BRAC).

The implications of BRAC in terms of CRM program at Fort Bliss can be seen in Figure 1.2. As illustrated in this chart, the number of archaeological contracts awarded during 2005, 2006, and 2007 is from two to four times the number of the previous ten years. The number of mitigation programs has increased significantly. The revised and updated significance standards have been tailored to provide a stronger focus on research issues for the design and conduct of mitigation programs. This shift in emphasis towards mitigation prompted the addition of new research dimensions and analysis methods to the current study as well as a greater appreciation of programmatic and thematic research programs beyond the more site-specific research directions driven by eligibility evaluation programs.

The revision of the title of the present document to *Significance and Research Standards* is a reflection of this new emphasis. However, this is not to state that eligibility evaluation programs will be eliminated or deemphasized. Instead, the growing number of mitigation projects requires a more concerted, communal effort among the Fort Bliss DPW-E, the SHPOs, and Fort Bliss contractors to ensure that sites are properly studied during this era of large-scale mitigation projects.

Roundtable Discussions

As part of the Geo-Marine, Inc., (GMI) proposal for the revision of the *Significance Standards*, it was suggested that representatives of the Environmental Division at Fort Bliss, Fort Bliss archaeological consultants, and other interested parties participate in a series of “roundtable” discussions to review and debate the design and structure of the research program. Three meetings were held in 2006 and 2007 and were attended by archaeological staff from Fort Bliss and the three companies that currently were contracted to perform archaeological investigation on Fort Bliss: GMI, Lone Mountain Archaeological Services, Inc., (LMAS) and TRC Environmental (TRC).

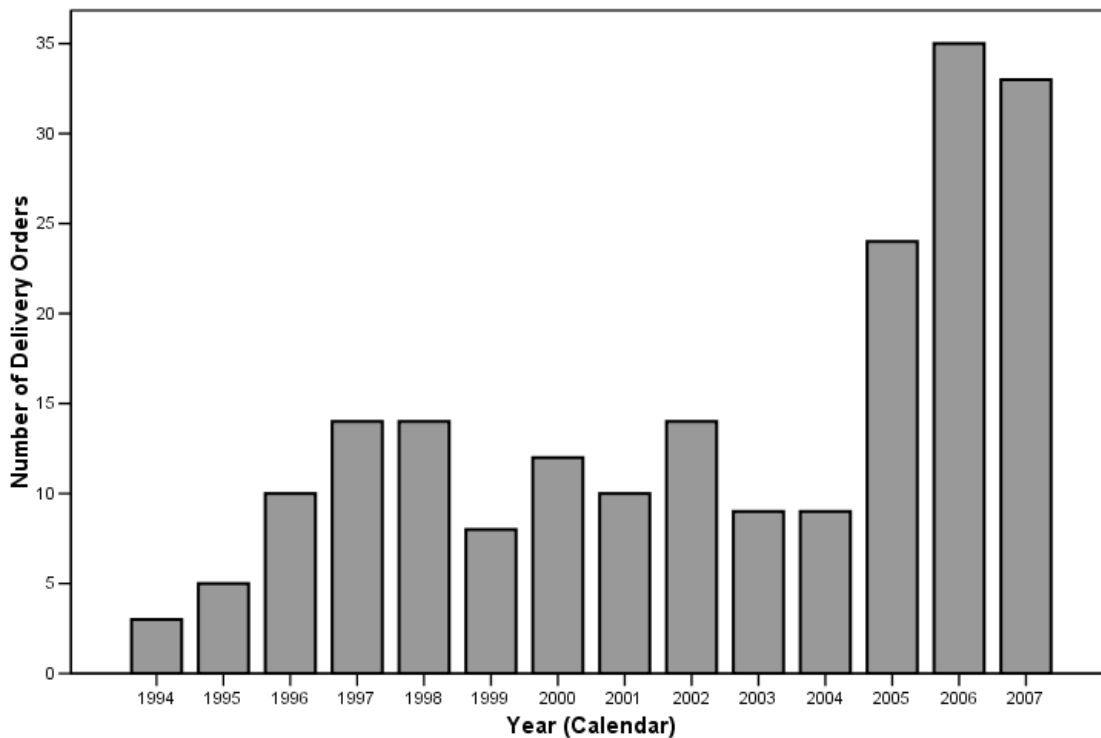


Figure 1.2. Numbers of delivery orders awarded for archaeological survey, evaluation, and data recovery investigations by calendar year.

The first meeting reviewed issues of geomorphology, geoarchaeology, and chronology. Theoretical issues and the proposed structural revisions and new research domains of the significance standards were reviewed at the second meeting. A third meeting was arranged to discuss the various analytical methods that could effectively be used to study the research

domains and the proposed thematic NRHP eligibility evaluation program. These meetings provided a forum for a representative group of regional archaeologists to arrive at consensus positions on research domains, analytical methods, and other issues of importance for the development of the *Significance and Research Standards*.

Of course, it would be unrealistically optimistic and naïve to assume that all attendees would concur on all matters, and indeed the decisions on some topics were not always unanimous. However, the meetings did help ensure that no single or individual perspective or agenda came to dominate the research and NRHP eligibility programs.

A fourth meeting was held between representatives of Fort Bliss DPW-E, the Texas and New Mexico SHPOs, and GMI. At this meeting, the proposed thematic eligibility evaluation program and general structure and research domains of the revised standards were presented. This provided an advance review of the proposed *Significance and Research Standards* and provided an informal context for the SHPO representatives to express any concerns or recommendations they had, thus streamlining their final concurrence in the evaluation process to be used at Fort Bliss.

STRUCTURE OF THE 2008 SIGNIFICANCE AND RESEARCH STANDARDS

This document is broadly structured in four parts. Part I consists of four chapters and presents a series of background discussions as a context for the research at Fort Bliss. Following the present introductory section (Chapter 1), Chapter 2 reviews the Fort Bliss study area in some detail and develops natural contexts for the research. Separate discussions review the climate, geology, physiography, biology, and hydrology of the study area. Building on the natural context, Chapter 3 introduces the dimension of time and provides a history of archaeological research within the region. Chapter 4 presents a critical review of current understanding of local culture history constructs. It concludes with a summary of new theoretical perspectives that will be employed at Fort Bliss.

Part II reviews the intrinsic site attributes and qualities that are critical in making evaluations of the significance of any site. These attributes were considered research domains in the 1996 *Significance Standards*. Here, however, they are viewed as factors to be considered in a determination of research potential and significance, but not specific research domains in and of themselves. Chapter 5 reviews the chronological record at Fort Bliss and provides updated recommendations for chronometric and relative chronological dating methods. Chapters 6 and 7 provide background on the geomorphology of the region and our understanding of the paleoenvironment and how it differed from the modern environment.

Part III is the heart of the research design aspect of the *Significance and Research Standards*, developing five individual domains for research. The five domains are presented in separate sections. The approach acknowledges the cross-linking between the research domains (i.e., as exists between “technology” and subsistence”) and thus it is acknowledged that any delineation of domains is arbitrary. The suggested structure of research domains is intended to facilitate research within a practical archaeological research framework. The research domains sections are: “Subsistence and Subsistence Economy” (Chapter 8); “Technology” (Chapter 9); “Site Formation Processes and Site Structure” (Chapter 10); “Settlement Pattern and Land Use” (Chapter 11); and “Social, Political, Economic, and Ritual Organization” (Chapter 12).

Several of these chapters include material published in the 1996 *Significance Standards* because that data continue to be relevant to evaluations of prehistoric sites at Fort Bliss. In this sense, the current version of the *Significance and Research Standards* is seen not only as an update and revision, but also as a companion to the 1996 document. However, relevant new data have been

added to each section, and in some cases substantial discussions have been removed. These discussions are still available for reference in the 1996 document. Chapter 10 is essentially a new addition and Chapter 12 is a thorough reworking and expansion of the original “Cultural Interaction” research domain of the 1996 document.

Each of these chapters presents background discussions, including theory and models, and identifies data gaps in the existing knowledge of the prehistory of the Fort Bliss and greater Jornada Mogollon region. Each chapter concludes with development of a series of specific research questions, followed by a statement of data requirements.

Part IV concludes the research design. This part consists of Chapter 13, which reviews and critiques the NRHP eligibility procedures that have been used at Fort Bliss over the past decade, including the use of ranking systems, and presents an efficient and streamlined approach to assessing archaeological resources on Fort Bliss. Chapter 14 sets forth revised procedures for NRHP eligibility decisions that will be implemented on future projects. Finally, Chapter 15 discusses several issues relevant to implementing the research design and management of the overall archaeological program at Fort Bliss.

CHAPTER 2. NATURAL ENVIRONMENT

James T. Abbott, Tim Church, Stephen Hall, Myles R. Miller, Elia Perez, and Martin Goetz

This section summarizes the modern character and historical development of the natural environment in the vicinity of Fort Bliss. It sets the stage for the discussions in Parts II and III of human adaptations to the environment, the types and distributions of natural resources exploited by prehistoric groups, and the natural processes affecting the preservation and integrity of the cultural record. Much of this chapter remains unchanged from the 1996 *Significance Standards*. Notable exceptions include “Section 2.3, Soils”, which includes more recently mapped and identified soils on Fort Bliss and “Section 2.4, Modern Vegetation and Fauna”, that adds an expanded discussion of prehistoric or archaeological flora and fauna, with a compendium of species identified in macrofloral and faunal assemblages from the region. “Section 2.5” has also been substantially revised to include a review of common stone materials and their geologic sources and locations that were used prehistorically for the manufacture of lithics, ground stone, ceramics, and other technologies.

PHYSIOGRAPHY

The general area of Fort Bliss is considered part of the Basin and Range province, which extends in an arc from Trans-Pecos Texas, southern New Mexico, and northern Chihuahua westward into Arizona and southeastern California, then northward between the Sierra Nevada and Rockies through Nevada, northeastern California, and western Utah into southern Oregon and Idaho (Fenneman 1931; Hunt 1967; Thornbury 1965). The Basin and Range province represents an area where the continental crust has been stretched, resulting in widespread normal faulting (Peterson 1981). Fort Bliss proper is situated entirely in the Mexican Highlands Section (Bolson Subsection) of the Basin and Range province, while McGregor Guided Missile Range extends northeast into the Sacramento Section of the Basin and Range (Hawley 1975; Thornbury 1965). The region is characterized by north-south trending, block-faulted mountain ranges separated by linear, graben-defined basins. These structural basins, or bolsons (Tight 1905), formed closed, internally drained sediment traps that were the site of tremendous deposition from the flanking ranges during the Cenozoic period. Although drainage is now partially integrated by the through-flowing Rio Grande and its tributaries, several of the basins (including the Tularosa Basin, which is occupied by a large portion of Fort Bliss) remain internally drained.

Principal landforms on and near Fort Bliss include the Tularosa Basin and Hueco Bolson, which represent two contiguous graben valleys underlain by thick Cenozoic sediments, and a variety of block-faulted mountain ranges and highlands flanking the valley floors (Figure 2.1). Occasionally, the Tularosa Basin is treated as part of the Hueco Bolson (e.g., Strain 1971); however, the two basins are structurally distinct (Collins and Raney 1991; Lozinsky and Bauer 1991) and should be considered separate entities. The valleys formed by these grabens are flanked by ranges composed of horsts completely interdigitated with intrusive igneous rocks. Principal ranges flanking the basins include the Franklin, Juarez, Organ, and San Andres mountains to the west, and the Hueco Mountains, Sacramento Mountains, and Otero Mesa to the east. Another series of graben valleys, including the Jornada del Muerto and Mesilla (or La Mesa) Bolson, is present west of the Franklin/Organ/San Andres Mountain chain. Here, the Rio Grande has entrenched up to 100 m into the bolson floors, forming the Mesilla Valley.

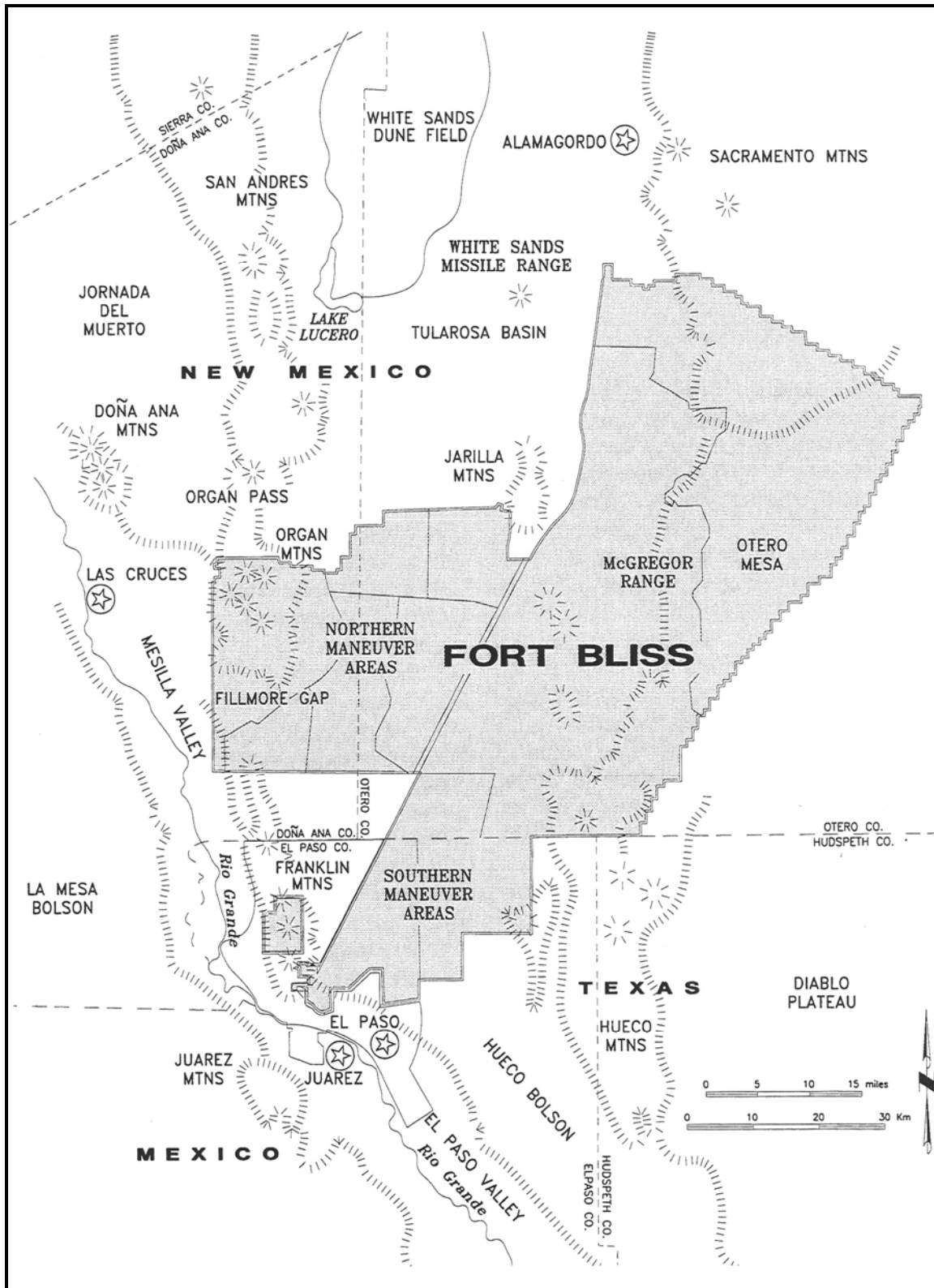


Figure 2.1. Major landscape features on Fort Bliss and surrounding areas.

The Rio Grande follows a series of north south oriented, normal *en echelon* faults termed the Rio Grande Rift through south-central Colorado and north-central New Mexico before entering the Basin and Range Province in central New Mexico (Callendar et al. 1989; Chapin and Seager 1975).

Although distinctive in its northern extent, the Rio Grande Rift is structurally related to the broader Basin and Range system and is not physiographically distinguishable from other graben valleys in the south (Baldrige et al. 1984); however, basins associated with the Rio Grande Rift are generally deeper than surrounding basins (Seager and Morgan 1979). South of Fort Bliss, the Rio Grande enters the Hueco Bolson in the gap between the Franklin and Juarez mountains (Paseo del Norte). Here too, the river has entrenched deeply into the bolson floor, forming a series of stepped terraces in the El Paso Valley (Hawley 1965; Kottowski 1958). At present, the Rio Grande is incised from 60-150 m (200-500 ft) below the bolson floor. The portion of Fort Bliss that is within the Hueco Bolson occupies the unentrenched northern part of the basin, and has no through-flowing trunk stream.

The Franklin, Organ, and San Andres mountains border the western side of the Tularosa Basin and Hueco Bolson. Each of these ranges represent complex normal faulting and smaller scale thrust faulting of westward-dipping Precambrian and Paleozoic rocks, with some outcrops of later Cretaceous age strata and intrusive igneous rocks of Tertiary age. On the eastern side of the Tularosa/Hueco Valley, the Hueco Mountains, Otero Mesa, and the Sacramento Mountains rise abruptly from the basin floor. The Sacramento and Hueco ranges also represent relatively complex block faulting, but dip primarily to the east. Otero Mesa, which lies between the Sacramento and Hueco ranges, also dips gently to the east, but exhibits no complex internal faulting.

To the east, the Hueco Mountains and Otero Mesa merge into the elevated Diablo Plateau. The eastern side of the Tularosa Valley and the northeastern side of the Hueco Bolson represent the boundary between the Mexican Highlands Section and Sacramento Section of the Basin and Range Province (Hawley 1975).

The Tularosa Basin and Hueco Bolson form a continuous valley that is oriented primarily north-south in the more northerly Tularosa Basin and turns northwest-southeast in the Hueco Bolson. The divide between these two basins consists of a subtle topographic rise. Intrusive igneous rocks related to the Laramide Orogeny protrude above the basin floor in places. Notable intrusives include the Jarilla Mountains in the southern Tularosa Basin and the rocks of Hueco Tanks State Park in the northeast Hueco Bolson. Small fault block hills are common on the margin of the valleys. However, the basins are dominated by broad, gently sloping alluvial fans and fan piedmonts that spread out from the surrounding mountains and flat, dune-mantled basin floors broken by numerous small extant and relict playas.

North of Fort Bliss, the extensive gypsum sand deposits of White Sands National Monument and White Sands Missile Range spread out north and northeast of Lake Lucero over the site of pluvial Lake Otero; however, the sand dunes and sheets within the boundary of Fort Bliss are essentially all siliceous. The mountains on the flanks of the valleys are characterized by steep, rugged slopes mantled by variable amounts of scree and colluvium. Otero Mesa consists of a gently sloping, undulating surface mantled with variable amounts of fine surficial sediment. Elevations on Fort Bliss range from approximately 1,200 m (3,900 ft) above mean sea level (amsl) in the cantonment area, which is situated on and just above the uppermost terraces of the Rio Grande, to approximately 2,690 m (8,829 ft) amsl in the Organ Mountains.

Satterwhite and Ehlen (1980) identify four principal landform units that they subdivide into a series of 13 landform map units distinguishable and able to be mapped from aerial photographs

(Table 2.1). The mountain unit includes subunits that encompass: (1) the relatively smooth, eastward-sloping surface of Otero Mesa; (2) dissected hills formed primarily on sedimentary rocks in the Hueco Mountains, along the Otero Mesa escarpment, in parts of the southern Sacramento Mountains, and on the margins of the Franklin, Jarilla, and Organ mountains; and (3) rugged, sharp-crested mountains typically developed on jointed intrusive igneous rocks that make up most of the Organ and Jarilla mountains, parts of the Franklin Mountains, and occasional isolated landforms along the eastern margin of the basins.

Table 2.1.
Relative Percentages of Total Area Occupied by Various Landforms on Fort Bliss.

Unit	Subunit	Percentage Cover
Mountains/Hills	Mesa	15.8
	Highly dissected hills	16.1
	Rugged, sharp-crested mountains	2.3
Alluvial Fans	Primary high-elevation fans	10.8
	Secondary high-elevation fans	1.2
	Mottled, intermediate-elevation fans	6.8
	Dark-toned, low-elevation fans/aprons	3.6
	Fans covered with deep eolian sand	3.5
	High-elevation, anomalous fans	0.7
Basin Area	Light-toned, speckled sand dunes	30.2
	Dark-toned, rough-textured sand dunes	2.6
	Low, smooth areas	2.5
	Small, dark-toned depressions	1.5
Washes		2.0

The Alluvial Fan landscape unit is subdivided into six subunits: (1) primary, high-elevation fans, that are dominantly gravelly, moderately to strongly dissected, situated near the mountain front, and typified by channeled, bypassing drainage; (2) secondary, high-elevation fans, that are also dissected, gravelly, characterized by bypassing drainage, and situated near the mountain front, but are lower and have a more restricted area than the preceding class; (3) mottled, intermediate elevation fans, that occur basinward of the higher fans and are typified by finer deposits, less dissection, and dendritic distributary drainage; (4) dark-toned, low-elevation fan/aprons that grade into the basin floor, are fine-grained, show little dissection, and exhibit marked distributary drainage; (5) fans covered with eolian sands; and (6) high-elevation, anomalous fans, that occur primarily as gravelly, low-gradient south-trending fans originating in the southern Sacramento Mountains and aggrading on Otero Mesa close to the mountain front.

The Basin landscape unit is subdivided into four subunits: (1) light-toned, speckled sand dunes, that represent areas dominated by mesquite coppice dunes and cover the majority of the basin floor; (2) dark-toned, rough-textured sand dunes representing larger dunes, and concentrated on the eastern side of the bolson adjacent to the distal fans; (3) low, smooth areas consisting of level, low-lying areas (probably largely dry playas); and (4) small, irregularly dark-toned depressions, often with light-colored margins (which also probably represent basin playas).

The Wash landscape unit is not subdivided, but includes U- and V-shaped gullies on the uplands and upper fans; deeper, rectilinear-shaped arroyos on the proximal and medial fans; and shallow, broad, dendritic distributaries on the lower fan surfaces. Appreciable channels are essentially unknown on the basin floor.

An alternative subdivision of the landscape is presented in Figure 2.2. Here, four basic landscape elements are also identified. The upland unit encompasses the steep, rocky terrain in the Sacramento, Hueco, and Organ mountains, and some broken terrain below Otero Mesa. The Otero Mesa unit provides a useful division between the gently sloping mesa surface and the rugged mountains, which are grouped in the Satterwhite and Ehlen classification. The Proximal-Medial Alluvial Fan unit encompasses the steeper, higher elevation fans and the erosional slopes of Otero Mesa escarpment; it includes portions of the upland, fan, and wash units of Satterwhite and Ehlen (1980). Finally, the Basin Floor-Distal Alluvial Fan unit encompasses the lowest parts of the landscape, including the level basin floor and gently sloping bajada; it includes portions of the Basin, Alluvial Fan, and Wash units of Satterwhite and Ehlen (1980).

MODERN CLIMATE

The modern climate of Fort Bliss varies from semiarid in the highest areas of the post (e.g., the Sacramento and Organ mountains) to arid in the Tularosa Basin and Hueco Bolson. The region is characterized by long, hot summers and relatively short, mild-to-moderately cold winters (Weather Bureau 1964). All of the long instrumental records in the immediate vicinity are from stations situated at low altitude; consequently, the characterizations of the highland portions of the post in the following summary are necessarily more generalized.

Temperature typically exhibits large diurnal and annual variability. At El Paso, Texas, on the southern end of the reservation, mean high temperature in July is 94°F (34°C), while mean low temperature in January is 32°F (0°C). At Alamogordo, New Mexico, north of the reservation, the mean high temperature in July is 95°F (35°C) and mean low temperature in January is 27°F (-3°C). Recorded temperature extremes at El Paso are 114°F (46°C) and -8°F (-22°C) (Kingston 1986), while a high of 116°F (47°C) was recorded at Orogrande, and a low of -16°F (-27°C) was recorded at Alamogordo (Derr 1981). In both locations, most years have at least one day above 105°F (41°C) in summer and below 10°F (-12°C) in winter, while typical diurnal variation is on the order of 26-29°F (14-16°C) in winter and 24-30°F (13-17°C) in summer. Temperatures in the mountains are only slightly cooler in the summer, but may be significantly cooler in winter due to the elevation difference.

Average annual precipitation is low, and occurs primarily in the form of thunderstorms from late summer through early autumn. Average annual precipitation at El Paso is less than eight inches (195 mm); while at Alamogordo it is approximately 10 inches (254 mm) (Derr 1981; Jaco 1971). Recorded annual precipitation extremes in El Paso range from 2.2 inches (56 mm) in 1891 to 18.3 inches (465 mm) in 2006, while over 22 inches (560 mm) was recorded in 1934 at Orogrande, New Mexico.

Over 65 percent of precipitation in El Paso and 66 percent in Alamogordo occur as brief, heavy thunderstorms in June through October. Most of this precipitation falls so rapidly that it cannot effectively infiltrate the ground surface, and brief, high-energy runoff is commonly associated with these storms. Measurable snowfall occurs in the basin occasionally, but rarely exceeds 1-2 inches or lasts on the ground more than 24 hours. In the higher mountains, annual precipitation is approximately 12-18 inches, and proportionally more of the precipitation occurs as snow in winter. Annual snowfall is approximately 3-5 inches in the basin and 12-25 inches at high elevations.

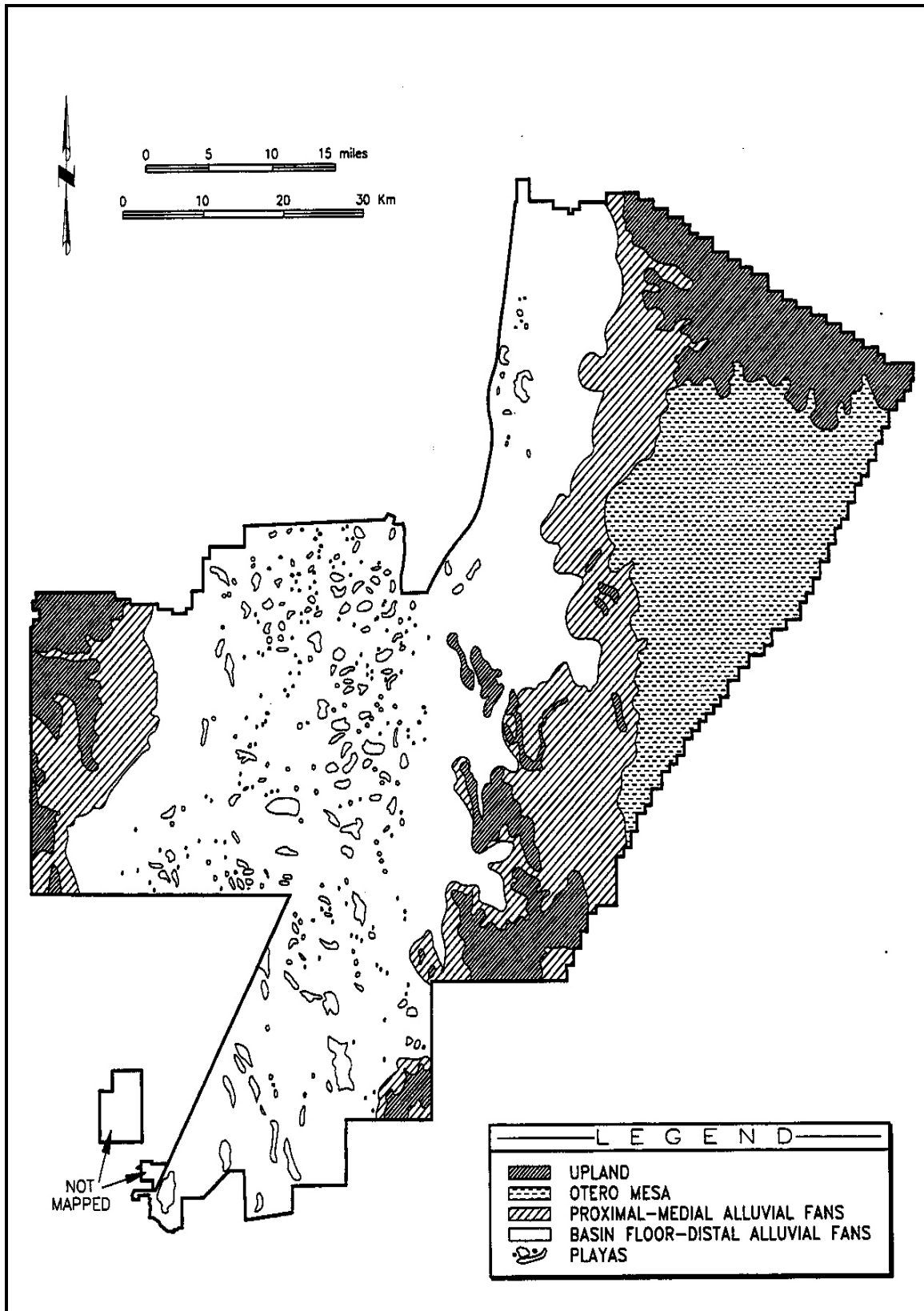


Figure 2.2. Distribution of principal landforms on Fort Bliss.

Convective storms in the summer reflect moisture originating over the Gulf of Mexico, while winter precipitation reflects easterly moving cyclonic storms originating over the Pacific. Because the study area is situated on the lee side of the mountains in western New Mexico, little of this winter moisture penetrates as far inland as Fort Bliss. Cloudiness is low, and over 80 percent of the possible sunlight reaches the ground on an annual basis (Derr 1981). Relative humidity averages approximately 30 percent during the day, but increases to over 70 percent at night, due to the high diurnal variability in temperature. Potential evapotranspiration rates are roughly 10-12 times annual precipitation, and are enhanced by light but sustained winds that prevail during much of the year. Although winds from the north, west, and south are common, the strongest winds originate almost entirely from the southwest and west, and are most common during the spring (McKee 1966).

SOILS

In general, the characteristics of soils reflect the combination of five soil-forming factors: climate, organisms, relief, parent material, and time (Jenny 1941). The soils on Fort Bliss are no exception. Three of the 11 principal soil orders recognized by the U.S. Soil Conservation Service are mapped on the post; all three of these soil orders (Aridisols, Mollisols, and Entisols) reflect the influence of the arid climate to varying degrees. Aridisols are classic well-developed, low-moisture soils, and occur on most of the older geomorphic surfaces. Entisols in the study area also typically reflect arid conditions, but are dominated by weak profiles resulting from a relatively short duration of pedogenesis. Mollisols in the project area typically resemble aridisols, but have a base-enriched surface horizon (mollic epipedon); they are typical of older surfaces and of higher elevations in the Sacramento and Organ mountains.

Soils have a profound affect on the location of cultural resources in a given area. The characteristics of a soil at a given location are determined by the physical and chemical properties, the mineralogical composition of its parent material, the climatic conditions under which the soil was formed, the flora and fauna on and in the soil, the topography, and the length of time the soil has been forming (Sprankle 2004). All of these factors interact in a very complex manner and the effects of a single factor are difficult to isolate and identify. A brief discussion on the effects of single factors will follow.

Time is perhaps the most important of the factors affecting soil formation as the length of time reveals to what extent the other formation processes have acted upon the parent material. Generally speaking younger soils have less-developed horizons if any at all (i.e. Aguena and Oryx soils), while soils that have been allowed to stay in a single general area have existed long enough to allow for the movement of clay and carbonates and to develop a weak B horizon or a calcic horizon, or both (i.e. Chaparral, Double, Salado, and Yippin soils; Sprankle 2004). Some soils on Fort Bliss have very strongly developed soil horizons. Examples of these would be the Modeama, Poblano, and Sotol soils which have developed a very thick surface layer that has a high amount of organic matter, or an argillic horizon (Sprankle 2004).

Parent material refers to the type of rock from which the soil originated. The soils in Fort Bliss are derived from a number of geological sources such as igneous and sedimentary rock and recent alluvial and eolian events. The parent material determines the texture, structure, consistency, color, erodibility, and natural fertility of the soils (Sprankle 2004). The main sources for soil in Fort Bliss are colluvial, alluvial, and eolian materials.

Colluvium is produced by “the physical and chemical weathering and breakdown of the parent rock” (Sprankle 2004: 199). Colluvial soils vary in chemical makeup due to the parent rock from which they were formed, i.e. Dozer soils are derived from limestone, Silktassel soils are derived

from tuff. Alluvial soils have formed from the movement of water and include sand, gravel, clay, silt, and mixtures of these. Often these types of soils have better developed B horizons due to the fact that since they are deposited by the movement of water, they often carry higher amounts of biological material. Lastly, eolian soils are wind-deposited sand or silt. Eolian soils may have been the surface of another type of soil, but becomes the parent material when it is eroded and redeposited. The most common type of this soil on Fort Bliss is the Copia series, which formed in material deposited on an old alluvial basin floor (Sprankle 2004).

Climate also has a role in soil formation as temperature, precipitation, and wind all play important roles. Temperature affects “the rate of decomposition of parent material, the rate of biological activity, and the rate of chemical change within both the organic and inorganic materials” (Sprankle 2004: 200). Precipitation affects the makeup of the soil because increased rainfall in a particular area can increase the amount of organic particulates in the soil, making it darker. Precipitation also increased plant growth, which in turn increased the break down of the soil matrix and the retention of the modified soil (Sprankle 2004). Wind not only causes the movement of soil, but in so doing can also affect the chemical makeup of the soil, i.e. wind carries alkaline dust into an area of pre-existing soils.

Topography (as the location of the soil on the landscape) is a factor in soil production. The two parts of topography that affect the soil are slope and aspect. The slope of the land affects the water retention of the soil, the amount of erosion present, and the depth of the soils. The aspect of the land affects the amount of sunlight the land receives and therefore the temperature and the amount of moisture the land receives and therefore the amount of bioturbation (Sprankle 2004).

The last factor to have an effect on soil formation is plant and animal life, or bioturbation. Plants change the chemical makeup of the soil through decomposition, increase porosity of the soil, and encourage the formation of structural units or aggregates (Sprankle 2004). Animals, from micro-organisms to mega-fauna affect the soil in a multitude of ways. Micro-organisms decompose organic remains, affecting soil chemistry; larger organisms can change soil chemistry as well as physically mix the soil.

There are approximately 90 different soil types currently recorded on Fort Bliss Military Reservation (Table 2.2). Due to the complexity of the soil types present on Fort Bliss, for the purpose of illustrating soil distribution the soil types will be consolidated into eight categories (Map Units) under three subgroups as defined by Sprankle (2004). Subgroup 1 contains Map Units 1, 2, and 3, that are composed of soils located on the floor of the Tularosa Basin, Subgroup 2 contains Map Units 4 and 5, which are composed of soils on the fan piedmonts, and Subgroup 3 contains Map Units 6, 7, and 8, which consist of soils identified on hills and mountains (Figure 2.3).

Map Unit 1. Copia-McNew-Elizario Association- Primarily composed of gently sloping, well drained and excessively drained, and very deep soils on alluvial flats and dunes on the basin floors. The general slope is 2 to 5 percent. Minor soils also included in this group are Foxtrot and Patriot soils on alluvial flats on basin floors and Pendero soils on sand sheets on basin floors. The list of all the soil types present in this group in order of largest surface coverage to smallest are McNew-Copia-Foxtrot complex (1-5 percent slope), Copia-Patriot complex (2-5 percent slope), Elizario-Copia complex (2-5 percent slope), McNew-Copia complex (2-5 percent slope), Copia-McNew-Pendero complex (1-5 percent slope), Pendero-Copia-Nations complex (2-5 percent slope), McNew sandy loam (1-3 percent slope), Cavalry loamy fine sand (1-3 percent slope), Delnorte-Canutio complex (3-15 percent slope), Wessly-Copia complex (1-3 percent slope), and Caticon silty clay (1-3 percent slope).

Table 2.2.
Summary of Principal Soil Series Occurring on Fort Bliss.

Soil Order Series Name	Subgroup	Typical Landscape Context	Parent Material	Typical Profile	Depth to Subsoil (cm)	Group No.
Aguena	Ustic Torripsamment	Dune on hill	Eolian sands	A-C	80	8
Aguja	Typic Haplustolls	Mountain	Colluvium derived from tuff	A-Bw1-Bw2-BC-Cr-R	80	7
Allamore	Lithic Ustic Haplocalcids	Hill	Colluvium over sandstone	A-Bk1-Bk2-R	80	8
Altuda	Lithic Calciustolls	Hill	Colluvium derived from limestone	A-Bk-R	80	8
Arbol	Lithic Haplustolls	Mountain	Colluvium derived from tuff	A-Bw1-Bw2-Cr-R	80	7
Armesa	Ustic Haplocalcids	Inset fan on fan piedmont	Eolian sands over calcareous upland alluvium derived from limestone	A-Bw-Bk1-Bk2-Bk3-Bk4	80	5
Bankston	Ustic Haplocalcids	Hill	Colluvium derived from dolomite and/or limestone	A-Bk1-Bk2-R	80	4, 8
Bissett	Ustic Haplocalcids	Hill	Colluvium derived from limestone	Ak-Bk-R	80	8
Brewster	Lithic Haplustolls	Mountain	Colluvium derived from monzonite	A1-A2-R	80	7
Cale	Aridic Argiustolls	Valley	Alluvium derived from limestone	A1-A2-Btk1-Btk2-Btk3-Btk4 Bk	80	6
Canutio	Typic Torriorthents	Fan piedmont	Gravelly alluvium	Ak-Bck	80	1
Caticon	Vertic Haplocambids	Lakebed on basin floor	Alluvium and/or clayey pluvial lacustrine deposits	A-Bw1-Bw2-Bk1-Bk2	80	1
Cavalry	Typic Calciargids	Alluvial flat on basin floor	Alluvium and/or eolian sands	A-Bt-Btk-Bk1-Bk2	80	1
Chaparral	Ustic Haplocambids	Erosion remnant on fan piedmont, alluvium fan	Gravelly alluvium	A-Bw1-Bw2-Bw3-C1-C2-C3	80	4
Chipotle	Ustic Torrifluvents	Inset fan on fan piedmont	Alluvium derived from tuff	A-2C1-3C2-4C3-5C4	80	7
Chuzzie	Pachic Haplustolls	Stream terrace	Alluvium derived from monzonite and/or tuff	A-C1-C2-2C3-2C4	80	7

Table 2.2.
Summary of Principal Soil Series Occurring on Fort Bliss.

Soil Order Series Name	Subgroup	Typical Landscape Context	Parent Material	Typical Profile	Depth to Subsoil (cm)	Group No.
Condron	Ustic Haplargids	Inset fan on fan piedmont	Eolian sands over alluvium derived from igneous rock	A-2Bt1-2Bt2-2Bt3-3Bt4	80	4
Copia	Typic Torripsamments	Dune	Eolian sands	A-C1-C2-C3-C4-2Btkb	80	1, 2, 3
Crossen	Calcic Petrocalcids	Fan remnant	Alluvium and/or colluvium derived from limestone	A-Bk1-Bk2-Bkm-Bck1-Bck2	80	4
Crotalus	Ustic Haplocalcids	Mountain	Colluvium derived from tuff	A-Bk1-Bk2-Bk3-Bk4	80	7
Deama	Lithic Calciustolls	Hill	Colluvium derived from limestone	A-Bk-R	80	6
Delnorte	Calcic Petrocalcids	Fan piedmont	Gravelly alluvium	Ak-Bk-Bkm-Bck	80	1
Double	Ustic Haplocambids	Alluvial fan	Calcareous alluvium derived from limestone	A-Bw1-Bw2-Bw3	80	5
Dozer	Lithic Torriorthents	Hill	Colluvium derived from limestone	A-C-R	80	6
Elizario	Typic Calciargids	Alluvial flat on basin floor	Eolian sands over alluvium	A-2Btk1-2Btk2-2Btk3-3Bk1-3Bk2-4C	80	1
Enash	Pachic Haplustolls	Mountain	Gravelly alluvium and/or gravelly colluvium derived from tuff	A-C1-C2-C3-C4-C5	80	7
Foxtrot	Argic Petrocalcids	Alluvial flat on basin floor	Eolian sands over alluvium	A-2Btk1-2Btk2-2Bkm-3Bk	80	3
Globe	Chromic Haplotorrerts	Lake plain on basin floor	Clayey pluvial lacustrine deposits	A-Bw-Bss1-Bss2-C	80	4
Hueco	Argic Petrocalcids	Basin floor	Eolian sands over alluvium	A-Bt1-Bt2-Bkm-C	80	3
Infantry	Calcic Petrocalcids	Fan piedmont	Alluvium derived from limestone and/or eolian sands	A-Bk-Bkm-2Bck1-3Bck2-4Bck3-5Bck4	80	4
Jerag	Ustalfic Petrocalcids	Fan piedmont	Eolian sands over alluvium derived from limestone	A-Bt-Bk-Bkm-2Bk	80	5

Table 2.2.
Summary of Principal Soil Series Occurring on Fort Bliss.

Soil Order Series Name	Subgroup	Typical Landscape Context	Parent Material	Typical Profile	Depth to Subsoil (cm)	Group No.
Malargo	Ustic Haplogypsiids	Fan piedmont	Alluvium derived from limestone and/or gypsum	A-Bw-By1-By2	80	4
Mariola	Ustalfic Petrocalcids	Fan piedmont	Eolian sands over alluvium	A-Bt-Btk-Bk-Bkm1-Bkm2-2Bk	80	8
McNew	Typic Calciargids	Alluvial flat on basin floor	Eolian sands over alluvium	A-Btk1-Btk2-Btk3-Btk4-Btk5-C	80	1
Missile	Ustic Petrocalcids	Fan piedmont	Alluvium derived from igneous rock	A-Bk-Bkm-2Bk1-2Bk2-2Bk3-2Bk4	80	4
Modeama	Typic Argiustolls	Hill	Colluvium derived from limestone	A-Btk-Bk-R	80	6
Nations	Typic Petrocalcids	Alluvial flat on basin floor	Eolian sands over alluvium	A-2Bw1-2Bw2-3Bkm-3Bk-4Btkb-5C	80	1, 3
Oryx	Ustic Torrfluvents	Inset fan on fan piedmont	Calcareous alluvium derived from limestone	A-2C1-3C2-3C3	80	5
Patriot	Typic Calciargids	Alluvial flat on basin floor	Eolian sands over alluvium	A-Bt-Btk1-Btk2-Btk3-Bk1-Bk2-Bk3	80	1
Penagua	Typic Calciustolls	Mountain	Colluvium derived from limestone	Ak1-Ak2-Bk1-Bk2-Bk3-Bk4	80	6
Penalto	Petrocalcic Calciustolls	Hill	Gravelly alluvium derived from limestone	Ak1-Ak2-Bkm1-Bkm2-Bkm3-	80	6, 8
Pendero	Typic Haplargids	Sand sheet on basin floor	Eolian sands	A-Bw-Bt1-Bt2-Btk1-Btk2-Bk	80	1, 2
Philder	Calcic Petrocalcids	Erosion remnant on fan piedmont	Eolian sands over alluvium derived from limestone	A-Bw-Bk-Bkm1-Bkm2-2Bk	80	5
Piquin	Typic Haplocalcids	Terrace	Alluvium	A-Bk1-Bk2-Bk3-Bk4-C	80	2
Poblano	Pachic Argiustolls	Mountain	Alluvium and/or colluvium derived from monzonite	A-Bt1-Bt2-Bt3-Btk-Crk-R	80	7
Reduff	Lithic Ustic Torriorthents	Mountain	Colluvium derived from tuff	A-C1-C2-R-	80	7

Table 2.2.
Summary of Principal Soil Series Occurring on Fort Bliss.

Soil Order Series Name	Subgroup	Typical Landscape Context	Parent Material	Typical Profile	Depth to Subsoil (cm)	Group No.
Reyab	Ustic Haplocambids	Inset fan on fan piedmont	Alluvium derived from limestone	A-Bw1-Bw2-C	80	4, 5
Rotagilla	Lithic Haplustolls	Mountain	Colluvium derived from monzonite	A-Bw1-Bw2-R	80	7
Salado	Ustic Haplocalcids	Fan piedmont	Calcareous alluvium derived from limestone	A1-A2-Bw-Bk1-Bk2-Bk3-Bk4	80	5
Silktassel	Aridic Lithic Argiustolls	Mountain	Colluvium derived from tuff	A1-A2-Bt1-Bt2-R	80	7
Sonic	Ustifluventic Haplocambids	Inset fan on fan piedmont	Alluvium derived from limestone	A-Bw1-Bw2-Bw3-Bw4	80	4, 8
Sotol	Aridic Argiustolls	Mountain	Colluvium derived from monzonite	A-Bt1-Bt2-C-Cr-R	80	7
Stallone	Aridic Haplustolls	Alluvial fan	Debris flow deposits derived from monzonite	A-Bw-C1-C2-C3	80	7
Stealth	Arenic Ustic Calciargids	Inset fan on fan piedmont	Eolian sands over alluvium	A-Bw-Bt-2Bk1-3Bk2	80	5
Thaad	Pachic Argiustolls	Mountain	Colluvium derived from tuff	A1-A2-Bt1-Bt2-Bt3-R	80	7
Tinney	Ustic Calciargids	Inset fan on fan piedmont	Alluvium	A-Bw-2Bt-3Bk1-3Bk2-3Bk3	80	4
Tuftuff	Pachic Argiustolls	Mountain	Colluvium derived from tuff	A1-A2-A3-Bt1-Bt2-R	80	7
Wessly	Typic Torriorthents	Depression on alluvial flat on basin floor	Alluvium	A-Bk1-Bk2-Bk3-Bk4-Bk5-Bk6	80	1
Yippin	Typic Haplocalcids	Erosion remnant on fan piedmont	Alluvium derived from igneous rock	A-Bw1-Bw2-Bk1-Bk2-C	80	2

Map Unit 2. Pendero-Copia-Piquin Association- Primarily composed of gently sloping to strongly sloping, somewhat excessively drained and excessively drained, and very deep soils on sand sheets, dunes, and relict terraces on basin floors. The general slope is 2-15 percent. Yippin soils are also included in this group and are located on erosion remnants on fan piedmonts. The list of all the soil types present in this group in order of largest surface coverage to smallest are Pendero fine sand (2-5 percent slope), Copia loamy fine sand (5-15 percent slope), Piquin very gravelly sandy loam (5-15 percent slope), and Yippin loamy sand (2-5 percent slope).

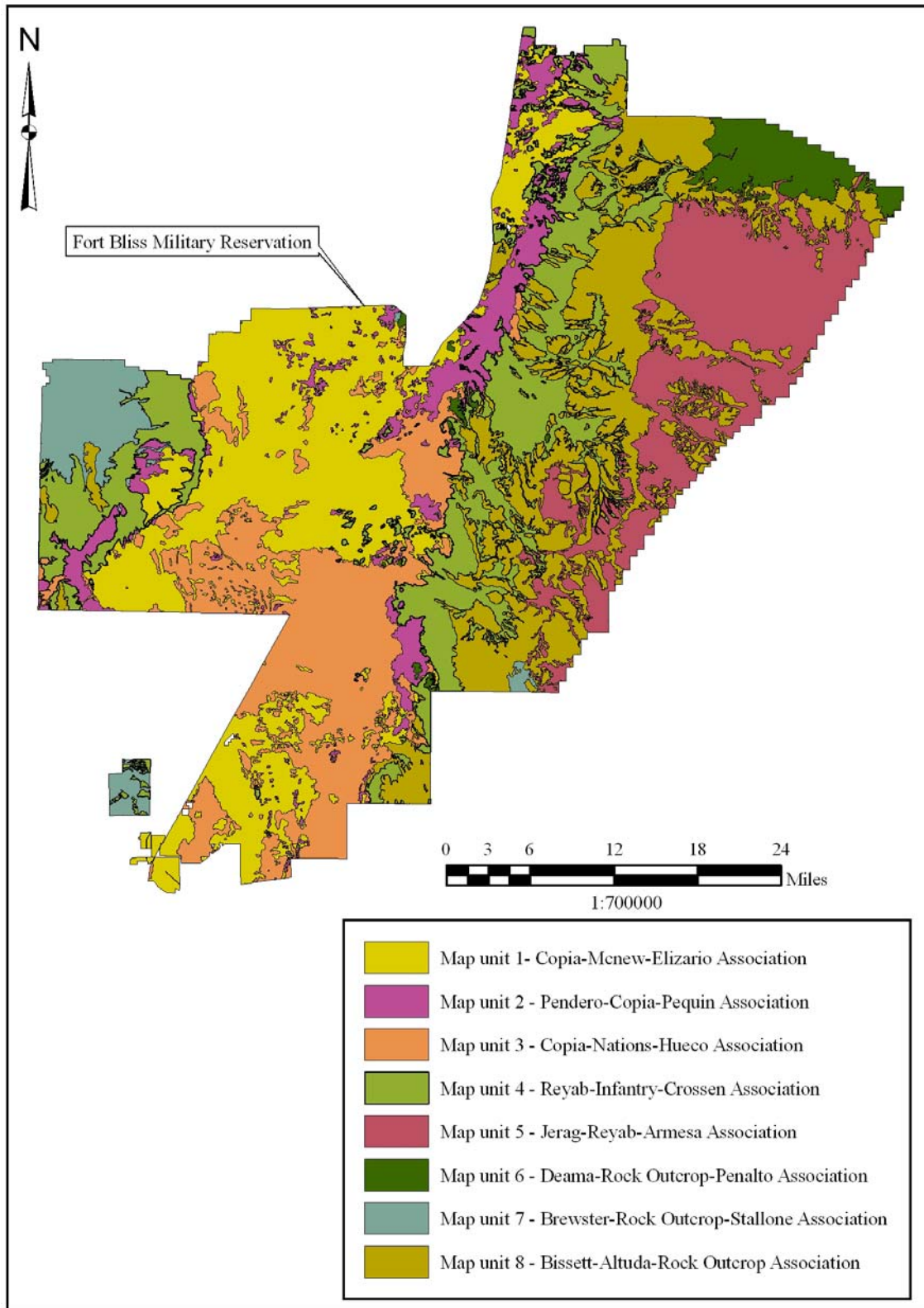


Figure 2.3. Simplified map of soil distribution on Fort Bliss.
(adapted from Sprankle 2004)

Map Unit 3. Copia-Nations-Hueco Association- Primarily consisting of nearly level to gently sloping, excessively drained and well drained, and moderately deep and very deep soils on alluvial flats and dunes on basin floors. The general slope is 0-5 percent. Foxtrot soils are also included in this group and are located on alluvial flats on basin floors. The list of all the soil types present in this group in order of largest surface coverage to smallest are Copia-Nations complex (1-3 percent slope), Hueco loamy fine sand (1-3 percent slope), and Foxtrot-Copia complex (0-5 percent slope).

Map Unit 4. Reyab-Infantry-Crossen Association- Primarily consisting of nearly level to strongly sloping, well drained, and very shallow, shallow, and very deep soils on inset fans and erosion remnants on fan piedmonts. The general slope is 0-10 percent. Minor soils in this group include Mariola soils on erosion remnants on fan piedmonts and Sonic soils on inset fans on fan piedmonts. The list of all the soil types present in this group in order of largest surface coverage to smallest are Reyab silt loam (0-3 percent slope), Infantry-Sonic complex (3-10 percent slope), Crossen-Tinney complex (1-3 percent slope), Tinney loam (1-3 percent slope), Missile very gravelly fine sandy loam (3-15 percent slope), Crossen gravelly fine sandy loam (2-5 percent slope), Malargo silt loam (1-3 percent slope), Condron sand (2-5 percent slope), Chaparral gravelly sandy loam (2-5 percent slope), and Globe clay (0-1 percent slope).

Map Unit 5. Jerag-Reyab-Armesa Association- Primarily composed of nearly level to gently sloping, well drained, and shallow and very deep soils on inset fans and on fan piedmonts. The general slope is 0-5 percent. Minor soils in this group include Philder soils on erosion remnants on fan piedmonts and Oryx soils on inset fans on fan piedmonts. The list of all the soil types present in this group in order of largest surface coverage to smallest are Jerag very fine sandy loam (1-5 percent slope), Reyab loam (0-5 percent slope), Jerag-Armesa complex (2-5 percent slope), Armesa-Salado complex (1-3 percent slope), Philder-Jerag complex (2-5 percent slope), Oryx loam (1-5 percent slope), Salado loam (1-3 percent slope), Double silt loam (2-5 percent slope), Oryx-Reyab complex (1-3 percent slope), and Stealth loamy fine sand (2-5 percent slope).

Map Unit 6. Deama-Rock Outcrop-Penalto Association- Primarily consists of moderately sloping to very steep, well drained, and very shallow and shallow soils and Rock outcrop on hills. The slope is generally 2-65 percent. Minor soils in the group include Cale soils in valleys and Modeama and Penagua soils on mountains. The list of all the soil types present in this group in order of largest surface coverage to smallest are Deama-Rock outcrop complex (5-65 percent slope), Deama-Penalto-Rock outcrop complex (5-65 percent slope), Dozer-Rock outcrop complex (5-65 percent slope), Cale silt loam (2-5 percent slope), Penagua-Modeama-Rock outcrop complex (15-35 percent slope), and Modeama-Rock outcrop complex (5-15 percent slope).

Map Unit 7. Brewster-Rock Outcrop-Stallone Association- Primarily consists of moderately sloping to very steep, well drained, very shallow, shallow, and very deep soils, and Rock outcrop on alluvial fans and mountains. The slope is generally 5-90 percent. Minor soils in this group include Chipotle soils on inset fans, Sotol and Crotalus soils on mountains, and Chuzzie soils on stream terraces. The list of all the soil types present in this group in order of largest surface coverage to smallest are Rock outcrop-Brewster complex (65-90 percent slope), Stallone extremely bouldery sandy loam (5-15 percent slope), Chipotle extremely gravelly sandy clay loam (0-3 percent slope), Reduff very gravelly loam (35-65 percent slope), Brewster very gravelly loam (35-65 percent slope), Rock outcrop-Rotagilla complex (65-90 percent slope), Sotol gravelly loam (15-35 percent slope), Arbol extremely gravelly loam (35-65 percent slope), Rock outcrop-Arbol complex (65-90 percent slope), Rotagilla very gravelly loam (35-65 percent slope), Rock outcrop-Reduff complex (65-90 percent slope), Crotalus extremely gravelly loam (15-35 percent slope), Chuzzie very gravelly loam (0-3 percent slope), Silktassel very gravelly loam (0-3 percent slope), Rock outcrop-Silktassel complex (65-95 percent slope), Brewster very bouldery loam (35-65 percent slope), Aguja-Rock outcrop complex (35-65 percent slope), Thaad

extremely gravelly loam (15-35 percent slope), Poblano very gravelly clay loam (5-35 percent slope), Tuftuff extremely gravelly loam (15-35 percent slope), Enash very gravelly loam (3-8 percent slope), and Rotagilla very bouldery loam (35-65 percent slope).

Map Unit 8. Bissett-Altuda-Rock Outcrop Association- Primarily consists of moderately sloping to very steep, well drained, very shallow and shallow soils, and Rock outcrop on hills. The slope is generally 5-65 percent. Minor soils in this group include Bankston and Allamore soils on hills. The list of all the soil types present in this group in order of largest surface coverage to smallest are Bissett-Rock outcrop complex (5-65 percent slope), Altuda-Rock outcrop (5-65 percent slope), Sonic very gravelly fine sandy loam (1-15 percent slope), Bankston extremely channery loam (8-35 percent slope), Mariola fine sandy loam (1-3 percent slope), Allamore very gravelly loam (10-35 percent slope), and Aguenta fine sand (5-35 percent slope).

FLORA AND FAUNA

Modern Vegetation

Similar to the soils, vegetation on Fort Bliss is strongly conditioned by landscape position, elevation, and parent materials (Kenmotsu 1977; Satterwhite and Ehlen 1980). The vegetation on the fort is transitional between the Chihuahuan Desert and the Southern Great Plains (Shreve 1942), and is included within the Chihuahuan Desert Biotic province. Although some grasses more typical of the southern short-grass prairie occur, the plants in the bolson are for the most part typical of the Chihuahuan Desert, and consist primarily of grasses, forbs, and shrubs adapted to xeric conditions. The higher elevations, in contrast, are dominated by grasses and trees indicative of greater moisture. There is considerable evidence that grassland was considerably more widespread on the bolson floor prior to historic disturbance, which allowed the xeric species to invade and dominate. Principal plants occurring on the installation are listed in Table 2.3.

Table 2.3
Flora of the Fort Bliss Region

Family	Taxon	Common Name	Ethnobotanical Uses
Pteridaceae	<i>Cheilanthes alabamensis</i>	Alabama lipfern	
Cupressaceae	<i>Juniperus monosperma</i>	One-seeded juniper; cedar	variety of medicinal, food, and material uses
Pinaceae (pine family)	<i>Pinus edulis</i>	piñon pine, twoneedle pinyon	food source (nuts); variety of sealing and adhering uses (sap); construction material (wood)
Ephedraceae (ephedra family)	<i>Ephedra aspera</i>	popotillo; Mormon tea	
	<i>Ephedra trifurca</i>	long-leaf ephedra; Mormon tea	medicinal (for diarrhea); beverage
Poaceae (grasses)	<i>Andropogon gerardii</i>	Big bluestem	
	<i>Aristida adscensionis</i>	six weeks three-awn	
	<i>Aristida divaricata</i>	Poverty three-awn	
	<i>Aristida longiseta</i>	three-awn	
	<i>Aristida pansa</i>	Wooten's three-awn	
	<i>Aristida purpurea</i>	purple three-awn	
	<i>Bouteloua breviseta</i>	six weeks grama	minor source of seed grain
	<i>Bouteloua barbata</i>		minor source of seed grain
	<i>Bouteloua curtipendula</i>	side oats grama	minor source of seed grain; used for brooms

Table 2.3
Flora of the Fort Bliss Region

Family	Taxon	Common Name	Ethnobotanical Uses
	<i>Bouteloua eriopoda</i>	black grama	minor source of seed grain; used for hair brushes
	<i>Bouteloua gracilis</i>	blue grama	minor source of seed grain
	<i>Bouteloua hirsuta</i>	hairy grama	minor source of seed grain
	<i>Chloris virgata</i>	feather fingergrass	
	<i>Echinochloa crusgalli</i>	barnyard grass	
	<i>Enneopogon desvauxii</i>	spiked pappusgrass	
	<i>Eragrostis intermedia</i>	plains lovegrass	seed grain
	<i>Leptochloa dubia</i>	green sprangletop	
	<i>Lycurus phleoides</i>	wolftail	
	<i>Muhlenbergia arenacea</i>		seed grain
	<i>Muhlenbergia arenicola</i>		seed grain
	<i>Muhlenbergia emersleyi</i>	bullgrass	seed grain
Poaceae (grasses) cont.	<i>Muhlenbergia pauciflora</i>	New Mexican muhly	seed grain
	<i>Muhlenbergia porteri</i>	bush muhly	seed grain
	<i>Muhlenbergia pungens</i>		seed grain
	<i>Muhlenbergia rigida</i>	purple muhly	seed grain
	<i>Muhlenbergia setifolia</i>		seed grain
	<i>Muhlenbergia torreyi</i>	ring grass	seed grain
	<i>Panicum obtusum</i>	vine-mesquite	food source (seeds)
	<i>Pleuraphis mutica</i>	tobosa grass	used in basketry, on prayer sticks
	<i>Scleropogon brevifolius</i>	burro grass	
	<i>Sporobolus contractus</i>	spike dropseed	
	<i>Sporobolus cryptandrus</i>	sand dropseed	seed grain
	<i>Sporobolus flexuosus</i>	mesa dropseed	
	<i>Sporobolus giganteus</i>	giant dropseed	
	<i>Sporobolus wrightii</i>	sacaton	
	<i>Tridens muticus</i>	slim tridens	
Agavaceae (agave family)	<i>Dasyilirion wheeleri</i>	Wheeler stool	food source; fiber source; stalk can be used as spear shaft
	<i>Agave lechuguilla</i>	lechuguilla	leaves yield fiber, roots can yield soap substitute
	<i>Nolina</i> spp.		fiber source (leaves); source of meal (seeds)
	<i>Yucca baccata</i>	datil; banana yucca	food source (fruit); fiber (leaves); soap (roots)
	<i>Yucca elata</i>	soaptree yucca	food source (crowns, young leaves and flower buds, fruit); soap (roots); fiber (leaves)
	<i>Yucca torreyi</i>	Spanish dagger, Torrey yucca	fiber (leaves)
Salicaceae (willow family)	<i>Salix</i> sp.	willow	construction material
	<i>Populus</i> sp.	cottonwood; poplar	construction material; wide variety of ceremonial uses (wood)
Fagaceae (beech family)	<i>Quercus undulata</i>	wavy leaf oak	food source (acorns), wood source
Ulmaceae (elm family)	<i>Celtis laevigata</i>	netleaf hackberry	fruit is a food source
Chenopodiaceae (goosefoot family)	<i>Ulmus</i> spp.	elm	
	<i>Atriplex canescens</i>	fourwing saltbush	food seasoning (leaves); medicinal (salve made from roots, blossoms); purple dye from inner bark

Table 2.3
Flora of the Fort Bliss Region

Family	Taxon	Common Name	Ethnobotanical Uses
Chenopodiaceae (goosefoot family) cont.	<i>Krascheninnikovia lanata</i>	common winterfat	food source (roots); medicinal (roots, leaves)
	<i>Salsola kali</i>	Russian thistle; tumbleweed	
Brassicaceae (mustard family)	<i>Dimorphocarpa wislizenii</i>	Tansy spectaclepod	
	<i>Lepidium montanum</i>	pepperweed	food (condiment)
Rosaceae (rose family)	<i>Cercocarpus montanus</i>	mountain mahogany	medicinal (laxative); food (beverage from outer bark)
	<i>Fallugia paradoxa</i>	Apache plume	branches used for arrow; leaves used for wash hair
Fabaceae	<i>Senna lindheimeriana</i>	velvet leaf sumac	
	<i>Acacia constricta</i>	mescat acacia; whitethorn	legume used as food source
Fabaceae cont.	<i>Caesalpinia jamesii</i>	bird-of-paradise	
	<i>Dalea lanata</i>	wooly prairie clover	
	<i>Hoffmanseggia glauca</i>	rush pea	
	<i>Parkinsonia aculeata</i>	Jerusalem thorn	
	<i>Prosopis glandulosa</i>	western honey mesquite	food source (seeds, pods)
Krameriaceae (ratany family)	<i>Krameria ramosissima</i>	many stem ratany	
	<i>Krameria parvifolia</i>	range ratany	
Zygophyllaceae (caltrop family)	<i>Larrea tridentata</i>	creosote; greasewood	medicinal (emetic)
Anacardiaceae (sumac family)	<i>Rhus microphylla</i>	littleleaf sumac	
	<i>Rhus trilobata</i>	skunkbush sumac	
Rhamnaceae (buckthorn family)	<i>Rhus virens</i>	fragrant sumac	food source (fruit)
	<i>Ceanothus greggii</i>	desert ceanothus	
Malvaceae (mallow family)	<i>Condalia ericoides</i>	javelina bush	
	<i>Hibiscus denudatus</i>	paleface rosemallow	
Fouquieriaceae (ocotillo family)	<i>Sphaeralcea</i> sp.	globemallow	
	<i>Fouquieria splendens</i>	ocotillo	stems bundled and used in construction
Capparaceae (allthorn family)	<i>Koeberlinia spinosa</i>	allthorn	
Cactaceae (cacti)	<i>Opuntia engelmannii</i>	Engelman prickly pear	food source (tunas, pads)
	<i>Opuntia imbricata</i> var. <i>imbricata</i>	cane cholla; tree cholla	food source (tunas)
	<i>Opuntia leptocaulis</i> var. <i>leptocaulis</i>	pencil cholla;	food source (tunas)
	<i>Opuntia</i> spp.	Christmas cactus	
	Tamaricaceae (tamarisk family)	<i>Tamarix ramosissima</i>	salt cedar
Convolvulaceae (morning glory family)	<i>Evolvulus</i> sp.	morning glory	
Verbenaceae (verbain family)	<i>Aloysia wrightii</i>	Wright's beebrush	
Solanaceae.	<i>Nicotiana trigonophylla</i>	desert tobacco	medicinal/ceremonial (smoked)

Table 2.3
Flora of the Fort Bliss Region

Family	Taxon	Common Name	Ethnobotanical Uses
Scrophulariaceae (verbain family)	<i>Solanum elaeagnifolium</i>	silverleaf nightshade	medicinal (analgesic)
	<i>Castilleja</i> sp.	Indian paintbrush	medicinal (stem menstrual flow, contraceptive)
Bignoniaceae (catalpa family)	<i>Chilopsis linearis</i> var. <i>linearis</i>	desert willow	
Cucurbitaceae (ground family)	<i>Cucurbita foetidissima</i>	buffalo gourd	food source (seeds); utensil, container, rattle; roots used as laxative
Asteraceae (sunflower family)	<i>Artemisia filifolia</i>	sand sagebrush	variety of medicinal uses (principally salves)
	<i>Baileya multiradiata</i>	desert marigold	
	<i>Chrysothamnus pulchellus</i>	rabbitbrush	often used as a binder in adobe
	<i>Dyssodia papposa</i>	fetid marigold	
	<i>Flourensia cernua</i>	tarbush; blackbrush	
	<i>Gaillardia pinnatifida</i>	slender gaillardia	medicinal (diuretic)
	<i>Gutierrezia microcephala</i>	threadleaf snakeweed	
	<i>Gutierrezia sarothrae</i>	broom snakeweed	
	<i>Parthenium incanum</i>	mariola parthenium	
	<i>Psilostrophe tagetina</i>	wooly paperflower	yellow dye source
	<i>Thelesperma longipes</i>	longstalk greenthread	
	<i>Viguiera stenoloba</i>	skeleton goldeneye	

Adapted from Satterwhite and Ehlen 1980, Kenmotsu 1977, and Fort Bliss DPW-E.

Satterwhite and Ehlen (1980) identified 22 distinct plant communities on Fort Bliss, while Budd and others (1979), working at a finer scale, identified 164 different, plant associations that could be mapped (which are composed of variable percentages of ten basic taxa: grasses, sand sage, creosote bush, tarbush, mesquite, broom dalea, fourwing saltbush, soaptree yucca, littleleaf sumac, and whitethorn). These communities comprise four basic physiognomic groups: grassland, which comprises 37 percent of the area of the fort; shrubland, which comprises 58 percent; forestland, which comprises 2 percent; and “other,” which includes bare ground, water bodies, and built-up areas, and comprises another 2 percent of the total area (Satterwhite and Ehlen 1980).

As is apparent in the preceding statistics, grasslands and shrublands make up the overwhelming majority of the fort. In general, each of the principal landform elements on Fort Bliss (e.g., bolson floor, alluvial fans, mountains, and Otero Mesa) supports a variety of distinct plant communities. The general distribution of these communities is illustrated in Figure 2.4. Much more detailed mapping of the vegetation on portions of Fort Bliss is provided by Satterwhite and Ehlen (1980) and Budd and others (1979).

The *Sand Dune-Mesquite* zone is typical of the bolson floor. Satterwhite and Ehlen (1980) identify a number of plant communities within this zone. The most prevalent is a mesquite, broom snakeweed, fourwing saltbush, grass community, which is typical of the areas occupied by coppice dunes.

The larger dune areas are typically vegetated by sand sage, grasses (especially dropseed grasses), some mesquite, broom snakeweed, and fourwing saltbush. Closed depressions, older playas, and level basin surfaces are typified by dropseed grasses and sand sage, with some creosote, tarbush, and soaptree yucca. Active playas are typified by a grassy association dominated by tobosa grass and bush muhly.

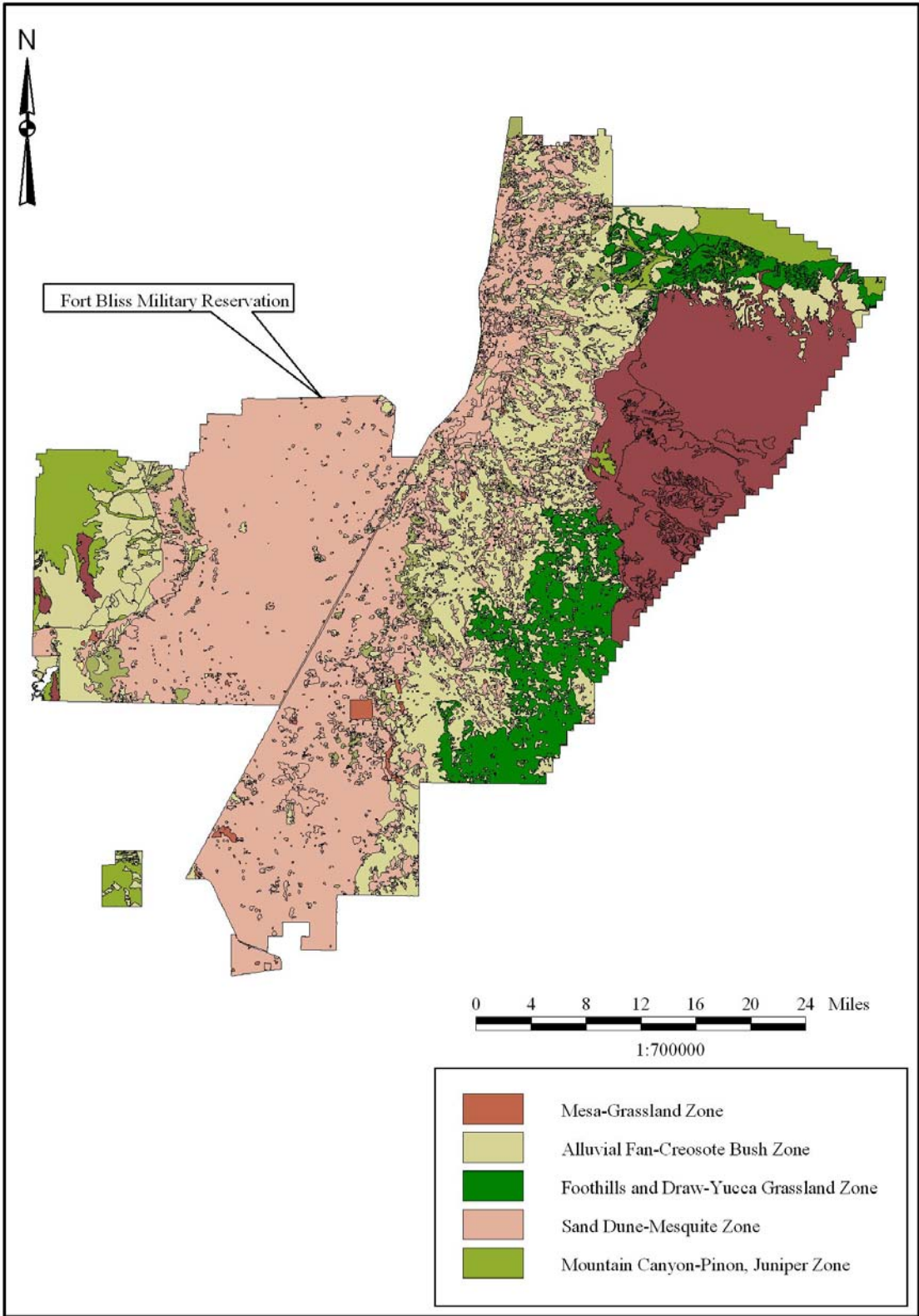


Figure 2.4. Map of the distribution of major vegetation communities on Fort Bliss. (adapted from Satterwhite and Ehlen 1980)

The *Alluvial Fan-Creosote* bush zone is typical of the broad, gently sloping bajada surfaces on the margins of the basin. As the name implies, this area is dominated by creosote, and contrasts markedly with the plant associations in the basin. On the higher, gravelly fan surfaces, creosote and occasional creosote-grassland communities are dominant, while yucca, ocotillo, and cacti are also present in very limited numbers. The lower, finer-grained fans support communities that are somewhat more diverse; while creosote is still frequently the dominant taxon, tarbush also dominates in places and occurs as an important secondary species in others. Other taxa such as mesquite, tarbush, broom snakeweed, tobosa grass, and burro grass also occur. In areas where the fans are covered by eolian sands, creosote competes with mesquite, fourwing saltbush, grasses, sand sage, and other species typical of the basin; with increasing sand depth and sediment influx, the creosote assemblage is replaced by a mesquite-four-wing saltbush assemblage (Satterwhite and Ehlen 1980; Kenmotsu 1977).

The *Foothills and Draws-Yucca Grassland* zone occurs on the Hueco Mountains, high fans, and dissected terrain below the Otero Mesa escarpment. It represents a transition from the creosote-dominated alluvial fans and the grassy uplands on Otero Mesa. Creosote is dominant on the higher parts of the terrain, but the assemblage is relatively diverse and may include ocotillo, Spanish dagger, Mormon tea, cholla, prickly pear, and a variety of xeric grasses. Relatively lush grasses, including muhlys, dropseeds, three-awns, grammas, and tobosa are typical of the lower parts of the dissected landscape, where they coexist with the same shrub species typical of the higher parts of the local landscape (Kenmotsu 1977; U.S. Army Corps of Engineers 1993).

The *Mesa-Grassland* zone is typical of Otero Mesa. Grasses, dominated by various species of grama, muhly, and dropseed, make up the principal association. Shrubs occur individually and in isolated stands on the mesa, but are primarily concentrated along arroyo drainages and the mesa margin. Common taxa include creosote, mariola parthenium, fourwing saltbush, soap tree yucca, cane cholla, javelina bush, and broom snakeweed, while little-leaf sumac and skeleton goldeneye are common on arroyo margins, and desert willow and apache plume are common in arroyo channels (Kenmotsu 1977; Satterwhite and Ehlen 1980).

The *Mountain Canyon-Piñon Juniper* zone is restricted to the Organ Mountains and southern Sacramento Mountains, generally above 6,000 ft amsl. Here, the typical *Yucca Grassland* taxa are joined by scattered piñon pine and juniper. Localized stands of ponderosa pine, Douglas fir, and quaking aspen are also present in relatively sheltered locations in the mountains. Secondary shrubs include wavy leaf oak, sotol, mountain mahogany, agave, and sumac. This zone is also characterized by patchy, but occasionally relatively lush stands of grass, including blue and side-oats grama, plains bristlegrass, and bush muhly (Pigott 1977; U.S. Army Corps of Engineers 1993).

Modern Fauna

Animals in the region of Fort Bliss are typical of the northern Chihuahuan Desert (Cully 1973a, 1973b). Table 2.4 presents a partial list of vertebrate taxa noted in the vicinity of Fort Bliss. In general, species diversity is highest in the mountains and lowest in the bolson (U.S. Army COE 1993). Larger animals are generally restricted to the higher elevations where cover and forage are more abundant. Fauna in the bolson is dominated by birds, rodents (especially rabbits), and lizards. However, a few larger game animals (e.g., pronghorn) are occasionally found in the bolson, as well as in the mountains and on Otero Mesa. Although other large game animals (e.g., bison) may have been present at different times in the past, archaeological investigations suggest that small game, and particularly rabbits, were much more important food sources during most of the prehistoric period.

Table 2.4.
Partial List of Faunal Taxa Occurring in the Vicinity of Fort Bliss.

Order	Taxon	Common Name		
Mammals	Chiroptera (bats)	<i>Tadarida brasiliensis</i>	Brazilian freetail bat	
		<i>Myotis californicus</i>	California myotis	
		<i>Lasiurus cinereus</i>	hoary bat	
		<i>Antrozous pallidus</i>	pallid bat	
		<i>Corynorhinus townsendii</i>	Townsend's big-eared bat	
	Rodentia (rodents)	<i>Tamiasciurus hudsonicus</i>	red squirrel	
		<i>Eutamias cinereicollis</i>	greyneck chipmunk	
		<i>Spermophilus variegatus</i>	rock squirrel	
		<i>Spermophilus spilosoma</i>	spotted ground squirrel	
		<i>Dipodomys merriami</i>	kangaroo rat	
		<i>Chaetodipus penicillatus</i>	desert pocket mouse	
		<i>Perognathus flavescens</i>	plains pocket mouse	
		<i>Thomomys bottae</i>	valley pocket gopher	
		<i>Peromyscus eremicus</i>	cactus mouse	
		<i>Peromyscus nasutus</i>	rock mouse	
		<i>Peromyscus boylii</i>	brush mouse	
		<i>Peromyscus maniculatus</i>	deer mouse	
		<i>Reithrodontomys megalotis</i>	western harvest mouse	
		<i>Neotoma albigula</i>	whitethroated woodrat	
		<i>Neotoma mexicana</i>	Mexican woodrat	
		<i>Microtus longicaudus</i>	long-tailed vole	
		<i>Microtus montanus</i>	mountain vole	
		<i>Erethizon dorsatum</i>	porcupine	
		Lagomorpha (hares, rabbits, and pikas)	<i>Lepus californicus</i>	blacktail jackrabbit
			<i>Sylvilagus audobonii</i>	desert cottontail
	<i>Canis latrans</i>		coyote	
	<i>Urocyon cinereoargenteus</i>		grey fox	
	<i>Bassariscus astutus</i>		ringtail cat	
	<i>Procyon lotor</i>		raccoon	
	<i>Mephitis mephitis</i>		striped skunk	
	<i>Taxidea taxus</i>		badger	
	<i>Felis concolor</i>		mountain lion	
	<i>Lynx rufus</i>		bobcat	
	<i>Ursus americanus</i>		black bear	
	Artiodactyla (even- toed ungulates)		<i>Odocoileus virginianus</i>	white-tailed deer
		<i>Odocoileus hemionus</i>	mule deer	
		<i>Antilocapra americana</i>	pronghorn	
<i>Pecari tajacu</i>		javelina, collared peccary		

Table 2.4.
Partial List of Faunal Taxa Occurring in the Vicinity of Fort Bliss.

Order	Taxon	Common Name
	<i>Cervus canadensis</i>	elk
Birds	<i>Cathartes aura</i>	turkey vulture
	<i>Accipiter striatus</i>	sharp-skinned hawk
	<i>Accipiter cooperi</i>	Cooper's hawk
	<i>Buteo jamaicensis</i>	red-tailed hawk
	<i>Aquila chrysaetos</i>	golden eagle
	<i>Falco sparverius</i>	American kestrel
	<i>Callipepla squamata</i>	scaled quail
	<i>Callipepla gambelii</i>	Gambel's quail
	<i>Meleagris gallopavo</i>	wild turkey
	<i>Columba fasciata</i>	band-tailed pigeon
	<i>Zeniandura macroura</i>	mourning dove
	<i>Geococcyx californianus</i>	roadrunner
	<i>Bubo virginianus</i>	great horned owl
	<i>Glaucidium gnoma</i>	northern pygmy owl
	<i>Phalaenoptilus nuttallii</i>	common poor-will
	<i>Chordeiles minor</i>	common nighthawk
	<i>Chordeiles acutipennis</i>	lesser nighthawk
	<i>Aeronautes saxatalis</i>	white-throated swift
	<i>Archilochus alexandri</i>	black-chinned hummingbird
	<i>Selasphorus platycercus</i>	broad-tailed hummingbird
	<i>Colaptes cafer</i>	red-shafted flicker
	<i>Melanerpes formicivorus</i>	acorn woodpecker
	<i>Sphyrapicus varius</i>	yellow-bellied sapsucker
	<i>Picoides villosus</i>	hairy woodpecker
	<i>Picoides scalaris</i>	ladder-backed woodpecker
	<i>Tyrannus verticalis</i>	western kingbird
	<i>Myiarchus cinerascens</i>	ash-throated flycatcher
	<i>Sayornis nigricans</i>	black phoebe
	<i>Sayornis saya</i>	Say's phoebe
	<i>Empidonax difficilis</i>	western flycatcher
	<i>Contopus sordidulus</i>	western wood peewee
	<i>Tachycineta thalassina</i>	violet-green swallow
	<i>Petrochelidon pyrrhonota</i>	cliff swallow
	<i>Progne subis</i>	purple martin
	<i>Cyanocitta stelleri</i>	Stellar's jay
	<i>Aphelocoma coerulescens</i>	scrub jay
	<i>Corvus corax</i>	common raven
	<i>Gymnorhinis cyanocephala</i>	piñon jay
	<i>Parus gambeli</i>	mountain chickadee

Table 2.4.
Partial List of Faunal Taxa Occurring in the Vicinity of Fort Bliss.

Order	Taxon	Common Name
Birds (cont.)	<i>Parus inornatus</i>	plain titmouse
	<i>Auriparus flaviceps</i>	verdin
	<i>Psaltriparus minimus</i>	common bushtit
	<i>Psaltriparus melanotis</i>	black-eared bushtit
	<i>Sitta carolinensis</i>	white-breasted nuthatch
	<i>Troglodytes aedon</i>	house wren
	<i>Thyromanes betivickii</i>	Bewick's wren
	<i>Catherpes mexicanus</i>	canon wren
	<i>Salpinctes obsoletus</i>	rock wren
	<i>Mimus polyglottos</i>	northern mockingbird
	<i>Toxostoma crissale</i>	Crissal thrasher
	<i>Turdus migratorius</i>	American robin
	<i>Catharus guttata</i>	hermit thrush
	<i>Sialia mexicana</i>	western bluebird
	<i>Polioptila caerulea</i>	blue-gray gnatcatcher
	<i>Lanius ludovicianus</i>	loggerhead shrike
	<i>Vireo solarius</i>	solitary vireo
	<i>Vireo gilvus</i>	warbling vireo
	<i>Vermivora virginiana</i>	Virginia's warbler
	<i>Dendroica audoboni</i>	Audubon's warbler
	<i>Dendroica nigrescens</i>	black-throated gray warbler
	<i>Dendroica graciae</i>	Grace's warbler
	<i>Oporornis tolmiei</i>	MacGillivray's warbler
	<i>Geothlypis trichas</i>	common yellowthroat
	<i>Icteria virens</i>	yellow-breasted chat
	<i>Cardellina rubrifrons</i>	red-faced warbler
	<i>Passer domesticus</i>	house sparrow
	<i>Icterus parisorum</i>	Scott's oriole
	<i>Molothrus ater</i>	brown-headed cowbird
	<i>Piranga ludoviciana</i>	western tanager
	<i>Pheucticus melanocephalus</i>	black-headed grosbeak
	<i>Giuraca caerulea</i>	blue grosbeak
	<i>Passerina cyanea</i>	indigo bunting
	<i>Hesperiphona vespertina</i>	evening grosbeak
	<i>Carpodacus mexicanus</i>	house finch
	<i>Spinus pinus</i>	pine siskin
	<i>Spinus tristis</i>	American goldfinch
	<i>Spinus psaltria</i>	lesser goldfinch
	<i>Chlorura chlorura</i>	green-tailed towhee
	<i>Pipilo fuscus</i>	brown towhee

Table 2.4.
Partial List of Faunal Taxa Occurring in the Vicinity of Fort Bliss.

Order	Taxon	Common Name	
Birds (cont.)	<i>Aimophila ruficeps</i>	rufous-crowned sparrow	
	<i>Amphispiza bilineata</i>	black-throated sparrow	
	<i>Junco caniceps</i>	gray-headed junco	
	<i>Spizella passerina</i>	chipping sparrow	
	<i>Spizella atrogularis</i>	black-chinned sparrow	
Reptiles	Sauria (lizards)	<i>Cophosaurus texanus</i>	greater earless lizard
		<i>Phrynosoma modestum</i>	round-tail horned lizard
		<i>Cnemidophorus</i> spp.	whiptail lizards
		<i>Sceloporus</i> spp.	spiny lizards
	Serpentes (snakes)	<i>Masticophis taeniatus</i> vars.	striped whipsnakes
		<i>Masticophis flagellum</i> var. <i>testaceus</i>	coachwhips
		<i>Elaphe</i> spp.	ratsnakes
		<i>Croatalus atrox</i>	western diamondback rattlesnake
		<i>Croatalus molossus</i>	black-tailed rattlesnake
		<i>Croatalus viridis</i> vars.	prairie rattlesnakes

Macroscopic invertebrate animals are also present in the vicinity in a number of diverse forms. Insects (e.g., flies, ants, beetles, and termites), chilopods (e.g., centipedes and millipede) and arachnids (spiders, ticks, and scorpions) are probably the most common types of macro invertebrates, but worms and snails also may be present, particular at higher altitudes. Ants and termites are common in the bolson, and are probably a very important factor in the pervasive bioturbation apparent in the eolian deposits of the bolson floor.

Prehistoric Utilization of Chihuahuan Desert Flora and Fauna

Many of the flora and fauna species occurring on Fort Bliss were exploited by the prehistoric people who resided in the region. Plants could be used for food, medicinal and ritual purposes, or for construction materials, clothing, tools, weapons, and ornamentation (e.g., fibers for basketry and sandals, wood and fibers for snares and throwing sticks; residues or extracts for glue, waterproofing sealers, and organic pigments and binders). The potential subsistence and economic uses of many of the common plants occurring on Fort Bliss are included in Table 2.3 (see Table 2.3). In addition, Kenmotsu (1977) includes a list of 116 taxa occurring on McGregor Range that were potentially used by prehistoric people; ethnohistorical literature documents the use of many of these species by Native American groups (Bell and Castetter 1941; Castetter and Bell 1937; Castetter and Opler 1936; Castetter and Underhill 1935; Castetter et al. 1938; Curtin 1949; Greenhouse et al. 1981; Kearney and Peebles 1960; Robbins et al. 1916).

Table 2.5 provides a summary review of plant remains recovered from prehistoric contexts throughout Fort Bliss and surrounding areas of the Hueco, Tularosa, and Mesilla basins. The table lists plant remains from pit houses, middens, hearths, and storage pits at a broad selection of Formative (Ceramic) period (A.D. 200/400-1450) settlements as well as plant remains recovered from rock-lined pits and other types of roasting or earth oven facilities. Rock-lined pits have often provided the most productive counts and varieties of prehistoric plant remains.

Table 2.5.
Overview of Charred Plant Remains Recovered from Ceramic Period Residential
Settlements* and Rock-lined Pit Thermal Features**

Formative (Ceramic) Period Residential Settlements

Common Name	Scientific Name of Taxon
<u>Cultigens</u>	
Corn	<i>Zea mays</i>
Common bean	<i>Phaseolus vulgaris</i>
Tepary bean	<i>Phaseolus acutifolius</i>
Lima bean	<i>Phaseolus lunatus</i>
Squash	<i>Cucurbita mixta</i>
Bottle Gourd	<i>Lagenaria siceraria</i>
Buffalo Gourd	<i>Cucurbita foetidissima</i>
<u>Mesquite</u>	
Honey mesquite	<i>Prosopis glandulosa/juliflora</i>
Screwbean mesquite	<i>Prosopis pubescens</i>
<u>Cacti and Leaf Succulents</u>	
Turk's cap, Hedgehog	<i>Echinocactus</i> sp.
Pitaya, Strawberry cactus	<i>Echinocereus</i> sp.
Prickly Pear	<i>Opuntia</i> sp.
Datil	<i>Yucca baccata</i>
Agave	Agavaceae family
Lechuguilla	<i>Agave lechuguilla</i>
Torrey yucca	<i>Yucca torreyi</i>
<u>Cheno-Ams, Purslane, Grasses</u>	
Pigweed	<i>Amaranthus</i> sp.
Goosefoot	<i>Chenopodium</i> sp.
Portulaca	<i>Portulaca</i> sp.
Dropseed	<i>Sporobolus</i> sp.
Grasses	Gramineae family
Grasses	<i>Panicum</i> sp.
<u>Miscellaneous Economic and Medicinal Plants</u>	
Hackberry	<i>Celtis pallida</i>
Mexican Buckeye	<i>Ungradia speciosa</i>
Verbena	<i>Verbesina</i> sp.
Sunflower	<i>Helianthus</i> sp.
Pepper-seed	<i>Lepidium</i> sp.
Four-Wing Saltbush	<i>Atriplex</i> sp.
Trianthema	<i>Trianthema</i> sp.
Clammy Weed	<i>Polanisia</i> sp.
Pine	<i>Pinus edulis</i>
Mallow	Malvaceae family
Milkvetch	<i>Astragalus</i> sp.
Tansy Mustard	<i>Descurainia pinnata</i>
Croton	<i>Croton</i> sp.
Little Leaf Sumac	<i>Rhus microphylla</i>
Bugseed	<i>Corispermum</i> sp.
Mustard family	Cruciferae family
Pink Family	Caryophyllaceae family

*From Dering 1999a, 2001; Goldborer 1985; Hutira 1990; O'Laughlin 2001, 2005b; Scott-Cummings 1989; Whalen 1994a.

Table 2.5.
Overview of Charred Plant Remains Recovered from Ceramic Period Residential Settlements* and Rock-lined Pit Thermal Features**

Rock-Lined Pits and Earth Ovens	
Common Name	Scientific Name of Taxon
<u>Cacti and Leaf Succulents</u>	
Lechuguilla	<i>Agave lechuguilla</i>
Soap-tree Yucca	<i>Yucca elata</i>
Datil or banana yucca	<i>Yucca baccata</i>
Sotol	<i>Dasyllirion wheeleri</i>
Prickly pear, Cholla	<i>Opuntia</i> sp.
Fishhook cactus	<i>Mammalaria</i> sp.
Hedgehog cactus	<i>Echinocactus</i> sp.
Strawberry cactus, Turk's Cap cactus	<i>Echinocereus</i> sp.
<u>Mesquite</u>	
Screwbean mesquite	<i>Prosopis pubescens</i>
Honey mesquite, mesquite	<i>Prosopis glandulosa</i> or <i>juliflora</i>
<u>Cheno-Ams, Purslane, Grasses</u>	
Goosefoot, Pigweed, Cheno-am	<i>Chenopodium/Amaranthus</i> sp.
Purslane	<i>Portulaca</i> sp.
Unidentified grass family	Gramineae family
Dropseed	<i>Sporobolus</i> sp.
Grass	<i>Bouteloua</i> sp.
<u>Cultigens</u>	
Corn	<i>Zea mays</i>
<u>Miscellaneous Economic and Medicinal Plants</u>	
Tansy mustard	<i>Descurainia pinnata</i>
Mexican poppy	<i>Kallstroemia</i> sp.
Morning-glory	<i>Ipomoea</i> sp.
Legume family	Leguminosae family
Four-wing saltbush	<i>Atriplex canescens</i>
Clammy weed	<i>Polanisia</i> sp.
Four O'Clock family	Nyctaginaceae family
Ground cherry	<i>Physalis</i> sp.
Spurge family	Euphorbiaceae family
Milkvetch, Locoweed	<i>Astragalus</i> sp.
Croton	<i>Croton</i> sp.
Mallow family	Malvaceae family
Trianthema	<i>Trianthema</i> sp.

**From Dering 1999a, 2002; Holloway 1983; Hutira 1990; Miller and Stuart 1991; Scott-Cummings 1989.

From the review of plant remains in Table 2.5 (see Table 2.5) it is found that approximately 40 individual taxa identified at the family, genus, or species level have been recovered from prehistoric sites in the region. Compared to the 126 species listed in Table 2.3 (see Table 2.3), as well as the 116 species listed in Kenmotsu (1977), the inventory of prehistoric plant remains is a surprisingly representative sample of the modern species present in the lowland desert basins of Fort Bliss.

Furthermore, many of the taxa listed in Table 2.3 (see Table 2.3) and Kenmotsu (1977) include multiple species within a single genus (e.g., *Muhlenbergia* sp., *Sporobolus* sp.). These often cannot be differentiated among charred prehistoric seeds, and it is likely that the numerous examples of charred *Sporobolus* sp., *Echinocereus* sp., *Echinocactus* sp., Gramineae, and

Euphorbiaceae and other plant remains identified at the family or genus taxonomic level consist of multiple species.

The 40 prehistoric taxa may account for approximately 30-40 percent of the modern plant species inventoried in the desert basins. Still, in all likelihood the inventory presents a biased picture of prehistoric plant exploitation. Many plant remains did not enter the archaeological record because their manner of consumption or use did not involve charring or exposure to fires (Minnis 1981). Preservation factors also play a role, particularly at open-air campsites.

A similar pattern can be observed for the prehistoric exploitation of fauna. A review of several of the more comprehensive analyses of well-preserved and quantitatively robust faunal assemblages from Fort Bliss (Bartlema 2003; Church and Sale 2003; Lear 2007; O’Laughlin 2005a; Presley and Shaffer 2001; Russell and Hard 1987; Shaffer 1999; Whalen 1994a) provides a summary list consisting of approximately 30 taxa. A cursory comparison would find that this count does not compare favorably to the 133 species listed in Table 2.4 (see Table 2.4). Considering that 84 of the taxa listed in Table 2.4 (see Table 2.4) consist of bird species and another 18 of rodent species, it then becomes apparent that the list of prehistoric taxa recovered from archaeological contexts is a representative, albeit not completely unbiased, portrayal of past and present species in the region.

BEDROCK GEOLOGY AND LITHIC MATERIAL SOURCES

Stratigraphy

The Fort Bliss region is dominated by rock and sediments of two broad ages: those predating the Laramide Orogeny and those penecontemporaneous with or postdating this tectonic episode. The block-faulted mountains expose sedimentary and metasedimentary rocks, primarily of Precambrian to Permian age that were strongly fractured and tilted by extensional tectonics during the (Tertiary) Laramide Orogeny. These exposed rocks represent the pre-Laramide sequence. Roughly coincident with this episode of mountain building, a number of intrusive plutons and extrusive volcanics were emplaced, including intrusive rocks forming the core of the Jarilla and Organ mountains. At the same time, sedimentary deposits began to accrete in the bolsons, eventually filling the structural basins with thousands of feet of sediments. Table 2.6 illustrates the generalized stratigraphic sequences in the bolsons and in the Franklin, Hueco, Organ, and Sacramento mountains.

The oldest exposed rocks in the region date to the latter Precambrian (Proterozoic), and include both intrusive igneous rocks and weakly to strongly metamorphosed igneous and sedimentary rocks (Barnes 1983; Denison and Hetherington 1969; Kottowski 1975; Nelson 1940; Nelson and Haigh 1958; Seager et al. 1987; Thomann and Hoffer 1985, 1989). The stratigraphically lowest rocks, termed the Castner Limestone (or Castner Marble) and the Mundy Breccia, are exposed in the Franklin and (possibly) Sacramento mountains. The Castner Limestone Formation consists of metasedimentary limestone, dolomite, conglomerate, chert, rocks strongly altered by contact metamorphism (hornfels), and sills of intrusive igneous rock (diabase; Hoffer 1976). The Mundy Breccia consists of black basalt boulders in a mudstone matrix. The youngest Precambrian metasedimentary rock is the Lanoria Quartzite Formation, which includes beds of sandstone, quartzite, siltstone, and shale. It too is described only from the Franklin Mountains, although an equivalent unit may occur in the so-called DeBaca Terrain at the base of the Sacramento Mountains. The most recent Precambrian rocks consist of rhyolitic and granitic intrusives, including the Franklin Mountain Rhyolite and Red Bluff Granite, which are noted in the Franklin and Hueco mountains (Barnes 1983; Denison and Hetherington 1969).

Table 2.6.
Generalized Stratigraphy of the Fort Bliss Region.

Franklin Mountains
(Denison and Hetherington 1969; Barnes 1983; LeMone 1969a; Lovejoy 1975)

Hueco Mountains
(Nelson and Haigh 1958; Denison and Hetherington 1969; Barnes 1983)

Organ Mountains
(Glover 1975; Seager 1981)

Sacramento Mountains
(Pray 1961; Pigott 1977)

Tularosa and Hueco Bolsons
(Strain 1966; Gustayson 1991; Seager et al. 1987)

Cenozoic	Quaternary	Holocene					Post-Santa Fe, fans, sheetwash, debris flows, paludal sediments, and colianites
		Pleistocene					Upper Santa Fe Group (Camp Rice Family, Ft. Hancock Family, Rincon Valley Family, Hayner Ranch Family); post Santa Fe deposits
	Tertiary	Pliocene					Upper Santa Fe Group (Ft. Hancock Family)
		Miocene					Lower Santa Fe Group
		Oligocene	Various Intrusives	Various Intrusives	Cueva Rhyolite, Soledad Rhyolite, Organ Mountain Quartz Monzonite	Various Intrusives	Lower Santa Fe Group; various intrusives, lava flows, and tuffs (includes Jarilla Mountain pluton)
		Eocene	Various Intrusives	Various Intrusives	Oregon Andesite	Various Intrusives	
		Paleocene				Love Ranch Fm.	Love Ranch Family

Table 2.6.
Generalized Stratigraphy of the Fort Bliss Region.

		Franklin Mountains (Denison and Hetherington 1969; Barnes 1983; LeMone 1969a; Lovejoy 1975)	Hueco Mountains (Nelson and Haigh 1958; Denison and Hetherington 1969; Barnes 1983)	Organ Mountains (Glover 1975; Seager 1981)	Sacramento Mountains (Pray 1961; Pigott 1977)	Tularosa and Hueco Bolsons (Strain 1966; Gustayson 1991; Seager et al. 1987)
Mesozoic	Cretaceous	Gulfian Series (undifferentiated limestone, marl, shale, and sandstone)				
		Comanchean Series (undifferentiated limestone, marl, shale, and sandstone)				Washita rocks undivided, Finlay Limestone, Cox Sandstone, Bluff Mesa Family, Campagrande Family
Paleozoic	Permian	Hueco Limestone Group (Alacran Mountain Family, Cerro Alto Limestone, Hueco Canyon Family.)	Hueco Limestone (Alacran Mountain Family, Cerro Alto Limestone, Hueco Canyon Family, Powwow Conglomerate Member)	Hueco Limestone	San Andres Limestone, Yeso Family (San Ysidro Member and Mesita Blanca Member), Abo Sandstone, Pendejo Siltstone, Hueco Limestone	
	Pennsylvanian	Magdalena Group (unnamed member, Bishops Cap Family., Berino Family., La Tuna Family)	Magdalena Limestone	Magdalena Group	Magdalena Group	
	Mississippian	Helms Family, Rancheria Family, Las Cruces Family	Helms Family	Rancheria Family, Las Cruces Family, Lake Valley Limestone, Caballero Family	Helms Family, Rancheria Family, Arcente Family, Alamagordo-Andrecito Family, Caballero Family	

Table 2.6.
Generalized Stratigraphy of the Fort Bliss Region.

		Franklin Mountains (Denison and Hetherington 1969; Barnes 1983; LeMone 1969a; Lovejoy 1975)	Hueco Mountains (Nelson and Haigh 1958; Denison and Hetherington 1969; Barnes 1983)	Organ Mountains (Glover 1975; Seager 1981)	Sacramento Mountains (Pray 1961; Pigott 1977)	Tularosa and Hueco Bolsons (Strain 1966; Gustayson 1991; Seager et al. 1987)
Paleozoic	Devonian	Percha Shale, Canutillo Family	Undifferentiated cherty limestone and shale	Percha Shale	Percha Shale, Onate Family	
	Silurian	Fusselman Dolomite	Fusselman Dolomite		Fusselman Dolomite	
	Ordovician	Montoya Dolomite (Cutter Member, Aleman Member, Upham Member, Cable Canyon Sandstone Member)	Montoya Dolomite (Cutter Member, Aleman Member, Upham Member, Cable Canyon Sandstone Member)	Montoya Group	Montoya Dolomite (Valmont Dolomite, Aleman Member, Upham Member, Cable Canyon Member)	
		El Paso Group (Florida Mountains Family, Scenic Drive Family, McKelligan Canyon Family, Jose Family, Victoria Hills Family, Cooks Family, Sierrite Family)	El Paso Group (Bat Cave Family, Sierrite Limestone)	El Paso Group	El Paso Family	
Cambrian-Ordovician	Bliss Sandstone	Bliss Sandstone	Bliss Sandstone	Bliss Sandstone		
Precambrian	Proterozoic	Red Bluff Granite, Franklin Mountain Rhyolite, Lanoria Quartzite, Hazel Family, Mundy Breccia, Castner Marble	Red Bluff Granit equiv.		DeBaca Terrane (quartzites, siltstone, shale cut with sills and dikes)	

Paleozoic rocks are widespread in the region, and occur in all of the block-faulted ranges (Harbour 1972; Kottowski 1975; LeMone 1969a, 1969b, 1982, 1989; LeMone and Cornell 1988; McAnulty 1967; Nelson and Haigh 1958; Toomey and Babcock 1983). The oldest formation noted in all of the ranges is the Bliss Sandstone, which dates from the upper Cambrian to lower Ordovician. It is roughly 250 ft thick and consists of thick-bedded sandstone that forms a relatively steep face in outcrop. The Bliss Sandstone is overlain by sedimentary rocks of the lower Ordovician El Paso Group, including limestone, dolomite, and sandstone rocks. The El Paso Group is up to 1,600 ft thick, and is subdivided into a variety of formations in the various ranges; like the Bliss Sandstone, it occurs in all the ranges flanking the bolsons and forms a significant fraction of the exposed rocks.

The overlying middle to upper Ordovician Montoya Group, which is also subdivided into a variety of members, consists primarily of limestone and dolomite with some sandstone. It is 300-400 ft thick, and is extensively exposed in the Franklin, Hueco, Organ, and Sacramento mountains. The middle Silurian Fusselman Dolomite, which consists of up to 900 ft of dolomite and dolomitic limestone, also has significant exposure in the ranges.

These rocks are overlain by a variety of Devonian and Mississippian rocks, including limestones, cherty limestones, and shales (Barnes 1983; Harbour 1972; Kottowski 1969; LeMone 1969a, 1982, 1989; McGlasson 1969; Nelson and Haigh 1958; Seager et al. 1987). These rocks, which include the Helms, Rancheria, Las Cruces, Arcente, Alamagordo-Andrecito, Caballero, Lake Valley Limestone, Percha Shale, Oate, and Canutillo Formations, achieve a total thickness of approximately 650 ft. The Magdalena Limestone (or Magdalena Group) consists of 1,300-2,700 ft of Pennsylvanian limestones, shales, and marls (Barnes 1983; Harbour 1972; Hardie 1958; LeMone 1969a, 1982, 1989; Seager et al. 1987).

Recognized subdivisions include the Bishops Cap, Berino, and La Tuna Formations in the Franklin Mountains. The Permian Hueco Limestone Group, which includes limestone, dolomite, sandstone, dolomite, shale, and conglomerate, occurs in all of the flanking ranges, where it achieves a total thickness of up to 2,200 ft (Barnes 1983; Seager et al. 1987). It is commonly subdivided into a number of formations, including the Alacran Mountain, Cerro Alto, Hueco Canyon, and Powwow Conglomerate formations.

Thick terrigenous clastic and evaporitic rocks of Permian age, including the Pendejo siltstone, Abo Sandstone, and Yeso Formation, are common in the Sacramento and San Andres mountains, but generally interfinger with the Hueco Limestone and pinch out to the south. Because the Yeso Formation, in particular, is a prominent source of evaporitic minerals, this transition is partly responsible for the marked difference in the amount of gypsum in the Cenozoic Tularosa Basin and Hueco Bolson fills (although more important differences include a higher degree of internal drainage, and hence evaporite formation, in the Tularosa, and the plentiful ancestral Rio Grande stream deposits in the Hueco).

The thick Paleozoic sequence is occasionally capped with thin, sparsely preserved Cretaceous rocks in the Franklin Mountains. The majority of these thin Mesozoic rocks in the ranges have long since been eroded away, if they were ever present. Cretaceous age rocks, primarily of the Washita series, are preserved at the top of the graben blocks in the Hueco Bolson. These rocks were originally deposited in the Chihuahua Trough, which is an older, northwest-southeast trending, Mesozoic-age basin that lies almost entirely in Mexico (Henry and Price 1985), but were shifted northeast toward the Diablo Plateau by pronounced thrust faulting during the compressional phase of the Laramide Orogeny (Albritton and Smith 1965). These few Cretaceous rocks represent the youngest pre-Laramide rocks in the region. The Tularosa Basin is apparently floored entirely by Paleozoic rocks (Lozinsky and Bauer 1991).

The earliest widely distributed Tertiary rock in the region is the Paleocene Love Ranch Formation, which consists of a pebbly to bouldery conglomerate derived from surrounding Paleozoic and Precambrian rocks during the initial phases of the Laramide Orogeny. By the Eocene, volcanism was initiated in the rift zone, depositing thick extrusive rocks of the Orejon Andesite in the vicinity of the Organ Mountains. Through the middle Tertiary, a wide variety of intrusive and extrusive igneous rocks, including tuffs, rhyolites, basalts, quartz monzonites, granites, and syenitic rocks were emplaced by intrusion and eruption (Seager et al. 1987). The most notable intrusives are associated with plutons forming the middle Organ and Jarilla Ranges, but smaller intrusives are also present in the Hueco and Franklin mountains (Hoffer 1969). Extrusives are concentrated around the volcanic epicenter of the Organ Cauldron, but ash fall tuffs associated with epicenters that are more distant are also probably present.

The depositional basins in the region are infilled with a variety of alluvial, eolian, and lacustrine deposits and interbedded volcanoclastics (Akerston 1970; Gustayson 1991; Hawley et al. 1969, 1976; Leonard and Fry 1975; Lozinsky and Bauer 1991; Strain 1966, 1969a, 1969b) that are generally correlated with rocks of the Santa Fe group (Hawley et al. 1969). They are discussed more fully in the historical overview of Cenozoic landscape evolution presented below.

Structure, Paleotectonics, and Neotectonics

The Tularosa Basin and Hueco Bolson are both structurally complex (Collins and Raney 1991; Lozinsky and Bauer 1991) and cut with numerous normal faults (Figure 2.5). The Tularosa Basin consists of two north-trending half-grabens bounded by the San Andres, Organ, and Artillery Range fault zones on the west, and the Alamogordo and Otero fault zone on the east. These half-grabens are separated by a series of buried faults termed the Jarilla fault zone, that trend north south in the basin west of the Jarilla Mountains. The eastern half-graben dips to the east, while the deeper western half-graben dips to the west (Figure 2.6). The basin fill attains maximum thicknesses of at least 4,000 ft (1,200 m) at the eastern side of the eastern half-graben, and at least 6,000 ft (1,800 m), and possibly as much as 8,000 ft (2,450 m), at the western side of the western half-graben (Jacobs et al. 1979; Lozinsky and Bauer 1991), but is somewhat shallower in the southern basin, particularly in the eastern half-graben (see Figure 2.6).

The Hueco Bolson is also a graben complex, bounded by and cut with numerous normal faults, including the East Franklin Mountains Fault on the western boundary and several unnamed faults on the eastern boundary (Figure 2.7). Once again, the thickness of Cenozoic basin-fill sediments on the western side of the structural trough is considerably greater than on the eastern side. In the northwestern Hueco Bolson, the basin fill adjacent to the Hueco Mountains is relatively thin (150-200 m, or 500-650 ft), but adjacent to the Franklin Mountains, the fill is extremely thick (up to 2,750 m, or almost 9,000 ft; Collins and Raney 1991). These two very different depocenters are separated by a series of unnamed, west-downthrown faults in the medial part of the basin (see Figure 2.5). These faults represent a continuation of the Jarilla fault zone in the Hueco Basin.

Normal faulting is continuing in both basins, and Cenozoic sediments in the basins and on the mountain piedmonts exhibit a number of offset fault scarps (Collins and Raney 1991; Gile 1987a; Machette 1987; Seager 1980). Several examined faults in the northwest Hueco Bolson offset middle Pleistocene surficial sediments between 2-5.5 m, while the very strongly offset East Franklin Mountain fault exhibits more than 25 m of movement since the middle Pleistocene (Collins and Raney 1991).

Despite the fact that the region is generally considered relatively tectonically quiescent, detailed investigation in the eastern margin of the basin and range province documented more than 300 relatively shallow, low-magnitude (m, <3.7) earthquakes between 1976 and 1979 (Dumas 1980), demonstrating that the area is still tectonically active. Most investigators (e.g., Collins and Raney 1991; Morgan et al. 1986; Muehlberger et al. 1978; Seager et al. 1984; Stevens and Stevens 1985)

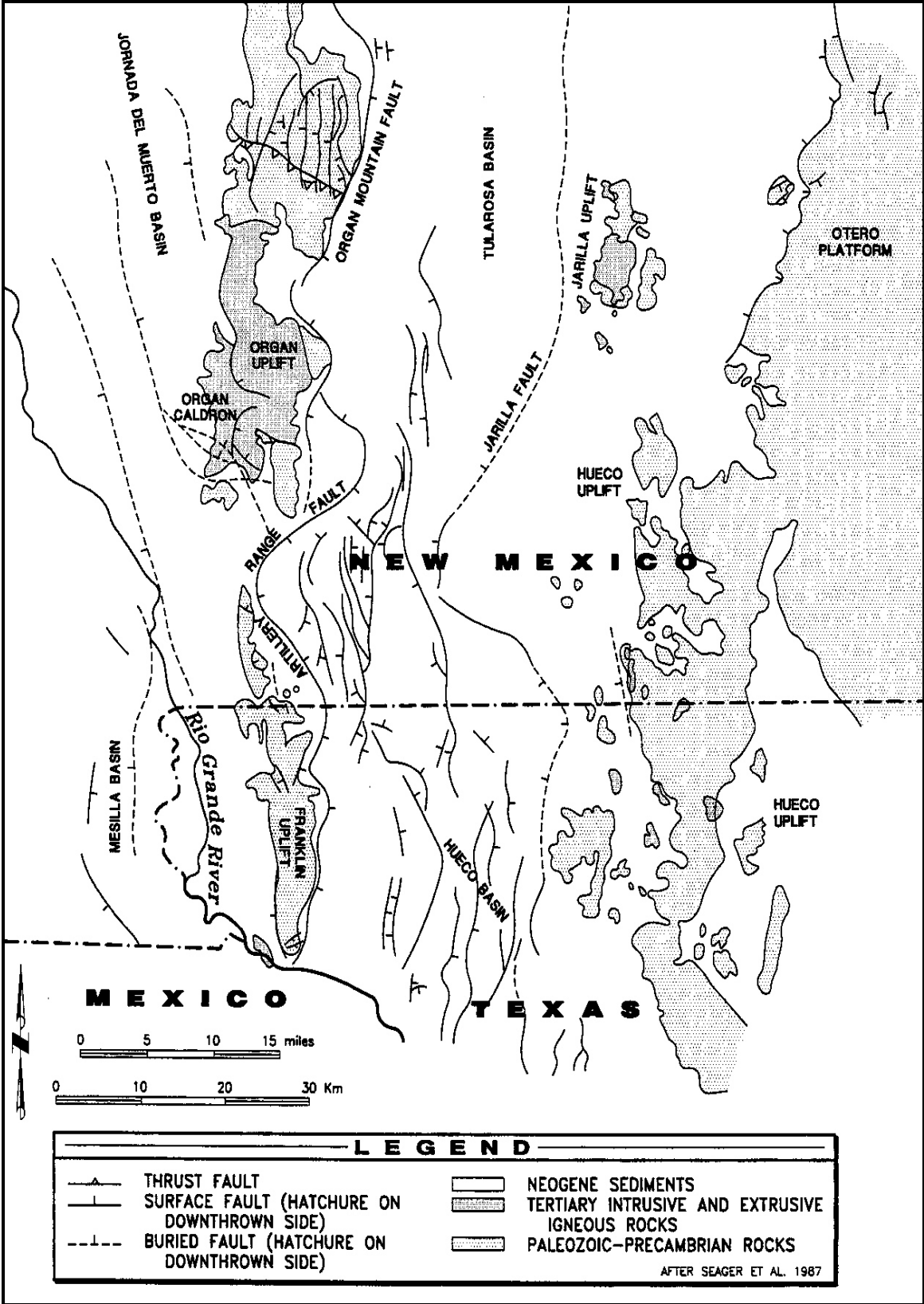


Figure 2.5. Tectonic map of the Fort Bliss region. (after Barnes 1983; Collins and Raney 1991; and Seager et al. 1987)

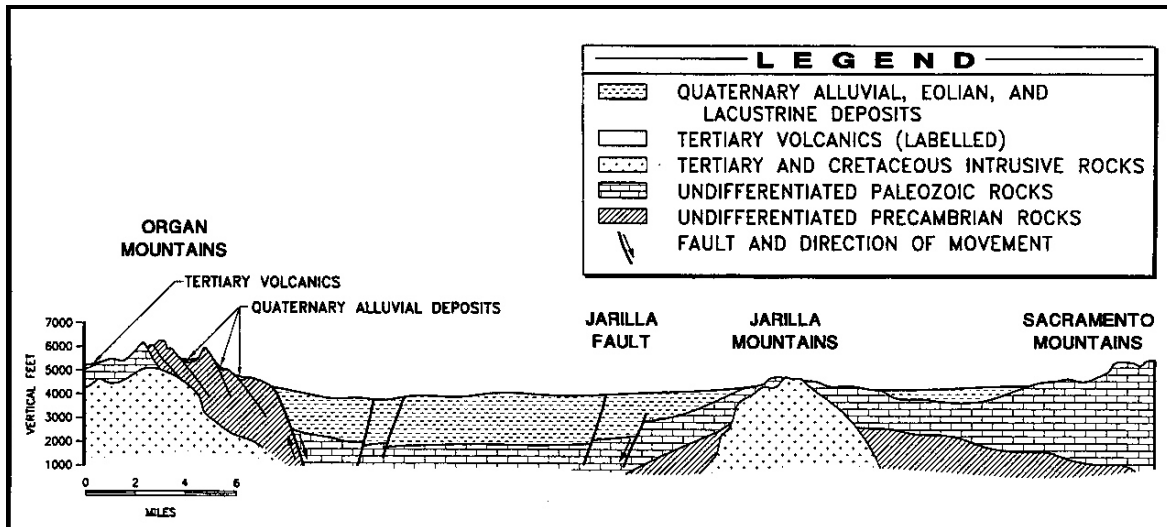


Figure 2.6. Schematic cross-section of the southern Tularosa Basin. (after Seaman et al. 1988)

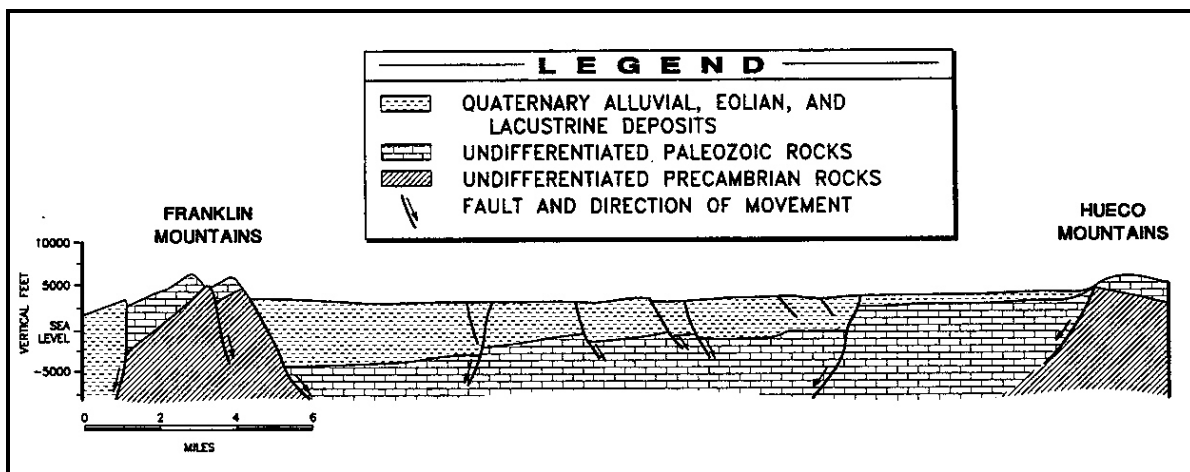


Figure 2.7. Generalized cross-section of the northern Hueco Bolson. (modified from Collins and Raney 1991, note the differences in vertical scale between Tularosa and Hueco cross-sections)

conclude that faulting in the region is both episodic and ongoing, and that long periods of relative quiescence are occasionally punctuated with significant fault movements. Although the timing of individual episodes of fault activity are generally difficult to determine (Collins and Raney 1991), individual fault movements can sometimes be isolated using a combination of radiometric, sedimentologic, and soil-geomorphic information (Gile 1987a; Machette 1987; Seager 1980). Perhaps the best-documented local example is a movement of the Organ Mountains fault that resulted in about 5 m of vertical displacement around 1000 B.P. (Gile 1987a), which clearly demonstrates that Holocene age fault movements have occurred in the culturally relevant timescale.

Neotectonic faulting has a number of implications relevant to the study of prehistory. As Monger (1993a) notes, intragaben fault zones provide localized depocenters and may be the locus for subsequent lacustrine (i.e., playa) and eolian deposition. Because this deposition occurs in areas

where surficial sediments are downdropped, the sediment that accumulates is relatively protected from subsequent erosion, and thus apt to preserve a relatively intact, prehistoric cultural record.

Fault scarps also tend to provide an outlet for soil water and ground water in the form of springs and seeps, especially when a subsurface calcic horizon is exposed. Meteoric water infiltrating through the surficial sediment mantle tends to be blocked by a relatively impermeable calcic horizon, and flows laterally downslope within the subsurface sediments above the impermeable horizon. If the line of flow is interrupted by a fault block, that water will tend to emerge at the elevation of the impermeable zone on the exposed face of the fault. Although deposition can quickly bury the scarp, available water can frequently still be obtained with rapid excavation.

Finally, faulting can drastically affect the configuration of the distributory drainage net on alluvial fan surfaces by diverting lines of flow. If a water management system is in place to divert runoff to specific parts of the fan for use in dryland agriculture or horticulture (Scarborough 1988), disruption of drainage net by faulting could conceivably strongly affect the function of such a system. However, the frequency of this type of effect was probably extremely low, and would have been far overshadowed by changes resulting from the intrinsic evolution of drainage on the fan surface. If such a tectonic event occurred, it is likely that the direct impact of the seismic shock and related mass movements in the basin and on the surrounding ranges on the population would far outstrip the impact of fresh scarp development on a rudimentary agricultural infrastructure.

THE GEOLOGICAL RESOURCE LANDSCAPE

Archaeologically, the use of the lithic resources by prehistoric groups is of considerable consequence. Because of this, it is necessary to review common stone materials that were used prehistorically and their geologic sources. This review is neither exhaustive nor is it to be considered the last word on sourcing lithic raw materials. As will be shown below, many lithic tools and manufacturing debris at sites on Fort Bliss are visually and chemically indistinguishable, at least using current techniques. Future chemical or other techniques may find ways to distinguish between raw material sources and offer insights into how and where different groups sought their raw materials. When these techniques become available, Fort Bliss should include such studies in its scopes of work. In the interim, some general guidelines are provided on the geologic resources across the landscape of the installation.

The Franklin Mountains

The Franklin Mountains are mainly composed of volcanic rocks, rhyolites in particular. Much of the rhyolite is not suitable for tool manufacture, but there are several formations that do contain suitable material. The Thunderbird Formation contains a moderate to high silica content rhyolite (discussed later in this section). The metamorphic zone that is exposed along the Transmountain Highway (Loop 375) as it crosses the Franklin Mountains contains some materials such as schists and hornfels that are suitable for tool production and may have been used by prehistoric populations. To date, however, artifacts that derive from these schists and hornfels have not been identified as such in archaeological assemblages. A large and noticeable outcropping on the eastern flanks of the Franklins is composed of Red Bluff Granite and this material is present in moderate quantities in archaeological assemblages, primarily among ground stone tools, hearthstones, and as a source of ceramic temper. The northern tip of the Franklin Mountains is primarily sedimentary. Rancheria Chert outcrops here and in places it has been moderately metamorphosed into an excellent quality chert that was exploited by prehistoric groups in the region.

The Organ Mountains

The Organ Mountains, like the Franklin Mountains to the south, are composed chiefly of igneous rocks with intruded and partly metamorphosed sedimentary beds on the western flanks of the range (Kottlowski 1958). The northern half of the Organ Mountains is composed of gravels and alluvium, volcanic and intrusive igneous rocks, and sedimentary rocks. Quartz monzonite (a variety of granite) is the dominant rock type exposed (and forms the jagged peaks for which the range is noted). The western slope of the Organ Mountains was faulted and uplifted by the monzonite intrusion. The southern half of the range may be a Tertiary age caldera with Orejon Andesite, Cueva Rhyolite, and Soledad Rhyolite occurring in the caldera. The Soledad Rhyolite is ubiquitous in archaeological assemblages around the Organ Mountains. The material ranges from moderate to good in quality, and pockets of high silica Soledad Rhyolite have been found.

The Jarilla Mountains

These mountains have a complex geology containing a diverse set of materials attractive to prehistoric populations. Red and yellow ochre, turquoise and azurite, granite, hornfels, jasperoids, and fine-grained meta-cherts are found in the Jarillas, many being visually distinctive, and many of these materials have been found in archaeological assemblages. Chert nodules and masses up to 5 cm thick are also abundant throughout the Pennsylvanian sequence in the Jarilla Mountains, especially in the southwestern edge of the range. However, much of the chert in this area is dense and opaque, and some is highly fractured with quartz filling in the cracks, making it less attractive for tool making. Metamorphism resulting from the intrusions changed many of the original sedimentary rocks.

The Sacramento Mountains

This mountain range is dominated by thick sequences of sedimentary rock that are mainly of marine origin. As a result, there are numerous formations containing cherts and silicified woods. Because many of these formations are marine in origin and date to the Pennsylvania age, many of the cherts contain bioclasts. The silicified wood can be found in the form of large logs and smaller pieces and are generally only of moderate quality as a toolstone.

The Hueco Mountains

The Hueco Mountains are a tilted, north-south trending Tertiary uplift block of Paleozoic sedimentary rocks (Freehling 1976; Hardie 1958). The exposed flanks of the Hueco Mountains are predominantly sedimentary in composition but are underlain by massive intrusive igneous formations that resulted in the uplift of the Hueco escarpment (Denison and Hetherington 1969). These formations are dominated by sedimentary deposits of limestone, dolomite, shale, and siltstone, and provided a convenient source of cherts and fine-grained siltstone materials for the production of chipped stone tools (Church et al. 1996). Syenite porphyry, an analog of the Red Bluff Granite and Thunderbird Rhyolite formations of the Franklin Mountains (Barnes 1983), is exposed in some locations along the Hueco escarpment, most notably at Hueco Tanks State Park and at Cerro Alto near the eastern boundary of Maneuver Area 2. This coarse material is commonly observed among ground stone assemblages at sites throughout the eastern Hueco Bolson.

CURRENT STATE OF KNOWLEDGE OF PREHISTORIC LITHIC RAW MATERIAL SOURCES

Three major studies concerning regional sources of the lithic materials have been published since 1996. The first was the lithic source survey undertaken by Fort Bliss (Church et al. 1996), although the study was not limited to sources only on Fort Bliss. Two hundred twenty-eight lithic sources were located, documented, and sampled during the fieldwork for the study. The lithic

material from these sources were predominantly materials suitable for chipped stone artifacts, but also included rocks and minerals used in or as ornaments, building stone, ground stone, ceramic manufacture, and pigments. Of these only a handful were exploited by prehistoric populations.

The results of this survey have had a somewhat disturbing effect on regional lithic source studies. First, the survey demonstrated that lithic materials are ubiquitous across much of the area, either as primary outcrops or as lag deposits. Second, and due in large part to the first finding, the study confirmed an almost complete absence of identified lithic procurement sites, especially formal quarries. These findings present several obstacles to lithic source studies and the analysis of raw material utilization in chipped stone technologies. To complicate matters more were the demonstrable problems in the accurate identification of lithic material types, even basic types, given the wide variation of the materials available.

The second study, which was an outgrowth of the first, was an examination of the obsidian types present naturally in the Rio Grande gravels (Church 2000). This study clearly showed that northern New Mexico obsidian flows were the dominant source present in the gravels, calling into question the interpretive value of obsidian source studies locally.

However, in a review of sourcing studies conducted on archaeological obsidian artifacts, Miller and Shackley (1997) identified a substantial quantity of obsidian items from recently identified sources in northern Chihuahua. Sites that contained the obsidian from Chihuahua were restricted to the Middle Archaic, Late Archaic, and Protohistoric time periods. If this trend is verified through subsequent studies, it implies that the territorial home ranges of hunter-gatherer groups during these periods may have extended throughout the basin-and-range region across what is now New Mexico, west Texas, and northern Chihuahua, or the prehistoric groups during these periods had social ties to those more distant lands and likely to the peoples who occupied those lands.

General Trends in Distribution of Geological Sources

The bedrock geology of the Tularosa Basin and Hueco Bolson is generally dominated by sedimentary rocks on their eastern margins (the Hueco and Sacramento Mountains, as well as the Otero Mesa escarpment) and volcanic rocks on the western margins (the Franklin and Organ mountains). Metamorphic rocks predominately occur in the Franklin, Jarilla, and Organ mountains. The sedimentary formations produce a variety of cherts, chalcedonies, sandstone, and silicified woods (Church et al. 1996). The volcanic deposits to the west include basalts, rhyolites, and granites. Finally, the metamorphic zones produce hornfels, silicified ironstone, metacherts, schists, and various minerals.

Because of the abundance of formations that produce cherts there is considerable visual overlap between these cherts, making formation level identification (identifying the specific geologic formation) let alone source level identification (identifying a specific outcrop within the formation) by archaeologists prone to high levels of error. For future reference, some guidelines are offered that allow a reasonable level of accurate identification of some lithic materials.

Cherts: Pennsylvania-aged cherts (outcropping mainly in the Sacramento Mountains) are typically bioclast rich (Figure 2.8a). Bioclasts are fragments of various marine fossils. A variety of formations produce a black chert, including the Rancheria Formation that is often cited in the archaeological literature. The Rancheria Formation is a marine, deep basin formation, and the cherts in the formation (see Figure 2.8b) can generally be distinguished by two attributes. The first is the fine, even, but sometimes laminated, structure of Rancheria Chert. The second is the lack of bioclasts that are found in almost all other black cherts of the area.

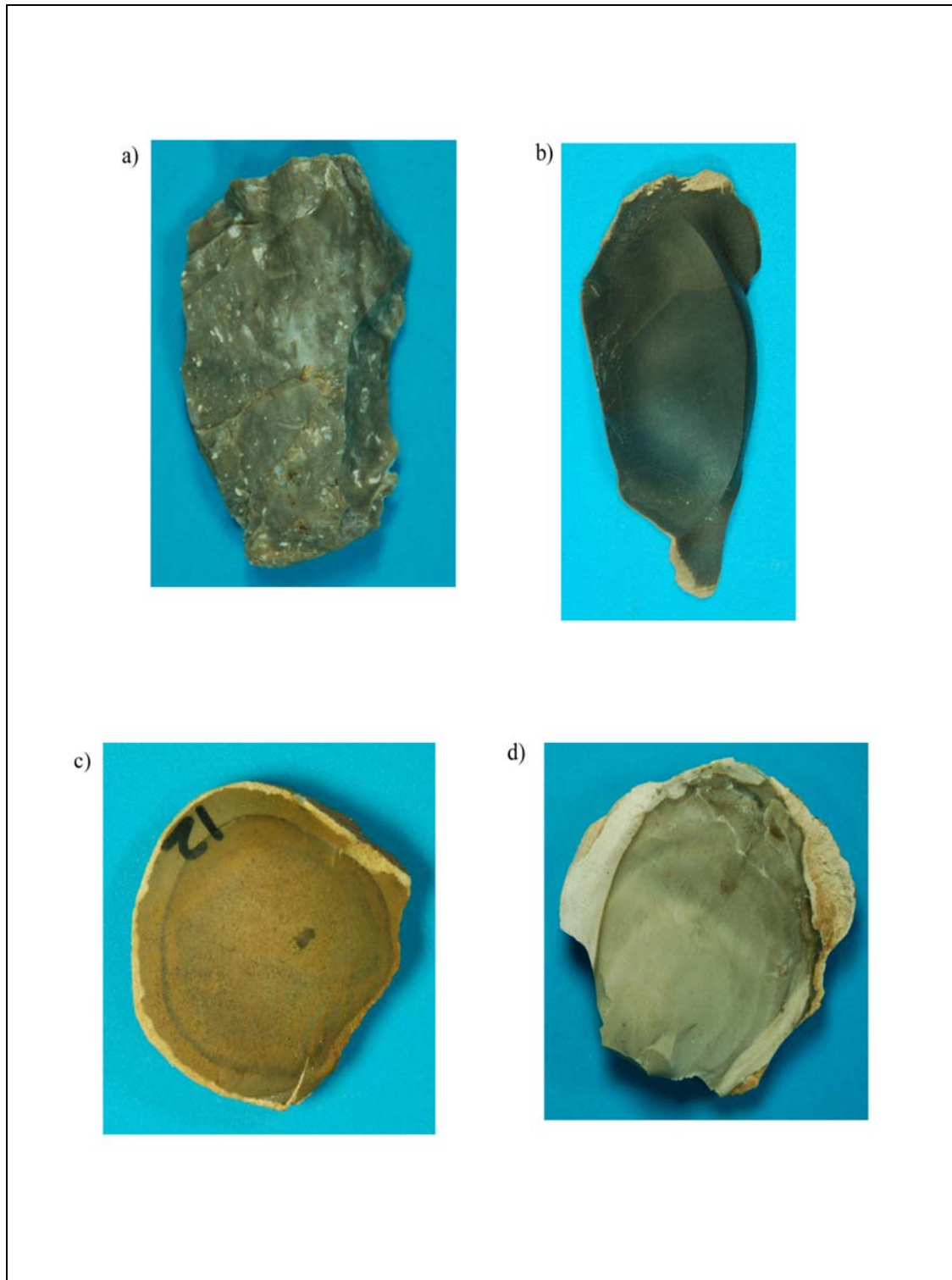


Figure 2.8. Visually distinctive cherts found on Fort Bliss.

- a) Pennsylvania-age chert from the Sacramento Mountains with bioclasts (white-colored inclusions);
- b) high-quality Rancheria Chert (note the lack of bioclasts and the presence of fine laminations);
- c) nodular, greenish/brown chert from the Yeso Formation on Otero Mesa;
- d) typical gray San Andres Formation chert with some bioclasts.

Another distinctive, nodular chert occurs along the edge of Otero Mesa in the Yeso Formation. This chert is greenish brown with some black speck-like inclusions (see Figure 2.8c). Finally, another common chert on Otero Mesa is from the San Andres Formation. Typically, this chert is gray in color, with bioclasts, and outcrops widely along the eastern edge of Fort Bliss on Otero Mesa. The area of Otero Mesa with this outcrop is actually named the Chert Plateau (see Figure 2.8d). Additional outcrops of chert used as prehistoric chipped stone procurement areas have been documented in the Hueco Mountains (Lukowski et al. 1999) and along the southern escarpment of the Sacramento Mountains (Knight and Miller 2003).

Quartzites: Quartzite is perhaps the most misidentified material present in the regional archaeological record. Quartzite is simply silicified sandstone. While some varieties are fine-grained, most of the quartzite locally available is coarse-grained with the sand grains easily visible. Materials without easily identifiable sand grains are probably not quartzite.

Rhyolites: One of the most distinctive and geographically restrictive rhyolites is the Thunderbird Rhyolite that outcrops only in the Franklin Mountains. The material exhibits large red to white phenocrysts in a black matrix that allows it to be easily distinguished from other rhyolites (Figure 2.9a). Thunderbird Rhyolite occurs in the upper member of the Thunderbird Group as defined by Thomann (1980). Commonly, the rock is a light red (5R6/6) with phenocrysts of moderate red (5R4/6) feldspar and clear to light gray (N7) quartz. Petrologically, the groundmass (43.7-67.4 percent) consists of grains less than 0.05 mm, while the phenocrysts range in size from 0.5-2.5 mm and contain feldspar (15.3-41 percent) and 0.12-2.5 mm quartz (3.9-17 percent).

Thunderbird Rhyolite is a common material type on archaeological sites, but is typically limited to sites around the southern Franklin Mountains. Like Soledad Rhyolite, much of the rhyolite in the Thunderbird Formation is not tool grade because of their large phenocrysts, although the best of the Thunderbird materials are suitable for large tools.

The rhyolites from the Organ Mountains are also distinctive, with a red to gray matrix and moderately sized phenocrysts. Archaeologists with experience in the region can distinguish between Thunderbird and other rhyolites. Soledad Rhyolite (see Figure 2.9b) has a weak red (10YR4/2) or gray (N5) matrix with white (N 8) and pinkish gray (7.5YR7/2) phenocrysts, with a porphyritic texture and a microcrystalline mosaic of quartz and feldspar. A subvariety, Quartzite Mountain Rhyolite, is visually similar but differs petrographically with a mosaic of orthoclase laths (Ruhe 1967: 5). Together, the deposits of Achenbach and Squaw Mountain tuff that make up the Soledad Rhyolite are more than 7,000-ft thick (Seager 1981).

Silica content tends to be higher at the base of these deposits, but high-silica areas can occur throughout a rhyolitic deposit because of the complex genesis involved in its formation. Because of the thickness of the formation, the extent of the area it encompasses, and the variable silicification in it, pockets of undiscovered (and perhaps unidentified) tool-grade materials undoubtedly exist in the southern Organ Mountains. Soledad Rhyolite was used prehistorically as a chipped stone material, although most of the known outcrops are not of tool-grade quality.

Further west, near Las Cruces, New Mexico, a number of high-quality rhyolite outcrops occur. One of these outcrops was reported by Stuart (1991), and forms a low ridgeline west of Picacho Peak in Box Canyon, in the Robledo Mountains. This material is a high quality siliceous rhyolite of variable color ranging in texture from microcrystalline to cryptocrystalline. The microcrystalline variety is similar in appearance to a fine-grained quartzite and the cryptocrystalline variety approaches the texture of chert. The material also visually overlaps the colors and color patterns of Alibates Chert from Texas. Similar materials are reported from the Robledo and Doña Ana mountains. Further to the west, in the Sierra de las Uvas, more rhyolites occur. One variety is often mistaken for high quality chert.

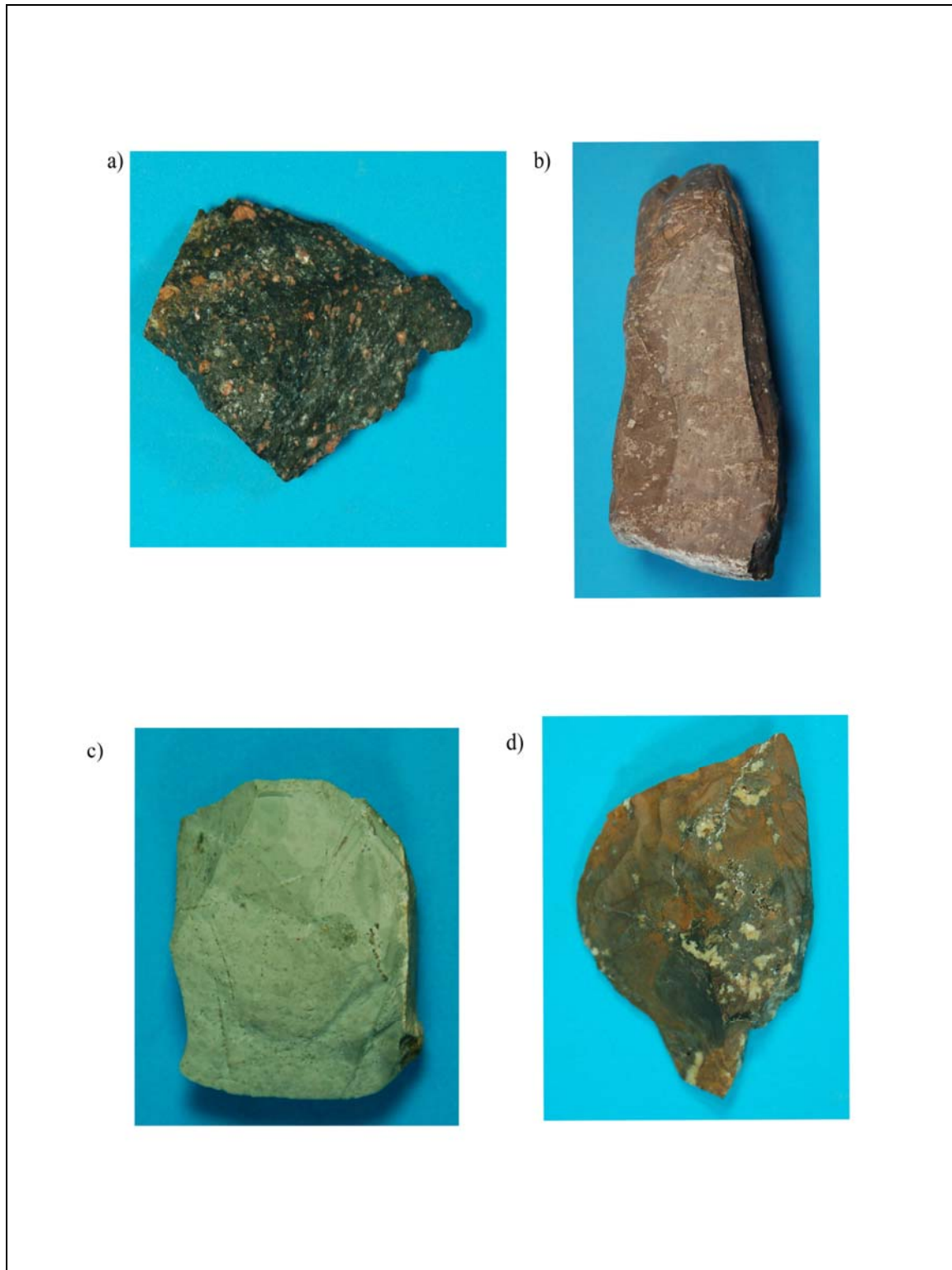


Figure 2.9. Other visually distinctive lithic materials found on Fort Bliss.

- a) Thunderbird Rhyolite from the Franklin Mountains with pink and white phenocrysts;
- b) Soledad Rhyolite from the Organ Mountains with white phenocrysts in reddish to brown matrix;
- c) greenish, chalky hornfels from the Jarilla Mountains;
- d) iron-rich (and hence heavy) jasperoid from the metamorphic areas of the Jarilla Mountains.

Granites: There are three main sources of granite. These include the Organ Mountains around San Augustin Pass that produces a quartz monzonite, the Jarilla Mountains that produce another quartz monzonite, and the Franklin Mountains that produce the Red Bluff Granite. Syenite is also present in several igneous extrusions along the Hueco Mountain escarpment.

Schist: Schist is a metamorphic rock that derives from the alteration of several types of rocks including sandstone, shale, rhyolite, and basalt. The rock is distinctive because of its coarse grain and prominent parallel mineral orientation that gives it a foliated appearance and cleavage. Schists are distinguished from each other by foliation-producing minerals such as chlorite, talc, muscovite, biotite, and talc. Colors of schists can range from white to brown and red with chlorite schist exhibiting a green color. Schist ranges from friable (easily broken) to compact, but soft material.

Pestles of chlorite schist are present in archaeological assemblages within the study area, in some areas comprising up to 18 percent of the pestle assemblage (Carmichael 1986a: 170). Two chlorite schist deposits are known to exist locally. The first source is a chlorite schist deposit at Mineral Hill in the northern Organ Mountains and on White Sands Missile Range lands (Dunham 1935: 30) in New Mexico. A second source is Mount Cristo Rey located at the confluence of the southern Franklin Mountains and the Rio Grande valley, near El Paso Texas and Sunland Park, New Mexico. Dunham suggested a second source exists in the Franklin Mountains but this remains unconfirmed.

Metamorphics: The metamorphic zone of the Jarilla Mountains produces several distinct materials discussed below:

Hornfels: Hornfels results from the metamorphism of fine-grained sedimentary rocks such as shale and claystones. It typically retains traces of the bedding and other sedimentary origins of those rocks. The material is typically green to gray but darker materials also occur, as do banded outcrops. The material ranges from poor to good quality in terms of chipped stone tool manufacture. The most visually distinctive variety is the green hornfels that looks like a somewhat chalky chert when viewed up close (see Figure 2.9c). There are other colors of hornfels but these overlap cherts in color and when viewed up close only an experienced geologist is likely to be able to differentiate the two.

Ironstone: The other distinctive metamorphic material from the Jarilla Mountains is silicified ironstone or jasperoid. This material is deep brown in color and heavy in the hand due to its high iron content (see Figure 2.9d).

Other Minerals: Other minerals of interest to prehistoric populations in the region include azurite and turquoise. Sources for both occur in the Jarilla Mountains. These sources were utilized during prehistory, although much of the evidence of prehistoric quarrying of these materials has been destroyed by historic prospecting and mining activities.

Lithic Procurement Patterns

In contrasting lithic procurement strategies between the Jornada and the Northern Plains, Church and others (1996) have suggested that the nature of the prehistoric prey base vis-à-vis risk management goals are at the heart of the differences between the two regions. On the Northern Plains, hunting centered around large ungulates, most notably bison. Most of the Northern Plains cultures depended on bison for a substantial part of their food. The migratory nature of the bison limited their availability to hunters to a fairly narrow window of time. If sufficient bison were not

procured during that time, the human population would suffer. Therefore, a high premium was placed on procuring the best quality lithic material and an abundant quantity of the material in order to reduce the risk of failure.

This resulted in the establishment of specific lithic quarry areas such as the Spanish Diggings in Wyoming, as well as other large, formal (subsurface excavation) quarries. In contrast, in the Jornada area, hunting centered around small game (primarily rabbits), that are present year-around. Because of this, the risk of hunting failure did not have the severe consequences that the northern populations faced. Hence, the need for high quality materials was diminished. Coupled with the rather ubiquitous nature of flaked-stone materials, Church and others (1996) argue that these factors contribute to why formal quarries, or even formal lithic procurement sites are rare in the Jornada area.

Miller (2007a) suggests similar phenomena in examining changes in chipped stone technological organization between the Archaic and Formative periods that reflect organizational responses to subsistence and environmental conditions. The organizational responses include logistical mobility, variations in residential stability, and resource intensification. Raw material issues were interwoven throughout the settlement and technological dimensions, but in a manner that was selective, opportunistic, and related to anticipated extractive and maintenance tasks. It is proposed that logistically organized hunting of artiodactyl species may account for a significant component of Late Archaic assemblage structure and raw material variation, as opposed to the subsequent Formative period lithic technologies that were designed to meet the increasing demands of bulk plant processing.

Recommendations for Future Work

To those planning a lithic sourcing study there are two aspects to carefully consider: accuracy and precision. Accuracy relates to how confident identification of the lithic material needs to be. Precision refers to how accurate the determination of the geographic source needs to be. It should be noted that it is possible to have high confidence in the identification of the material (for example rhyolite versus hornfels) but still have only a vague idea of the actual geographic source.

There are ways to improve accuracy and precision, although each carries its own burdens. For example, geochemical sourcing of sedimentary rocks would involve time consuming and expensive sampling and the geochemical characterization would probably result in only a minor increase in identification accuracy. Metamorphic materials tend to be very localized geographically, and in many cases visually distinctive. Therefore, geochemical analysis of metamorphic materials would probably not be productive except in relation to specific research questions. Volcanics (basalts and rhyolites, as well as obsidian) offer reduced sampling and analytical investment costs, as well as the likelihood of better source/artifact matching (e.g., Dello-Russo 2004).

The Fort Bliss DPW-E staff and archaeological contractors attending the Significance Standards meetings agreed that some level of effort should be directed towards isolating and tracking several of the distinctive and geographically localized “signature” raw materials known in the region. The Fort Bliss curation facility houses the samples collected during the *Lithic Source Survey* (Church et al. 1996) as well as a database of the collections providing detailed geologic and locational information. Archaeologists and contractors who wish to pursue lithic raw material identification should use this resource as a starting point.

HISTORICAL GEOLOGY AND LATE CENOZOIC STRATIGRAPHY

The modern configuration of the Fort Bliss region is due to compression and subsequent extension associated with the Laramide Orogeny. The timing of initial Laramide compression is

poorly understood, but appears to have begun no earlier than the late Cretaceous (Collins and Raney 1991). This compression had a number of effects, including thrust faulting and folding of Paleozoic and Precambrian rocks (cf. thrust fault in the southern San Andres Mountains, Figure 2.5), and large-scale thrust faulting of Cretaceous rocks deposited in the Mesozoic Chihuahua trough, which were detached from underlying Triassic evaporites and thrust northward toward the Diablo Plateau (Albritton and Smith 1965; Collins and Raney 1991). This compressive stress was waning by 50 million years ago (Price and Henry 1985), and gave way to extensional stress by about 30 million years ago in the Oligocene-Miocene (Collins and Raney 1991; Henry and Price 1989).

As regional compression waned through the Eocene, volcanic activity in the region increased, resulting in the emplacement of a number of intrusive igneous bodies, including the Organ batholith, the Jarilla pluton, and a number of smaller plutons, dikes, and sills in the general area of Fort Bliss. This activity continued through the Eocene and Oligocene into the early Miocene. Extrusive lavas and volcanoclastics in the region are also associated with this general period of time (approximately 48-17 million years ago), although the peak in volcanic activity appears to have occurred 38-28 million years ago (Henry and Price 1985; Henry and McDowell 1986; Henry et al. 1986; Seager 1981). Associated tectonic activity, such as the structural subsidence of the volcanic Organ cauldron (Seager 1975; 1981; Seager and Brown 1978), also occurred during this period of volcanism.

Extensional stress developed in the Oligocene, and initial rifting was progressing by the early Miocene (approximately 24 million years ago), forming the basin-and-range province as normal faults developed and blocks were downthrown (Henry and Price 1985). This faulting has continued episodically to the present, and resulted in fault offsets of up to 3,000 m. Although the timing of accelerated fault movement is not well constrained, Stevens and Stevens (1985) identify accelerated periods of movement around 24-17, 10, and 7 million years ago in the Trans-Pecos area of Texas and it is likely that the timing of increased activity in the Fort Bliss area was similar. The modern landscape is dominated by the effects of this extensional faulting.

As the bolsons of the basin-and-range province developed through the late Tertiary, a variety of colluvial, alluvial fan, fluvial, and lacustrine sediments began to accrete in the deepening basins (Figure 2.10). During most of this time, the basins were largely closed depressions. The basin-fill sediments in these depressions, collectively termed the Santa Fe Group (Gile et al. 1981; Gustayson 1991; Hawley 1969), were derived from local material shed off the surrounding mountains. The Hueco Bolson is infilled with up to 3,000 m of clastic material (Collins and Raney 1991), most of which remains unexamined except through remote means such as seismic and gravity investigation.

Although the deep-basin fill is relatively poorly understood (Collins and Raney 1991), two formations are identified in the upper basin fill. The older and thicker of these formations is termed the Fort Hancock Formation (Strain 1966). It is composed primarily of lacustrine and alluvial fan deposits with very little fluvial deposition evident, suggesting that it accumulated in a closed basin (Albritton and Smith 1965; Gustayson 1991; Strain 1966, 1969a, 1969b, 1980). In the Tularosa Basin, the deeper basin deposits are typically referred to simply as Santa Fe group (Hawley et al. 1976; Lozinsky and Bauer 1991), although these deposits are sometimes correlated with the Fort Hancock Formation (Collins and Raney 1991 Figure 2; Pigott 1977) or the Rincon Valley and Hayner Ranch formations in the Jornada-Rincon-Palomas basins (Gile et al. 1981).

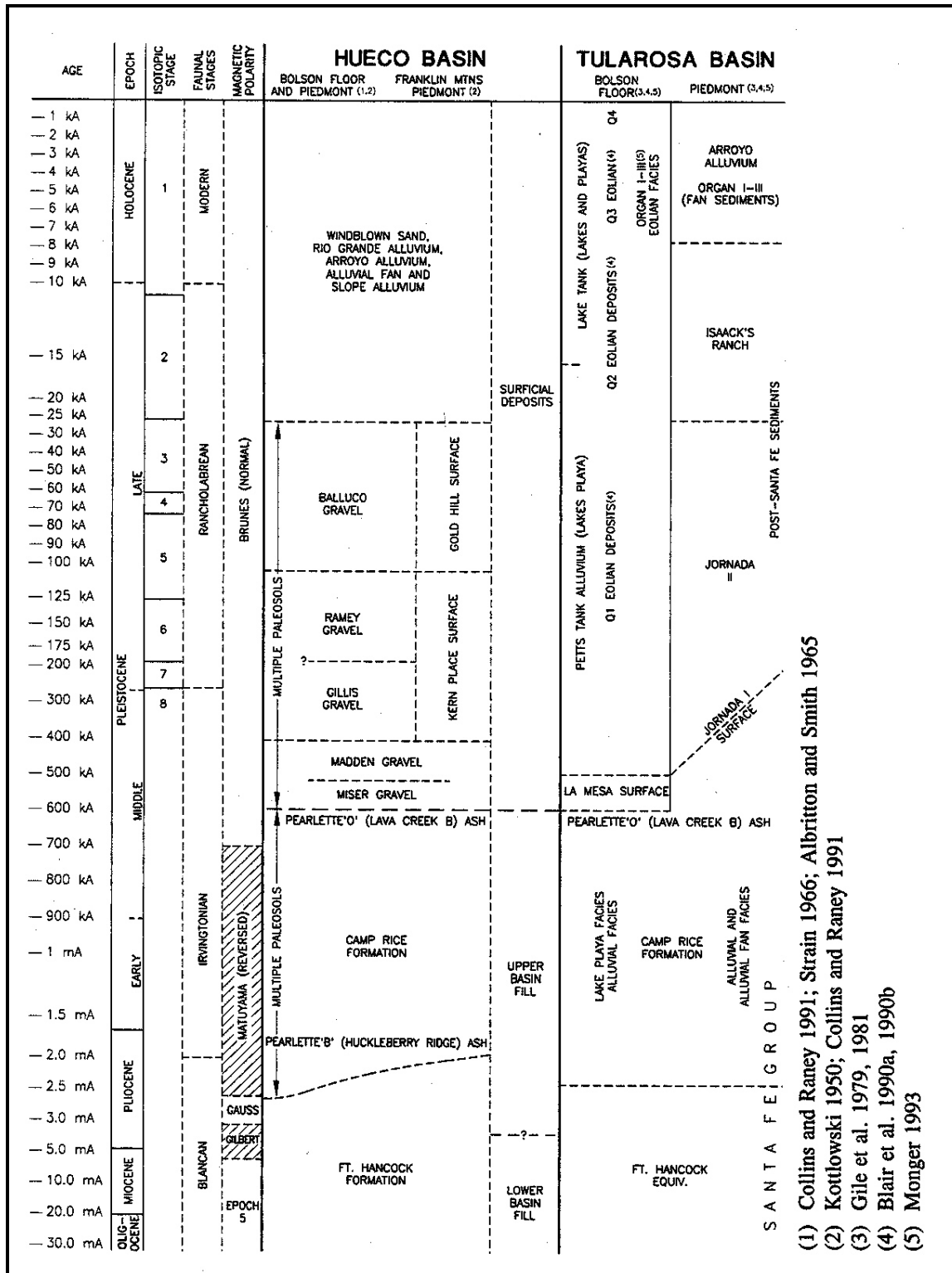


Figure 2.10. Quaternary stratigraphy of the Hueco Bolson and Tularosa Basin. (modified from Collins and Raney 1991 and Gile et al. 1981)

Strain (1971) does not recognize the Tularosa Basin as a separate entity, and maps the entire Tularosa-Hueco complex as the Hueco Basin; however, it appears likely that the two basins were discrete depocenters during the accumulation of Fort Hancock and equivalent sediments. In any case, the deep Tularosa Basin deposits are similar in character to the deposits in the Hueco Basin.

However, approximately 4-3.5 million years ago, the closed basins were successively breached and the Rio Grande became a through-flowing stream in southern New Mexico (Seager et al. 1984), resulting in long-distance sediment transport and a shift from dominantly lacustrine and fan sedimentation to widespread fluvial sedimentation (Gustavson 1991). The deposits resulting from this shift are termed the Camp Rice Formation (Strain 1966), that underlie the surface of the bolson floor and associated fan-piedmont surfaces on the margin of the basin.

As the Camp Rice bolson floor rapidly aggraded, the more slowly accreting alluvial piedmont deposits on the bolson margins were buried by the expanding level basin floor. Camp Rice sediments have been dated from the late Pliocene to early Pleistocene through paleomagnetism (Vanderhill 1986) and the inclusion of the Huckleberry Ridge Ash of the Pearlette Ash family (Gile et al. 1981).

Strain (1971) outlines a sequence of events that occurred during integration of the bolsons. Prior to integration of the drainage net, water entering the basin and range from the north (e.g., the ancestral upper Rio Grande) and the south (e.g., the eastern Sierra Madre) accumulated in the basins as lakes, which were sometimes shallow and ephemeral and other times relatively deep and extensive. As the basins accreted, the topographic divides between various basins were surmounted, and a vast lake, termed Lake Cabeza de Vaca by Strain (1966, 1971) developed in the Mesilla, Hueco/Tularosa, and Bolson de los Muertos in northern Chihuahua (which should not be confused with the Jornada del Muerto in south-central New Mexico). This lake was fed primarily by the ancestral Rio Grande, which delivered melt water from the southern Rockies, and attained an elevation of at least 1,234 m (4,050 ft) amsl and possibly as much as 1,295 m (4,250 ft) amsl in the Hueco Bolson (Gustavson 1991; Strain 1971).

In Strain's model, integration of the bolson segments proceeded upstream through either overtopping of topographic divides by the lake, which stimulated erosion of the drainage divides, or by headward cutting of tributaries of the ancestral lower Rio Grande, or both. This model suggests that the divide between the Hueco Bolson and the Red Light Bolson was breached first, initiating significant erosion of Fort Hancock strata in the southern Hueco Bolson and deposition of the Camp Rice strata.

On the basis of constraining faunal and paleomagnetic ages for the upper Fort Hancock and volcanic ash in the lower Camp Rice, Gustavson (1991) argues that the Hueco Bolson was integrated into the lower Rio Grande drainage system by approximately 2.25 million years ago, implying that Lake Cabeza de Vaca was a phenomenon of the latter Pliocene. This is considerably older than Strain's (1966, 1971) previous interpretation that it was of middle Pleistocene age, that was a result of imperfect understanding of the provenance of the Pearlette family ash in the lower Camp Rice (Gustavson 1991). Somewhat later, the divide between the Mesilla and Hueco Bolsons was breached, draining the remainder of Lake Cabeza de Vaca. However, smaller lakes, including Lake Otero in the Tularosa Basin (Blair et al. 1990a; Herrick 1904) and Lake Palomas in the Bolson de los Muertos (Reeves 1965; 1969), were intermittently maintained as pluvial lakes within the boundary of Lake Cabeza de Vaca through much of the Pleistocene. Relict gravel deposits in Fillmore Pass, between the Franklin and Organ mountains, suggest that the ancestral Rio Grande flowed here rather than between the Franklin and Juarez mountains, at one point (Seager 1981; Strain 1966, 1971).

Although Hawley (1981) suggests that this high channel represents the remnant of an integrated Pliocene drainage (in a sense, a true ancestral Rio Grande) that was disrupted by renewed

tectonism and range uplift (presumably in the late Pliocene), others (e.g., Blair et al. 1990a; Seager 1981;) have suggested that the Fillmore Pass alluvium represents Rio Grande alluvium post-dating Lake Cabeza de Vaca. The mapped distribution of Camp Rice fluvial facies in the southern Tularosa Basin (Seager et al. 1987) suggests that the Rio Grande drainage may have been diverted back into the Tularosa Basin at some time in the middle Pleistocene, forming or contributing to Lake Otero (Blair et al. 1990a). In either case, the conduit between the Mesilla and Hueco bolsons shifted to its present position south of the Franklins in Paseo del Norte prior to entrenchment of the modern Rio Grande roughly 600,000 years ago.

As integration of the Rio Grande drainage progressed through the Quaternary, the stream became a more efficient conduit and basin-wide aggradation gave way to incision of the modern Rio Grande valley, effectively terminating the deposition of the Santa Fe Group/Camp Rice Formation and forming the La Mesa geomorphic surface on the level bolson floor (Gile et al. 1981). Associated geomorphic surfaces/morphostratigraphic units on the fan-piedmont include the older Doña Ana and younger Jornada I piedmont surfaces, which are underlain by piedmont facies (i.e., alluvial fan sediments) of the Camp Rice. Both of these constructional surfaces formed prior to entrenchment of the Rio Grande and are considered part of the Santa Fe Group.

The Doña Ana and Jornada I surfaces exhibit very strong soil development, suggesting that they were stable for a considerable period of time. However, active fan deposition continued into the late Pleistocene in the form of broad piedmont alluvium termed the Jornada II in New Mexico (Gile et al. 1981). Roughly equivalent deposits in Texas have been divided into a series of fan and piedmont sediments termed, in order of decreasing age, the Miser, Madden, Gills, Ramey, and Balluco Gravels (Collins and Raney 1991). Monger (1993b) adapted the terminology of Gile and others (1981) to the deposits on Fort Bliss, and this terminology is also employed here.

Jornada II deposits reflect a basinward shift in the locus of deposition as the proximal fans were trenched and bypassed, resulting in a thin, broad mantle of gravelly sediments prograding out over the distal Jornada I surface and onto the basin floor. At the same time, activity on the margin of the entrenching Rio Grande valley led to the formation of a series of distinct pediment and terrace surfaces, including the Kern Place surface and the Gold Hill surface, inset against the Franklin Mountains and the elevated plain formed by the bolson floor (Kottlowski 1958). The proximal Jornada I and Doña Ana piedmont, bypassed by incised fan channels, continued to sub aeri ally weather, and were subject to slow lateral dissection throughout this period. On the bolson floor, fine-grained alluvium termed the Petts Tank alluvium began to accumulate in depressions on top of the La Mesa surface (Gile et al. 1981).

The Late Pleistocene and Holocene saw renewed alluvial fan deposition and an increase in eolian activity on the piedmont and basin floor. Several morphostratigraphic units/geomorphic surfaces of this age are identified in the region. The Isaack's Ranch morphostratigraphic unit/geomorphic surface consists of alluvial fan/piedmont alluvium that began to accrete sometime during the very late Pleistocene, after a period of relative quiescence and soil formation following cessation of Jornada II deposition (Gile et al. 1981). Like Jornada II, the Isaack's Ranch alluvium generally bypassed the more proximal older piedmont surfaces in entrenched channels, then spread out as fan deposits over the distal older fans. The Isaack's Ranch unit remains poorly dated, but appears to correspond to the last full glacial through late glacial era; in any case, deposition terminated by the early Holocene (approximately 7,000 years ago). Isaack's Ranch alluvium typically consists of relatively narrow, confined channels and associated unconfined sheet deposits of gravelly alluvium typically bounded by Jornada II deposits. Associated fine-grained deposits on the basin floor are termed the Lake Tank unit; other than a much less-pronounced degree of soil development, they are very similar to the earlier Petts Tank deposits (Gile et al. 1981; Monger 1993b). Monger (1993b) also identifies an Isaack's Ranch eolian unit, which is characterized by the development of an argillic horizon and well-developed Stage II carbonate morphology (i.e.,

distinct, relatively large carbonate nodules). Frequently, the Isaack's Ranch eolian unit is erosively truncated, leaving a lag of these nodules strewn across an exposed or buried truncation surface.

The majority of the Holocene is characterized by continued deposition of the Lake Tank unit in depressions on the La Mesa surface, by deposition of the Organ morphostratigraphic unit on the piedmont and as eolian sands on the basin floor. Like the preceding piedmont units, the Organ Alluvium generally bypassed the older proximal fan sediments in entrenched channels, but buried distal elements of the older units under fan and sheet alluvium. An idealized block diagram illustrating architectural relationships between these major depositional units is presented in Figure 2.11.

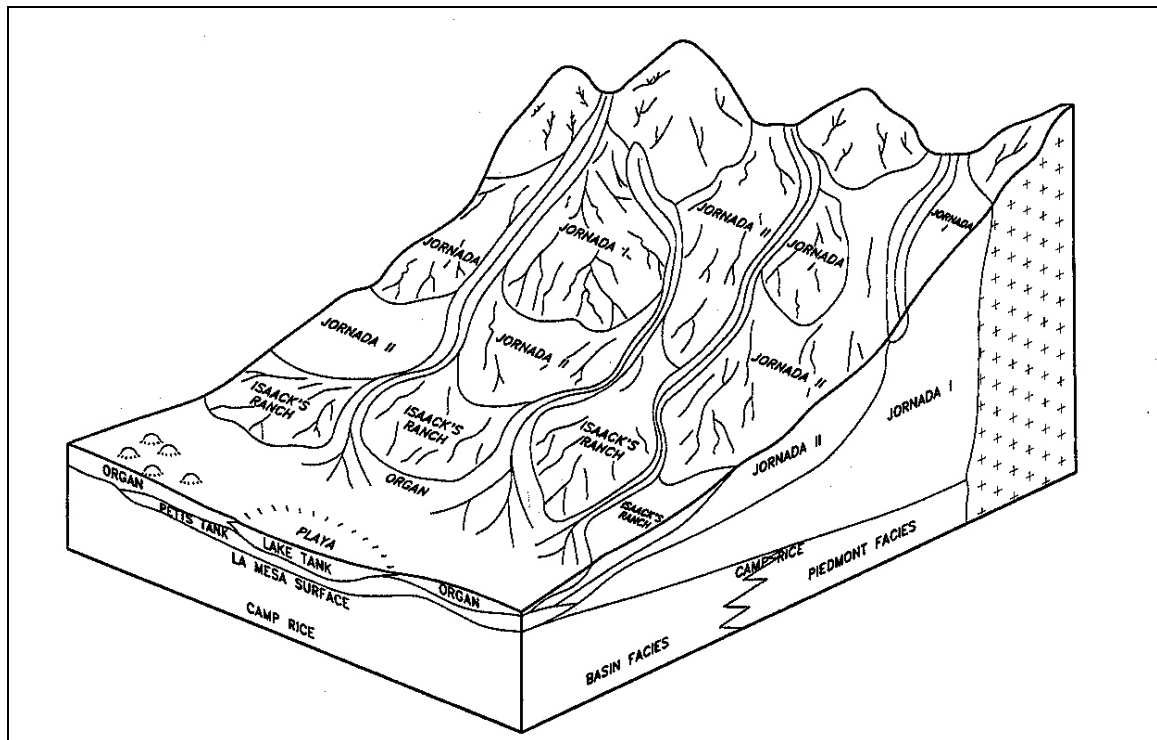


Figure 2.11. Block diagram illustrating relationships between morphostratigraphic units in the bolson.
(modified from Monger 1993a)

The Organ unit was originally defined as alluvial fan and piedmont alluvium by Ruhe (1964, 1967) but has since been expanded to also encompass eolian facies on the fans and basin floor (Monger 1993b). Organ alluvial deposition has been subdivided into three phases (termed Organ I, II, and III) that span the period from 7000 B.P. to immediately before the historic period (Gile et al. 1981). Monger (1993e) identifies three eolian phases and equates them both terminologically and temporally with the previously identified Organ alluvial sequence.

Organ I sands were deposited between 7000-2100 B.P., and exhibit moderate to good Stage I carbonate development and weak argillic development. Organ II was deposited between 2100-1100 B.P. and exhibits very faint Stage I morphology. Organ III was deposited from 1100-100 B.P. and exhibits no real pedogenic modification except formation of an A horizon (frequently absent due to erosive truncation) and bioturbation, which has eliminated evidence of primary

bedding. The three Organ units correlate to the single Quaternary depositional unit, Q3, as defined by Blair and others (1990a, 1990b). The dating and terminology of Monger's Organ eolian sequence has been the subject of several debates and proposed revision that are reviewed in Chapter 6.

A final series of deposits of historic age, including arroyo alluvium and extensive sheet sands, partially vegetated, mounded, and ridge like dunes, and mounded coppice dune sands, are nearly ubiquitous in the basin, particularly on the bolson floor. These deposits appear to represent the response of the landscape to grazing following Euro-American settlement of the region in the latter half of the nineteenth century. Historic eolian deposits are easily distinguished in section because they exhibit distinct primary crossbedding.

Because they are the sediments of culturally relevant age on Fort Bliss, Organ and post-Organ sediments, and to a lesser extent the sediments of Isaack's Ranch age, are of primary interest in this study, and will be addressed in a greater level of detail in the treatments of eolian and alluvial sediments in Chapter 6.

HYDROLOGY

Surface water on Fort Bliss is rare and ephemeral. With the exception of the Rio Grande south of the cantonment area and the Tularosa, Peñasco, and Hondo, rivers north of McGregor Range, permanent water sources presently do not exist in the immediate vicinity of Fort Bliss. Historically documented springs and seeps are known in the Franklin, Organ, San Andres, and Sacramento mountains.

Like other basins in south-central New Mexico (Leggat et al. 1963), ground water in the Tularosa Basin and Hueco Bolson is associated with aquifers in basin-fill sediments (Meisner and Hare 1915), particularly the Camp Rice and Fort Hancock Formations (Knowles and Kennedy 1956; Cliett 1969). Brackish groundwater can occur within a few hundred feet of the bolson floor, and becomes increasingly mineralized with depth. Some fresh water is available in the Camp Rice Formation, particularly adjacent to the Franklin Mountains, while water in the Fort Hancock Formation is highly saline. In general, this groundwater was completely unavailable to the prehistoric population and to plants. However, some shallow subsurface water was occasionally available to plants following rains due to the presence of the strongly developed La Mesa and Jornada calcretes, which effectively prevent deep infiltration. Although probably not often utilized as a source of drinking water, this ephemeral subsurface water would have been very important to wild plant production in the arid environment.

Due to the steep slopes of local mountain chains, shallow soils, and poor plant cover, runoff from the occasional heavy precipitation events can be very heavy, and surface drainages can rapidly become swollen and very active. In general, such surface drainages on Fort Bliss head as dendritic catchments in the mountains flanking the basin and emerge from the mountain front onto large, moderately sloping alluvial fan surfaces. These drainages tend to cut through the upper fans in incised arroyo channels before emerging into dendritic distributary channel networks on the distal fan surfaces. Thus, the drainages can be subdivided into three basic zones: a zone of erosion and entrainment, situated in the mountains; a zone of sediment bypassing where transport is relatively efficient in the channelized upper fans; and a zone of deposition, where the incised channel gives way to a dendritic distributary network of shifting, less-competent channels on the lower fan. In general, the distributary network of minor channels tends to die out before reaching the basin floor. In some situations such drainages concentrate within playa depressions situated at the interface of the distal fan and basin floor.

Innumerable playas are distributed across the Tularosa Basin and Hueco Bolson. They range in size from shallow depressions a few hundred square meters in size to the over 20 square miles of playa basin comprising Lake Lucero. Because of their size and histories of ponding water, many of these fan-margin playas have been called lakes and given names, such as Old Coe Lake, Davies Lake, and Lake Lucero. Hydrologically, there are two varieties of playas: 1) those that are hydrologically closed, referred to as discharge playas; and 2) those that are hydrologically open, termed through-flow playas (Rosen 1994). The latter are playas that are filled by ground water fluctuations; the former are filled by rainfall and runoff. The majority, if not all of the playas on Fort Bliss, are hydrologically closed discharge playas.

The nature of these playas has received increasing interest over the past few years (Church 2002; Miller 2004b). This includes their obvious benefit as locations of ponded runoff water for use by prehistoric populations, but also their role as focal points of increased biomass. Playas and the broad dendritic alluvial fans are probably the most critical natural catchment areas for understanding the relationships between hydrology and prehistoric settlement on Fort Bliss. Although numerous ecological, edaphic (soil formation), geomorphic, and hydrological aspects of playas have been studied, two are of primary importance for prehistoric research: the timing, duration, and frequency of water ponding in playas and the salinity of water and soils in playas. These issues are reviewed in greater depth in Chapter 6.

Several important aspects of water availability relevant to modeling prehistoric settlement and agricultural potential can be integrated from a closer consideration of these studies. First, in order for water to pond within many isolated playas and *bajos* (shallow depressions or swales), rainfall must be localized and fall directly within the immediate drainage basin of the playa. Second, rainfall must be of a rather substantial amount to result in the infilling of playas. Third, the duration and extent of water ponding will be highly variable, depending on the amount and duration of precipitation, evaporation rates resulting from seasonal and climatic variations in temperature and wind velocities, the nature of soil substrates, along with several as yet undefined parameters and conditions. On the whole, it is evident that the presence of water within a given playa or bajo is a highly variable natural phenomenon that has numerous implications for modeling prehistoric land use by agriculturalists and hunter-gatherer groups. For example, the scheduling of agricultural production on the basis of water being present in a given playa would involve a substantial degree of uncertainty and risk.

PALEOCLIMATE AND PALEOENVIRONMENT

At best, the paleoenvironmental conditions affecting the Fort Bliss region throughout the culturally relevant period are imperfectly understood, and much more basic research is needed to clarify the sequence of climatic and environmental change. Over the past decade since publication of the 1996 *Significance Standards*, only a small number of studies have been published describing paleoenvironmental and paleoclimatic conditions in southern New Mexico. Some of these studies, presented below, have questioned the conclusions of previous research based on pollen and isotope data, although no substantial body of new data has been compiled that would allow for significant modification of the paleoenvironmental trends during most of the Late Pleistocene and Holocene. A significant exception is the publication of a 1,373-year dendrochronological reconstruction of precipitation for south-central New Mexico.

Boundary Conditions of the Paleoenvironmental Record

The paleoenvironmental record from southern New Mexico, as well as any region of the world, is delimited by the age and nature of local sedimentary deposits. However, this introduces another issue, namely linking together and blending paleoenvironmental information derived from

different sources. Each methodology has its own limitations and nuances of interpretation, and each sedimentary deposit has a distinct origin that in turn places additional limits on the record.

Three basic avenues of information provide a basis for clarifying the paleoenvironmental record. First, instrumental records of historic patterns in temperature and precipitation provide a baseline for understanding deviation from the modern “norm” during the prehistoric period. This is most effectively accomplished through the analysis of tree-ring sequences. Second, a variety of types of proxy evidence that describe the landscape response to changes in climate can be employed to infer paleoclimatic conditions (Bradley 1985; Lowe and Walker 1984). Proxy sources of paleoenvironmental information relevant or potentially relevant to the Fort Bliss region are addressed in detail in Chapter 7. Finally, conceptual and numerical models of atmospheric dynamics and global circulation can be used to infer the mechanisms dictating the character of climate and climate change (Bryson et al. 1970; COHMAP Members 1988; Kutzbach et al. 1993).

Although a number of paleoenvironmental studies have been conducted in the bolson, their results have not resulted in more than a rudimentary level of information on local paleoenvironmental and paleoclimatic history. A very large part of the problem is a general absence of suitable localities where paleoenvironmental studies could be successfully pursued. At this point in time, paleoenvironmental information of various levels of usefulness has originated from four situations in the bolson and surrounding region. These include the analyses of pollen samples and stratified sequences from archaeological sites, woodrat middens and geological deposits; plant macro-remains from archaeological sites and woodrat middens; vertebrate faunal remains from geological deposits; and stable isotopes derived from stratified sequences of soil carbonate samples.

PALEOENVIRONMENTAL SUMMARIES

The late Quaternary vegetational history of the Southwest, including New Mexico, has been reviewed by Martin (1963) and Hall (1985, 1997, 2005). Only a few pollen studies have been conducted in south-central New Mexico, but they are all short of producing a long, well-dated record that would provide a clear picture of vegetation history spanning the past 20,000 years.

At a regional scale, the collective paleoenvironmental data from the Fort Bliss region present a picture of a stable, mesic terminal Pleistocene, followed by steadily increasing aridity through the Holocene. Figure 2.12 summarizes several paleoclimatic reconstructions from Fort Bliss and surrounding areas.

Late Pleistocene and Pleistocene-Holocene Transition

The Late Pleistocene Full Glacial was apparently a time of relatively cool, moist conditions, with widespread coniferous and mixed coniferous-deciduous woodlands. The entire region seems to have supported piñon juniper-oak woodland, while Douglas fir was present at elevations as low as 1,200 m (3,850 ft) (Van Devender 1990). On the other hand, insect data from packrat middens suggests that a well-developed grassy understory was present from at least 18,000 B.P. (Elias and Van Devender 1992). No modern Chihuahuan desert taxa appear to have been present (Van Devender et al. 1984). A Full Glacial (approximately 18,000 B.P.) faunal record from Dry Cave in southeastern New Mexico includes small mammals (e.g., prairie vole, least shrew) that occur now on the northern Great Plains, suggesting that winter precipitation was greater and temperatures were cooler, particularly in summer (Harris 1989, 1990). Lake levels from the San Augustin Plain in west-central New Mexico indicate that precipitation was high enough and evapotranspiration low enough to maintain a deep, permanent lake (Markgraf et al. 1984).

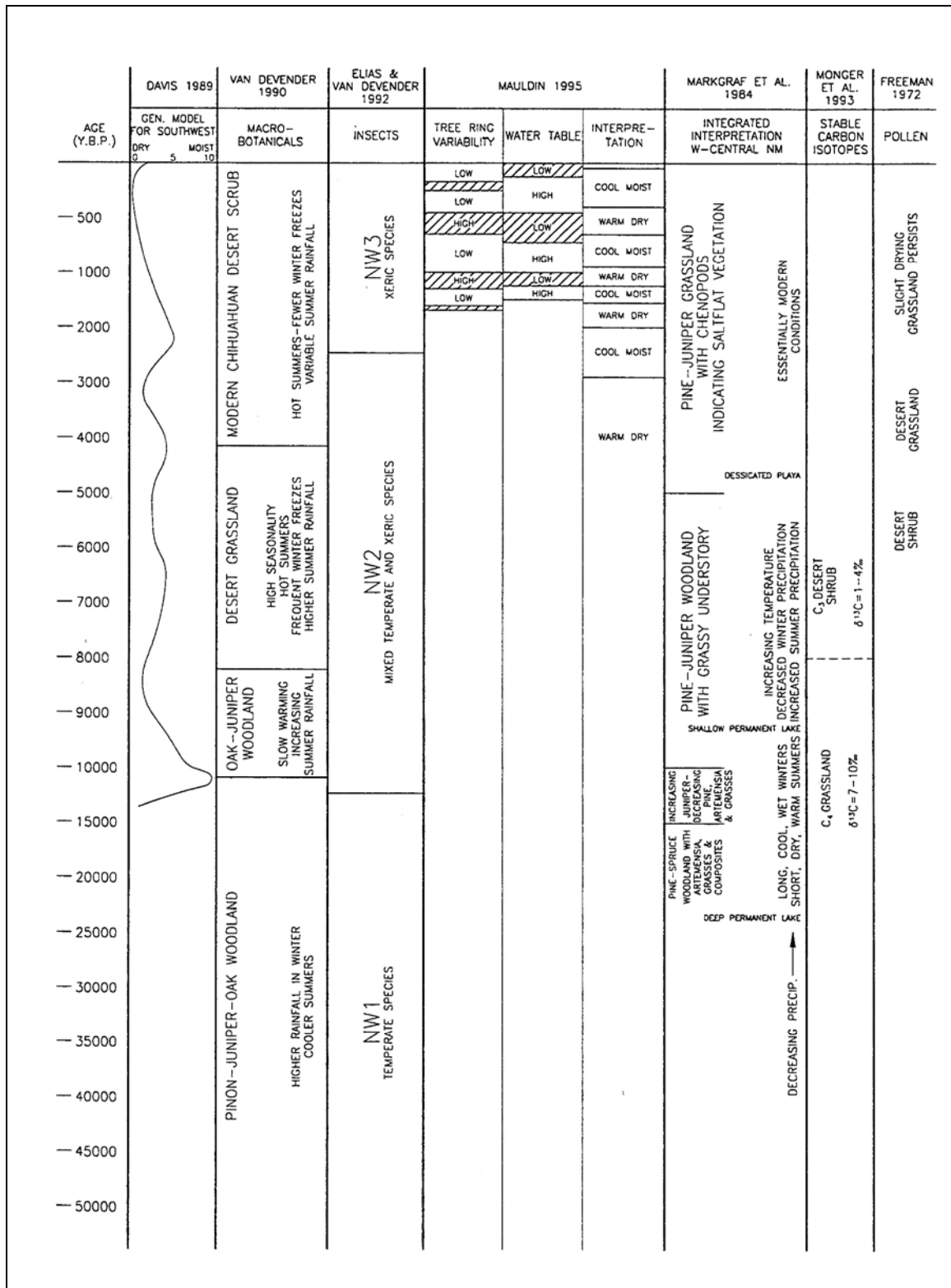


Figure 2.12. Summary of paleoenvironmental data from the southern New Mexico region.

In Late Glacial time (approximately 12,000 B.P.), the piñon-juniper forest continued to persist throughout the region, but the northward migration of a few cold-intolerant plants suggests that conditions were beginning to ameliorate, and particularly that the incidence of hard winter freezes was declining (Van Devender 1990). By about 12,000 B.P., effective moisture was also decreasing, resulting in gradual disappearance of mesic woodland species (e.g., Douglas fir, Rocky Mountain juniper) at the expense of more xeric species (e.g., piñon pine, one-seed juniper) between approximately 11,500-10,000 B.P. At about the same time, xeric insect species began to appear at the expense of temperate species (Elias and Van Devender 1992).

New investigations of fossil woodrat middens from the Playas Valley and Peloncillo Mountains south of Lordsburg, New Mexico, have been reported (Holmgren et al. 2003, 2006). According to Holmgren and others (2003, 2006), the Wisconsinian glacial-age flora was dominated by C4 grasslands with local trees.

Vertebrate fossils have provided valuable insights to past environments and climate. The Quaternary paleoecology of vertebrate fossil assemblages has been investigated for more than a century (Bell et al. 2004). Of the few discoveries of vertebrate fossils in the Tularosa Basin and Hueco Bolson, the most extensive record comes from Pendejo Cave. More than 41,000 identifiable bones were recovered from the cave; 93 percent of them were mammals and the remainder was reptiles, birds, and amphibians (Harris 2003). The vertebrate fauna shows that the Wisconsinian (late Pleistocene) climate was significantly cooler than the Holocene. A list of all taxa recovered from Quaternary vertebrate localities in New Mexico can be found in Harris (1993).

The Lake Otero Fauna is a series of fossil vertebrate records from the Lake Otero lakebeds (Morgan and Lucas 2002), that have recently been named the Otero Formation (Lucas and Hawley 2002). The fauna indicates cooler and wetter climate during the late Pleistocene and thus supports the studies described above. Fossil bones of *Mammuthus columbi* and *Camelops* sp. occur in the Lake Otero Fauna (Morgan and Lucas 2002), and mammoth (*Mammuthus* sp.) and camelid (*Camelops* sp.) tracks were also found preserved in the lake bed deposits (Lucas et al. 2002). Unfortunately, Holocene fossil vertebrates are rare in the region. Vertebrate remains are seldom recovered from archaeological sites and bone preservation in thin eolian sand deposits is generally poor.

Early through Middle Holocene

By the early Holocene (approximately 9000 B.P.), the transition from a mesic environment to a xeric environment was well underway in the vicinity of Fort Bliss. Packrat midden data from the Sacramento Mountains indicate that Douglas fir and Rocky Mountain juniper had disappeared, leaving piñon pine-juniper-oak woodland, which persisted until about 8000 B.P., when it was replaced by desert grassland (Van Devender et al. 1984). In the Hueco Mountains, piñon pine disappeared by 10,800 B.P. (Van Devender 1990). The next few thousand years were dominated by transitional woodland as the community continued to shift toward drier conditions. Van Devender (1990) interprets the changes as indicating that while winter rains were still dominant, summer precipitation increased to up to 40 percent of the annual total.

A clear transition toward a xeric community is indicated by data from about 8000 B.P. Vegetation shifts in the region include the appearance of desert scrub and succulents, including *Opuntia* sp. and honey mesquite, and the complete disappearance of temperate taxa. Arthropods also indicate the establishment of desert grassland conditions in the Hueco Mountains (Elias and Van Devender 1992), while stable carbon isotopes of pedogenic carbonates in the bolsons suggest a strong shift from C₄ grasslands toward C₃ desert scrub plants (Monger et al. 1993).

Van Devender (1990) argues that the shift at 8000 B.P. represents the onset of dramatically higher summer temperatures, continued frequent winter freezes, and a shift to dominantly summer precipitation. Somewhat later (approximately 7000 B.P.), geomorphic activity on the alluvial fans (Gile et al. 1981) and in the bolsons (Blair et al. 1990a; Monger 1993b) increased markedly, presumably in response to these climate changes.

Studies of soil carbonates in southern New Mexico, the Tularosa Basin and Hueco Bolson, and the Rio Grande Valley, have resulted in large data sets with $\delta^{13}\text{C}$ values that, based on the above information, represent C₄-dominated plant communities (Cole and Monger 1994; Monger 1993d; Monger et al. 1998; Deutz et al. 2001, 2002). The Tularosa Basin and Hueco Bolson record, however, has been interpreted as showing a shift from C₄-dominated grass to C₃-dominated shrub vegetation about 8000 years B.P. (Cole and Monger 1994). The study was criticized on a number of issues, including the fact that a number of Chihuahuan Desert communities today contain 50-90 percent standing crop biomass of C₄ plants (Boutton et al. 1994).

The Rio Grande Valley study (Deutz et al. 2001) does not support the Cole and Monger (1994) interpretation. Indeed, the data show a trend towards higher $\delta^{13}\text{C}$ values rather than the lower values as reported by Cole and Monger. All of the above isotope data and their correlation are dependent upon one assumption: that the radiocarbon ages of soil carbonates accurately represent true radiocarbon years and there is chronometric evidence (reviewed in Chapter 6) indicating that this is not the case. Accordingly, assertions concerning the environmental significance and timing of these isotopic trends and their correlation with more firmly dated paleoecological records may be spurious.

By about 6000 B.P., desert species such as mesquite and sotol were well established, but cold-sensitive Chihuahuan Desert taxa (e.g., lechuguilla) were generally absent, presumably due to continued severe winter freezes, and xeric grasslands were still widespread. Mesic plant and insect taxa were still present, but in low numbers. Lakes in west-central New Mexico suggest that by 5000 B.P., the Pleistocene pluvial lakes had been replaced by desiccated playa pans (Markgraf et al. 1984).

By about 4000 B.P., all of the modern Chihuahuan Desert Scrub taxa were present (Van Devender 1990), albeit possibly in relative frequencies and distributions dramatically different than at present, and the last of the temperate arthropod species disappeared by about 2500 B.P. (Elias and Van Devender 1992). According to the work of Holmgren and others (2003, 2006, 2007), after about 5000-4000 yrs B.P., C₃ desert shrubs abruptly became more prominent in the local flora. However, the paleofloral record of plant species presence is incomplete; only one dated midden was reported from the critical time period between 10,350-4990 14C yrs B.P. (Holmgren et al. 2006). The early Holocene and early mid-Holocene are missing from the midden record.

From approximately 4000 B.P. onward, major changes in biota are not apparent. However, variations in stream activity (i.e., episodes of aggradation and incision) and fluctuations in tree ring widths for the last millennium suggest that smaller scale fluctuations in climate continued to occur throughout the last few thousand years. Although grasslands in the mountains appear to be replaced by desert scrub by roughly 4000 B.P., the configuration of the eolian sand sheets in the bolson suggest that they were probably deposited in an environment with some grassy groundcover.

Late Holocene – Reconstruction of Precipitation and Temperature

One of the more noteworthy and significant paleoenvironmental studies of the past decade is the 1,373-year-long dendrochronological and dendroclimatological reconstruction of temperature and precipitation for the southern Rio Grande basin (Grissino-Mayer et al. 1997). The period of time covered by the reconstruction effectively spans the majority of the Formative period from A.D.

622-1450 and through the historic and modern periods to A.D. 1995. The sequence offers both high and low frequency resolution and demonstrates the presence of small-scale climatic fluctuations that were undoubtedly present throughout the entire Holocene.

The reconstruction is based on several existing tree-ring sequences, including the small number of archaeological samples available from prehistoric sites in the Sacramento and Capitan mountain region. These were augmented by tree-ring samples collected from the Magdalena, San Mateo, and Organ mountains that allowed local sequences to be extended back in time by several centuries. The Organ Mountain sequence has been extended back in time to A.D. 1306 based on several living and deadwood ponderosa pine samples collected at high elevations along the Organ Mountain needles.

Figure 2.13 presents the 100-year spline-smoothed curve for reconstructed precipitation patterns. Of interest are several periods of drought and high rainfall that correlate with major transitions in the Jornada Mogollon cultural sequence (phase boundaries) as recently defined by Miller (2005c) as well as approximate chronological intervals - termed "hinge points" (after Cordell and Gumerman 1989) - that characterize distinct, pan-regional times of change across the greater Southwest.

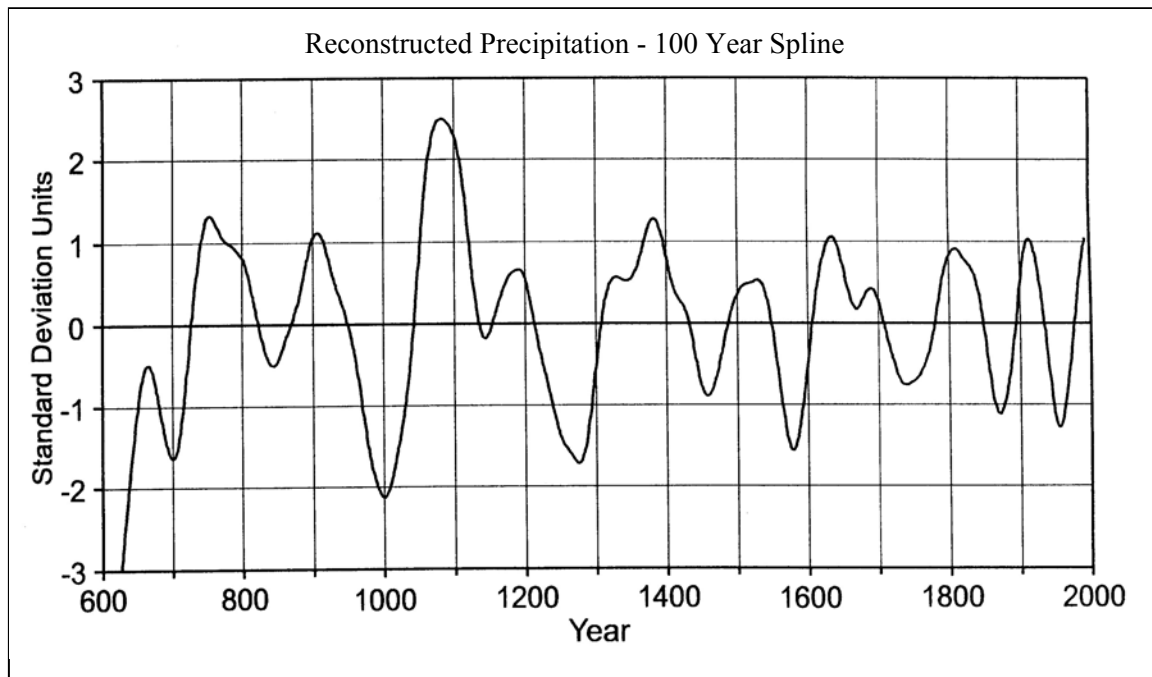


Figure 2.13. Dendrochronological reconstruction of precipitation for southern New Mexico and west Texas, A.D. 622-1995. (adapted from Grissino-Mayer et al. 1997)

As shown in Table 2.7, several of the more pronounced and prolonged drought episodes roughly correlate with important transitional periods in Jornada prehistory at circa A.D. 1000, 1150, 1275/1300, and 1450. Grissino-Mayer and his colleagues (1997) note that several of these drought intervals, including the "Great Drought" between A.D. 1210-1305 across the entire Southwest (A.D. 1246-1296 in the southern Rio Grande basin sequence), are correlated with major periods of cultural instability and demographic changes in the Mimbres Valley, northern Chihuahua, and Anasazi region.

In summary, the paleoenvironmental record of the Late Pleistocene through the Middle Holocene is based on information derived from vertebrate macrofossils, pollen, packrat middens, and stable isotopes. Late Holocene climatic records can now be based on empirically sound tree-ring reconstructions. With the exception of the dendroclimatic studies, many of these data are subject to debate or conflicting interpretation.

Table 2.7.
Rank Ordering of Decadal Length Prehistoric Droughts*

Rank	Period	Magnitude	Duration (yr)	Cultural Event or Transition
1	1272 – 1296	7.88	25	Transition to pueblo settlements (?)
5	881 – 885	6.75	5	
8	1445 – 1450	6.93	6	Abandonment of El Paso phase pueblos
9	998 – 1014	7.84	17	Mesilla to Early Doña Ana transition (?)
10	1246 – 1258	7.54	13	Transition to pueblo settlements (?)
11	1031 – 985	7.53	12	Mesilla to Early Doña Ana transition (?)
13	972 – 985	7.79	14	
14	1125 – 1140	8.18	16	Early to Late Doña Ana phase transition
17	1405 – 1415	7.90	10	

The rank sequence includes only prehistoric intervals; historic droughts between A.D. 1451-1995 are not included in this table. Magnitude measures the average precipitation per year for the specified period compared to the total average of 9.14 inches.

(?) denotes a general period of cultural transition that may relate to two or more sequential drought episodes.

*Modified from Grissino Mayer and others 1997: Table 6.

Yet, when considered in tandem, the Late Pleistocene and Holocene paleoenvironmental record in the vicinity of Fort Bliss reflects a basic trend toward increasingly warm and arid conditions throughout the Holocene, culminating in an arid environment that would have yielded resources grudgingly. It is almost certain that smaller scale fluctuations, such as are evident in the tree ring record, were superimposed on this long-term trend. It is likely that these smaller fluctuations had significant impacts on the abundance and distribution of water, plants, and animals that would have required adjustments in cultural systems designed to optimally exploit the marginal environment.

HISTORIC AND MODERN ENVIRONMENTS

Historic and modern climatic and environmental conditions have been reconstructed through dendrochronology, ethnohistorical and oral histories of explorers and settlers in the region, and through the study of historic records. Overgrazing and drought during the latter part of the nineteenth and early twentieth centuries resulted in severe soil degradation and radically altered vegetation patterns throughout much of west Texas and southern New Mexico; the most visible change being the widespread expansion of mesquite shrub communities (Buffington and Herbel 1965; Dick-Peddie 1975; Gardner 1951; York and Dick-Peddie 1969). The characteristic coppice dune topography of the present day interior basins is a result of these combined factors of drought, overgrazing, and soil erosion.

CHAPTER 3. PREVIOUS RESEARCH AND CULTURAL CONTEXT

Raymond Maudlin and Myles R. Miller

This section provides an overview of previous research and an outline of culture historical sequences in the southern or lowland section, of the Jornada area around Fort Bliss and its environs. This review is extensive, though not exhaustive. The discussion has been updated with new information available since 1996, but much of the original section remains relevant and has been left intact. A large number of archaeological projects have been conducted within the region since the early 1970s and particularly during the past decade since the publication of the 1996 *Significance Standards*, and it is not feasible to review all of these investigations. This review of work conducted after 1970, therefore, focuses on investigations on Fort Bliss, on larger projects outside of the military reservation, and on projects that have synthesized the overall state of research in the southern Jornada area.

The revision of this section incorporates several articles published since 1996 that provided comprehensive overviews of regional cultural historic sequences and settlement adaptations. Miller and Kenmotsu's (2004) contribution to the *Prehistory of Texas* (Pertulla 2004) volume provides a contemporary and updated overview of the 10,000 year-long prehistory and early history of the Jornada Mogollon and neighboring eastern Trans-Pecos region. After over 20 years of debate and dissension over the existence and nature of transitional periods between the pit house and pueblo periods, the Formative period phase sequence has been critically evaluated and a proposed revision to the original three ceramic phases (Mesilla, Doña Ana, and El Paso) has been published (Miller 2005c). Both of these studies build upon the chronometric trends among subsistence economies, architectural form, site structure, material culture, and land use using data compiled during the Fort Bliss CRCP report (Miller 1996).

The first discussion of this section introduces the taxonomic phase system commonly used in the lowland Jornada area and provides a synthesis of the current understanding of cultural history in that region. This discussion has been expanded with discussions adopted from Miller and Kenmotsu (2004). The next section provides a historical perspective on the development and implementation of culture history models in the region, and the final section summarizes recent developments in the region.

CURRENT CULTURAL HISTORICAL SEQUENCES AND PHASE TAXONOMIES

Currently, the archaeological systematics used to synthesize the organization of cultural systems across space, and to account for how these systems change through time, is a variation of cultural history models developed in the 1940s (see Lehmer 1948). While a variety of alternative schemes have been suggested for the southern Jornada area, most of these essentially rely on variations in artifact type or architecture on a site to assign the site, or components within a site, into temporal phases. Table 3.1 provides a summary of cultural periods, phase names, chronological time periods, and diagnostic artifacts and architectural characteristics commonly used in the region.

It should be noted that the diagnostic artifacts used to identify cultural periods in Table 3.1 are subject to debate and revision. The projectile point sequence is particularly in need of critical review as Jornada studies continue to rely on extraregional typologies. This often results in different names being assigned to the same morphological projectile point type. Additional

problems exist with the ceramic sequence, especially for the Doña Ana phase. These issues are addressed in greater depth in Chapter 5.

Revised Formative Period Phase Sequence

Problems with phase sequences are well known and critiques of their theoretical and normative foundations have often been cited (Cordell and Plog 1979; Plog 1983; Upham 1984), including criticisms of their utility in the Jornada region (Carmichael 1984, 1985a, 1985b, 1986a, 1986b; Mauldin 1995, 1996; Mauldin et al. 1998; Miller 1990, 1995). Among the criticisms is that they often assume homogeneity of material culture across regions. That is, they obscure variation because they tend to emphasize normative trait lists, ignoring or downplaying the fact that material traits often cross-cut phase boundaries.

Table 3.1
Summary of Cultural Periods, Phase Names, Chronological Periods,
Diagnostic Artifacts, and Architectural Characteristics

Years B.P.	Period Name	Phase	Diagnostic Artifacts / Architectural Characteristics
11,500			
		Paleo-Indian Clovis	Lanceolate fluted points
11,000			
		Paleo-Indian Folsom	Fluted points, endscrapers, Edwards Chert
10,000			
		Paleo-Indian Plano/Cody	Lanceolate points, parallel flaking "Cody", knife, endscrapers
8000			
	Archaic	Gardner Springs Jay and Bajada points	
6000			
	Archaic	Keystone	Todsen, Amargosa, Shumla points; shallow circular huts
4500			
	Archaic	Fresnal	Chiricahua, San Jose, Maljamar, Augustin, Fresnal points; shallow circular huts
2900			
	Archaic	Hueco	San Pedro, Hueco, Armijo points; houses similar to Fresnal
1850			
	Formative	Mesilla	El Paso brownware, Mimbres Black-on-white ceramics; pit structures, shallow circular huts
800			
	Formative	Doña Ana	El Paso Bichrome, Polychrome, Mimbres, Chupadero Black-on-white ceramics; rectangular pit houses with adobe
700			
	Formative	El Paso	El Paso Polychrome, Chupadero, Three Rivers Red-on-terracotta, Gila Polychrome ceramics; adobe rooms, square, shallow huts
500			

As chronological devices, they tend to be static and conservative, emphasize within-phase stability, and thus often give a false impression of a gradual, linear evolutionary trajectory that lacks episodes of rapid change. Yet it is difficult to avoid imposing some form of temporal taxonomic structure on broad evolutionary and developmental trends in prehistory. As with most

taxonomic systems, archaeological phase sequences serve as a convenient means of ordering information, and as such, an important point to consider is that they facilitate communication among archaeologists.

Generalized phase sequences serve as an integrative concept to examine broad developmental trends both within regions and that transcend regional boundaries. When Anasazi researchers speak of the Pueblo III period, most recognize a fundamental time interval of A.D. 1150-1350 (using the revised chronology in Adler 1996a) and an associated constellation of settlement, architecture, community structure, and material culture developments in the post-Chaco era of the northern Southwest. Similarly, archaeologists familiar with neighboring regions of the southern Southwest will recognize the Mimbres Classic period (A.D. 1000-1130, after Hegmon et al. 1999) and its attendant architectural, ceramic, and settlement attributes.

It has long been acknowledged that the Jornada Mogollon phase sequence was in need of critical review. This was particularly needed given the long term debate surrounding the nature, timing, and even the existence of the Doña Ana phase, whether as originally defined by Lehmer (1948) or as defined through several alternative phase sequences (see Miller 2005c: 61, Figure 1, for an illustration of 11 alternative sequences proposed since 1948). The intention was not to argue for or against the Doña Ana phase or any form of transitional temporal division between the pit house (Mesilla) and pueblo (El Paso) periods in the region.

Instead, the intent was to critically examine the sequence using the vast body of chronometric and contextual information compiled during the Fort Bliss CRCP report (Miller 1996) and ultimately to develop an empirically based sequence that could be used to compare and communicate prehistoric developments in the Jornada region with those across the southern Southwest. Based on an exhaustive review of over 1,600 radiocarbon and archaeomagnetic dates and the various temporal trends in subsistence, land use, and architecture illuminated by these dates, Miller (2005c) has proposed a revised Formative period phase sequence (Table 3.2).

Table 3.2.
Revised Formative or Ceramic Period Phase Sequence
(after Miller 2005c)

Phase	Calendar Dates	Common Diagnostic Ceramics
Mesilla phase	A.D. 200/400 - 1000	El Paso Brown, Mimbres Style I and II, San Francisco Red
Early Doña Ana phase	A.D. 1000 - 1150	El Paso Brown, El Paso Bichrome, El Paso Polychrome (early variant), Mimbres Style III, Viejo period wares
Late Doña Ana phase	A.D. 1150 - 1275/1300 (A.D. 1300 most likely)	El Paso Bichrome, El Paso Polychrome (early or transitional variant), Chupadero B/W, Playas Redware, Three Rivers Red-on-terracotta, St. Johns Polychrome, Viejo period wares
El Paso phase	A.D. 1275/1300 - 1450	El Paso Polychrome (Classic variant), Chupadero B/W, Three Rivers Red-on-terracotta, Lincoln Black-on-red, White Mountain Redware (Pinedale, Fourmile), Chihuahuan polychromes, Roosevelt Redware

The sequence is based on distinctive trends and transitions in land use, subsistence, technology, and architecture as is independent of local and regional chronologies based on ceramic seriation or typological variation. Of even greater significance and interest is that the proposed sequence serves to align developmental trends in the Jornada Mogollon region with those of adjacent

regions of the Southwest and north-central Mexico. Major transitions in the Jornada sequence occur at A.D. 1000, 1150, 1275/1300, and 1450.

In viewing the commonality of cultural processes that occurred across multiple regions of the Southwest, participants of the “Dynamics of Southwest Prehistory” seminar identified a series of approximate chronological intervals - or “hinge points” (after Cordell and Gumerman 1989: 6) - that characterized distinct, pan-regional times of change. It is quite interesting to note that these “hinge points” are closely aligned with the periods of transition now recognized in the Jornada region. The significance of this observation is summarized by Miller (2005c: 77):

Cultural evolutionary developments in the Jornada Mogollon have generally been viewed as peripheral to, and in a sense disconnected from, the more prominent and archaeologically visible regional systems of the Casas Grandes, Mimbres, western Mogollon, and eastern Anasazi areas. A number of factors have contributed to this perception, one of the foremost being the absence of a reliable chronology allowing the Jornada region to be incorporated into the broader picture of Southwestern prehistory. It is hoped that the proposed revisions to the Jornada chronological sequence will remedy this problem. Certainly, these can offer important insights into economic and social interaction between the Jornada region and the southern Southwest (including the Mexican Northwest) between the second and fifteenth centuries. If expanded to a larger scale, this perspective can in turn lead to new concepts and a more thorough understanding of regional trends in the Mogollon, Anasazi, and Casas Grandes regions.

Revised Terminal Formative and Protohistoric Period Phase Sequence

Another alternative sequence (Table 3.3) for the El Paso phase and subsequent Protohistoric and Early Historic/Spanish Colonial periods has been proposed by Seymour (2002). The proposed inception and terminal dates for the El Paso phase are based on a small number of radiocarbon age estimates and are not in agreement with those proposed above. The two phases proposed for post-pueblo or Protohistoric period prior to establishment of mission settlements establish a framework for future analysis. Seymour also presents a useful argument that the term Classic period be used in preference to Formative period when referring to the El Paso phase.

Table 3.3.
Alternative Pueblo and Protohistoric Phase Sequence
(after Seymour 2002)

Phase	Calendar Dates
El Paso (Classic Period)	A.D. 1200 - 1350
Canutillo	A.D. 1350 - 1535
Entrada	A.D. 1535 - 1659

GENERAL OUTLINE OF JORNADA MOGOLLON CULTURAL HISTORY

The earliest accepted occupation in the area is associated with Paleo-Indian (11,000-8000 B.P.) occupations, though MacNeish and others (1993) and MacNeish and Libby (2004) have recently claimed the recovery of material from Pendejo Cave in the Otero Mesa area that they argue dates prior to 35,000 B.P. Chrisman and others (1996) contend that human friction finger imprints from the cave also date to this time frame. These claims, however, have been questioned by other researchers (Dincauze 1997; Miller and Kenmotsu 2004: 211-212; Shaffer and Baker 1997) and cannot yet be reliably used. Paleo-Indian occupations are represented primarily by isolated finds

of projectile points and a small number of open sites in the Tularosa Valley (see Amick 1994a; Beckes 1977a; Carmichael 1986a; Krone 1975).

Relative to later periods, little is currently known of the Paleo-Indian occupations in the region. While at least 100 whole and fragmentary Clovis points have been recovered from the large Mockingbird Gap Site (Weber and Agogino 1968), and late Paleo-Indian (e.g., Plano/Cody) finds have been reported in the region (Human Systems Research [HSR] 1973), there are no well documented sites for either end of the Paleo-Indian temporal span, and little is known about Paleo-Indian adaptations in the region. At present, it is not clear whether this reflects actually sparse use of the region during the period, or if it is a result of problematic diagnostic criteria.

The Folsom manifestation of the Paleo-Indian period is well represented in the Tularosa Valley by both isolated projectile points and several Folsom sites (see Amick 1991, 1994a, 1996; Carmichael 1986a; Beckett 1983; see also Mauldin and O'Leary 1994). In an exhaustive review of Folsom assemblages from the region, Amick has argued that the Tularosa Folsom material represents only a component of a large-scale mobility system that involved assemblages on the southern Plains. He argues that the Tularosa Valley material represents a residential land-use pattern focused on nonbison game, while the southern Plains was focused on logistical bison procurement.

The final Paleo-Indian manifestations are known collectively as the Plano and Cody complexes (Wheat 1972) dating from approximately 8000-6000 B.C. Sites of this time period in the Hueco Bolson and Tularosa Basin occur with approximately the same frequency as the earlier Folsom components. The majority have been found near major water sources, including large playas (Carmichael 1986a), perhaps a reflection that these would be the locales most likely to attract large game animals. Investigations and analysis of the materials recovered from site LA 63880 on Fort Bliss provide the best documentation in the region about this period (Elyea 1988). Based on the extensive size of that site (78,000 square meters) and the high quantity of tools relative to other Plano/Cody complex sites, Elyea (1988) concluded that the site represented the remains of several small bands at a base camp.

The Archaic period (6000 B.C.-A.D. 200) in the El Paso area is better represented in the record. Often, however, sites have been assigned an Archaic period date based on the presence of dart points in their assemblages. In other parts of the country, seriation of dart point styles, combined with radiocarbon dates of those styles taken from good stratigraphic context and association, provide reasonable chronological control for such sites. In the Jornada region, many point styles have never actually been chronometrically dated, and no true seriation of Jornada types has been attempted (Miller 1996: 70). As a result, studies of settlement systems, mobility, and other important issues in Archaic lifeways are seriously impeded.

Excavations, many of which have been located on Fort Bliss, have documented substantial Archaic use of the area, especially late in the sequence, although "diagnostic" artifacts are rare. For example, Whalen (1980) excavated a series of hearths from small sites in Maneuver Area 1 that lacked any temporally diagnostic artifacts. Radiocarbon dates from this excavation, when corrected, range from 2480 B.C.-A.D. 939, although most of his 19 dates fall in the Late Archaic and early Mesilla phase date range. Mauldin, Graves, and Bentley (1994) completed a report on Project 90-11, located in Maneuver Area 1 that also focused on small sites. They suggest, based on a synthesis of radiocarbon dates for the region that a substantial number of small sites fall in the Late Archaic period. Similarly, the report for the Loop 375 project (Dering et al. 2001) suggests a substantial Late Archaic focus that was not revealed by diagnostics.

While an increasing number of dates are available that suggest Archaic use of the region, models of adaptations during this long period are limited. MacNeish and others (1993) have recently

outlined a phase sequence and Anderson (1993), relying primarily on survey data generated by Carmichael (1986a), used that phase sequence to produce a settlement systems model. Anderson (1993) suggests a reduction in mobility through time, increased regional population, and increased seasonality (see also Carmichael 1986a). While cultigens are clearly present in the area by 3000 B.P. (see Tagg 1996; Upham et al. 1987), most researchers suggest that a broad-spectrum adaptation tied to hunting and gathering characterizes the entire period.

The Formative period (A.D. 200-1450) is traditionally divided into three phases. These are the Mesilla phase (A.D. 200/400-1000), the Doña Ana phase (A.D. 1000-1300), and the El Paso phase (A.D. 1275-1450). The Mesilla phase is distinguished from the Archaic period by the presence of brownware ceramics. Mimbres Black-on-whitewares may come into the area after A.D. 750, though they generally are not common. Although true pit houses occur in the Mesilla phase (Lehmer 1948), most domestic structures associated with this phase are shallow, basin-shaped huts reminiscent of the earlier Archaic period structures (Hard 1983b; O'Laughlin 1980).

Sites became larger during the Mesilla phase and many more Mesilla sites and artifacts have been identified than have their Archaic counterparts. Whalen's (1977, 1978) survey of Maneuver Areas 1 and 2 recorded Mesilla phase sites in all environmental zones. Based on the wide distribution of sites, Whalen suggests that subsistence was derived primarily from hunted and gathered resources. Whalen's characterization of the phase is supported by several other studies, including Carmichael's (1986a) survey in the Tularosa Basin and macrobotanical studies by Hard and others (1996) and Miller and Kenmotsu (2004). In the latter study, data from more than 300 flotation samples obtained from seven pit house components dating between A.D. 400-1000, three pit house components dating between A.D. 1000-1150, two pit house and isolated room components dating primarily between A.D. 1150-1250/1300, and four pueblo and three isolated room sites dating from A.D. 1250/1300-1450 were utilized.

Although the results must be viewed with caution due to low quantities of samples containing macrobotanical materials, they do show ubiquity values for maize at no more than ten percent in the Mesilla phase. These findings are supported by the analyses completed for the Loop 375 project where Dering (2001: 457) compared density of maize in a Mesilla phase site (41EP2805) to two El Paso phase sites (41EP2724 and 41EP1602). The Mesilla phase site density index was extremely low (0.05 fragments per liter across all samples from the site) versus 0.28 and 0.16 fragments per liter, respectively, at the other two sites. Similar results were obtained from recent re-analysis of the Conejo Site (Goldborer 1985; Miller and Burt 2007).

Associated with his work at Turquoise Ridge on Fort Bliss, Whalen (1994a) proposed a Formative site classification based on the complexity of sites, with Class 1 sites being the most internally complex and Class 4 sites the least. He argued that the classification represented differing seasonal uses of the Jornada region. Class 1 sites thus are large, with large pit houses, extensive site and structure modifications, evidence of reoccupation, middens, and storage features, and are concluded to have served as winter base camps; they are located only along fans or rivers. In contrast, Class 4 sites are small, lack formal structures, and have low artifact content and diversity. Whalen argues that Classes 2, 3, and 4 reflect sites used as spring/summer provisioning camps. He also notes that the frequencies of Class 3 and 4 sites relative to Class 2 sites seem to change after A.D. 750, with no Class 2 sites observed prior to that date. Conversely, there are fewer Class 3 and 4 sites after A.D. 750. Whalen suggests that this pattern reflects intensification in the collection of nondomesticated resources during the warm season.

Hard (1983a, 1986, 1994) has outlined a detailed settlement/subsistence model in which environmental differences dictate seasonal rounds and activities. Hard's model shares many characteristics with that of Whalen; Hard argues that winter and spring residential sites are

located near the mountain alluvial fans with the central basin used in a logistical manner. During the summer and fall, Hard suggests a use of the central basin for short-term residences.

Recent investigations at the Conejo Site, one of the sites that Hard used to test his model, and re-analysis of the data from the site support Hard's suggestion that there was variable use of different parts of the landscape based on seasonality (Miller and Burt 2007) but are at odds with other parts of his model. Re-evaluation of the radiocarbon analyses for the site indicates that the site may not have been a winter base camp used by a number of families but rather a site used by one or two households and subsequently re-occupied. Moreover, the ceramic analyses suggest Mesilla phase pots were manufactured for durability and ease of transport throughout the region. In summarizing the Mesilla phase, Miller and Burt (2007: 9-6) state:

The Mesilla phase was a time of slightly increasing population aggregation within small settlements comprised of two or three household clusters. Distinct changes in regional land use have been detected, particularly between A.D. 650 and A.D. 1000 (Maudlin 1995, 1996; Maudlin et al. 1998; Miller 2002). Several variables indicate that during the latter part of the Mesilla phase territorial mobility ranges may have begun to be restricted by extra-regional population growth (Miller 2002) but it was not until the early and late Doña Ana phase that these patterns become pronounced.

The Doña Ana phase, first introduced by Lehmer (1948) and extensively employed by Carmichael (1985b, 1986a; see also Kegley 1982), is essentially equivalent to Way's (1979) designation of the Early Pueblo period (see also Whalen 1978). Carmichael (1986a) provided the first synthesis for this period. Based on survey data, he argues that it was during this phase that prehistoric occupational intensity was at its height in the region. While several researchers have questioned the ability of archaeologists to distinguish Doña Ana phase occupations from multicomponent occupations given the definitional characteristics (see Mauldin 1993a; Miller 1989, 1995, 2005c), Hard and others (1994) have argued that this phase can be distinguished with a detailed focus on ceramic attributes, and Dering (2001: 459) has noted that there is evidence of the increased use of domesticated plants during this phase.

Excavations at Doña Ana phase sites of Gobernadora (Miller 1989; Shafer et al. 1999), North Hills (Miller 1990), Meyer Range (Scarborough 1986, 1992), Tobin Well (Lukowski et al. 2006), and Hueco Tanks (Kegley 1982) have helped to re-define the period. Miller (2005c) presents a sound argument that the Doña Ana phase has often been misunderstood due to an over-reliance on outdated and erroneous ceramic associations, and the transitional period between Mesilla pit house settlements and El Paso phase pueblos should instead be conceptualized in terms of changing settlement and technological organization. Furthermore, the overly short 100-year duration of the phase as originally proposed by Lehmer should be expanded to the period of A.D. 1000-1275/1300.

The Late Formative period or Classic period occupation, the El Paso phase, is distinguished from the preceding Doña Ana phase by settlement in contiguous room pueblos, the continued development of locally made painted pottery (El Paso Polychrome), and the replacement of Mimbres Black-on-white with Chupadero Black-on-white as the primary intrusive ceramic ware. Regional survey data suggest that the most intensive prehistoric use of the region may have occurred during the El Paso phase. This period is marked by more and larger sites, greater artifact densities, and a clustered settlement pattern (Carmichael 1985b, 1986a; Whalen 1977, 1978). Pueblos are present along the Rio Grande, and both the western and eastern margins of the Hueco Bolson have large El Paso phase settlements.

Along the western bolson, Whalen (1977) found that nearly half of the El Paso phase villages were along low gradient alluvial fans, with many additional sites present near alluvial fans with

playas. On the eastern margin of the Hueco Bolson, villages associated with alluvial fans are documented as well (Whalen 1978). Whalen suggests that this location, in well-watered areas, hints at an agricultural focus during this period. While direct data on subsistence is limited, ethnobotanical and faunal data from a variety of excavations in the region support Whalen's view.

Agriculture becomes important during this period, though wild plants and animals, including fish, continued to play an important subsistence role (Bradley 1983; Foster and Bradley 1984; Foster et al. 1981; O'Laughlin 1977a). The flotation study by Miller and Kenmotsu (2004) shows a clear spike in ubiquity values of maize during the El Paso phase. While ubiquity values for maize hover around 10 percent in the Mesilla phase, they increase to 60 percent between A.D. 1275/1300 and A.D. 1400 (see Miller and Kenmotsu 2004: 249, Figure 7.29). Using the same calculation methods, Dering (2001:457) found similar results from site 41EP2724, an El Paso phase village where the ubiquity value for maize was 81.8 percent.

The actual degree of sedentism during the El Paso phase is unclear, as is the pattern of mobility. Mauldin (1986) developed a settlement and subsistence model for the El Paso phase. Mauldin's model is based on Hard's (1983a) Mesilla phase work, but assumes that agricultural dependence is somewhat greater. He suggests a dichotomy between primary and secondary villages. Primary villages should be located in well watered areas near mountain slopes. Mauldin argues that these sites will have a fluctuating population throughout the year and a high intensity of use. Subsistence is primarily based on agriculture. Secondary villages, located both along mountain slopes and in the central basin associated with playas, represent late summer residential occupations with a focus on gathering and hunting. While several researchers (e.g., Browning et al. 1992) have used the model to describe El Paso phase distributions, it has not been subject to any degree of testing.

In contrast, Miller (2004a, 2004b, 2005b) views the wide variety of El Paso puebloan settlements - including pit houses, formal rooms, and modular pueblo room blocks - as representative of a highly fluid settlement organization that was responsive to local environmental risk and stress. The El Paso phase settlement system involved periods of population aggregation and dispersion in response to the geographically patchy and temporally unpredictable rainfall patterns of the region. These settlement adaptations are seen in the social organization of puebloan groups as manifested in the construction of communal or socially integrative rooms at intermediate and larger pueblos.

Results of the excavations undertaken by the EPAS during the 1960s and 1970s at the Hot Well (41EP5) and Sgt. Doyle (41EP18) pueblos were recently published (Lowry 2005). While data from these sites are important in interpretations of the El Paso phase, that data should be used with some caution as the sites were excavated many years ago without modern techniques and research paradigms. Both sites are multiroom pueblos with individual room blocks. At Hot Well, individual room blocks were often spaced at some distance from each other; a cistern was also identified and partially excavated (Scarborough 1988). Based on the lack of bone recovered from room floors in Area 1 at Hot Well, O'Laughlin (2005a: 255) concludes that the room block was not occupied for long periods.

At both sites, El Paso brownware constitutes more than 95 percent of the ceramic assemblages; the few non-local wares indicate contact with other regions but suggest that the contact was limited. Within the two pueblos, evidence indicates that residents disposed of refuse in extramural pits (O'Laughlin 2005a: 248, 263). When comparing the two assemblages to other El Paso phase sites, Mesilla phase sites, and Archaic period sites in similar settings, O'Laughlin (2005a: 270) notes that these two sites both have much higher percentages of bone in their assemblages than all the other sites, even those of the El Paso phase, as well as significantly

higher proportions of identifiable bone indicating that there was either greater preservation operating at the Hot Well and Sgt. Doyle pueblos or different site maintenance behaviors operated at the various pueblos. Nonetheless:

there is no good evidence for either a shift in target faunal resources [in the El Paso phase], their relative contribution to the diet, or their acquisition through logistical strategies during this period. The same taxa are identified again and again in low-elevation regional assemblages, and in proportions that vary little....This is not only true of pueblo sites but of earlier and more ephemerally occupied sites (O'Laughlin 2005a: 273).

The end of the El Paso phase and prehistoric sequence occurred sometime between A.D. 1400-1450 (Miller 2005c). The large pueblo sites in the southern Jornada were clearly abandoned by this time, perhaps in response to the extended droughts throughout the greater Southwest. Upham (1984) argues that the local populations returned to non-sedentary adaptations. Spanish contact, which did not occur until the sixteenth century, documents the presence of local populations as dependent on limited agriculture and hunting and gathering (see Beckett and Corbett 1992). These populations are variously described as Manso and Suma (see Schroeder 1947; Kenmotsu 1994).

The period between the close of the El Paso phase and the first Spanish contact documenting these populations is not well understood in the region (Miller 2001). Thompson and Beckett (1979) report the recovery of metal worked into projectile points and Bentley (1992a), Beckett and Corbett (1992), Miller (2001) and Seymour (2002) provide summaries of known or suspected archaeological sites in the region that may date to this period. The most promising site that may represent a Manso settlement is LA 26780 located about 10 km west of Fort Bliss (Batcho 1987; Batcho et al. 1985; Miller 2001). The site consists of several hearths and artifact clusters. The artifact assemblage includes poorly fired sand-tempered brownware, small Harrell-style projectile points, and a partial rowel from a Spanish spur. These data, along with Spanish documents suggest the Manso, like the Suma, were at least semi-nomadic. Some native populations were partially assimilated by the Spanish (see Hammond and Rey 1966; Timmons 1990), while others moved south into Mexico and others intermarried with the Tigua and Piro settlements established southeast of El Paso after the Pueblo Revolt of 1680. Established mission settlements were present by the seventeenth century, and Euro-American populations were established during the early nineteenth century.

In an effort to better understand the historic Native American sites on its lands, Fort Bliss recently funded efforts to identify sites of Apache, Manso, Suma, Jano, and Jcome as well as Spanish affiliation (Baugh and Sechrist 2001; Seymour 2002). Baugh and Sechrist (2001: 276), using information from previous surveys on the military reservation, identified 48 previously recorded sites or localities that might have Apache components and revisited them for more intensive mapping and surface inspection to evaluate their potential for these components. Five were found to have high potential for such components and 12 were considered to have moderate potential for early Apache or Protohistoric period components (Sechrist and Baugh 2001: 283-290). In their conclusions, Baugh and Sechrist (2001: 290) note that sites from this time period are not only underrepresented on the reservation, they are very difficult to detect or evaluate as they have little artifactual or feature remains. Most have little material culture that would distinguish them from hunter-gatherer camps of earlier times.

Seymour (2002), in an attempt to develop a means to distinguish these components from earlier sites, did more intensive mapping and surface collections at 34 sites both on and off Fort Bliss Military Reservation, and from that work developed models for early Apache and Protohistoric period (Manso and Suma) sites in west Texas and southern New Mexico (Seymour 2002: 319-

340). Those models are largely based on geographic factors gleaned from passages in historic Spanish and English documents and have yet to be tested.

HISTORY OF ARCHAEOLOGICAL INVESTIGATIONS

The history of archaeological investigations at Fort Bliss and the greater Jornada region are reviewed in the following discussion. Professional archaeological investigation in the region generally lagged behind that of both the northern and western Southwest. While the surrounding Mogollon, Casas Grandes, and Anasazi regions were the subject of large-scale excavation projects during 1950s through the 1980s, the Jornada region received little attention from academic archaeologists and the larger archaeological community. Much of the earliest work in the area was conducted by avocational and amateur archaeologists, and while no formal reports are available for much of this work, reference to such undertakings are occasionally made in published reports in the late 1920s. With the enactment of historic preservation legislation in 1966 and the advent of CRM archaeology during the 1970s, Fort Bliss and the surrounding regions became the focus of the first long-term professional archaeological study, resulting in the large-scale surveys of the Fort Bliss maneuver areas (Beckes et al. 1977; Carmichael 1986a; Skelton et al. 1981; Whalen 1977, 1978).

The intent of the following discussion is not strictly historical. Rather, it is intended to illustrate the broad trends in cultural resources management and research programs of the past 60 or more years. Since the beginnings of CRM archaeology in the region, including the first Section 106 compliance review completed as part of a proposed land transfer on Castner Range (Aten 1972), Fort Bliss has funded and supported the vast majority of archaeological work in the region. However, over the course of the following 30 years, the emphasis, goals, and practice of CRM archaeology on the base have generally been designed in response to the changing nature of the military mission. The changing emphasis on survey, evaluation, programmatic research projects, and excavation have often been as influential in either limiting or illuminating our understanding of the past as have the advances in archaeological theory, method, and technology of the past three decades. For example, the focus on large-scale survey coverage designed to inventory the Texas and New Mexico maneuver areas during the 1970s and 1980s was not accompanied by extensive excavation data. Therefore, much of the interpretive focus during this period was on site typologies, phase assignments, and settlement pattern analysis.

Initial Explorations

Adolf Bandelier (1890) and J. W. Fewkes (1902), two early explorers and anthropologists, both played a part in the history of the immediate El Paso area with their descriptive archaeological knowledge and ethnographic accounts of vanishing peoples and lifeways. Several short summaries of archaeological work in the region were presented during the late 1920s and early 1930s. Chapman (1926) reported on pueblo sites on the west side of the San Andres Mountains; Crimmins (1929, 1931) provided short summaries of observations in the region prior to 1929, with special attention on the pictographs and petroglyphs; and Alves (1930) presented an early summary of caves and shelters in the region. While much of the published work for this period is strictly descriptive, those that do undertake any classificatory or synthetic statements seem to rely on the culture history scheme developed by Kidder (1927, 1962) for the northern Southwest.

C. B. and Harriet Cosgrove conducted some of the earliest professional work in the region in 1928, in the southern Hueco Mountains. Working in a series of caves currently located on Fort Bliss, the Cosgrove excavations and collections resulted in a variety of "Puebloan" and "Basket-maker" artifacts, including a large number of sandals, several atlatls, burials, and basketry. While a manuscript of this work was completed in 1934, it was not published until 1947. Cosgrove (1947) classified the wide array of artifactual material recovered from these excavations using the

cultural history scheme developed by Kidder (1962). Special attention was focused on the “Basket-maker” artifacts. In conjunction with cave and shelter excavation data from the Gila region and the middle Rio Grande, Cosgrove (1947: 164-170) compared the Hueco cave materials with those from the San Juan. He concluded that the Hueco and Upper-Gila material should be classified as similar, and that this material reflected the “Hueco Basket-maker” people. Cosgrove (1947: 170) further concluded “...the Hueco Basket-makers were an off-shoot of the San Juan Basket-maker, that...spread southeast along the Rio Grande into western Texas and perhaps into Coahuila, Mexico....”

With the exception of Cosgrove’s work, and a cursory survey of the region by Sayles (1935), the pre-1940s excavations and surveys were primarily concerned with the Pueblo period. For example, Bradfield (1929) and Stubbs (1930) report on pueblo excavations conducted around Alamogordo, New Mexico, information that was subsequently reported by Lehmer (1948). Both Bradfield (1929: 5-6) and Stubbs (1930) made reference to the artifactual remains present at these sites as reflecting cultural influence from outside the region, primarily based on ceramics from better studied regions.

In addition to these early excavations, Mera (1931, 1938, 1943), Stallings (1931) and Mera and Stallings (1931), provided early summaries of ceramics types in the region, and Alves (1930, 1932a, 1932b, 1934) provides early accounts of material culture, again primarily associated with Pueblo occupations in the region. Stallings (1932) provides a brief overview of the region’s ceramics and limited information on several known sites, concluding that the artifacts in the region reflected a “pueblo” occupation. Finally, Herbert Yeo provided descriptions of sites along the Rio Grande, including observations in Sierra and Doña Ana counties, which are on file at the Laboratory of Anthropology in Santa Fe.

The pre-1940 period, then, focused primarily on the Pueblo period. This was probably related to the higher visibility of such sites, their large size, and their location along the fans and river that were undergoing modern development. The presence of painted ceramics of both local and extra-local origin, along with a high frequency of shell beads and stone “fetishes,” also contributed to this pueblo focus. As the work of the Cosgroves had not yet appeared in print, there were essentially no syntheses of pre-puebloan archaeology in the region. The pueblo focus had resulted in descriptions of artifacts and architecture, which were primarily explained by reference to interaction with surrounding areas. Information on ceramics was of special concern, as ceramics, especially those that were “intrusive,” provided both chronological data and ways to trace cultural interaction, a position consistent with the culture history focus. This focus was to dominate the region until the early 1970s.

Initial Synthesis and Supporting Work

Lehmer (1948) provided the first truly synthetic framework for the region. Working essentially under the same theoretical position as early researchers, but with a “Mogollon” (Haury 1936) rather than “Anasazi” (Kidder 1962) focus, Lehmer conducted a series of excavations throughout the region in 1940. Lehmer’s excavations essentially focused on three sites. In conjunction with previous survey and excavations, he conducted work at the Los Tules Site, a large pit house site located along the Rio Grande, La Cueva, a cave located in the Organ Mountains, and the Bradfield Site, a pueblo located in the Tularosa Basin near the Organ Mountains. He also relied on the earlier work of Stubbs (1930) and Bradfield (1929) at pueblo sites near Alamogordo. These excavations and observations in the region provided the first detailed synthesis of the prehistory of the region. Lehmer (1948: 70-90) used these data to define the Jornada Branch of the Mogollon people (see Haury 1936).

Lehmer's excavations at Los Tules represent the first systematic research into the Pit house period. Los Tules is, in effect, the type-site for the Mesilla phase. Lehmer excavated 11 pit houses at the site. In light of subsequent excavations in the region, these structures are somewhat anomalous, being both quite large and deep. Several additional features, including two internal storage pits and two external, bell-shaped pits of substantial size, were located at the site. Over 5,600 ceramics were collected from Los Tules, and "intrusive" wares accounted for roughly 14 percent of this total. The intrusives were exclusively from the Gila/Mimbres area, and included Mimbres Black-on-white, Mimbres Corrugated, San Francisco Red, and Alma Plain.

Work at La Cueva provided stratigraphic evidence that allowed the elucidation of ceramic change through time. Excavating primarily on the talus of the "hideously disturbed" cave (Lehmer 1948: 35), Lehmer's excavations apparently produced few artifacts, but did uncover El Paso Polychrome, El Paso Brown, Chupadero Black-on-white, Mimbres Black-on-white, and Three Rivers Red-on-terracotta ceramics. It appears that intrusive ceramics were confined to the upper 30 cm of the deposits and El Paso Polychrome ceramics were confined to the upper 60 cm. Below 60 cm, only El Paso Brown ceramics were recovered (Lehmer 1948: 38).

The final site investigated by Lehmer was the Bradfield Site. In conjunction with the previous work of Stubbs and Bradfield at the Alamogordo sites, it allowed for definition of the El Paso phase. The Bradfield Site consisted of 16 rooms, 13 of which were excavated. Over 94 percent of the ceramics recovered were El Paso Polychrome, with Chupadero Black-on-white, Three Rivers Red-on-terracotta, Gila Polychrome, and Ramos Polychrome being the primary intrusive wares (Lehmer 1948: 47). Lehmer reports on a similar range of ceramic types from the Alamogordo sites; the principal difference is an increased occurrence of Lincoln Black-on-white in these northern sites (1948: 59).

Lehmer's synthesis resulted in the establishment of a basic phase sequence, with phases serving as time and space boundaries for cultures in the area. Employing the dendritic model of Gladwin (1934, 1936; Gladwin and Gladwin 1934; see also Haury 1936), he identified the region as the "Jornada Branch of the Mogollon Culture." His primary spatial boundary was between the northern and southern regions, the latter of which includes the El Paso area.

In the southern region, Lehmer identified four phases. The earliest was the Hueco phase, which predated A.D. 900. It was described as a "manifestation of the Cochise pattern," a pattern seen as the "concrete expression of the Mogollon Root" (Lehmer 1948: 90). While none of Lehmer's excavations dealt with this phase, he relied on early work of Sayles (1935), Cosgrove's yet unpublished work, and conversations with local amateur archaeologists to provide a brief description of common artifacts and a discussion of the distribution of similar "Cochise" artifacts from the surrounding regions.

The Hueco phase was followed by the Mesilla phase. Defined based on his excavations at Los Tules, La Cueva, and surface collections on sites in the region, Lehmer argued that the phase consisted of circular and rectangular pit houses, El Paso Brown ceramics, and occasional Mimbres Black-on-white. While infrequent, several cases of painting on the local ceramics were uncovered. Lehmer argued that the Mesilla phase arose from the Hueco phase as a result of interaction with surrounding cultures, primarily the San Marcial phase to the north, and to a lesser extent, the San Francisco and Three-circle phases in the Gila area (Lehmer 1948:77). Ground stone assemblages were dominated by basin metates and one-hand manos. Based on the occurrence of Mimbres Black-on-white, and the lack of later ceramic wares, Lehmer suggests a time range of A.D. 900-1100 for this phase.

Lehmer defined a third phase primarily on his work at La Cueva and surface collections of sites in the region (Lehmer 1948: 78-80). He suggests that the upper deposits of this cave, which contained aspects of both the preceding Mesilla phase and the later El Paso phase, reflected a

“Doña Ana phase” occupation. The application of paint to the El Paso Brown ceramics increased and Lehmer suggests rim form changes on vessels relative to earlier and later phases, a suggestion subsequently explored by West (1982), and Whalen (1993). Though no formal excavations of open sites had been conducted, Lehmer suggested that the architecture consisted of both adobe surface structures and pit houses. Intrusive ceramics, including the occurrence of both Mimbres Black-on-white and Chupadero Black-on-white, were used to assign a date range for the phase from A.D. 1100-1200.

Lehmer’s final phase, El Paso, was the best known, having received the most attention by both Lehmer and earlier researchers. Defined by the occurrence of El Paso Polychrome and contiguous adobe surface rooms, the phase was argued to reflect the supreme prehistoric development in the cultural sequence. Basin metates and one-hand manos were less common than in previous phases, having been increasingly replaced by slab and trough metates and larger manos. Interestingly, the pottery seems to represent a complete replacement of El Paso Brown. That is, there is no undecorated pottery during this phase. The principal intrusive ceramics include Chupadero Black-on-white, Gila Polychrome, and wares from Chihuahua (e.g., Ramos Polychrome). Based on the intrusive ceramics, Lehmer suggested a time frame of A.D. 1200-1400.

Following Lehmer’s synthesis, and the publication of Cosgroves’ work on the “Hueco Basketmakers,” little professional work was published in the region between 1948 and the late 1960s. Moore (1947) published a description of a 12-room house ruin and a small Pueblo period site located on Fort Bliss, along with a description of a cache of local and regional vessels (Moore and Wheat 1951) recovered from northeast El Paso. The local amateur archaeology society, EPAS, became increasingly active in the late 1960s and throughout the 1970s. The journal of the society, *The Artifact*, provided an important outlet for both amateur and professional investigation in the region, a role that it still fills. Much of the work conducted by EPAS during this time period was conducted on Pueblo-period occupations. These El Paso phase excavations included work at the Sergeant Doyle Site, the McGregor Site, Condon Field, Escondido Pueblo, Three-Lakes Pueblo, and Hot Wells Pueblo.

While many of these excavations revealed small (fewer than about 15 rooms) pueblos, work at the large site of Hot Well Pueblo, located on Fort Bliss near the Texas/New Mexico border, revealed over 100 rooms (Lowry 2005). Although the site had a long history of excavation, work by EPAS (e.g., Brook 1966a, 1970, 1971, 1980) revealed several rooms with evidence that suggested a variety of special functions. In addition, a reservoir was uncovered that may have supplied water to the site’s inhabitants (see Brook 1966a; Scarborough 1988).

In addition to the Pueblo period focus, Paleo-Indian occupations of the area were also increasingly investigated, primarily by EPAS members (Quimby and Brook 1967; Russell 1968). Of special interest was the Three Buttes locality, located on McGregor Range. Krone (1975) provides details on collections from this locality; over 140 Folsom points, 26 preforms, and several channel flakes have been collected from this location (Amick 1994a: 102).

The Large-Scale Surveys and Establishment of the Cultural-Ecological/Processual Paradigm

By the late 1960s, it was still the case that the majority of work was concentrated on the highly visible El Paso phase pueblo occupations or the Paleo-Indian (primarily Folsom) finds in the region. Knowledge of the Mesilla phase had changed little from Lehmer’s original 1940s work, and knowledge regarding the Archaic period was essentially limited to Cosgrove’s early excavations. As late as the mid-1970s, researchers still relied on Lehmer’s cultural history scheme to identify stylistic markers, and assigned sites to phases based on similarities in artifact

types. The chronology for both the close of the Archaic period and all of the Formative period was consistent with Lehmer's suggestions. However, the focus on the ends of the prehistoric continuum, the acceptance of Lehmer's basic chronology, and the focus on cultural interaction as a prime cause of cultural developments, was all about to change.

The changes in the post-1960s archaeology work in the area were the result of two factors. First, primarily as a result of mandated CRM work in the region, a large survey and excavation database was generated, and second, changes in the explanatory focus, which were occurring in archaeology in general, began to filter into the lowland Jornada region. As noted by Chapman (1988), the enactment of Federal historic preservation laws had a direct effect on archaeological practice in the region, particularly at military installations such as Fort Bliss and White Sands Missile Range, the two largest landowners in the region. Section 110 and 106 compliance programs required archaeological inventory surveys of military training areas. At Fort Bliss, these included Maneuver Areas 1 and 2 in Texas (Whalen 1977, 1978), Maneuver Areas 3 through 8 in New Mexico (Carmichael 1986a; Way 1979); and sample surveys of the Doña Ana Firing Ranges (Beckes et al. 1977) and McGregor Range (Skelton et al. 1981).

The results of these two developments were: (1) the identification of a substantial number of sites in the central basin landforms of the Tularosa Basin and Hueco Bolson (2) the realization that the vast majority of sites lacked any temporally diagnostic artifacts; (3) the documentation of significant Archaic period and Mesilla phase occupations in the region; and (4) the rise of several debates over time-space systematics, phase taxonomies, site typologies, and cultural evolutionary interpretations of settlement pattern data.

Accompanying this expansion in survey and site data was an increasing emphasis on cultural ecological and processual explanations for changes in the archaeological record, but the data were still grouped in terms of the cultural history time blocks established by Lehmer. HSR was one of the first groups to introduce a "systemic" perspective into the region. Though much of their work was conducted in the northern portion of the Tularosa Basin and Sacramento Mountains, the Human Systems Research Technical Manual (1973) and its report on a survey of the Three Rivers Drainage (Wimberly and Rodgers 1977) were explicit calls for a "...systems theoretical approach to explain the adaptation of extant human populations to their environment..." (Human Systems Research 1973: 16). Human Systems Research deserves credit as one of the first groups to incorporate changes in the broader archaeological discipline, initiated in the early 1960s, into the Jornada region.

This concern with adaptation and settlement organization was increasingly incorporated into local professional and amateur projects in the region, including a number of early CRM projects conducted in the El Paso area during the 1970s and early 1980s. These included projects located on the eastern slopes of the Franklin alluvial fans (e.g., Aten 1972; Hard 1983b; O'Laughlin 1979, 1980; O'Laughlin and Greiser 1973; Thompson and Beckett 1979), western El Paso (Carmichael 1985a), and Fort Bliss (Hard 1983a, 1987). The concern with settlement mobility and landscape use reflected the broader disciplinary focus on processual archaeology of the period.

However, while literally thousands of sites had been identified and recorded during the surveys of the late 1970s and early 1980s, few were excavated. The few excavations that were conducted were often unreported or under reported. While some radiocarbon dates had been obtained, the sample of dates was geographically scattered and often from questionable contexts and associations (see Hard 1983b for an exception). In his 1981 summary of chronological studies, Whalen (1985) could list only 72 radiocarbon age estimates. Due to the paucity of excavation data and consequent reliance on surface survey data, many of the larger questions of the processual research agenda could be addressed only in a cursory manner. Basic issues of

chronology remained unresolved, and even a reliable chronological ceramic sequence was lacking.

This situation improved during the mid and late 1980s with the publication of several landscape-scale excavation projects of multiple small sites such as the Navajo-Hopi Land Exchange west of El Paso (Camilli et al. 1988; O’Leary 1987) and the Loop 375 project on Fort Bliss in the Hueco Bolson (Dering et al. 2001; O’Laughlin and Martin 1989, 1990; O’Laughlin et al. 1988). The results of intensive excavation projects at Keystone Dam (Carmichael 1985a), Meyer Range Pit House Village (Scarborough 1986), the Doña Ana Airport Pit House Settlement (Batcho et al. 1985), and Gobernadora and Ojasen sites (Miller 1989) were reported during this period.

These projects represented a fundamental change in the design and importance of chronometric studies for local research, building upon the statistical treatment of multiple dates applied by Hard (1983b) at the Castner Range sites. The chronometric dating programs at these sites involved upwards of 30 dates, often using multiple samples from single proveniences that were subjected to statistical contemporaneity tests to identify and eliminate faulty dates. Multiple techniques such as obsidian hydration, archaeomagnetism, and ceramic thermoluminescence were used in an attempt to obtain corroborative dates and crosschecks.

In all, over 200 radiocarbon age estimates were reported during the two-year period of 1988 and 1989. As with the fluorescence of geomorphic research, these chronometric studies generated considerable interest and an appreciation for the role of well-designed chronometric studies, as well as the need to obtain multiple dates from complex sites. As noted by Miller (1996: 1), as of 1996 over 90 percent of the radiocarbon dates from the entire Jornada Mogollon region were obtained during the ten-year period between 1986 and 1996 (Figure 3.1)

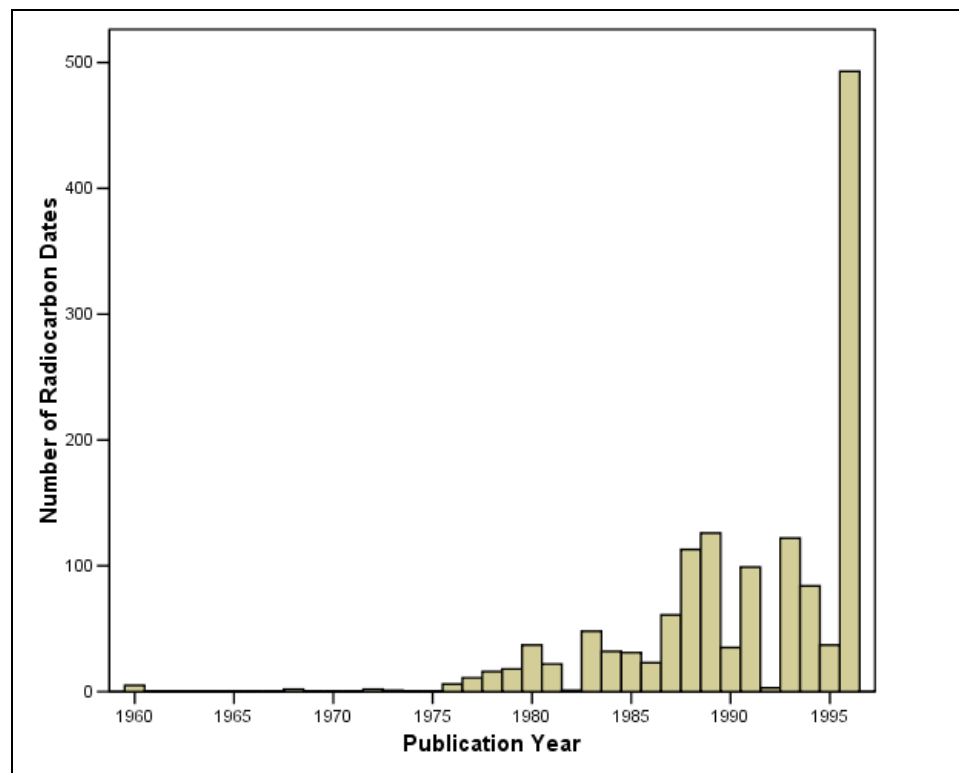


Figure 3.1. Histogram of published radiocarbon dates by year, 1960 - 1996.

The predominant research directions of this period involved synchronic, middle-range investigations. Whereas under the traditional cultural history position sites were seen as locations that contained artifact types that reflected similarity in culture, sites were now seen as locations of past behavior that reflected differences in adaptations to environmental and economic conditions. A variety of projects fell under the synchronic umbrella. These included the surveys and excavations conducted by Whalen (1977, 1978, 1980, 1986, 1994a) and Hard (1983a, 1983b, 1987) for the Mesilla phase, the work of Anderson (1993), Carmichael (1985a), and MacNeish (1993) for the Archaic period, and the work of Mauldin (1986) for the El Paso phase. Using temporally diagnostic artifacts to place sites into periods, site distributions were considered against environmental variables. Ethnographic models were then consulted, and the adaptation during a given period of time was reconstructed. These synchronic models were then stacked in time, differences between the models exposed, and diachronic explanations provided for these differences. The primary explanation for change involved some form of population growth resulting in subsistence and settlement changes.

While these synchronic/diachronic models provided a useful synthesis of phases, the large majority of sites at Fort Bliss lacked any diagnostic artifacts. For example, the Fort Bliss site files contained data on nearly 13,000 prehistoric sites in 1996, 86 percent of which lacked any diagnostic artifacts. Thus, without the availability of absolute chronometric dates, these synchronic models accounted for only a small percentage of the known record. The failure of synchronic models to effectively integrate the vast majority of the record led several researchers to propose alternative systematics for describing and explaining the record.

Fluctuating/Competing Adaptations: The focus on large sites to the exclusion of the more numerous smaller occupations characteristic of synchronic models led several researchers to question both the utility and reliability of the dominant phase-based synchronic sequence. Several researchers suggested alternative schemes, ones in which either distinctive adaptive trajectories were represented, or ones in which a fluctuation between a dependence on wild foods and a dependence on farming occurred (see Carmichael 1983, 1985a, 1986b; Johnson and Upham 1988; Kauffman and Batcho 1983, 1988; Stuart and Gauthier 1984; Upham 1984, 1988). Following Cordell and Plog (1979), these researchers argued that the linear models of adaptation, such as those inherent in the phase-based perspective, obscured cultural variation by focusing on modal characteristics and emphasized within-phase continuity as opposed to periods of change. The nondiagnostic sites were seen as evidence for that cultural variation. Alternative schemes were eventually suggested in which the archaeological record was argued to reflect either distinctive adaptive systems or economic fluctuation between a dependence on wild foods and a dependence on farming.

Relying on terminologies developed to describe ecological systems, researchers began to identify “stable” or “power-based” systems that were characterized by large, architectural sites, often with substantial dependence on agriculture and “resilient” or “efficient” systems characterized by small, nonarchitectural artifact scatters (see Carmichael 1985a; Johnson and Upham 1988; Kauffman and Batcho 1983; Stuart and Gauthier 1984; Upham 1984, 1994). Carmichael (1985a: 30) summarized aspects of this position in noting that “Sites used to define a phase sequence will represent the remains of a stable strategy while the others (perhaps the majority) could be the byproducts of several strategies.”

Both the focus on economic fluctuations and the “adaptive diversity” approach involved the suggestion that these small lithic sites represented different hunting and gathering adaptations. In the fluctuating adaptive position, cultural systems oscillated between an emphasis on agriculture and an emphasis on hunting and gathering. For example, Carmichael (1983, 1986a) argues that the archaeological record from the central Jornada indicates a “cyclical pattern” in energy production. In the competing adaptive approach, which is the more frequently relied upon

scenario, these small sites are contemporary with the larger sites. As Johnson and Upham (1988: 69) note:

In the Jornada Mogollon region, the model of adaptive diversity suggests that sedentary agriculturalists could have settled in the Rio Grande River Valley and in other areas where deep alluvium exists... At the same time, other parts of the environment...could have been utilized by groups relying on a mobile settlement strategy that were largely dependent on hunting and gathering.

Clearly, a variety of adaptations may have been present at various points in the past. The “adaptive diversity” or fluctuating adaptive scenarios recognized this possibility. Unfortunately, there was no well-developed methodology for recognizing these distinct systems. Whereas in earlier periods of research the differences between sites were “explained” by reference to the different cultures that produced them, or by differences in adaptation to different environmental conditions, those sites that did not fit into the traditional phase system were “explained” by creating a new category of “adaptation” that was not required to conform to the traditional phases.

Nonsite and Landscape Issues: Finally, a number of nonsite or landscape approaches have been attempted in the region as well (see Camilli and Ebert 1992; Camilli et al. 1988; Seaman et al. 1988). Using point provenience artifact data from a series of 400-m by 400-m blocks along the west mesa region northwest of El Paso, Camilli demonstrated that a variety of different clusters could be isolated, depending on the scale of analysis. She concludes that “varying archaeological densities within a region are likely the result of different histories of debris accumulation” rather than any single “function” (1988: 61). In contrast to a site-based analysis, Camilli (1988) analyzed these distributions by grouping them into “clusters” using a cluster algorithm, and investigated patterns in artifact variety and number as a function of “occupational history” (see also Camilli and Ebert 1992) rather than as a distinct settlement type.

Camilli’s analysis, as well as that of others who take a “nonsite” approach, clearly recognized important problems with the site concept. Yet the interpretations of the archaeological patterns, either in terms of past systemic, behavioral, or nonbehavioral processes, remain problematic. The nonsite approach clearly allows the identification of different patterns, but the proponents of this approach still do not have any systematic way to interpret those patterns.

Several researchers during the late 1980s and 1990s echoed the arguments of the “nonsite” advocates that interpreting sites as directly informative of discrete past activities may be unwise (see Doleman et al. 1991; Mauldin 1995, 1996; Mauldin et al 1988; Seaman et al. 1988). Relying on geomorphic mapping of Fort Bliss by Monger (1993a), as well as studies of the impact of survey transect spacing on site size, Mauldin (1995, 1996) argued that many of the variables commonly used to classify sites (e.g., artifact variety, artifact density, the presence of temporally diagnostic artifacts) into different site types (e.g., Fresnal phase macrobands, Mesilla phase residential sites) are in part, a function of geomorphology and survey intensity.

Working from this “landscape” perspective, several researchers began to examine patterns of material culture across broad landforms and time frames. These studies were immensely aided through the use of extensive data compilations obtained at Fort Bliss during the mid-1990s, including macrobotanical samples (Hard et al. 1996; Miller and Kenmotsu 2004), ground stone (Hard et al. 1996; Mauldin 1995), thermal features (Mauldin 1995, 1996; Mauldin et al. 1998) and a database of several thousand chronometric dates organized by topographic landform and prehistoric feature types (Miller 1996).

Mauldin (1995, 1996) used radiocarbon and obsidian hydration dates, ground stone data, and paleoenvironmental data to argue that a significant reorganization of mobility and subsistence occurred in the local sequence between A.D. 700-1000. This shift, which may have involved a

change in the way that the central portion of the Hueco Bolson was used, along with a shift in the importance of agriculture in the subsistence base, is not associated with a shift in artifact types traditionally used to isolate phase sequences. Additional studies by Miller (2001, 2002, 2005c) and Miller and Kenmotsu (2004) provided crucial insights into changing patterns in subsistence economies, landscape use, feature technological variation, and regional exchange patterns.

Non-Site Survey Methods

The non-site survey programs of the late 1980s had a significant long-term impact on the design of archaeological survey. During survey of several land parcels west of El Paso for the Navajo-Hopi Land Exchange, Eileen Camilli and her colleagues adopted a non-site inventory strategy (Camilli et al. 1988). All surface cultural materials were plotted, assigned to a descriptive artifact class, and mapped. The mapped artifact and feature distributions represent spatially discontinuous patterns of highly variable density formed through multiple prehistoric occupations and discard events. Accordingly, the practice of defining “sites” on the basis of surface material density or perceived breaks in distributional patterns is seen as arbitrary and fundamentally flawed.

While the theoretical and methodological basis of this approach was broadly accepted, the method could not be reconciled with the need to define spatially bounded “sites” as management entities for evaluation and treatment mandated under Section 106 and Section 110 compliance programs. Since the preponderance of archaeological work in the region was conducted under Federal and State historic preservation laws requiring the identification, evaluation, and treatment of sites, the non-site approach could not be effectively operationalized. Most cultural resource managers affiliated with federal agencies in the region did not look favorably upon the method.

Still, the method resonated among many archaeologists who were struggling to define and interpret “sites” among the extensive artifact distributions across the central basins in any consistent manner. Those familiar with the underlying theoretical and conceptual basis of the method - involving hunter-gatherer land use, settlement organization, and site formation processes derived from processual and behavioral archaeology - were also favorably disposed towards non-site survey methods. Attempts were made to apply hybrid forms of non-site methods, such as the landscape sampling survey method utilizing systematically spaced recording transects developed at Fort Bliss during the mid-1980s.

This method was mandated for use during the BorderStar 85 survey and was found to be inappropriate both for standard site definition and non-site research (see Seaman et al. 1988 for a detailed critique). Non-site methods were generally discontinued soon after the publication of the BorderStar 85 survey. However, with recent advances in computer and global positioning system technologies, aerial imagery, and geographic information systems, a thoroughly revised and modernized version of non-site survey has recently been applied at Fort Bliss.

As noted in Chapter 1, the non-site approach has led to the current survey methodology that is employed at Fort Bliss DPW-E. This methodology, called TRU survey, has led to greater consistency in recording of archaeological materials, and generated a database that can be employed to better manage archaeological materials at Fort Bliss and to conduct future research regardless of theoretical perspective.

Geomorphic Investigations

During the investigation of several sites on the Mesilla Bolson west of Las Cruces, New Mexico, Kirkpatrick and Laumbach (1983) first observed an apparent association between prehistoric artifacts and features and the stratum of coarse, reddish sands underlying the modern coppice dunes across the project area. While the issue of site burial and exposure and artifact movement in active eolian landscapes had received passing attention in several studies (Beckett 1980;

Carmichael 1986a; Kauffman 1984; Whalen 1980), systematic efforts to characterize the effects of eolian deflation and burial were seldom considered (but see Beckett 1980).

Archaeological surveyors observed the phenomenon of sites and portions of sites disappearing and appearing after particularly intense dust storms across the Hueco Bolson and Tularosa Basin, and were confronted with the growing realization that surface manifestations were not an entirely reliable or complete representation of the archaeological record. Problems of surface visibility and changing site inventories were recognized during the Office of Contract Archeology (OCA) survey of the BorderStar 85 training area on White Sands Missile Range. Acknowledging the potential effects on site content and interpretation, Seaman and others (1988: 143) note that:

“...it has become increasingly obvious that understanding the geomorphological context of archaeological remains in terms of site formation processes and how the surface visible portion of the record relates to subsurface distributions, is a kind of information critical in assessing the validity of any interpretations made using survey data.”

With this perspective in mind, Seaman and colleagues further suggested that the integration of geomorphic and archaeological studies was paramount for future research. Their advice was taken seriously, and during the subsequent survey and test excavations for the Ground-based Free Electron Laser Technology Integration Experiment (GBFEL-TIE) project, OCA brought together geomorphologists, soil specialists, and archaeologists in a multidisciplinary effort to characterize local geomorphic processes and stratigraphic formations (Doleman and Blair 1991; Doleman and Swift 1991; Doleman et al. 1991, 1992).

The result of this effort was the identification and definition of the Quaternary stratigraphic sequence for the Tularosa Basin (Blair et al. 1990a, 1990b). Additional studies were conducted in the Mesilla Bolson that demonstrated the sequence extended beyond the Tularosa Basin (Blair 1988; Miller 1988). Meanwhile, Basabivazo and Earl (1987) addressed the issue of how variable dune formations and corresponding erosional landscapes affected the surface visibility of prehistoric artifacts.

It is not unrealistic to state that these studies had a revolutionary effect on the design and conduct of archaeological work in the region, although it is understood that this local development also reflects the widespread incorporation of geomorphic research in CRM practice across North America during the late 1980s and 1990s. Geomorphic and geoarchaeological studies became a common component of archaeological survey and excavation projects (Doleman et al. 1991, 1992; D. Johnson 1997; Miller 1988; Monger 1993a, 1993b, 1993c; Smith 1999, 2005). Geomorphic factors influencing site formation processes, including differential burial and exposure and artifact size sorting, are routinely taken into consideration (Burgett 1994; Doleman 1992; Mauldin et al. 1998; Schutt 1992). Archaeologists continue their efforts to understand the effects of coppice dunes and sheet sands on site visibility and preservation and the effects of partial data sets on analyses of assemblage composition.

Programmatic and Thematic Research at Fort Bliss

Prehistoric archaeological research in the Jornada region during the 1990s was dominated by projects conducted on or sponsored by Fort Bliss. During the early and mid-1990s, the Environmental Division of Fort Bliss sponsored several programmatic projects that were designed to address specific problems and deficiencies in the regional database. The projects included the *Small Site Project* (Mauldin et al. 1998), *Lithic Source Project* (Church et al. 1996), *Chronometric and Relative Chronology Project* (CRCP; Miller 1996), *Geomorphology and Landscape Mapping Project* (Monger 1993a), *Fort Bliss Pre-Acquisition Historical Project* (Faunce 1997), *Military Impact Assessment Project* (unpublished), and the analysis and

publication of EPAS excavations at Hot Well and Sgt. Doyle pueblos (Bentley 1993; Lowry 2005). These projects presented a rare and unprecedented opportunity to compile and synthesize data from multiple projects or to conduct focused investigation on a particular problem domain, such as the sources of stone material used for chipped stone tools or the reliability of obsidian hydration dating. Over the course of the following decade, the projects generated a diverse series of publications and publicity for the Fort Bliss CRM program (Church 2000; Mauldin 1995, 1996; Miller 2001, 2005c; Miller and Kenmotsu 2004; Monger and Buck 1995).

These projects were instrumental to many advances in understanding regional developments. It is also evident that, beginning in the early 1990s, the volume of archaeological work sponsored by Fort Bliss has essentially set and defined the research agenda for the Jornada Mogollon region. As seen in Figure 3.1 (see Figure 3.1), the pace and dimensions of this research program can be gauged by the five fold increase in reported radiocarbon dates for the 1996, with nearly 500 dates submitted by the thematic and compliance projects sponsored by Fort Bliss between 1992 and 1996.

SUMMARY - 1996 TO THE PRESENT

With the completion of the programmatic and thematic projects between 1996 and 1998, Fort Bliss initiated a strong Section 106 compliance program in consultation with the Texas and New Mexico SHPOs. With the expansion of training activities and base facilities, projects conducted at Fort Bliss during the late 1990s and early 2000s have been driven more by specific military construction and training undertakings rather than broad thematic programs. However, as noted in Chapter 1, the development of the *Significance Standards* in 1996 established a benchmark summary of current research domains and analytical issues.

Large-scale surveys continued to be a major focus of investigation and more than 100,000 acres have been surveyed on McGregor Range in New Mexico and Maneuver Area 1 in Texas. The scope and extent of these surveys inspired a modern refinement of the TRU survey method (Kludt et al. 2007; Lukowski and Stuart 1996; Mauldin et al. 1997; O'Leary et al. 1997; Stowe et al. 2005). The foundations of this new approach share similarities with certain aspects of non-site archaeology as applied during the Navajo-Hopi Land Exchange project (Camilli et al. 1988) but include Geographic Information System (GIS) mapping routines to define the "sites" required for evaluation and management under Section 110 and 106 of NHPA.

At the present time, archaeologists working at Fort Bliss and the greater Jornada Mogollon region are witnessing the convergence of several of the developments reviewed throughout this section, as well as the continued integration of modern computer hardware and software such as GIS and hand-held portable data recorders (PDA), the use of GPS technology, aerial imagery, remote sensing, and various analytical technologies (neutron activation analysis, residue analysis, luminescence dating).

As an example of such convergence, non-site survey methods have been integrated in the TRU survey method and made more accurate and replicable with the use of GPS and PDAs during fieldwork. Geomorphic mapping and field inspection are then used to evaluate site densities and predictive models based on the likelihood of burial and exposure. Spatial models derived from cultural ecology and based on ethnographically documented patterns of site formation are used to examine the non-site artifact distributions. GIS-defined sites are then evaluated for research significance and NRHP eligibility based on a refined understanding of geomorphology, chronology, and settlement patterning obtained during the thematic projects of the 1990s.

Geomorphology remains a significant component of research and site evaluation. As reviewed in Chapter 6, many of the issues regarding terminology, field identification of strata, and the

chronology of the Quaternary (Q1-Q4) or Organ (Organ I-II-III) depositional units remain unresolved. Recent advances using optically-stimulated luminescence (OSL) suggest previous conceptions of the age of these units may be in error. Archaeologists continue to wrestle with issues of artifact visibility and site discovery, artifact size sorting, and problems of biased assemblages recovered from deflated surfaces that may represent only a fragment of the total prehistoric occupation area within a particular site.

The history of research in the El Paso area for much of the twentieth century reflected a concern with space-time systematics, site typologies, and potential interpretive biases resulting from inappropriate field methods and geomorphic factors influencing site visibility. It is put forward here that archaeological research at Fort Bliss and the greater Jornada Mogollon region is moving beyond the conventional concerns with space-time systematics and typological constructions. Beginning in the late 1980s and continuing to the present time, research in the area has seen a greater emphasis on theoretical issues of broader archaeological and anthropological relevance.

CHAPTER 4. THEORETICAL PERSPECTIVES

Myles R. Miller and Tim Church

Chapter 4 is a new addition to the *Significance and Research Standards* and is intended to provide a brief overview of theoretical perspectives that should be considered during the design and conduct of archaeological research at Fort Bliss. The current version of the Significance and Research Standards takes into account the need to broaden and diversify the theoretical basis of archaeological research conducted at Fort Bliss and Jornada Mogollon region. The 1996 *Significance Standards* was weighted towards a synchronic cultural-ecological and systems theory paradigm. It must be emphasized that the intent here is not to disparage the cultural ecological/systems theory paradigm - a paradigm that has served well for over 30 years as an overarching framework to model prehistoric adaptations at Fort Bliss.

However, we do take issue with this being the sole perspective, particularly if the end result is the neglect of social and behavioral theories. An extensive body of anthropological and archaeological literature dealing with social, behavioral, political, and ritual aspects of human interaction, adaptation, and economy has been published over the past decade.

While a certain proportion of such research admittedly falls within hyper-relativistic [i.e., subjective, non-scientific, and humanistic] realms of post-processualism theory (*sensu* Hodder 1985; Shanks 1992; Shanks and Tilley 1992), there nevertheless exists a substantial amount of social and behavioral archaeology that is both firmly grounded in a long tradition of anthropological theory and has a firm empirical basis (see for example Adler 1994, 1996b; Feinman et al. 2000; Spielmann 1994; Varien 1999; Walker 1995, 2000; and various articles in Hegmon 2000; Lipe and Hegmon 1989; Mills 2000, 2004; Varien and Wilshusen 2002; and Wills and Leonard 1994, to provide but a small sample of recent Southwestern references).

In critiquing the overt bias toward ecological factors common among many Southwestern archaeologists, Wilcox observes that:

The resulting models treat the humans who occupied the prehistoric cultural landscapes of the Southwest as animals helplessly subject to the forces of environmental change or demographic densities.....The possibility that the prehistoric people had social organizations, economic organizations, political organizations or ideals that affected what they did, is not seriously considered [Wilcox 1996: 241].

While Wilcox's case is clearly overstated, it nevertheless conveys the potential pitfalls of failing to consider alternate social, political, and economic models. Moreover, many of the topics once subsumed under the broad umbrella of cultural ecology have been supplanted by theoretical developments in the fields of evolutionary ecology and human behavioral ecology (HBE). Several subdisciplines of HBE have investigated the adaptive significance of food sharing, social distance and residence, sexual division of labor, historic demographic patterns, and residential movement (Winterhalder and Smith 2004), several of which overlap with the dimension of human social and political organization.

Accordingly, Chapter 4 sets forth a proposal for broadening research perspectives beyond cultural ecology and processualism and is intended to provide a summary discussion of a selection of current theory. The competing and complementary theoretical perspectives reviewed in the following section include:

- Cultural ecology and processualism
- Behavioral archaeology
- Human behavioral ecology
- Evolutionary archaeology
- Theories of social, political, and ritual organization
- Post-processual critiques and perspectives

In the corroborative spirit, this expanded theoretical mosaic represents a consensus (although by no means unanimous) position of the regional archaeologists and cultural resource managers present at the roundtable discussions hosted by Fort Bliss. The attendees of this meeting engaged in debate over which theoretical approaches would be most appropriate for the cultural and environmental contexts of Fort Bliss and the greater Jornada region, as well as which approaches could be effectively operationalized and empirically tested using the archaeological data commonly recovered from prehistoric sites at Fort Bliss. It was agreed that five of the six domains listed above were appropriate; post-processual approaches were generally viewed with disfavor among the participants. However, recognizing that some post-processual ideas, such as agency theory, were worthy of consideration, a review of the post-processual critique is included.

It is also recognized that no single theory will achieve the goal of understanding prehistoric human behavior, social dynamics, ecological adaptation, or cultural change and evolution, and that multiple perspectives serve to enhance our understanding of the variety of prehistoric settlements and technologies represented by the material remains at Fort Bliss. Schiffer (1999: 167) perhaps best expresses this sentiment:

Given the wide range of current questions, we must acknowledge that theories from diverse programs are needed to help answer them....No theoretical program in archaeology – or elsewhere in the sciences – is comprehensive when it comes to explaining variability and change in *human* behavior. [emphasis in original]

For example, if the goal is to understand the shift from game hunting to intensified bulk plant processing during the Jornada Mogollon Formative period, it would be useful to refer to optimal foraging models derived from human behavioral ecology. In contrast, behavioral and materialist models do not adequately explain the construction and use of communal or ritual facilities at residential settlements. The use of these distinctive structures is most productively studied through reference to social theories of political organization, land tenure, and power relationships. It is also noted, however, that Fort Bliss may at times elect to use other approaches if: 1) a site has unique characteristics that warrant such an approach; or 2) when Fort Bliss has tried the primary approach set forth in this chapter and found that it is not as productive as hoped.

PROCESSUAL ARCHAEOLOGY, CULTURAL ECOLOGY, AND SYSTEMS THEORY

The theoretical tenets of processual archaeology and cultural ecology – representing the predominant archaeological and anthropological paradigm of North American archaeology for the past 40 years - are well known to most archaeologists and cultural resources managers working at Fort Bliss and throughout the Jornada region. Accordingly, an extensive and detailed overview of all aspects of processual archaeology is not necessary. Instead, the manner in which the concepts and approaches of processual archaeology have been applied to – as well as constrained by – archaeological research at Fort Bliss are considered in greater depth.

As with several of the theoretical domains to be reviewed in the following section, processual archaeology represents a fusion of theories and methods rather than a single monolithic idea or concept. Processual archaeology was ultimately an expression of the integration of several currents of thought, as well the expansion and development of new methods and approaches in

the field and laboratory. The “new” archaeology of the 1960s incorporated the cultural ecology and multilineal evolution of Julian Steward (1955, 1956, 1968), the evolutionary thoughts of Leslie White (1949, 1959), and systems theory of Karl von Bertalanffy and other biologists and sociologists. These were then brought together under the positivist and scientific outlook derived from Hempel and Popper. As a reaction against the historical particularistic, descriptive focus of archaeology prior to the 1960s, this explicitly scientific approach was also very much a confident and optimistic outlook on the potentially larger contribution of archaeology to the sciences (Binford 1962a, 1965a, 1965b; Binford and Binford 1968; Clarke 1968; Flannery 1968; Plog 1974; Watson et al. 1971), although at times this confidence was manifested in the form of polemical debates.

The essential tenets of thought and action comprising processual archaeology may be summarized as follows:

- a belief in the ecological and evolutionary basis of culture and culture change;
- a materialist focus, in that technological and economic factors were thought to play a primary role in the evolution of cultures and social formations;
- a reference to biological systems theory, where cultural systems consisted of components and subsystems regulated by feedback mechanisms;
- an explicitly scientific epistemology, including the search for laws and testing of hypotheses and development of “middle-range” theory; and
- the borrowing of methods from multiple disciplines, development of new methods, and application of these methods to archaeological problems.

Cultural Ecology and Cultural Evolution: Processual archaeology was much more than just cultural ecology, yet nonetheless cultural ecology was the nucleus of principles and models from which processualism and its various components derived their primary inspiration and foundational concepts. As defined by Julian Steward (1968: 337), cultural ecology is “...the study of the processes by which a society adapts to its environment.” Steward divided cultures into core and secondary elements. The culture core consisted of elements such as technology, as well as political, social, and religious organization, that defined “...the constellation of features which are most closely related to subsistence activities and economic arrangement” (Steward 1955: 37). In other words, the culture core contributed to successful adaptation to the physical environment and, in turn, was most directly structured or influenced by the environment.

The nature of the core components was determined by structural and functional relationships among themselves and with aspects of the surrounding environment that were most critical to survival. Similar environmental conditions would lead to similar technological adaptations and social institutions, ultimately resulting in *generalized* similarities among cultures that were otherwise geographically and historically unrelated. Secondary elements were those that did not contribute to the adaptation and survival of a culture and were unaffected by environmental conditions. The presence of secondary elements was due to historical events and processes such as diffusion and random invention. These attributes manifested themselves through the diversity of cultural expression but served to obscure the regularities among culture cores.

The observation of generalized similarities among cultures led to a more salient and influential development in Steward’s (1955) concept of multilineal evolution. In contrast to the unilinear trajectory proposed by White (1959) in which cultures were thought to pass through a uniform sequence of developmental stages, Steward argued that each culture would pass through its own, independent evolutionary trajectory in response to differing environmental circumstances and core elements. However, some commonalities could be found based on similar environments and

technologies, such as the relationship between irrigation and social complexity (Steward 1956, 1960).

For anthropologists and archaeologists, Steward's ideas that similarities in environment would lead to cross-cultural regularities in core culture elements of subsistence base, technology, and social organization were immensely influential. It is also easy to understand the influence of Steward's work because it proposed a materialist framework for the study of human adaptation that was well-suited to hunter-gatherers. But while ecology and culture were important factors, it must be emphasized that it was the structural relationships of the components of the culture "core" that was the central problem domain of cultural ecology: "The problem is to ascertain whether the adjustments of human societies to their environments require particular modes of behavior or whether they permit latitude for a certain range of possible behavior patterns" (Steward 1955: 36). Furthermore, an often overlooked factor is that Steward included social factors as part of the environment, which is perhaps best exemplified by his study of Shoshone social organization (Steward 1970). In the introduction to the compilation volume of Steward's writings, *Evolution and Ecology*, Murphy (1977: 22) provides a succinct statement of this often overlooked aspect of Steward's work:

...the theory and method of cultural ecology posit a relationship between the resources of the environment, the tools and knowledge available to exploit them, and the patterns of work necessary to bring the technology to bear upon the resources. The organization of work, in turn, is hypothesized as having a determinant effect upon other social institutions and practices. The key element in the equation is not the environment, nor is it the culture. Rather, it is the process of work in the fullest sense: the division of labor and the organization, timing, cycling, and management of human work in pursuit of subsistence.

It is perhaps this perspective that best summarizes the more enduring and pervasive influence of Steward on North American hunter-gatherer archaeology and its focus on subsistence economy, seasonal scheduling, settlement organization and mobility, group composition, and technological organization.

The new archaeology was also influenced by Leslie White's (1949, 1959) concepts of cultural evolution and energy capture. Leslie's fundamental premise is that culture is viewed as the "extrasomatic" (non-biological or non-genetic) means of environmental adaptation. White proposed three components of culture: the technological base, social organizational, and ideological. The technological base was the primary determinant of cultural evolution. Culture was viewed as a system; changes in one component resulted in changes in other components. Evolutionary changes from simple to complex societies took place as a result of increased efficiency in energy capture: "Culture advances as the proportion of nonhuman energy to human energy increases" (White 1959: 47). Thus, increased technological efficiency in energy capture was viewed as the primary cause for changing social and ideological structures.

Systems Theory: Based on the evolutionary principles of Steward and White, processual archaeologists conceived of cultural evolution as a regular and predictable process that, like biological evolution, could be scientifically studied. Cultural could be studied through an analysis of its components - the "core" elements of Steward or the technological base of White - in relation to environmental variables. Changes in one component would result in changes in other components. How such changes occurred and under what rules they occurred thus became the focus of inquiry, leading to the incorporation of systems theory (Clarke 1968; Flannery 1968; Plog 1975).

Systems theory proposes that, within complex systems composed of subsystems, the interactions between the subsystems are governed by "feedback" mechanisms (see Clarke 1968: 43, 147 for a

review of the influential system theorists). The overall dynamics of the system can be understood through formal rules describing the effects of the feedback mechanisms on the individual subsystems. As shown by Steward, White, and Binford, culture was considered a complex system consisting of various subsystems. These subsystems were systemically interconnected; changes in one subsystem would result in changes in the other subsystems. Thus, archaeologists could explain how factors such as environmental changes affected subsistence, which in turn provided feedback for the adoption or modification of extractive technologies, which in turn would have feedback consequences on the social organization of production. By studying individual subsystems and their relations to other variables, the overall cultural system and evolutionary process could be reconstructed. Ultimately, general laws explaining the operation of the cultural system could be derived and the process by which cultures evolved and changed could be explained.

The translation of cultural ecology, cultural evolution, and systems theory in terms of archaeological study led to the underlying postulates of processual archaeology as practice and science. The spatial and morphological properties of material culture produced by human culture are patterned. The archaeological record, created through past cultural processes, is therefore also patterned. By applying scientific methods to the study of archaeological patterns created by past cultural subsystems and their interrelationships, archaeologists could explain culture change (Binford and Binford 1968; Plog 1974; Watson et al. 1971).

This new scientific focus and problem orientation of processual archaeology necessitated the development of new data collection and analytical methods. As part of the increasingly scientific outlook, processual archaeologists focused on refining typological constructs used in cross-cultural analyses and improving data collection techniques. For example, Struever (1968) questioned how archaeologists could understand the relationship of the subsistence and economic base of a culture - one of the fundamental attributes of Steward's culture core - without any direct empirical data. The response to this data requirement was the development of flotation for the recovery of botanical remains. Other tools included statistical hypothesis testing, sampling designs for survey and excavations, and the incorporation of locational and spatial analysis from geography and ecology. Archaeological projects soon required the assistance of specialist in several fields, leading to the multidisciplinary projects in the Tehuacan Valley (Byers and MacNeish 1967-1976) and at the Koster Site (Struever and Holton 1979).

Another tool was the use of ethnographic analogy and ethnoarchaeology for the development of Middle Range theories (Binford 1978, 1980, 2001). As best exemplified by Nunamiut Ethnoarchaeology (Binford 1978) and, more recently in *Frames of Reference* (Binford 2001), Binford strove to find ways to productively incorporate ethnographic observations with the process of archaeological theory building. The development of Middle Range theory based on ethnographic and ethnoarchaeological research was a fundamental component of processual archaeology during the 1980s and 1990s.

Multiple critiques - too numerous to review here - have been mounted against the processual agenda. Schiffer (1976) and the behavioral archaeologists criticized processual archaeologists for failing to account for how the archaeological record had been transformed through natural and cultural processes. As the work of Binford and his emphasis on Middle Range constructions came to dominate much of the discourse during the 1970s and 1980s, the social dimension of cultural ecology and processualism were left wanting. This neglect of social theory is surprising, given Steward's focus on social organization and modes of production, and has been a source of criticism, particularly among post-processualists who have questioned the environmental determinism underlying many processual inferences. Systems theory was found by many, including its own practitioners (e.g., Flannery 1968), as difficult to model using archaeological

data. Moreover, systems theory invoked closed-systems with no provision for external stimuli or causation. More recently, systems theory has been supplanted by the broader field of complex adaptive systems (Gumerman and Gell-Mann 1994).

Jornada Research: Most archaeologists working in the Jornada Mogollon region and elsewhere in the Southwest would consider themselves processual archaeologists. The legacies of processualism still remain throughout current archaeological thought and practice, although somewhat tempered by the critiques of behavioral, evolutionary, and post-processual archaeologists. The scientific perspective, the incorporation of scientific methods and ideas from other sciences, and materialist and ecological focus remain forceful. Ethnographic analogy and ethnoarchaeological studies continue to be widely referenced, and the numerous advances in field and lab methods are now commonplace practice.

The most pointed criticism of processual archaeology as applied at Fort Bliss and the greater Jornada region is that it has primarily been framed within synchronic research programs and Binford's middle-range organizational and settlement theories. Several models of settlement and subsistence organization were developed during the 1980s and early 1990s (Anderson 1993; Hard 1983a, 1987; Mauldin 1986; Whalen 1980, 1994b). Sites were assigned to a period based on temporally diagnostic artifacts of poor temporal resolution, the site distributions and material culture were then measured against environmental variables, and the cultural adaptation of a given period of time was reconstructed. Ethnographic models were occasionally consulted during this process. In discussing the most prominent of such constructions, Hard's Mesilla phase settlement and subsistence model, Seaman (1988: 129) observes that:

Hard's model is essentially static. It does not specify factors that might cause it to change through time. The model provides only a series of behavioral expectations for an idealized adaptational system on a regional scale. It provides few, if any, empirical expectations that take into account the effects of long-term operation of this system on intra- and inter-assembly variability.

In retrospect, such criticism is perhaps unduly harsh. Lacking even fundamental chronology and phase sequences, accurate material culture typologies, and the fact that 80 percent of recorded sites lacked diagnostic material and could not be included in evolutionary reconstructions, it was difficult to model long-term change in regional adaptive systems. As noted previously in Chapter 3, the combination of landscape archaeological studies combined with extensive chronometric dating programs has begun to shift the focus of Jornada investigations to more diachronic concerns.

BEHAVIORAL ARCHAEOLOGY

Behavioral archaeology was developed as a "particular configuration of principles, activities, and interests" offered as means to reintegrate archaeology in response to what was perceived as a fragmentation of the discipline during the mid-1970s (Reid et al. 1974, 1975; Schiffer 1976, 1995a). The fundamental position statement of the behavioral archaeology program is simply yet profoundly defined as "...the subject matter of archaeology is the relationship between human behavior and material culture in all times and places" (Schiffer 1976: 4, see also Reid et al. 1975: 864). The behavioral approach seeks to explain variability and change in human behavior through a unique focus on the interaction between people and their material culture. Thus, the ultimate goal of behavioral archaeology is essentially the same as that of archaeology and other social and behavioral sciences, although it involves a different set of approaches to reach that goal.

As with processual archaeology and the general outlook of the discipline during the 1970s, behavioral archaeology adopted an explicitly positivist position that archaeology should and could pursue the development of laws of human behavior. In pursuit of the formulation and testing of laws, Reid, Schiffer, and Rathje (1975, see also Schiffer 1976) define four strategies through which the behavioral archaeology program would be conducted:

The first strategy is that the material culture of the past is used to answer specified descriptive and explanatory questions about behavioral and organizational properties of past cultural systems. This strategy does not appreciably depart from conventional archaeological practice except with the provision that such research should be conducted with the goal of formulating laws.

The second strategy is to use observations of present material culture to acquire laws useful for the study of the past. This would include questions dealing with, for example, the wear patterns on grinding implements resulting from different processing tasks or the use-life of ceramic vessels by various contemporary groups. Two major forms of research have been conducted under this strategy: “experimental archaeology” (see Ingersoll et al. 1977 for an influential compilation of studies) and “living archaeology” or what is more commonly referred to as ethnoarchaeology (see Gould 1978).

The third strategy is defined as the study of past material remains to derive widely applicable and relevant laws that could illuminate both past and present human behavior. The pivotal aspect of this strategy is that the laws and law-like propositions regarding human behavior have no temporal or spatial boundaries. That is, a particular law of human behavior or human-artifact interaction would apply to all human individuals or groups in all places and all times, including the past, present, and future. This position also privileges the status of archaeology within the broader discipline of anthropology by acknowledging that only archaeology can provide the time depth necessary for the study long-term culture change (cf. Plog 1974).

The fourth strategy is the study of contemporary material culture and specific objects in contemporary cultural systems to describe and explain modern or present-day human behavior. This strategy has generally been concerned with industrial societies with the intent of demonstrating the relevance of archaeological method and theory for understanding modern cultural practice and problems. The most well-known of such projects is the Garbage Project (Rathje 1974, 1979).

It is important to note that although it is not a formal component of the four strategies outlined above, perhaps the most influential aspect of behavioral archaeology has been the recognition of the role of site formation processes in conditioning the archaeological record. Schiffer (1972) differentiates between two primary contexts for archaeological materials: systemic context and archaeological context. Systemic context is the result of the original behaviors that produced archaeological remains; archaeological context is what is observed through archaeological investigation. Schiffer (1976, 1983, and 1987) recognizes that systemic contexts become archaeological contexts through various natural and cultural processes, termed n-transforms and c-transforms. Schiffer and colleagues further acknowledge that it is first necessary to deal with the variability and biases these formation processes introduce into the archaeological record in order to establish a firm foundation for making behavioral (as well as cultural and social) inferences based on that record.

Over the years a variety of conceptual tools and principles have been codified that help identify and evaluate the effects of natural and cultural formation processes. These include natural processes that serve to destroy, preserve, or move artifacts and cultural deposits (Nash and Petraglia 1987; Wood and Johnson 1978), studies of life histories of artifacts (termed behavioral chains; Schiffer 1975) and behavioral patterns of artifact discard, of which perhaps the most

eloquent expression is in the differentiation of de facto, primary, and secondary refuse (Schiffer 1972), and even the influence of prehistoric use of old deadwood on modern radiocarbon dating studies (Schiffer 1982, 1986).

More recently, behavioral archaeology has focused on explanatory issues surrounding technology in the design and use life of artifacts, taking into account the variety of behavioral factors that influence design and performance characteristics (Schiffer et al. 2001; Schiffer and Skibo 1987, 1997; Schiffer et al. 1994). These have often been linked to broader social theories and perhaps underlie recent attempts to establish a rapprochement among behavioral and evolutionary approaches (Schiffer 1996) and social archaeology (Schiffer 1995b). Indeed, the principle criticism directed toward behavioral archaeology has been the apparent absence of broader social or evolutionary theories (Binford 1981)

Behavioral archaeology has been a fundamental component of archaeological research at Fort Bliss and the Jornada region, although it is difficult to measure this influence based on a perusal of the regional literature. For example, it is interesting to conduct a citation review and compare the frequency with which Schiffer has been cited as opposed to Lewis Binford. Binford is cited 22 times in the 1996 Fort Bliss *Significance Standards* while Schiffer is mentioned only three times. In a recent report on the El Arenal Site (Miller 2007a) Binford is referenced 25 times while Schiffer receives just three citations. The comparatively small number of citations for Schiffer clearly does not reflect the scope or scale of his influence, as significant components of both documents involve experimental and ethnoarchaeological research and extensive discussions of natural and cultural site formation processes, all of which have their origins directly from the behavioral archaeology agenda.

Behavioral archaeology has had an equally profound influence compared to that of processual archaeology that has dominated much of the work in the region and a significant number and variety of current research directions have their origins in behavioral archaeology. For example, the differentiation of “dated events” and “target events” (Dean 1978) and potential biases of old wood effects (Schiffer 1986) on the interpretation of radiocarbon dates has been a significant component of chronometric research (Batcho 1987; Carmichael 1985a; Hard 1983b, 1987; Mauldin et al. 1998; Miller 1996, 2005c; Miller and Burt 2007; Swift 1991a). Experimental work with fire-cracked rock breakage, discoloration, and heat retention (Doleman 1997; Duncan and Doleman 1991; Mauldin et al. 1998; Tennis et al. 1997), and experimental and performance characteristics of ceramic tempers, finish, and other production attributes (Brewington and Shafer 1999; Jackson et al. 2004; Miller 1990; Miller and Burt 2007; Whalen 1994a) are all a direct reflection of the emphasis on experimental archaeology set forth under Strategy 2.

Similarly, recent interests in hunter-gatherer site structure and spatial analysis (Miller 2007a) are based on experimental and ethnoarchaeological work. Perhaps the greatest influence is evident among the vast body of geomorphic and geoarchaeological site formation literature. These include studies of the effects of eolian erosion on artifact movement and size sorting (Burgett 1994; Doleman 1992; Mauldin et al. 1998; Schutt 1992) and how site visibility and preservation are conditioned in active eolian environments (Doleman et al. 1991, 1992; D. Johnson 1997; Smith 1999, 2005). Finally, cultural site formation processes have also been examined, including the effects of multiple occupations at low-density hunter-gatherer sites (Doleman 1992; Doleman et al. 1992; Mauldin 1995; Mauldin et al. 1998; Miller 2007a; Seaman et al. 1988) and more intensively-occupied pit house settlements (Carmichael 1985a; Church and Sale 2003; Miller 1990, 1995, 2003; Whalen 1994a). As is evident from the variety and range of studies listed above, the influence of Schiffer and the behavioral archaeology program has been much more profound and far-reaching than might be inferred on the basis of a citation review of the regional literature.

HUMAN BEHAVIORAL ECOLOGY

Cultural ecology, the dominant perspective in the original *Significance Standards*, has, at least partially, been replaced by HBE. HBE grew out of evolutionary Ecology and within anthropology has been articulated by Bruce Winterhalder and colleagues (Smith and Winterhalder 1992; Winterhalder 1980; Winterhalder and Smith 2004; Winterhalder et al. 1988, 1999). Archaeologically, the paradigm has been developed by Dr. James O'Connell and his students at the University of Utah (Bettinger 1991; Bird and O'Connell 2006; Simms 1984). Even though its roots are in evolutionary ecology it shares little in common with evolutionary archaeology (Shennan 2002; but see also Neff 2000).

Human behavioral ecologists see an array of 'natural experiments'. If modern people who forage for a living are constrained by features of local ecology, then variation in these constraints, the behavioral trade-offs they impose, and the solutions adopted by individuals differing in age, sex, and reproductive status are open to direct ethnographic observation. If relationships between constraints, trade-offs, and variability in behavior can be understood in general terms, then that understanding can provide a basis for hypotheses about human behavior in the past - behavior that cannot be observed directly. These hypotheses would be about likely patterns of behavior that extend outside the modern range. This approach, unlike conventional ethnographic analogy, can generate expectations about differences as well as similarities between the past and present (Hawkes et al. 1997: 29).

The ambition in this line of inquiry is to examine prehistoric human behavioral variation in relation to the structure of required resources and their spatio-temporal variation and how that variation is reflected in the archaeological record. As Bamforth (1988: 16-17) summarizes:

the species of plants and animals exploited by the people in a region, though, provides only part of the information needed to assess the relationship between environment and human adaptation. Thomas, Winterhalder, and McCrae (1979) have argued that human beings adapt to the overall spatial and temporal pattern of resource abundance and scarcity in a region and to the nature and degree of variation in this pattern rather than just to the specific species of plants and animals found there. Besides directing our attention to more general characteristics of a region's resources, this position particularly implies that the general structure of an environment is not adequately described by average conditions alone and that an emphasis on such conditions severely limits our understanding of cultural-ecological relationships (cf. Winterhalder 1980).

This emphasis on the structure of resources allows us to use generalized structural models of resource availability and production as analogs that, when coupled with anthropological models, generate testable predictions. Thus, a key goal of this approach is "to construct complex, sophisticated models that predict the results of different behavioral trade-offs and to translate these into predictions that are testable with archaeological data" (Kelly 2000: 115). These are the explanatory predictive models first advocated in the late 1980s. As Ebert and Kohler (1988: 105) pointed out: "To make predictions we need to have models, and those models must span the entire explanatory framework, rather than simply concentrating on those things we want to predict". Further, as Madsen and Janetski (1990) argue, these behavioral models must be drawn from general theory which "allows us to predict human behavior in a situational context."

These formal models under HBE are derived from several perspectives, including demographics, optimal foraging theory, nutritional studies, and simulation studies. These approaches can be used to provide the explanatory framework that Ebert and Kohler (1988) advocated under HBE. Brief summaries of these approaches are provided below.

Prehistoric demographics: Hassan (1981) has been main author on this topic. His book *Demographic Archaeology* (1981) remains a touchstone for the few researchers in this area, although the more recent work by Boone (2003) and Chamberlain (2006) are welcome updates to the topic. Prehistoric demographics have come to be dominated by bioarchaeological studies of skeletal remains (e.g., Larsen 1997). However, it is much more than that, and includes topics such as fertility, mortality, migration, and age structure.

Optimal foraging theory: Optimal foraging is a key component in HBE. Optimal foraging is simply the theoretical examination of how an organism best forages under different conditions. Here, 'best' means the greatest return as measured in energy (kilocalories) per resource exploited. Optimal foraging has a rich history and literature in the biological sciences with the key publication being Stephens and Krebs's *Foraging Theory* (1986). One cultural resource management study explicitly used optimal foraging theory in trying to understand the distribution of prehistoric archaeological sites. This is Raven and Elston's (1989) survey and study in the Carson Desert. That effort has been followed up more recently by Zeanah's (1996) study, also in the Carson Desert of Nevada.

Nutritional studies: While nutritional studies are common in the anthropological literature, the topic has rarely been extended to archaeological issues, Keene (1981) being an early and rare attempt. Keene's early efforts at examining the topic in reference to archaeology used linear programming. Since then studies have been more narrowly focused on specific resources and processing (e.g., processing for marrow [Munro and Bar-Oz 2005; Outram 2001]). The emphases shifted from a bioarchaeological approach to nutrition that focuses on chemical analysis of human bone to indicate general nutritional status (e.g., Larsen 1997).

EVOLUTIONARY ARCHAEOLOGY (ALSO DARWINIAN AND SELECTIONIST ARCHAEOLOGY)

Evolutionary archaeology (also termed Darwinian archaeology and selectionist archaeology) is an attempt to apply explicit Darwinian evolutionary theory to the study of culture change. The concept of cultural evolution was a central tenet of the new archaeology and processual archaeology as influenced by the work of Steward and White. Yet, cultural evolution was defined in rather generalized terms as exemplified by the use of such terms as "adaptive strategies" or "technological adaptations." In opposition to these seemingly generalized and rather nebulous definitions, the strict Darwinian approach sought to bring a more scientifically rigorous framework to the study of cultural evolution (Dunnell 1980; Lyman and O'Brien 1998).

As suggested by the use of the term "Darwinian," evolutionary archaeology seeks to apply and adapt concepts of biological evolution such as inheritance, variation, fitness, and natural selection to archaeological problems. The focus of study is on the replicative success of archaeological traits (seen as analogous to biological alleles and phenotypes), where traits that are functionally beneficial to reproductive success will be selected over nonfunctional traits. Nonfunctional traits are viewed as "stylistic" and subject to evolutionary processes analogous to genetic drift (statistically random variations over time with no direction). Thus beneficial traits will increase through time, while non-beneficial or benign traits will show random fluctuations through time. As might be expected from this description, most applications of evolutionary archaeology tend to deal with developments and changes in material culture and technology (e.g., Lipo et al. 1997; Neff 1992; Niemann 1995), although Leonard and Reed (1993) take on a broader subject matter in their attempt to apply selectionist theory to strategies of corporate labor organization as a means of explaining population aggregation in the Southwest (see also Larson et al. 1996).

Evolutionary archaeology has been the subject of several critiques (Bamforth 2002a; Boone and Smith 1998), of which Bamforth has provided perhaps the most pointed and detailed. Bamforth (2002a: 442) points out that a fundamental fallacy of evolutionary theory as applied to

archaeological studies of human groups is that the linkages between evolutionary archaeology and Darwinian processes are incorrect “because of the difference between the individual level at which selection is known to operate among human beings and the aggregate, or group, scale at which archaeologists observe past humans.” In other words, Darwinian biological evolutionary processes of inheritance and natural selection (and by extension evolutionary archaeological processes) operate at the level of individual entities, while archaeological observations involve groups and populations.

Bamforth (2002a) also argues that the Darwinian concepts of fitness and selection as conceptualized and applied in evolutionary archaeology have been generalized, and thus are best viewed as metaphors rather than explicit natural processes. Additional problems with evolutionary archaeology involve a lack of consensus on, or explicit definitions of, the principal terms used to model and measure change. In particular, the concepts of style and function as conceptualized by evolutionary archaeologists are seldom looked upon favorably by non-Darwinian archaeologists. These concepts fare especially poorly when viewed through social theories (Hegmon 2003) where the concept of style involves important “functional” roles such as conveying social information and establishing and maintaining social boundaries.

Ceramics, being a plastic medium responsive to performance, design, and stylistic pressures, are thought to be ideal for the study of evolutionary archaeological theory (Neff 1992), and therefore the Jornada region may offer a productive laboratory for application of evolutionary method and theory. As noted in several overviews (e.g., Perttula et al. 1995) the El Paso brownware ceramic tradition represents a 1,000-year period of technological continuity in manufacturing methods and raw material utilization, and thereby occupies a rather unique position among prehistoric Southwestern cultures and ceramic technologies. Variations in vessel form (Hard et al. 1994), temper (Miller and Burt 2007; Whalen 1994a), and the application of design fields occurred through time. These changes may have had potential adaptive utility and could be examined for fitness under an evolutionary scheme. However, at the present time no evolutionary archaeological approaches to Jornada Mogollon material culture have been attempted.

SOCIAL, POLITICAL, AND RITUAL ORGANIZATION (SOCIAL ARCHAEOLOGY)

Theories of social, political, and ritual organization have only recently been applied to the study of prehistoric settlement and material culture at Fort Bliss. In this regard, the Jornada region appears to have been somewhat disconnected with broader trends in Southwestern archaeology. In part, this outcome reflects the focus on synchronic cultural-ecological research issues common to hunter-gatherer archaeology that have dominated Jornada archaeology during the past three decades. While not a prominent focus of Jornada archaeologists, however, it would be very misleading to suggest that political and social theorizing has not been a prominent component of processual archaeology in the American Southwest. Indeed, the most contentious and divisive debates of the 1980s revolved around the nature of social and political organization among prehistoric Southwestern societies and whether such societies had social formations that were hierarchical and stratified (Cordell and Plog 1979; Upham 1982; Upham et al. 1989) or were predominantly egalitarian (Graves and Reid 1984; Reid 1985; Reid and Whittlesey 1990).

For purposes of the *Significance and Research Standards*, it is useful to maintain a distinction between social theories and the more formalized and politicized agendas occasionally defined under the banner of “social archaeology.” Here, the term “social theories” refer to a broad range of theories and interpretations involving the roles of human actors and agents, political leaders and subjects, or ritual specialists and observers as agents of culture stability and change. These actors and agents create and participate in a range of dynamic social relationships that may be expressed through phenomena ranging from boundary maintenance, communal feasting, and

ritual performance to political leadership strategies, group identity, and warfare. Some theories, for example those dealing with feasting and other manifestations of political economies, may be thought of as essentially middle-range constructs linked to larger issues of power relations, leadership strategies, and other forms of social production. Social theories and inferences affiliated with processual archaeology usually involved a “top down” approach where cultural institutions and political and other organizational structures were given primacy over the roles of individuals and their actions. In contrast, more recent theories of social dynamics and agency may be considered more of a “bottom up” approach in that the motives, actions, and strategies of individuals are seen as the primary cause of conflict and change.

Thus, as with other broad and diverse theoretical programs, social archaeology subsumes a diverse range of theories and methods and the essential nature and scope of social archaeology would be difficult to define with any consensus. As originally conceived in the 1970s, social archaeology was proposed as a means of incorporating the reconstruction of past social systems and social organization into the broader processualism program (Redman 1978; Renfrew 1974). More recently, in Britain and elsewhere, the contemporary practice of social archaeology is often concerned with more narrowly defined subject matter derived from the post-processualist agenda. In this sense, social archaeology is concerned with the dynamics of social relationships in the past. This is accomplished by examining how power relations and identities are formed and maintained along the lines of class, gender, and identity (or ethnicity) and how this is expressed archaeologically through material culture and symbols. As such, it is a much more explicitly political agenda, as Shanks and Tilley (1988: 59) state in no uncertain terms in proposing that social archaeology should “...stress the primacy of the political: political negotiation, strategy, and power in the structuring of social reality.”

Setting aside the overt political agenda, most social theories reference the concept of social “power” and how this is manifested, manipulated, reproduced, or coerced via leadership strategies, ritual performance or knowledge, and the creation or accumulation of material or symbolic capital. For example, dual processual theory proposes two strategies of socio-political leadership, corporate and network, each of which utilizes - and is legitimized by - different forms of economic and symbolic power (Blanton et al. 1996; Feinman et al. 2000). Analysis of political economies (and political ecologies) reference how certain components of economies transcend domestic groups, thus linking households and kinship lineages to larger hierarchical institutions and networks (Feinman and Nicholas 2004; Johnson and Earle 1987).

The transactions conducted within and across such linkages are often mediated through various forms of material (economic or surplus appropriation) and symbolic capital (ritual power). Site structure, community layouts, and architectural form may establish and reinforce social stature and power relationships (Adler 1989; Hegmon 1989). Post-processual and Marxist theoretical influences are apparent throughout several of these perspectives, but often these are tempered with a concern for larger issues of culture process, and many of the concerns with power, ritual, and internal social dynamics have been fully incorporated into the processual agenda of culture change and adaptation, or what Hegmon (2003) refers to as “processual plus.”

The archaeological manifestations common across Fort Bliss and throughout the Jornada region offer productive and important contexts for the study of prehistoric social and political organization. Unfortunately, social theories have received only passing reference. For example, the concept of “adaptive diversity” promoted by several researchers at New Mexico State University during the 1980s (Carmichael 1985a, 1986b; Johnson and Upham 1988; Upham 1984, 1988) theorized that mobile hunter-gatherers could have coexisted with sedentary agriculturalists in the Jornada region. The theory was largely framed in adaptive and ecological terms. The unmistakable social and political implications of co-existent hunter-gatherer and agriculturalist groups were mostly left unstated: how did two groups with such divergent subsistence and land

use needs manage to mediate issues of land tenure and access to resources, maintain boundaries (both social and territorial), and conduct economic exchanges under such conditions?

One reason for the rarity of social analysis is that the preponderance of archaeological remains in the Jornada Mogollon are the result of occupations by seemingly “simple” egalitarian hunter-gatherer and horticultural band societies, and this perhaps has contributed to the view that complex social, ritual, and political relationships did not exist among these groups or their material remains. However, even “simple” societies have been found to be much more complex than previously thought. For example, Flanagan (1989) and Paynter (1989) have shown that egalitarian social arrangements are difficult to maintain and thus apparently “simple” societies will be much more complex than suspected. In the Jornada Mogollon region, a relatively common architectural manifestation of socio-political organization is the presence of communal structures at small residential settlements. How such communal structures reflect increasing levels of social complexity, group composition, and perhaps even issues of land tenure, ritual, and political economy, has not yet been fully addressed (although see Whalen 1994a for an early reference linking the presence of a communal structure at Turquoise Ridge to Gregory Johnson’s [1982] concept of sequential hierarchies).

POST-PROCESSUAL CRITIQUES AND PERSPECTIVES

It is perhaps useful to maintain some separation between post-modernism, with its hyper-relativistic cant, and post-processual critiques. Although the term post-processual was coined by Hodder (1985), the term actually subsumes a broad range of theoretical approaches whose main unifying theme is a challenge mounted against processual archaeology. Many aspects of the post-processual critique reflect the broader post-modern challenge that rejects the foundations underlying Western enlightenment values, including modern conceptions of truth and objectivity, materialist reality, and the positivist foundational claims of science in general (Shanks and Tilley 1992). Instead, it is claimed that knowledge is socially constructed and any claims to truth are mediated through socially determined systems of language and symbols defined by power relationships. Often characterized as the “hyper-relativistic” perspective (VanPool and VanPool 1999), such a worldview is clearly anathema to current scientific orientation of the majority of archaeologists working at Fort Bliss and Jornada Mogollon region.

Here, certain limitations and failings of processualism revealed by the post-processualist critique are reviewed. While not necessarily embracing its relativist and anti-scientific stance, such an approach is sure to thoroughly displease any post-processual archaeologist. Nevertheless, while science certainly has issues with internal and external social biases, Hull’s (1988: 26) statement best summarizes the position of the authors of the *Significance and Research Standards*: “Science is not a perfect machine for grinding out true claims about the world...but it is the best of all the imperfect machines developed to date.”

Post-processualism refers to an assortment of critiques, most of which reflect disillusionment or disenchantment with the positivist foundation and scientific claims of processualism (Hodder 1985; Shanks and Tilley 1992) as well as the inherent biases among several of its overarching interpretive positions. This includes, for example, arguments against the environmental determinism underlying many processual inferences; the failure to consider human actors and actions as a causal factor of culture change, instead relying on external causal factors such as environmental or demographic pressures; and the failure to consider the dynamics of social relations as mediated through gender, class, and identity.

If the relativistic and anti-scientific post-processual stance is overlooked for the moment, several of these critiques are worthy of consideration and have actually been expressed in criticisms

presented via other theoretical positions (e.g., feminist and Marxist archaeologies). In an attempt at bridge-building, Hegmon (2003) suggests that many components of the post-processual critique have been incorporated into the processual program, resulting in an expanded and more robust interpretive program she terms “processual plus.” In this spirit, one of the more relevant and useful developments resulting from the post-processual critique is briefly discussed below.

Post-processual theorizing has resulted in the incorporation of concepts of human agency and a broader acknowledgment that internal social dynamics may be a foundational cause of culture change. Agency “theory” refers to a broad range of theories and methods sharing a basic premise that human individuals and groups play an active role in the formation of social realities. Derived from the highly influential “practice theory” of Bourdieu (1977) and “structuration” theory of Giddens (1979), agency is seen as a counter to the deterministic structuralist and functionalist models of processualist archaeology (Dobres and Robb 2000) and other social sciences. As such, agency serves to re-introduce history to archaeology by demonstrating that human agents and actions can alter the external world and thus be a source of cultural change. This perspective has led to a growing recognition that ideology, as expressed through ritual and symbolic acts, serves to legitimize and sustain power structures and social relations. Material culture may be viewed as a form of “currency” of meaning and symbol (although this is an oversimplification) in such social interactions in that human agency both derives meaning from, and imparts meaning to, material culture (e.g., Pauketat 2001).

Agency theory may be more productively applied to historical societies, prehistoric urban cultures, and even modern groups, for which some form of archival or historical documentation, oral history, or other textual information (e.g., hieroglyphic texts) is available, although Pauketat’s (2001) study of Cahokia and Joyce’s (2000) examination of the establishment of political authority at Monte Alban present recent attempts to apply agency to the interpretation of societal evolution in prehistoric cultures. Some conceptions of human agency also underlie the expression of dual-processual theory of political organization and leadership (Blanton et al. 1996; Feinman et al. 2000). Using Hopi narratives, Whiteley (1988) clearly identifies human agency as the underlying cause of two major historic events (or episodes of culture change): the destruction of the pueblo of Awat’ovi in A.D. 1700 and the Oraibi split of A.D. 1906. Hopi oral traditions include named individuals who plotted and lead these major population schisms and migrations, and Whiteley’s study illustrates an unequivocal case of culture change shaped through human actors and actions rather than external environmental or demographic causes.

SUMMARY AND RESOLUTION

The preceding discussion presents a brief and elemental treatment of several complex theoretical perspectives. The reviews are not intended to be comprehensive, nor do they provide a representative survey of even a small fraction of the vast selection of literature published over the past forty years. Specialists in any of the theories may note the absence of important publications and may also disagree with some of the statements as overly simplistic portrayals of complex and multi-layered issues. They would be justified in doing so. However, the intent of this section is not to provide an exhaustive overview of six major theories or theoretical domains; such overviews are available in the major literature citations within each subsection. Rather, the intent is to broaden and enhance theory building by providing a more diverse mosaic of theoretical perspectives that should be considered during the design and conduct of archaeological research at Fort Bliss.

With the exception of evolutionary archaeology, each of the theoretical domains and examples of their practical application are examined in greater detail in Part III of this document. Human behavioral ecology receives more thorough methodological treatments in Chapters 9 and 11; site

formation processes and behavioral chains receive greater attention in Chapter 10; and social theories and their applications to Jornada research are reviewed in Chapter 12. As befitting the long-standing preeminence of processual archaeology, processual studies are woven throughout all five of the research domains in Part III.

Some of the theoretical approaches are seemingly abstract concepts that would appear difficult to operationalize using the types of archaeological data available at Fort Bliss. This is particularly true of social theories, which perhaps partly explains the apparent reticence to apply them to archaeological problems in the region. As will be shown in Chapter 12, this concern is unfounded. Many theories involving the formation and maintenance of social boundaries and power relations through leadership strategies, communal feasting, and symbolic or material exchange may be measured and tested using archaeological data available from many sites on Fort Bliss and across the Jornada region.

As Lekson and others note (1994), Southwestern archaeologists have one of the more detailed records of prehistoric material culture, settlement patterns, and architectural forms of any region in the world. Add to this is the fact that acceptably accurate paleoenvironmental records extending back in time over 1,400 years are available for many areas of the Southwest. Both small and large-scale events are well-documented, ranging multiple transitions from pit house to pueblo architecture at local scales to widespread regional abandonment and population movements that took place across major segments of the Southwest. Southwestern (and more recently Jornada) archaeologists are acutely aware that many of these events are roughly contemporaneous with periodic phenomena in climatic records across the Southwest (Dean and Robinson 1978; Dean and Van West 2002; Dean et al. 1985; Euler et al. 1979; Karlstrom et al. 1976; Van West 1994; Van West and Dean 2000).

In light of these high-resolution temporal and spatial correlations, to deny the role of environmental and ecological foundations of human technology and social organization would be unrealistic. In turn, to gloss over or discount the influence of human agency on culture change would be equally unwise. It is the dynamic interplay between environment, ecology, and human agency that perhaps best reveals the underlying processes of culture change and should thus be the focus of analysis.

Recalling Schiffer's admonition that no one theory can adequately explain the totality of human culture and behavior, it is suggested that the most productive means of advancing archaeological theory and method at Fort Bliss would involve the adoption of several perspectives. These would be used to mutually reinforce and support each other rather than to critique and discredit each other. The research agenda envisioned under these criteria would be best described as follows: a scientific processual program, with its foundational archaeological observations and assumptions strengthened by behavioral archaeology and human behavioral ecology, along with an explicit consideration of the transformative role of social and ideological formations in culture change and evolution. Theoretical posturing and stubborn emphasis on univariate causes will not allow us to further these goals.

**PART II.
INTRINSIC SITE ATTRIBUTES AND QUALITIES:
CHRONOMETRICS AND CHRONOLOGY, GEOMORPHIC
CONTEXT AND GEOARCHAEOLOGICAL INTEGRITY, AND
PALEOENVIRONMENTAL DATA**



Interdunal depression (blowout) on Otero Mesa
containing a scatter of prehistoric ceramic and chipped stone artifacts

CHAPTER 5. CHRONOMETRICS AND CHRONOLOGY

James T. Abbott, Myles R. Miller, and Raymond Mauldin

Of all the types of information potentially obtainable from archaeological sites on Fort Bliss, chronometric information is probably the most crucial because it provides the information necessary to place each site within a temporal context, and thus facilitate intrasite and intersite analyses. Almost every type of meaningful analysis, from investigations of intrasite patterning to examinations of regional settlement and subsistence systems, require identification and isolation of contemporaneous components. During the development of the 1996 *Significance Standards* document and the CRCP report (Miller 1996), the percentage of identified sites on Fort Bliss with any temporal assignment was extremely low, and many of those were tentatively identified with a particular timespan on the basis of only one or two diagnostic artifacts that may not have been representative of the occupations that formed the site. As a result, investigations of technological change, subsistence, settlement patterning, and cultural interaction were seriously hampered.

Since 1996, this situation has improved considerably with the completion of numerous projects with intensive dating programs and publication of the CRCP report (Miller 1996). The Jornada radiocarbon database now contains over 2,200 age estimates and additional thermoluminescence, archaeomagnetic, and tree-ring dates have been obtained. Several studies have used these chronometric data to examine broad patterns of landscape use, settlement adaptations, and technological change (Mauldin 1995, 1996; Mauldin et al. 1998; Miller 2001, 2002, 2005c; Miller and Kenmotsu 2004). Nevertheless, in a comparative sense, only a very small proportion of the estimated 50,000 to 100,000 archaeological features at Fort Bliss have been dated. Therefore, the arguments expressed in the 1996 *Significance Standards* regarding the importance of chronometric and chronological research still hold true. It is argued that no significant progress in unraveling the cultural record can be made without accompanying progress in dating the constituent components. The fact that the sites on Fort Bliss have proven difficult to date requires a continued and focused resolve to use a wide range of resources for dating, including the exploitation of innovative techniques.

In the 1996 *Significance Standards* document, chronometrics were treated as one of the seven research domains. This was partly due to the fact that few chronometric studies had been completed at that time, as well as the fact that concerns with dating methods and refining relative ceramic and chipped stone temporal markers remained a major problem domain for the Jornada region. Here, chronometrics has been moved to the part of the *Significance and Research Standards* dealing with intrinsic attributes of sites. This move reflects the fact that a comprehensive study of dating has been undertaken at Fort Bliss since the 1996 document was completed (Miller 1996), as well as the fact that chronometric studies are viewed as tools to be employed to address research problems.

This change in status does not necessarily imply that chronometric research - whether in and of itself or as a component of the research goals of a specific projects - is no longer necessary. Continued experimentation and refinement of chronometric methods is still encouraged. However, many of the chronometric issues that were the subject of sometimes heated debate prior to 1996, such as the reliability of obsidian hydration dating, the potential for luminescence dating of burned caliche, and possibility of mesquite tree-ring dating, were resolved through the CRCP. For example, the CRCP established that obsidian hydration dating is too problematic and unreliable to be used even as a relative chronological method, thus serving to end nearly 15 years

of controversy over discordant hydration dates and erroneous site chronologies based on this method.

Since 1996, a number of chronometric methods have undergone notable improvements in laboratory instrumentation, measurement, and age calculation and thus have had corresponding improvements in accuracy and precision. This is particularly true for luminescence dating, including thermoluminescence dating of ceramics and optically stimulated luminescence dating of eolian sediments. Other methods, such as archaeomagnetism and dendrochronology, have seen expanded use as a result of an increasing number of contexts being excavated at Fort Bliss. Finally, controlled experimental studies of several once-promising methods such as obsidian hydration and oxidizable carbon ratio dating have proven unsuccessful.

In light of these developments, the current focus is on applying established, reliable, accurate, and unambiguous chronometric techniques to the fundamental problem of chronological placement of sites, components, features, and occupation areas at Fort Bliss. It is unlikely that any new chronometric method will be developed in the coming years. Instead, archaeologists must stay informed about refinements to current methods as well as new ways of analyzing and interpreting chronometric data.

The following section outlines problems and prospects of a variety of dating techniques. The methods are arranged in general order of their relevance for use at Fort Bliss. While basic descriptions of the fundamental principals underlying each method are presented, readers interested in more detailed background discussions are referred to the CRCP report (Miller 1996), general treatments of dating methods (e.g., Michels 1973; Rutter 1985;), and to specific references cited in each section. Much of the 1996 text on chronometrics remains relevant and has been retained, although a brief update has been added to each method using results from the CRCP as well as other developments and applications of dating methods since 1996. The CRCP report should be considered a reference document for this section and readers are referred to this report for more detailed treatments of chronometric methods and examples of their applications at Fort Bliss. The final discussion in this chapter (*Chronometric Design, Sampling Analysis, and Data Presentation*) is new, and is intended to assist researchers in the design and conduct of chronometric research covering topics such as appropriate sample counts and selection procedures, graphical and statistical analysis, data presentation, and interpretive problems.

CLASSIFICATION OF CHRONOMETRIC METHODS

A number of dating techniques have been, and continue to be, developed for application in the Quaternary sciences, and many of these techniques have great potential utility for archaeology. Table 5.1 provides a list of these methods, which vary considerably in applicability and precision. Six different classes of methods are identified. Sidereal methods are the most accurate, in that they allow unambiguous assignment of a calendar age. Isotopic methods measure changes in material composition due to radioactive decay or changes in isotopic composition due to cosmic ray bombardment, while radiogenic methods measure cumulative non-isotopic effects of isotopic decay, such as electron trapping or crystal damage. Both of these groups of methods also provide a numerical age, but one that is based on a statistical expression of probability and that typically has an associated error estimate. Chemical and biological methods measure the results of time-dependent chemical or biological processes, while geomorphic methods address the cumulative effects of complex, interrelated physical, chemical, and biological processes on elements of the landscape. Finally, correlation methods allow for dating by establishing equivalence with dated baselines using time-independent properties.

Table 5.1.
Quaternary Dating Methods

TYPE OF RESULT					
Numerical Age		Calibrated Age		Relative Age	
				Correlated Age	
TYPE OF METHOD					
Sidereal	Isotopic	Radiogenic	Chemical and Biological	Geomorphic	Correlation
Historical Records	Radiocarbon (conventional and AMS)	Fission Track		Soil Profile Development	Lithostratigraphy
Dendrochronology	Potassium-Argon		Amino Acid Racemization	Rock Mineral Weathering	Tephrochronology
Varve Chronology	Uranium-Series	Thermoluminescence	Obsidian and Tephra Hydration	Progressive Landscape Modification	Paleomagnetism
		Optically-stimulated Luminescence	Lichenometry	Rate Deposition	of Archaeomagnetism
	Uranium-trend	Infrared-stimulated Luminescence	Soil Chemistry	Rate Deformation	of Fossils
	Cosmogenic Isotopes	Electro-spin Resonance	Rock Varnish Chemistry	Stratigraphic Superposition	Serialized Artifacts
			Oxidizable Carbon Ratio (OCR)	Geomorphic Position	Stable Isotopes

Black bars represent most common application, while gray bars represent less common applications (e.g., exceptionally cautious or bold interpretations). Methods above line in the first four columns routinely produce reliable numerical ages, while methods below line are more experimental and/or involve nonradioactive processes or processes whose effects on age estimates are not well established.

As noted in Table 5.1, the results of these methods vary in precision. As a general rule, the precision of the dating methods increases from left to right across the columns of Table 5.1. Typically, dating methods are classified as either chronometric or relative techniques (Michels 1973). Chronometric methods are also frequently termed “absolute” methods, but this term is presently discouraged as hyperbolic and misleading (Colman et al. 1987). Chronometrics provide a numerical age (with or without an error factor), while relative methods provide a nonscalar indication of age relative to a point of reference (e.g., A is older than or younger than B). Taking this classification one step further, Colman and others (1987) identified four levels of precision in results: numerical age, calibrated age, relative age, and correlated age. In this scheme, numeric and calibrated ages are equivalent to the chronometric techniques, but differ in that calibrated ages are dependent on calibration with independent methods to minimize the effects of external environmental variables, while numeric methods are not. Correlated ages are those that use non-temporally dependent attributes to obtain an age estimate. The connotation of relative methods is unchanged; it describes methods that provide an ordinal indication of the age of different entities, with or without a qualitative assessment of the magnitude of difference. Note that most techniques can be applied to achieve several different types of results with differing degrees of precision, depending on the depth of information and the aggressiveness of the interpretation.

CHRONOMETRIC DATING TECHNIQUES

Chronometric dating techniques are methods that yield a numerical age, either directly or through calibration with an independent method. They are equivalent to the numerical and calibrated ages of Colman and others (1987).

Luminescence Dating

Luminescence dating has existed in principal for many years (Daniels et al. 1953; Kennedy and Knopf 1960), but has seen only limited application in North America, due primarily to the expense and time requirements, remaining ambiguities in the method, and a shortage of facilities capable of conducting the analysis. Three different variants of luminescence dating (all of which are based on the same basic principle) are recognized: thermoluminescence (TL), OSL, and infrared stimulated luminescence (IRSL). Good, generalized reviews of the principles and prospects of various aspects of luminescence dating include Aitken (1985, 1989, and 1994), Dreimanis and others (1985), Smith and others (1990), Wintle (1993), and Wintle and Huntley (1982).

Luminescence dating is a radiogenic, numeric, age determination method. Age estimates are based on constant accumulation rates measured within a sample. One of the problems that separate luminescence from other radiogenic methods is that the clock used in luminescence dating is local rather than global (Dunnell and Feathers 1994: 116). The radiation doses are dependent upon sample composition and particularly local environmental conditions that determine the radiation history to which a sample has been exposed.

Luminescence dating is based on the fact that irregularities in the crystal lattice of silicate minerals (e.g., quartz, feldspar) can trap stray electrons produced by radioactive decay of radioactive atoms in the material or in the surrounding matrix. Over time, more and more of these electrons are trapped until they are released by kinetic excitation of the lattice structure, which is caused by the input of electromagnetic energy (i.e., light or heat). This release produces a faint flash of light that is proportional in intensity to the number of electrons released. Captured by a photomultiplier cell, this energy can be used to calculate the length of time that has elapsed since it was last "zeroed" by exposure to the same type of energy, provided that its composition and radiation history are known.

Electron traps within a crystal lattice have different characteristics, which are reflected in the temperature necessary to cause release of the electron. "Shallower" traps are capable of trapping and holding an electron for a short time, and release the electron after low-level stimulation, while "deeper" traps can hold electrons for extremely long periods (millions of years) and release the electrons only after the crystal lattice is increasingly stimulated. In TL dating, this equates to heating to higher temperatures. As a result, heating of a specimen for measurement results in a characteristic "glow curve" when thermoluminescence is plotted against temperature, as increasingly deeply trapped electrons are released. In addition, various minerals have significantly different types of traps due to unique characteristics of each crystal structure.

The age of TL samples is obtained by solving for the equation:

$$\text{age} = \frac{\text{natural TL (TL sensitivity)} \times (\text{annual dose of radiation})}{\text{annual dose of radiation}}$$

where natural TL is the amount of thermoluminescence given off during the initial heating, TL sensitivity is a measure of the ability of the sample to trap electrons, and annual dose refers to the natural influx of alpha, beta, and gamma particles that the sample was exposed to. TL sensitivity is determined relatively easily by zeroing the sample, subjecting it to a known dose of radiation, and measuring the amount of trapped TL. Determination of the annual dose is considerably more difficult. One approach is to determine the content of radioactive elements (uranium, thorium, potassium-40, and rubidium) by a combination of neutron activation and atomic absorption photometry; the contributions of this fraction to the annual dose are calculated from empirically derived tables, while the contribution of cosmic rays is calculated by the thickness of the overburden. Alternatively, direct particle-counting techniques may be employed, or measurements may be made on-site with a sensitive dosimeter or a portable gamma spectrometer. In all cases, this calculation of annual dose is complex and requires assumptions about burial history (which affect the influx of cosmic rays) and long-term soil moisture trends (which are very important due to the sharp attenuation of radioactive particle travel by water) (Aitken 1989).

TL is commonly applied to heated artifacts, such as ceramics and burned chert (Göksu et al. 1974; Ichikawa 1965; Kennedy and Knopff 1960; Valladas 1978). In fact, much of the time available in TL laboratories is given over to "authentication" of antiquities prior to the sale by auction houses, such as Sotheby's in London (which, because background information on annual dosimetry is typically lacking, usually amounts to verification that the piece is indeed old, rather than a true estimate of age). Refinements to the technique, such as dating based on zircon crystals (e.g., Sutton and Zimmerman 1976) have some potential.

Optical and infrared-stimulated luminescence are relatively newer methods (Huntley et al. 1985; Hutt and Jaek 1989) that have received widespread interest and increasing utilization by Quaternary scientists (e.g., Edwards 1993; Smith et al. 1990; Stokes 1992; Wintle et al. 1994). They are very similar in principle to TL, differing primarily in that the initial zeroing and the analytical stimulation is provided by light rather than heat. In OSL dating, a monochromatic green laser (514 nanometer [nm]) is typically used, stimulating emission in the blue-ultraviolet range (approximately 325-450 nm). IRSL involves stimulation in the near infrared (approximately 800-1,000 nm), and emits in the visible and ultraviolet range (approximately 300-700 nm). IRSL is not applicable to quartz (which has no response to infrared stimulation) and has currently been applied only to feldspars. It has the advantage of being relatively simple to determine, however, and is amenable to automation (Aitken 1994).

The characteristics of traps in optical methods is treated somewhat differently, as optical stimulation does not evacuate thermal traps, and there is no good method for differentiating between shallow and deep traps (Aitken 1994). Typically, samples are preheated to evacuate traps with poor stability before measurement (Aitken 1994; Wintle 1993). Age is then calculated by the equation:

Age (a) Equivalent dose (Gy) Dose rate (Gy a⁻¹)

The advantage of OSL and IRSL is that initial zeroing can be accomplished by sunlight, which allows for sediment dating. Most applications to this point have been directed at eolian sediments (e.g., Clarke 1994; Edwards 1993; Stokes 1992; Wintle 1993), which are best exposed to sunlight and thus zeroed most completely, but optical dating of alluvial, lacustrine, and colluvial sediments is also theoretically possible (Aitken 1994) and has been demonstrated to a limited extent (Clarke 1994; Fuller et al. 1994).

Recent Developments in Luminescence Dating

Of the wide assortment of dating methods described in this section and the CRCP report (Miller 1996), luminescence dating has by far undergone the greatest degree of refinement and improvement over the past decade. In particular, OSL and TL dating of ceramic pastes and OSL dating of eolian sediments has seen widespread application at Fort Bliss and throughout southern New Mexico and west Texas over the past five years (Hall 2002, 2007; Hall et al. in prep; Miller and Feathers 2005; Seymour 2002, 2003).

OSL dating has benefited from several laboratory and analytical improvements, including the refinement of the single aliquot measurement for OSL and IRSL dating of fine-grained material such as natural sediments and fine-tempered ceramic pastes (Banerjee et al. 2001; Jain and Singhvi 2001; Murray and Wintle 2000; Roberts and Wintle 2001). Several luminescence dating facilities have been established or expanded in North America (University of Washington, University of Nebraska, University of Georgia, and University of Nevada at Reno) and have the potential to greatly facilitate less expensive, more frequent application of the method to the wide range of problems and contexts. At the present time however, TL and OSL dating is not as rapid or as easily obtained as radiocarbon dating.

The first attempt to use OSL dating on Fort Bliss yielded disappointing results (see Monger and Buck 1995). Since that time the method has been considerably improved and has become an accepted method among soil scientists, geomorphologists, and other Quaternary researchers. Series of OSL dates from eolian depositional units in southeastern New Mexico and the Hueco Bolson of Fort Bliss may indicate a major revision of the ages of Holocene and Late Pleistocene depositional units are in order (Hall 2002, 2007; Hall et al. in prep). These findings and their implications for regional geomorphology are reviewed in greater detail in Chapter 6 of this document.

For archaeological applications, recent improvements in ceramic luminescence dating hold considerable promise (Dunnell and Feathers 1994; Dykeman et al. 2002; Feathers and Rhode 1998). Seymour (2002, 2003) has experimented with ceramic TL and OSL dating to identify Protohistoric and early Historic ceramics at Fort Bliss. In several cases, post A.D. 1450 luminescence dates were obtained on historic ceramics. Controlled experimental approaches included submission of historic Valle Bajo brownware and prehistoric El Paso brownware sherds from the same context and the submission of conjoinable Valle Bajo brownware sherds. In both cases, the TL and OSL age estimates generally matched the expected ages of the ceramic items. Age discrepancies did occur, such as the case of two conjoinable sherds yielding dates that were 85 years apart. However, it should be noted that these differences are of lesser magnitude than the typical chronological resolution provided by radiocarbon dating.

Another controlled experimental study of prehistoric and historic ceramics was undertaken with the support of the Directorate of Environment and Safety at White Sands Missile Range (Miller and Feathers 2005). Seven ceramic TL samples were selected from secure contexts at previously excavated sites on Fort Bliss and adjacent areas. The group of sites was chosen to represent a relatively consistent distribution of well-dated contexts ranging in age from ca. A.D. 800-1880, a

span of approximately 1,000 years that effectively subsumes the majority of time that ceramics were produced in southern New Mexico and west Texas (Perttula et al. 1995). The results of the dating study are shown in Figure 5.1.

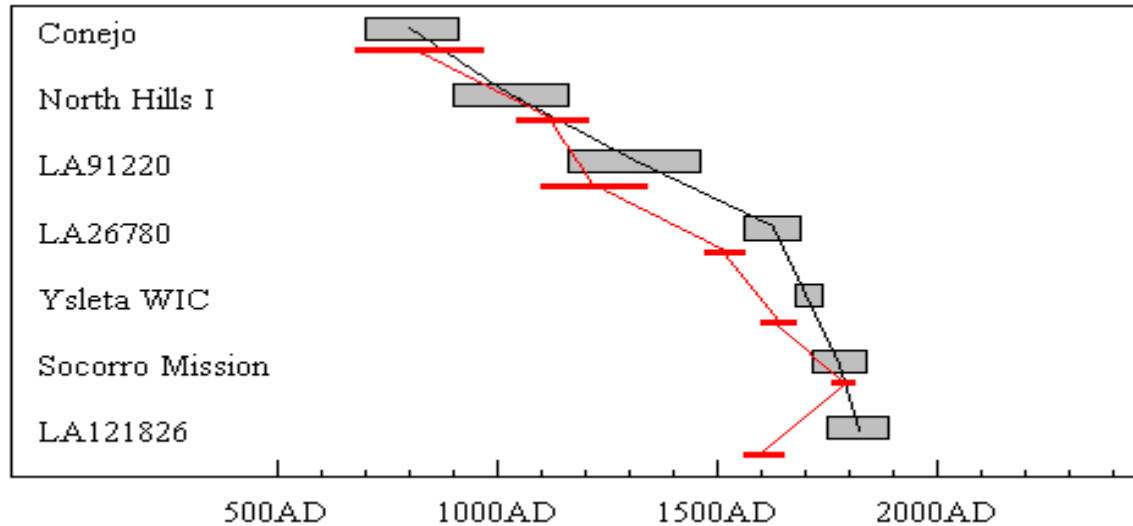


Figure 5.1. Correlation of ceramic thermoluminescence dates with known dates of occupation (from Miller and Feathers 2005).

Red bars indicate the age spans of ceramic thermoluminescence dates; grey bars denote the known age of the associated contexts as established through independent chronometric dates, relative artifact dates, and archival research.

The consistent linear relationship between ceramic luminescence dates and known occupation spans suggests that ceramic luminescence dating method can be of important use for differentiating between prehistoric ceramics and those produced during the Protohistoric, Spanish Colonial, and Late Historic time periods of southern New Mexico and west Texas. This would be of particular use for suspected post-Pueblo occupations with plain brownware sherds that otherwise lack any form of relative or absolute chronometric dating potential.

It is evident however, from Figure 5.1 and Seymour's studies, that minor age offsets and discrepancies continue to be a problem. Compared to the usual age spans of radiocarbon dates on the order of 200-300 years, the age discrepancies and offsets among the series of ceramic luminescence dates are comparatively minor. Yet, the existence of 100-year age offsets indicates that some caution is required in the interpretation of ceramic luminescence dates, particularly if being used to identify historic temporal intervals or discriminate among short-lived historical phenomena. Continued research is needed to find ways to better control and measure the background radiation environment of ceramic luminescence dating specimens and identify factors that contribute to anomalous fading in ceramic sherds. Until such issues are resolved, luminescence dating should not be seen as an alternative or replacement for radiocarbon dating at Formative period sites, unless ceramic luminescence offers the only option for dating a particularly important or unusual context or item.

Improved instrumentation techniques, measurement methods, and control over sample and soil environments have resulted in substantial refinements to the luminescence dating method for ceramics over the past decade. Miller's (1996) observation of systematic age offsets appears to

no longer be an issue for ceramic luminescence dating in the region. However, additional refinements are needed and issues involving dating accuracy, determination of background radiation doses, and the effects of burial or surface exposure still require investigation.

Certainly, luminescence dating can provide a valuable compliment to radiocarbon dating, and is applicable to many situations where carbon dating is impossible. In particular, the potential for dating of eolian sediments has tremendous implications for elucidation of the archaeological, geomorphic, and paleoenvironmental histories of the Fort Bliss region. The most striking result of the White Sands Missile Range and Fort Bliss studies is that ceramic luminescence dating may provide a reliable means of identifying post-Pueblo occupations and incidences of early ceramic exchange or production in the region. In other words, ceramic luminescence dating can be particularly useful for differentiating very old ceramics (western Mogollon trade wares or early cases of El Paso brownware production) and very young ceramics (Protohistoric, Spanish Colonial, Athapaskan) from the usual Formative period El Paso brownwares.

ARCHAEOMAGNETIC DATING

Archaeomagnetic dating is a correlation technique that can nonetheless provide relatively precise dates for fired features. Archaeomagnetism and paleomagnetism are *correlated age determination* methods. Observations of the direction and intensity of magnetized samples collected from archaeological features are correlated with tree-ring or radiocarbon dates and sometimes historic records from associated contexts in order to construct master curves of geomagnetic secular variation for a region. Subsequent archaeomagnetic samples can then be compared against the curves allowing for additional age determinations to be made. Archaeomagnetic dating is also classified as a *regional pattern-matching* method (Sternberg 1990: 26) since differing geographic regions yield distinct records of secular magnetic variation through time.

Archaeomagnetic dating is based on the fact that heating of clays causes small regions (domains) within magnetic minerals contained within the clays to reorient. Although normally randomly oriented, upon heating these minerals behave like tiny dipolar magnets and align themselves with the earth's magnetic field in the same way that a compass needle points north. Upon cooling, the domains are locked into place, indicating the direction of the North Pole by their declination and inclination (Breiner 1973). Because the North Pole wanders with time, this information can be used to reconstruct the polar position at the time of feature use, once a curve indicating polar position is developed (Eighmy 1980). Despite its potential utility, archaeomagnetic dating has been underutilized in the Jornada region (Miller 1996: 31). While at present the technique can only be used at sites younger than A.D. 600, the CRCP report recommended its mandatory use at Fort Bliss particularly during testing or data recovery projects at pit house and pueblo components. Follow up on that recommendation has been limited and is summarized below

Recent Developments in Archaeomagnetic Dating

The expansion of mitigation programs at Fort Bliss has resulted in the addition of 8 new archaeomagnetic dates to those listed in the CRCP chronometric database (this total does not include an additional seven samples that did not yield age estimates). Six archaeomagnetic dates have been obtained from LA 91220, the Madera Quemada Pueblo (Miller and Graves 2006), one from 41EP4719 in the Tobin Well project area (Lukowski et al. 2006), and one from 41EP1661 in Maneuver Area 1B (Kenmotsu et al. in prep). The eight dates obtained during the past decade represent a 30 percent increase in the total number of archaeomagnetic dates from the previous 30 years of research in the region. It is expected that an increasing number of formal architectural features will be encountered during future mitigation programs at Fort Bliss and additional archaeomagnetic dates will be forthcoming.

Several of the dates from Madera Quemada Pueblo are significant because of their high degree of precision. A combination of the presence of well-preserved collared floor hearths and careful sample collection procedures provided a series of exceptionally precise age estimates. Four of the dates have age spans of between 30 and 55 years, a significant advance in chronological precision over radiocarbon dating.

Given the likely expansion of archaeomagnetic dating, researchers should be aware of new developments in the method. Research on archaeomagnetic secular variation curves and statistical age determinations has continued over the past decade through the work of Stacey Lengyel at the Illinois State Museum. In 2002, a revision to the Southwest master virtual geomagnetic pole (VGP) curve was published (Lengyel and Eighmy 2002). In addition, statistical procedures for assessing contemporaneity and for averaging multiple archaeomagnetic dates have been developed (Butler 1990; Lengyel and Sternberg 2007; McFadden and Lowes 1981; Walton 1998). The sum of these developments is that, if suitable contexts are available, archaeomagnetic dating can be used as a primary chronometric technique rather than its previous role as more of a corroborative method to support radiocarbon-based chronologies.

Given the refined temporal resolution offered by this method, one of the most critical aspects involves the collection of sample cubes in the field. Archaeomagnetic date reports often reference the poor condition of archaeomagnetic sample cubes that either resulted in decreased precision of the resulting age estimates or prevented the measurement of any date at all. Thus, unlike other dating methods where sample materials can be collected with little or no formal training, good archaeomagnetic dating results are highly dependent on the availability of trained personnel to collect the sample cubes. Chris Lowry of the Fort Bliss DPW-E has attended the three-day training session conducted by Stacey Lengyel. The benefits of the intensive training program are apparent by the fact that his careful and precise collection of sample cubes was a major factor in the precision of the dates obtained from Madera Quemada.

DENDROCHRONOLOGY

Tree ring dating is based on the fact that trees add visually distinguishable annual growth rings composed of cycles of relatively light, high-growth season wood and dense, low-growth season wood. Although many other factors (e.g., ring variations due to age and height of the tree) must be accounted for, the width of individual rings reflects in a large part the vigor of growth on a year-to-year basis, and thus the response of the tree to climatic conditions. Because of this control, patterns in ring width are apparent between different trees (usually of the same species) within a limited geographic area. By counting backwards from the center ring of a living tree, it is possible to find the calendar age of any ring within the tree. Correlation of patterns in ring width with old wood can extend that sequence farther back in time, provided that the *fossil* and modern sequences overlap sufficiently. Given a sufficient baseline, ages of wooden artifacts can be determined by matching a statistically standardized expression of the ring pattern to the continuous record, allowing the age of any ring within the tree (typically either the center ring, which approximates the year of germination, or the outermost ring, which approximates the year of death). If fossil curves cannot be connected to a living tree, a "floating" chronology (usually grounded with radiocarbon ages) can still provide a level of chronological control (Lowe and Walker 1984).

Although there are several extant tree-ring sequences from south central New Mexico, including a sequence extending to A.D. 1306 from the Organ Mountains on Fort Bliss (Grissino-Mayer et al. 1997), the potential for dendrochronological dating on Fort Bliss is hampered by the generally poor preservation of wood, as well as the common prehistoric use of wood species such as mesquite, cottonwood, and juniper that are unsuitable for tree-ring dating. As discussed below,

even collections of well-preserved piñon and ponderosa pine wood beams recovered from a pueblo settlement could not be dated because of several problems. However, applications of this technique are possible and it needs to be included in the arsenal of chronologic tools brought to bear on the problem at Fort Bliss whenever suitable contexts and wood samples are encountered.

Recent Developments in Dendrochronological Dating

Since the publication of the 1996 *Significance Standards* and CRCP report, the first dendrochronological dates have been obtained from lowland sites in the Jornada region. Two dates have been reported from the Scorpion Site in Alamogordo, New Mexico (Turnbow and Kurota 2007). Two burned piñon pine beams on the floor of a pit house at this site yielded dendrochronological ages of 1070_{vv} (NMM-66) and 1064_{vv} (NMM-167). While the notation “vv” indicates that neither date is a cutting date, the ages are thought to be within a few years of the cutting date.

Madera Quemada Pueblo on Fort Bliss has provided a date of 1090+B (NMV-71). The notations for this sample indicate that there is a potential missing outer ring (+) and that bark was present (B). Thus, the tree represented by this sample died or was harvested in A.D. 1090 or 1091. Unfortunately, this date is at least 200 years too young for the occupation of the pueblo.

Madera Quemada pueblo provides an illustrative example of problems with dendrochronological dating even from well-preserved sites. Over 50 samples of roof support and superstructure beams were recovered from the burned pueblo. Among these were species of piñon pine and even ponderosa pine that had been harvested or obtained from the Organ Mountains. These species typically yield dates in other regions of the Southwest and were the primary species used to develop the local Organ Mountain dendrochronological sequence (Grissino-Mayer et al. 1997). Many of the samples from Madera Quemada measured 5-10 cm in width and had visible ring sequences and outer bark surfaces.

Despite these positive attributes, only one specimen yielded a date, although as noted above that date is too early. Most of the samples could not be dated as they had too many individual and collective problems. All but nine of the specimens had less than the minimum 40 or 50 rings required for accurate cross dating. The nine potentially datable specimens also had various problems, including borderline ring counts (ca. 50 rings), missing growth rings, and inconsistent growth patterns. The small number of specimens with sufficient counts of 60 to 70 rings had unusual and inconsistent growth patterns that probably reflect the highly variable rainfall conditions in the Organ Mountains. Several of these specimens yielded multiple dates, and multiple tree-ring dates are not reliable. The one sample that yielded the excessively early date was likely a deadwood limb or branch collected from the canyons in the Organ Mountains.

ELECTRON-SPIN RESONANCE

Electron-spin resonance dating is a technique that has the potential to date crystalline substances (e.g., carbonates, silicates) over an extremely wide span of time. Electron spin resonance (ESR) is a radiogenic, numeric age-determination method. As with luminescence dating, ESR age estimates are based on constant accumulation rates that can be measured within a sample and the clock used in ESR dating is local rather than global. The radiation doses are dependent upon sample composition and particularly local environmental conditions, which determine the radiation history to which the sample has been exposed.

Like luminescence dating, ESR is based on the measurement of progressive effects of radiation on crystalline substances; namely, the number of unpaired electrons formed by ionizing radiation and trapped in crystal lattice defects. While luminescence measures the extent of trapping by freeing the electrons from the traps, ESR measures absorption of microwave energy by the

electrons trapped in the sample, which is proportional to the number of unpaired electrons trapped in the crystalline structure. Because the electrons are not liberated from the traps in the process, ESR is a nondestructive technique that can be performed repeatedly on the same sample (Ikeya 1985). Once the total radiation dose represented by those trapped electrons is known, calculation of age is performed in the same manner as in luminescence dating:

$$ESR \text{ age } (T) = \frac{\text{Total Radiation Dose } (Gy)}{\text{Average Annual Dose } (D(mGy \text{ l } y))}$$

Unlike luminescence dating, ESR can be applied to a wide range of crystalline materials, including shell, bone, speleothems, and soil carbonates, as well as heated siliceous artifacts (Chen et al. 1994; Garrison et al. 1981; Grun et al. 1988; Ikeya and Miki 1980; Ozer et al. 1989; Skinner and Shawl 1994; Walther and Zilles 1994).

Unfortunately, each of these applications carries with it some degree of complication, not all of which have been overcome (Aitken 1994). The ESR dating method has several critical limitations, foremost of which is that ESR signals are easily affected by the presence of impurities. In particular, ions of manganese and iron are unpaired electrons. These can overlap the true ESR signal originating from trap defects in the crystalline structure of a sample, and thus their presence will give "false" ESR signals when exposed to a magnetic field (Chen et al. 1994; Cowan et al. 1995; Ikeya 1978, 1993; Rossi and Poupeau 1989). This problem is often present in limestone, caliche, shell, and other impure calcium carbonate materials and severely limits the range of materials that can be reliably dated using ESR. Attempts to date prehistoric shell (Skinner and Shawl 1994) and siliceous materials such as chert and flint (Garrison et al. 1981) have proven difficult due to the common presence of impurities. ESR dating of bone has also been attempted (Ikeya and Miki 1980), but bone tends to absorb uranium from groundwater and therefore it is extremely difficult to accurately measure or estimate environmental dose rates.

Another critical concern for use of the method at Fort Bliss is that ESR is seldom useful for dating materials of Holocene age; only the use of very pure calcites and extremely sensitive ESR spectrometers has allowed for ages younger than 1,000 or 2,000 years to be determined accurately (Rink and Schwarcz 1993).

The feasibility of using ESR to date burned caliche used in prehistoric hearths was examined at Fort Bliss (Cowan et al. 1995). ESR signals were measured in 17 specimens of burned caliche along with five samples of natural, unburned caliche. All of the burned samples had complex ESR signals due to high concentrations of impurities; true ESR signals in these samples were mostly obscured and therefore conventional ESR dating of burned caliche will not be possible within the age limits (<10,000 years) useful for archaeological dating in the Jornada.

Cowan and his colleagues observed that the very impurities which hinder the measurement of conventional ESR signals might have their own particular signals which can be used for dating. When unburned control samples were examined, it was found that none had the pronounced magnesium ion ESR signal observed for all of the burned specimens. Cowan and others (1995: 11) suggest it is unlikely that this is due to differences in the amount of natural magnesium present in the samples, but rather resulted from chemical changes brought about by exposure to heat. These findings suggest a promising new direction for chronometric dating, although much more research would be necessary to resolve the issue of impurities in caliche samples, their relationship to heating, and subsequent effects on the intensity of ESR signals. Therefore, while ESR may offer an option for dating otherwise undatable burned caliche hearths at Fort Bliss, it remains a highly experimental and undeveloped method. Substantial funding and experimentation will be required to develop the method and determine whether it can provide the requisite level of accuracy and precision for Holocene-aged archaeological contexts at Fort Bliss. Additional drawbacks to the method include the rarity of laboratories that can conduct ESR

dating and long laboratory processing time that can seldom be incorporated within typical CRM mitigation schedules.

URANIUM SERIES DISEQUILIBRIUM DATING

Uranium series dating involves the decay of radioactive uranium isotopes (e.g., ^{238}U and ^{235}U) to lead. This decay progresses through a variety of stages, each with a specific half-life, or time period necessary for half of the atoms to decay to a daughter product (Figure 5.2). At Quaternary time scales, uranium-series dating focuses on intermediate nuclides with relatively short half-lives. However, because equilibrium develops over long time scales (e.g., the sequence of decay creates new atoms of the intermediate nuclides as older atoms of the intermediate nuclides decay), some factor is necessary to disrupt the system and selectively remove some of the decay products. Uranium series dating is possible because different nuclides have strongly different solubility characteristics. For example, uranium is highly soluble, where other nuclides such as thorium and protactinium are highly insoluble. Thus, water tends to fractionate the nuclides; marine organisms and terrestrial precipitates, such as speleothems and travertine, are initially uranium-rich and thorium-free because the water would have contained only uranium, while ocean-bottom sediments are initially thorium-rich, because the thorium created through decay precipitates and settles as quickly as it forms. Comparison of the ratios to yield an age is then possible, because one element can be assumed to have been absent (which is not strictly true in some cases). Methods can measure either the loss of parent nuclides or the gain of daughter nuclides. Commonly used uranium-series dating ratios include $^{230}\text{Th}/^{234}\text{U}$, $^{231}\text{Pa}/^{235}\text{U}$, and $^{234}\text{U}/^{238}\text{U}$ (Bradley 1985; Lowe and Walker 1984; Schwarcz and Blackwell 1985).

Although uranium-series methods have been used to date fossil carbonates (e.g., Ku and Liang 1984; Ku et al. 1979), the very long half-lives of the radionuclides of interest generally preclude application to archaeological problems in North America (the same is true of other common radiometric methods, such as potassium-argon and argon-argon dating, which are not discussed here). At the opposite end of the decay chain, $^{210}\text{Pb}/^{206}\text{Pb}$ dating can provide age control for very young sediments (<0.2 ka; e.g., Popp et al. 1988). The ^{210}Pb isotope is a product of radioactive decay of radon gas (^{222}Rn) and is deposited over the landscape and incorporated in sediments.

Another radioactive isotope, ^{137}Cs , is not a product of uranium series decay, but rather was created through the human use of uranium in the construction and testing of nuclear weapons. The presence of ^{137}Cs in the environment is a consequence of aboveground testing of nuclear weapons (McHenry et al. 1973). Due to global circulation patterns, this isotope is present in sediments and waters throughout the world. Detectable amounts of ^{137}Cs occurred first in 1954 followed by peak amounts in 1963 in sediments worldwide (Jeter 2000). As with ^{210}Pb , the presence of ^{137}Cs can be used to identify modern soils and sediments formed during the past half-century.

Unfortunately, the time resolution of ^{210}Pb and ^{137}Cs is of little use to most archaeological problems, and no use of these isotopic dating methods was recommended in the CRCP for use in strictly archaeological contexts (Miller 1996: 35). However, they may be of use for identifying very recent sediments for geomorphic study and may also be of use for geoarchaeological considerations of site integrity. The presence of these isotopes in buried archaeological deposits or features would indicate that the deposits have been affected by some level of disturbance or bioturbation.

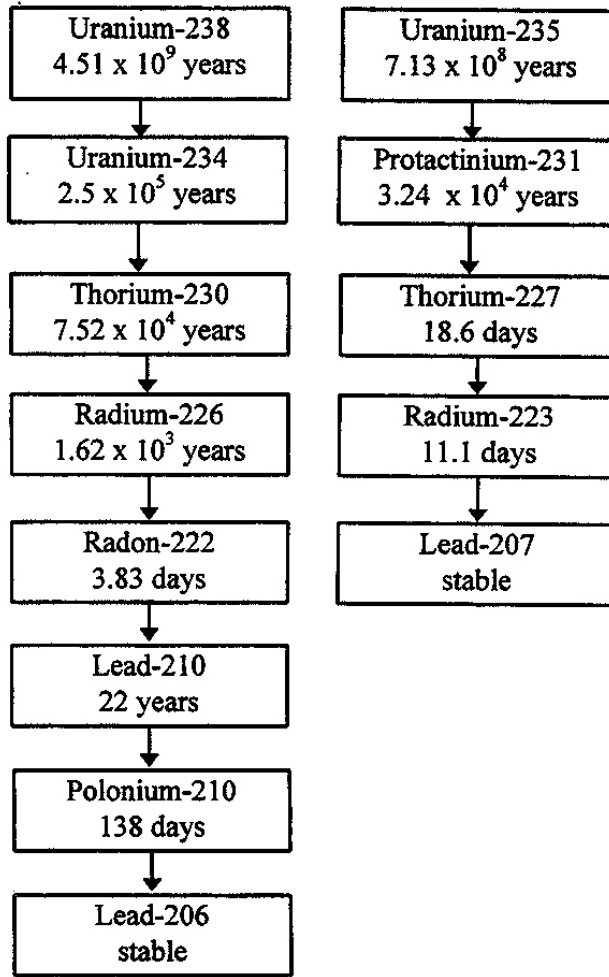


Figure 5.2. Simplified decay-series of Uranium-235 and Uranium-238.

Recent Developments in Uranium Series Isotope Dating

While the CRCP report recommended against using uranium series dating for archaeological research, the potential applications for geomorphic and geoarchaeological investigations were noted. The use of ^{210}Pb and ^{137}Cs dating has proven useful in geomorphic research for verifying the age of very young (historic and modern) sediments. Steve Hall (2002, 2007) has applied these methods to establish the modern age of laminated eolian sediments in modern and historic coppice dunes at the El Arenal Site on Fort Bliss and in the Mescalero sands of southeastern New Mexico. The results of ^{210}Pb were not as productive as ^{137}Cs , supporting previous findings that ^{210}Pb best accumulates at measurable rates in ponds and slow-aggrading environments (Appleby et al. 1979; El Daousky 1986). Measurable amounts of ^{137}Cs have been detected in coppice dunes, verifying that these formations are historic in age.

FISSION-TRACK DATING

Fission-track dating is based on the fact that spontaneous fission of ^{238}U atoms in microcrystalline rocks causes high-energy ejection of particles that can visibly damage the crystalline structure by ionizing atoms that come into contact with the fission products. Thus, the number of tracks is a

function of the uranium content of the rock and the duration of fission events. If the former is known, then the latter can be estimated from the number of tracks per unit area (Hurford and Green 1982). Fission-track dating of archaeological materials (e.g., lithic raw material, ceramics) is possible because heating can cause old tracks to heal in a process termed annealing, which essentially resets the clock (Michels 1973). If heating was insufficient to anneal the extant tracks, then dating of artifacts is not possible; however, there is little possibility of incorrectly dating an artifact in this manner because the derived age will be several orders of magnitude greater than it should be.

Fission-track counting requires that the surface be polished and etched with a solvent that preferentially attacks the damaged particle paths in the crystal lattice. Calculation is accomplished by counting the number of fission tracks in a representative area, heating the sample to anneal existing tracks, and then bombarding the sample with a slow neutron beam, which stimulates fresh fission of uranium. The number of tracks resulting from this treatment is proportional to uranium content, which allows the calculation of age.

In order to be suitable for fission-track dating of archaeological phenomena in the Holocene timescale, the material must be relatively uranium-rich (but not too rich) and susceptible to annealing with moderate temperatures. Suitable materials may include cherts, obsidian, a variety of minerals incorporated into ceramics, and apatite (calcium phosphate), which occurs extensively in bones, teeth, and shell. In addition, it is crucial that the artifacts were subjected to sufficient heat to anneal previous fission tracks. Unfortunately, the error margins of fission-track age estimates for Holocene-aged materials are too large to be of use (Miller 1996:35). Consequently, the use of this chronometric technique is not recommended at Fort Bliss. There have been few refinements of fission-track dating as a chronometric technique since the 1996 *Significance Standards*.

RADIOCARBON DATING

Radiocarbon age determinations are the most common method of obtaining numerical ages used in archaeology. The method is by far the most common and consistently reliable chronometric method for use at Fort Bliss, and it is unlikely that any developmental or future method will supplant it for many decades. As noted in the summary of the CRCP, radiocarbon dating has been and will continue to be the most common and useful isotopic chronometric method for Fort Bliss (Miller 1996: 31). NRHP eligibility is often tied to the presence of organic remains that provide chronological control. It has become the standard against which all other chronological methods are measured. The radiocarbon discussion has been moved from first to last among the reviews of chronometric dating methods in the current version of the *Significance and Research Standards*. This does not reflect any demotion in status or stature, but rather the fact that the method is so thoroughly developed and researched. It was felt that other chronometric methods deserved to be presented first.

Radiocarbon dating is based on determinations of the ratio between ^{12}C and ^{14}C atoms in the substance being dated. Like uranium-series dating, radiocarbon dating is possible because ^{14}C is radioactive, and decays to ^{12}C with time. Radiocarbon dating is applicable to a wide range of organic and inorganic substances, including wood, charcoal, seeds, leaves, resin, lichen, peat, humus, bone, ivory, tissue, horn, hair, shell, secondary carbonate, soil, sediment, groundwater, and ice. Other substances that have been dated with limited or debatable success include mortar, iron, potsherds, and rock varnish (Geyh and Schleicher 1990; Quigg et al. 2002).

Radiocarbon is produced in the upper atmosphere by bombardment of nitrogen by cosmic rays, where it quickly oxidizes to $^{14}\text{CO}_2$, and enters the carbon cycle in the biosphere. Thus, living organisms are in equilibrium with the atmospheric ^{14}C , but once they die, the material begins to

decay to ^{12}C . The half-life of ^{14}C is 5730 ± 40 years, but by convention a half-life of 5,568 years originally determined by Libby (1955) is used for most dating to provide comparability between measurements (this is not true in most geophysical applications, which typically base calculations on the correct half-life). As a result, ages on materials older than approximately 40,000 years (roughly eight half-lives) are impractical, because the frequency of individual radioactive decay events declines so steeply that they become impossible to separate from the natural background in counting (Lowe and Walker 1984). By convention, radiocarbon ages are reported in years before A.D. 1950, which is abbreviated as years B.P. or simply B.P.

Several factors are involved in the interpretation and correction of radiocarbon ages. First, organisms tend to incorporate ^{14}C and ^{12}C differently, depending on the characteristics of their metabolic pathways, and physical and chemical fractionation can also occur due to slight differences in the properties of ^{14}C and ^{12}C . These fractionation effects can be compensated for by examination of the ratio between ^{12}C and ^{13}C , which is also a stable isotope and occurs in the carbon reservoir in an amount proportional to the amount of ^{14}C . Because the fractionation effect on ^{14}C is roughly double the fractionation of ^{13}C , this ratio can be used to correct for fractionation of ^{14}C in the calculation of age. Such ages are referred to as $\delta^{13}\text{C}$ corrected ages, or simply corrected ages (Bradley 1985; Geyh and Schleicher 1990).

In addition, while one of the basic assumptions of the radiocarbon method is that the reservoir of atmospheric ^{14}C has been constant, this is not the case. Rather, the amount of atmospheric ^{14}C varied through time as a result of changes in cosmic ray influx, with the result that ages before 2000 B.P. are clearly too old (by up to 1 ka by 6000 B.P.). However, correction of this effect is possible through calibration of the age against a continuous, independently derived record that is based on sidereal data like tree rings (Bradley 1985). A variety of calibration datasets with differing time-depths and degrees of precision exist (Reimer et al. 2004; Stuiver et al. 1998), but calibration is generally not possible with samples older than 24 ka and less accurate with samples greater than 7 to 8 ka. After calibration, ages are reported on the sidereal (A.D. / B.C.) scale and referred to as "calibrated ages."

More problematic are variations in atmospheric ^{14}C caused by the burning of fossil fuels in recent centuries (the Suess Effect) and by creation of atmospheric ^{14}C by thermonuclear airbursts since 1945 (the Atomic Bomb Effect; Bradley 1985). While the Suess Effect typically results in large error estimates for young samples (typically less than 400 years), samples that include ^{14}C created by nuclear detonations (e.g., since 1945) typically yield ultramodern ages.

Another important concept to bear in mind is that radiocarbon ages, like all other radiometric techniques, are probability statements. Each radiocarbon age includes not only a numerical age, but also an expression of error, which is a function of a variety of physical factors (e.g., background radiation, self-absorption of beta particles, and statistical uncertainty in radioactive decay); this error function can be reduced, but not eliminated, by increasing sample size and/or counting time. Given a radiocarbon age of 1000 B.P. and an error factor of 100 years, there is a 68 percent probability that the true age lies in the range 900 to 1100 B.P., a 95 percent probability that it lies between 800 and 1200 B.P., and a 99 percent chance that it lays between 700 and 1300 B.P. Thus, there is a 1 percent probability that the true age of a sample dated at 1000 ± 100 B.P. is either younger than 700 or older than 1300 B.P.

Traditional radiocarbon dating employs an instrument, such as a gas proportional counter or a liquid scintillation counter, to measure the number of emitted beta particles, and hence the amount of decay activity, in the sample. One of the most important innovations in radiocarbon dating since its inception is the advent of common application of particle accelerator mass spectrometer (AMS) methods during the last decade. This technique is capable of directly counting the number of ^{14}C atoms in a sample, rather than the beta particles emitted by the tiny

fraction of total ^{14}C atoms that decay during the counting period. Thus, samples that are many times smaller (micrograms rather than grams) may be effectively dated, and dates can theoretically be extended to 15 to 16 half-lives (i.e., up to approximately 80 to 90 ka).

Radiocarbon Dating of Wood, Charcoal, and Other Plant Remains

The classic application of radiocarbon dating in archaeology is to date discrete plant remains like wood, seeds, leaves, and (in particular) charcoal created by incomplete combustion of such materials in fires. While radiocarbon ages are the basis of dating used in the packrat midden studies that provide much of the extant paleoenvironmental information (e.g., Van Devender 1990), unfortunately such materials are seldom preserved in archaeological sites on Fort Bliss, which is in large part responsible for the general lack of available chronometric information.

However, the advent of AMS techniques holds considerable promise to improve the ability to date sites with limited amounts of wood or charcoal. While conventional radiocarbon dating requires a minimum of 3 to 4 g of charcoal, AMS ages can be obtained from a few flecks of charcoal or a single seed. Naturally, the likelihood of recovering these minute amounts of plant tissue or charcoal is many times greater than it is for recovering significant masses of datable material.

Radiocarbon Dating of Bone and Shell

Bone and shell are also amenable to radiocarbon dating, albeit with some limitations. Dry modern bone is composed of a variety of fractions, including apatite (calcium phosphate), calcite (calcium carbonate), collagen (an organic protein), and fat. Collagen ages are the most reliable, but collagen tends to quickly weather away, particularly in harsh arid environments. Errors are frequently introduced in ages derived from other fractions (e.g., apatite and calcite), because these fractions tend to exchange carbon with the environment, particularly when buried in the presence of soil water or groundwater (Michels 1973). In these cases, the carbon dioxide in the surrounding water may be either younger than the sample (if in rough equilibrium with the atmosphere, as most soil water is) or considerably older than the sample if the water contains "dead" carbon (i.e., carbon so old that all measurable ^{14}C has decayed) dissolved from carbonate rocks. This latter problem, termed the hard water error, is even more acute in ages of terrestrial and freshwater shell, because such organisms often incorporate dead carbon into their shells directly from the surrounding environment while living (Bradley 1985). Nevertheless, judiciously applied and interpreted radiocarbon dating can provide reasonable control on the ages of bone and shell in most cases.

Radiocarbon Dating of Soils and Sediments

Radiocarbon determinations on soil and sediment differ fundamentally from assays conducted on materials such as wood, charcoal, bone, and shell in that the material assayed represents an amalgam of a large number of different organic sources of many different possible ages, rather than the remains of a single organism or a few discrete, related organisms (Figure 5.3). Thus, because the exact origin(s) of the organic matter being assayed is essentially unknown, even greater care than usual must be exercised in the selection of samples for dating and in the interpretation of the results.

Organic matter is incorporated and maintained in soils and sediments through a number of different mechanisms, and may take several different forms. The most obvious source of organic enrichment is through the death of animals and plants living on and in the soil, but it may also result from transport of allochthonous organic material to a site by fluvial, eolian, lacustrine, or

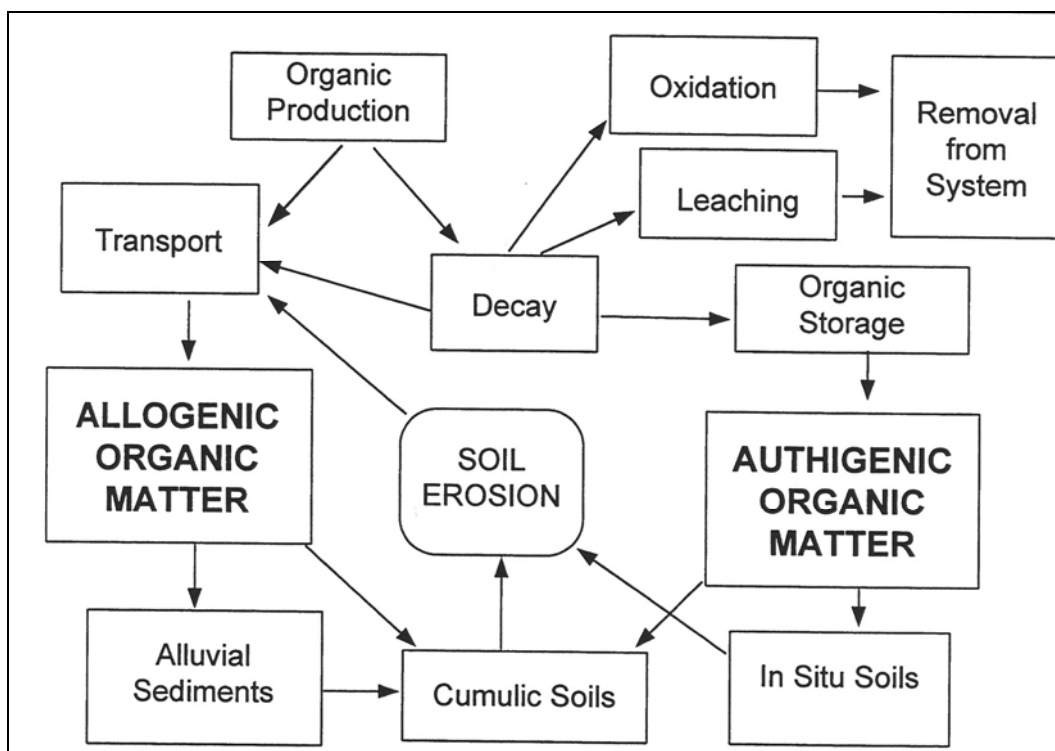


Figure 5.3. Flow diagram of organic matter routes through the soil/sediment system.

gravity-driven processes. Forms of organic material occurring in soils and sediments include fresh and partly decayed macrofossils, finely divided solid detritus, and a wealth of chemical decay products, including humic substances, cellulose, lipids, proteins, and carbohydrates. While many of these compounds are subject to further decay and rapid leaching or oxidation, others can be maintained in an active soil for thousands of years (Evans 1985; Matthews 1985). The major problem with radiocarbon dating of soils and sediments in arid environments like Fort Bliss is that the rate of production is so low, and the rate of oxidation so high, that substantial accumulations of organic matter are rare.

The most common mechanisms for holding organic compounds in soils and sediments involve (1) adsorption on various soil components (particularly clays and other colloidal substances) through physical, hydrogen, and electrostatic bonding and (2) complexing (coordination bonding) with clay minerals or metals. In addition, relatively simple organic compounds may be absorbed into the lattice of expandable clays (Schnitzer and Khan 1972; Tan 1982). Thus, clay-rich sediments and illuvial soil horizons provide an excellent environment for the recovery of humic substances suitable for dating. Organic substances and water typically occupy the same exchange sites on host clays. Adsorption frequently involves substitution of the organic molecule for a water molecule at the bonding site on a clay mineral; washing with water (as in hydraulic transport) can result in reversal of this process and release of the organic molecule (Tan 1982: 155).

Although the merits of radiocarbon determinations on soil organics have been widely debated for almost 30 years (e.g., Geyh et al. 1971, 1983; Goh and Molloy 1978; Gilet-Blein et al. 1980; Matthews 1985; Perrin et al. 1964; Scharpenseel 1971), opinion is still divided on the range of valid applications (Evans 1985; Geyh and Schleicher 1990). However, it is universally recognized that radiocarbon determinations on soil are problematic and must be treated and interpreted with great care. The principle difficulties inherent in soil dating lie in the complexity

of organic incorporation and maintenance in the soil system and in the myriad possibilities for contamination of organic matter in soils.

Radiocarbon age determinations on *in situ* soils measure a suite of organic materials and substances of different individual ages that have accumulated over the "life" of the soil. Each year, new organic matter is introduced as more plants die, decompose, and are incorporated, while leaching and oxidation remove a portion of the highly decomposed fraction. For this reason, radiocarbon ages on soil are commonly termed the apparent mean residence time (Campbell et al. 1967; Geyh et al. 1971; Matthews 1985; Scharpenseel 1971). Thus, because the radiometric measure obtained is always intermediate between the oldest and youngest organic matter present, radiocarbon determinations on soil organics only yield a minimum age for the onset of pedogenesis, while determinations on buried paleosols provide only a maximum age for burial. One of the advantages of the Fort Bliss environment is that the high rate of turnover resulting from slow accumulation and rapid destruction of organics implies that mean residence of organics in the soil system is relatively short; unfortunately, it also means that few organics are available for dating.

Four factors further complicating dating of older soils are (1) variations in depth, (2) variation in results between various humus fractions, (3) the achievement of equilibrium conditions in organic content, and (4) contamination by older or younger carbon. A number of investigators (e.g., Becker-Heidmann and Scharpenseel 1986; Scharpenseel 1971) have demonstrated a trend of increasing age with depth in many different types of soil profiles. This effect is believed to be due to a combination of higher organic production near the surface, more rapid decomposition of older organic matter in the more highly oxygenated upper solum, and gradual translocation of older organics into the lower horizons. It follows that ages most closely approximating the initiation of pedogenesis should be obtained from deep in the profile, while assays from the upper solum in buried paleosols should most closely approximate termination of pedogenesis.

A second factor lies in the difference in age apparent in determinations on different humate fractions documented by several researchers (Matthews 1980; Polach and Costin 1971; Scharpenseel 1979). In general, apparent age increases through the successive decomposition products of humus, so that fulvic acid generally yields the youngest ages, hymantomelanic acid, brown humic acid, and gray humic acid yields intermediate ages, and humin yields the greatest ages (Goh 1980; Matthews 1985). This effect is believed to result from more pronounced decomposition and the higher rate of removal of the less stable acids.

Finally, a major complicating factor in assaying soils is the presumed tendency for active soil systems to reach a state of equilibrium, such that the rate of incoming fresh organic matter is equal to the rate of decomposition and leaching of older organic matter. In such situations, the apparent mean residence time theoretically stabilizes due to organic turnover as the age of the soil continues to increase (Evans 1985; Martel and Paul 1974; Matthews 1980), leading to increasingly erroneous estimates with older and older soils. However, there is little understanding of the timeframe necessary to achieve equilibrium in various types of environments, while the stability of many organic products (e.g., charcoal, some humus substances, opal phytoliths, some microbial enzymes) virtually eliminates the possibility of complete organic turnover (Matthews 1985). Still, the rate of turnover is clearly very rapid in warm arid environments, such as the Fort Bliss region.

Contamination of soils with older or younger carbon can occur through a number of different mechanisms. Additions of younger carbon, resulting in age underestimation, can result from root penetration, other forms of bioturbation and pedoturbation, cultivation, and other forms of anthropic disturbance, illuviation of finely divided organic matter and humic substances, and bacterial or fungal growth (Evans 1985; Matthews 1985). Additions of older carbon, leading to

an overestimation of age, can result from the depositional inclusion of fossil carbon (e.g., graphite, lignite, old wood, fossil carbonates), or the incorporation of old carbon into organic compounds or soil carbonates derived from dissolution of fossil carbonates in groundwater (Fowler et al. 1986; Geyh et al. 1971; Geyh and Schleicher 1990). While considerably old carbon is necessary to substantially bias a radiocarbon age, the relatively high $^{14}\text{C}/^{12}\text{C}$ ratio in young carbon makes even minor contamination highly problematic.

Unlike soils, the problems and prospects associated with radiocarbon dating of sediments remain little explored. The principal reason that the radiocarbon method has not been widely applied to mineral sediments probably lies in an assumption on the part of most investigators that radiocarbon age determinations on organic material from clastic sediments, like those from soils, are unreliable measures of the age of deposition. However, sediments are fundamentally different from soils in that organic matter is typically allochthonous rather than autochthonous and predates rather than postdates deposition. Moreover, salient chemical and environmental variables are typically less complex than is the case with soils, making suitability judgments and contextual interpretations somewhat easier.

The major assumption that must be made in dating sediments is that the organic material is penecontemporaneous and can provide a good estimate of the sediment age (Blum and Valastro 1989; Haas et al. 1986). If the organics have previously been in storage elsewhere (e.g., accumulating for thousands of years as a soil that is then converted to sediment by erosion), then the estimate provided can be significantly older than the age of deposition. Fortunately, this scenario is not likely to have occurred in the Fort Bliss region during the Holocene.

While soil ages provide only a minimum age for the onset of pedogenesis and sediments yield only a maximum age for their deposition, a combination of these two problems is presented by cumulic soils. In this situation, organic sediment that frequently contains older organic matter accumulates slowly on a surface, which is also undergoing contemporary pedogenesis and incorporating fresh organics; resulting ages can be either older or younger than the true age of sediment deposition, depending on a large number of interrelated pedogenic and geomorphic factors. Therefore, radiocarbon ages obtained from cumulic soils can be very difficult to interpret.

Radiocarbon dating of organic soils and sediments involves a complex sequence of pretreatment steps during which possible contaminants are removed and the organic carbon is concentrated (e.g., Haas et al. 1986; White and Valastro 1984). Determinations can be made on several different humus fractions leached from the sample or on residual solid organic matter. Humin and humic acid, which are relatively stable compounds, are the most common humus fractions dated, while water-soluble fulvic acid is rarely dated due to its high mobility. Figure 5.4 presents a summary of the different routes that organic matter can take through the environment and the relationship between in situ soils, cumulic soils, and sediments.

Several factors can be identified as important considerations, both in evaluating the suitability of sediment for radiocarbon dating and in interpreting the significance and possible implications of any ages obtained. The most important single consideration is the origin of organic matter incorporated in the fill. Ideally, sediments used for radiometric dating of stratigraphic sequences should ideally contain only penecontemporaneous organic matter, as fossil carbon and organics derived from other soils only introduce error.

Unfortunately, in most situations the prospects for identifying the original source(s) of incorporated humus, and for evaluating the relative temporal context of the organic matter and the encasing sediment with any degree of confidence, range from extremely difficult to impossible.

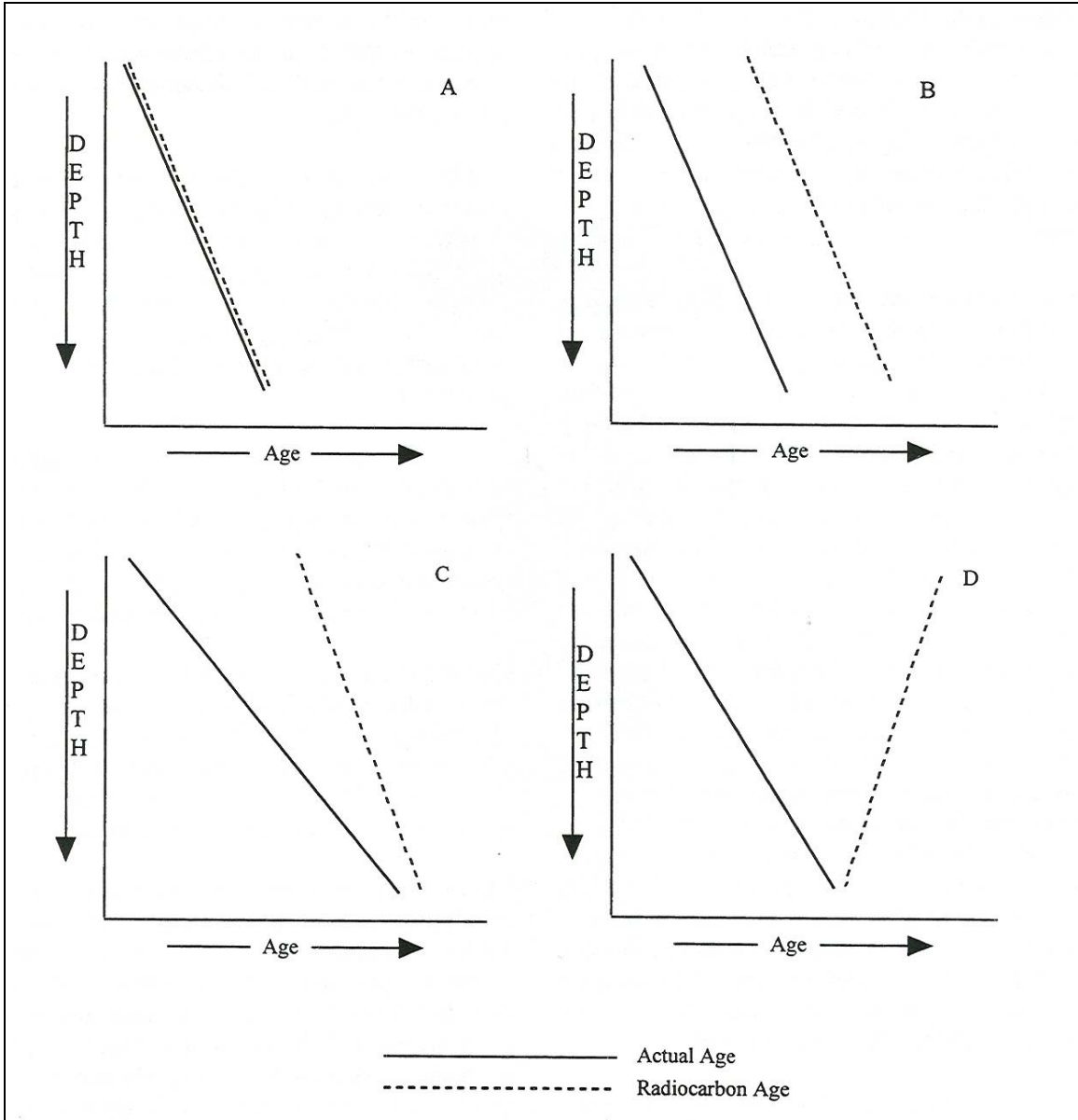


Figure 5.4. Idealized models for the relationship between actual sediment age and apparent (radiocarbon) age in a small catchment. (Under conditions of [a] no soil erosion; [b] erosion in equilibrium with organic production; [c] accelerated soil erosion; and [d] catastrophic erosion).

Nevertheless, it is possible to identify several characteristics that may indicate contamination with older carbon from eroding soils: (1) relatively high organic matter content; (2) variability or visual stratification in color due to organic matter differences; and (3) the presence of other soil constituents, such as carbonate nodules, reworked from original context.

A second major consideration in evaluating radiocarbon ages on alluvial sediment is the size of the catchment upstream from the point of deposition. Along with the addition of relatively organic-rich sediment from erosion of A horizons, old organic matter can be introduced bound to clays derived from the erosion of illuvial B horizons upstream. Although it can be assumed as a component, the odds of detecting the presence of this material prior to dating are negligible. Thus, fine deposits in a small catchment must always be considered suspect. However, if the

distance of transport is sufficient, washing of the clays can result in the release of much of this adsorbed organic matter prior to deposition (Tan 1982), improving the odds of obtaining an acceptable radiocarbon age.

Finally, like soils, sediments are subject to contamination by older or younger carbon after deposition and burial. The two major sources of contamination that should be evaluated are younger, intrusive organics delivered by root penetration or leaching of overlying humus, and older carbon delivered as dissolved bicarbonate in groundwater.

The following treatment presents a simplified conceptual model of four possible relationships between apparent age profile of a sediment column as measured by radiocarbon determinations on bulk sediment and the actual age of deposition. Figure 5.4 presents a graphic depiction of each model (see Figure 5.4).

Contemporaneity, the situation represented by Figure 5.4a (see Figure 5.4), is the ideal situation for use in age determinations. In this model, the ratio of penecontemporaneous organic matter to old organic matter is so high that the obtained age closely approximates the actual age of the sediments.

Figure 5.4b represents an idealized case of equilibrium loss of soils in catchment (see Figure 5.4). In this model, organic matter exhibits an average residence span that remains relatively constant through time on the slopes of the catchment before being eroded and deposited as sediment. This is not meant to suggest that all organic matter in the system resides on the slopes for the same length of time, or even that all is converted to sediment.

Indeed, much of the total organic production is decomposing and being translocated deep into the profile, more is being immediately converted to sediment. The soil as a whole is experiencing no net degradation. What the model does depict is a balanced delivery of contemporary and stored organics, such that the average age of organics being delivered with the sediment does not change with time.

Figure 5.4c represents a model of accelerated soil loss in the same theoretical catchment (see Figure 5.4). Although the rate of sediment yield does not change dramatically, the soils in the catchment do begin to degrade. As a result, the ratio of old organics to contemporary organics delivered increases. At the same time, the mean residence age of stored organic matter being delivered to the sedimentary system increases as the soil is degraded and the older organic matter at depth is converted to sediment.

Finally, Figure 5.4d represents a model of catastrophic erosion in catchment (see Figure 5.4). Here, the sediment yield increases dramatically as the soils are degraded, and the age profile exhibits an apparent stratigraphic inversion as the normal age/depth profile of the basin soils is reversed due to deposition of the upper solum at the base of the sediment profile, followed by material derived from successively deeper in the original soil. Thus, the apparent age is almost entirely a function of reworked old organics. Note that the profile should return to the model presented in 5.4a (see Figure 5.4) after the soil has been exhausted.

In general, dating of sediments in arid alluvial fans and sandsheets has historically proven very difficult, which has led to the development of alternate methods of age determination (e.g., Dorn et al. 1986, 1987). However, the growing availability of AMS methods of radiocarbon dating reduces the carbon requirement by several orders of magnitude, suggesting that radiocarbon dating can be applied much more widely than it has been up to this point. One significant possible application is to anthropic humic substances. Many of the sites in the bolson are marked by the presence of ill-defined "stains" or localized dark discolorations of the sand, that are usually believed to be the remains of prehistoric features. The composition of these stains is poorly understood and probably variable; some may consist almost entirely of finely divided charcoal,

while others probably include uncarbonized plant material and humic substances. Still others may be entirely composed of the latter material, and often probably represent in situ decomposition of a shrub (particularly one that was buried by eolian activity), and thus are unrelated to cultural activity. In all cases, such stains are amenable to radiocarbon dating, although initial sediment processing may require vigorous methods and AMS measurement may frequently be required. AMS dating of dispersed, finely divided charcoal has proven to be a valuable technique in other regions (e.g., Gillespie et al. 1992).

Radiocarbon Dating of Soil Carbonates

Another use of radiocarbon applicable to the Fort Bliss region is dating of secondary carbonates, which has been applied in the region several times (e.g., Monger 1993d; Monger et al. 1993; Rightmire 1967). This technique can provide ages for geomorphic surfaces and episodes of pedogenesis, and can thus provide a measure of chronometric constraints on associated archaeological sites. However, radiocarbon dating of carbonate is complex for several reasons. First, the complex development of indurated calcrete is a slow, nonuniform process; consequently, various contiguous parts of a caliche horizon can strongly reflect differing ages, and sample selection must be performed carefully (Goudie 1983). Even if internal structures are carefully noted and sampling is structured accordingly, hard water effects are a common pitfall, particularly in dating relatively advanced stages of calcrete (e.g., Stages IV-VI) where solution and reprecipitation has probably occurred repeatedly. As water attacks and dissolves old indurated carbonates, dead carbon is released into the system, diluting the relative content of ^{14}C and making the determined age artificially old (Gile and Grossman 1979; Williams and Polach 1969, 1971). Recent chronometric studies using OSL dating have cast some doubt on the accuracy of soil carbonate dating (see Chapter 6).

Other Applications of Radiocarbon Dating

Another application that has great potential utility on Fort Bliss is radiocarbon dating of pollen grains with the AMS method. This is significant because pollen grains are relatively resistant to degradation and can be preserved long after other organic remains are gone. Even more significantly, opal phytoliths also contain carbon. At least some of this carbon is occluded and therefore relatively protected from oxidation. Wilding (1967) demonstrated that this carbon is amenable to radiocarbon dating, while more recently Kelly and others (1991) have recently demonstrated that stable carbon isotope ratios can be obtained from the carbon occluded in phytoliths. This is very significant because opal phytoliths, which are composed of silica, are very stable structures and provide an opportunity to date otherwise undatable strata. Of course, both pollen and phytoliths are highly subject to erosional reworking and vertical movement in section due to their small size; great care is therefore required in sample selection. Radiocarbon dating of organic matter in ceramic sherds and organic residues extracted from limestone rock used as heating elements in hearths has also been investigated (Quigg et al. 2002).

QUASI-CHRONOMETRIC DATING TECHNIQUES

The following techniques can also be used to obtain numerical ages through calibration with independently derived chronometric data. They are classified as quasi-chronometric here because the accuracy, precision and/or utility of the methods remains somewhat controversial.

Obsidian Hydration

Obsidian hydration dating has a long and complicated history of use at Fort Bliss and throughout the Jornada Mogollon region. The use of obsidian hydration dating in the Jornada was among the first applications of the method in the Southwest, and much of the history of the development of the method was pioneered in the Jornada region, especially during the operation of the Obsidian

Hydration Laboratory at New Mexico State University from 1985 to 1987 and during the CRCP at Fort Bliss in the early 1990s. As noted by Miller (1996), over 2,300 obsidian artifacts from 314 sites (of which 181 were on Fort Bliss) were submitted for hydration rim measurement between 1979 and 1996, making this by far the most intensively used dating method at that time. Unfortunately, due to a variety of methodological and experimental problems, none of the calendar dates provided by the method are considered reliable.

Obsidian-hydration dating is a relative dating technique that can be extended through correlation to provide numerical age estimates (albeit with large error factors). Obsidian hydration is based on the fact that freshly exposed obsidian surfaces take up water from the environment, forming a hydrated obsidian termed perlite. Hydration rind development slows with time, but overall thickness of the rind is a nonlinear function of time, temperature, and obsidian chemistry (interestingly, variability in humidity has little effect on the rate of hydration); thus, examination of the thickness of the rind provides a good estimate of the relative age of the surface. The thickness of the hydration rind was traditionally measured optically via thin-section but has since been supplanted by newly developed methods such as secondary ion mass spectrometry (SIMS) and infrared photoacoustic measurement (Anovitz et al. 1999; Stevenson et al. 2000, 2004). This makes the technique ideal for relative dating of obsidian flakes in intrasite and regional contexts (Bradley 1985; Lowe and Walker 1984).

Obsidian hydration can also provide quantitative, material-dependent, and location-dependent estimates of age when calibrated to an independent time scale. Obsidian hydration follows this diffusion law:

$$M^2 = Kt$$

where M = hydration rind thickness in microns; K = the diffusion coefficient; and t = time. The diffusion coefficient K is a function of several variables, notably the chemistry of the obsidian (which will not change appreciably with time) and the temperature (which does change with time, and is largely a function of climatic change and burial history). Thus, the rate of hydration can be expected to change through time, not only as a function of increasing rind thickness (which slows the rate logarithmically, and is thus predictable), but also as a function of climatic change and burial history. These latter factors are difficult to factor in and are therefore typically ignored; K is considered a constant. Nevertheless, once curves are constructed for commonly occurring varieties, obsidian hydration can provide valuable, albeit approximate, chronometric estimates (Michels 1973).

Obsidian-hydration dating received a thorough historical and experimental treatment during the CRCP (Miller 1996, Vol. III). A review of the history of obsidian dating found numerous problems in chemical characterization and source identification, experimentally determined hydration rate constants, and measurement or estimation of ambient temperature and exposure conditions. A highly controlled experimental study was conducted using obsidian from securely dated contexts, temperature models based on soil temperature measurement cells left at sites for a period of one year, and artifact-specific hydration rates calculated on the basis of intrinsic water content. Even under these controlled experimental conditions, widely discordant series of hydration dates were obtained for all the sites included in the study. The ultimate result of the CRCP investigation is that obsidian hydration dating is not recommended for use as a chronometric method at Fort Bliss. The reasons for this recommendation include a variety of uncontrolled and poorly understood physical and chemical factors affecting the rate of water diffusion into obsidian glass as well as natural and cultural depositional patterns that make it difficult, if not impossible, to control for micro- and macro-environmental parameters that effect the chemical hydration process. For additional details on these issues, the reader is referred to Volume III of the CRCP report.

Oxidizable Carbon Ratio Dating

Oxidizable carbon ratio (OCR) dating was a relatively new technique that created a stir of excitement when first reported in the early 1990s. It was thought that the potential for widespread application (any form of carbon-bearing sediment) and low cost per sample would provide a reliable and highly cost-effective alternative to radiocarbon dating for obtaining ages from carbonaceous sediments (Frink 1992, 1994, 1995). One of the advantages of the method is cost; roughly 12 OCR dates can be obtained for the price of a single AMS radiocarbon age.

OCR dating is based on the observation that carbonized organic matter is not as stable as previously believed, and undergoes changes that can be measured using standard soil analytical techniques (Frink 1992). In essence, OCR dating involves the comparison of oxidizable organic matter content as expressed by Walkley-Black wet combustion and total organic content as expressed by loss on ignition. Oxidizable organic matter only provides a measure of more reactive organic compounds, while loss-on-ignition provides a measure of total organic content. Frink has found that the ratio of these two fractions decreases linearly through time as the reactive components are removed at a higher rate. If the various environmental factors (e.g., temperature, moisture, soil texture and pH, and depth) are controlled, then the OCR ratio correlates quite well ($r=0.98$) with radiocarbon age, and can thus be used to predict the radiocarbon-equivalent age of unknown samples.

Control for the various environmental factors governing the rate of carbon loss is accomplished using the following formula:

$$OCRDATE = \frac{OCR \times Depth \times MeanTemperature \times MeanRainfall}{MeanTexture \times 2^{j^{(-\%C)} \times 14.4888}}$$

where OCR is the measured ratio between oxidizable carbon (per Walkley-Black wet combustion) and total carbon (per Ball loss-on-ignition); depth is the depth below present ground surface in cm; mean temperature is the modern mean annual temperature in degrees F; mean rainfall is the modern mean annual precipitation in cm; mean texture is a specialized measure of texture determined by dry screening, pH is determined by measurement of a 1:1 soil/water paste; %C is percent carbon based on loss-on-ignition, and 14.4888 is an empirically-derived constant.

Although once thought promising, OCR dating is based on a number of significant assumptions, and many problems with the method remain to be worked out. Several of these problems have already been identified, contraindicating application of OCR in some environmental situations (Frink 1995). For example, because anaerobic conditions change the character and rate of biological decomposition, samples from contexts that were saturated, even intermittently, do not appear to be reliable. Similarly, samples from contexts that are sealed by impermeable strata, very deeply buried, or protected from precipitation (e.g., in a rock shelter) are problematic because oxygen and moisture influx are not predictable by the existing equation. Samples with very low (<0.05 percent) carbon content (Frink 1994, 1995) have also proved problematic. In addition, one important factor downplayed by Frink (1995) may also prove important to application of the method on Fort Bliss; namely, the possibility that paleoclimatic fluctuations have significantly affected the rates of carbon loss over the Holocene period. While Frink (1995: 100) recognizes this factor, he downplays it, arguing that deviations from modern mean precipitation and temperature and precipitation have been relatively minor during the Holocene and should not exceed the standard error of the OCR estimate. Although this basic assertion is debatable, it does appear that environmental shifts were insufficient to seriously bias the samples addressed by Frink from the eastern United States. However, Fort Bliss is situated in a much more arid environment, and minor changes in precipitation could conceivably have major consequences for rates of biologic activity.

Recent Developments with Oxidizable Carbon Ratio Dating

The OCR dating method was thought to have tremendous potential to address the archaeological record at Fort Bliss, particularly the myriad small hearths and areas of localized, carbon stained sands in the bolson. In addition, the OCR method does not suffer from the problems imposed on recent (i.e., less than 400 years B.P.) radiocarbon samples by the Seuss Effect, DeVries Effect, and Atomic Bomb Effect (Bradley 1985), and it was thought that the method could effectively address Protohistoric and Historic features plagued by the typically wide error factors of radiocarbon ages in this timeframe.

Given this potential, OCR dating was attempted during two recent projects at Fort Bliss (Baugh and Sechrist 2001; Sitton et al. 2005), the former of which took into consideration the prospective application of the method for identifying Protohistoric features and occupations. In each case, OCR sediment samples were paired with wood charcoal samples submitted for radiocarbon dating. The results are presented in Table 5.2 and illustrated in the scatterplot of Figure 5.5. Features with radiocarbon age estimates ranging from 1000-3000 B.P. have corresponding OCR dates that range between 22-493 B.P. The two oldest radiocarbon-dated features of 5780 and 7070 B.P. yielded OCR dates of 163 and 271 B.P., respectively. As shown by the regression statistics and line, no statistically significant relationship exists between the two series of age estimates. If the point distribution in Figure 5.5 (see Figure 5.5) could be fit to some form of exponential or power curve, an argument could be made that the OCR method might be calibrated for local environmental histories. In contrast, the poor correlation and scatter of points indicates that the method is not measuring chronometric trends with any degree of accuracy, consistency, or reliability.

Table 5.2.
Comparison of Radiocarbon and OCR Dates from the Hueco Bolson and Tularosa Basin

Site Number	Feature	OCR Date	Radiocarbon Date (uncalibrated)
FB 9423	4	493	920
LA 36790	17	386	1520
FB 13147	3	364	1570
41EP3145	1	n/a	2110
41EP3145	3	93	2240
41EP3145	9	135	970
41EP3145	10	179	2250
41EP3145	22	202	380
41EP3148	5	271	7070
41EP3148	6	376	2330
41EP3152	4	175	2900
41EP3152	5	85	2930
41EP3152	7	224	1500
41EP3152	9	66	1320
41EP3152	15	181	1330
41EP3152	16	196	n/a
41EP3152	21	181	380
41EP3375	1	163	5780
41EP3385	1	261	3740
41EP3385	2	97	2880
41EP3385	3	22	2450

(data from Baugh and Sechrist 2001; Sitton et al. 2005).

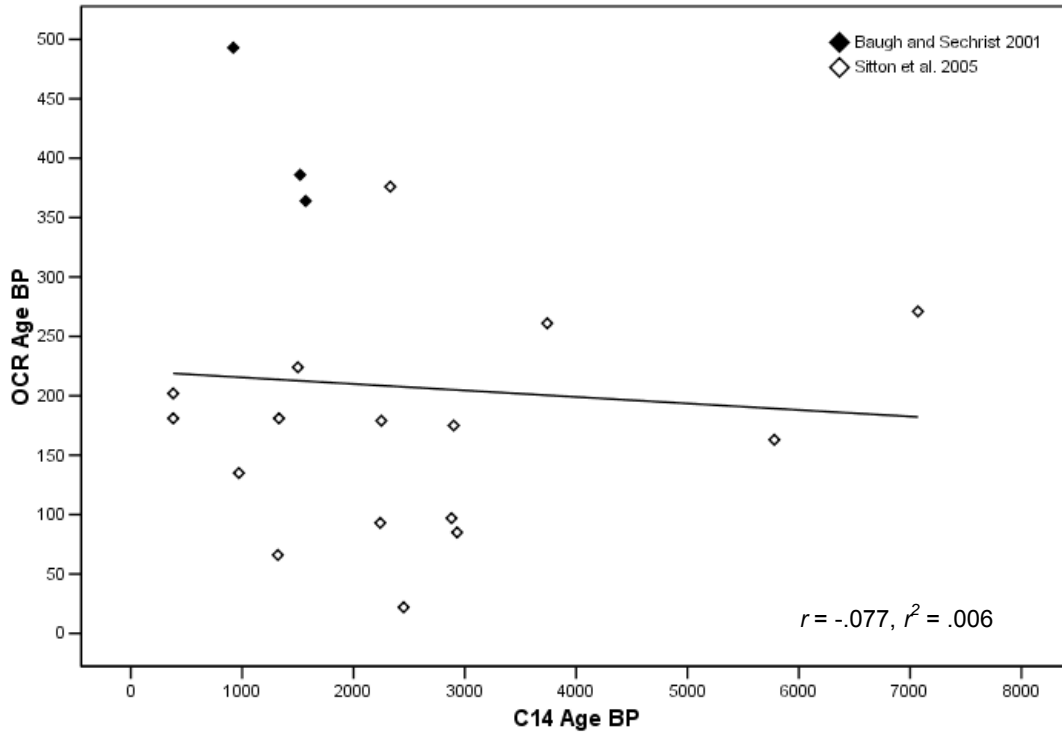


Figure 5.5. Scatterplot of paired radiocarbon and oxidizable carbon ratio age estimates from hearth features in the Hueco Bolson (data from Table 5.2) showing the complete lack of correspondence between the trends of age estimates provided by the two methods.

The most troubling aspect of the method is that calculation of OCR dates depends on the use of the same exponential Arrhenius temperature equation required to calculate obsidian hydration dates. This temperature-dependent formula requires that the entire temperature and exposure history be understood. As a result, OCR dating suffers from many of the same drawbacks as obsidian hydration dating. A disturbing amount of after-the-fact tinkering with temperature estimates, soil erosion factors, and other ambient and measurement variables is required to bring OCR age estimates anywhere close to a series of paired radiocarbon dates. Despite some reports of successful dating studies using OCR (e.g., Pertulla 1997), the method is not recommended for use at Fort Bliss.

Cosmogenic Isotope Dating

This category includes a number of different, emerging techniques termed “surface exposure dating methods” (Beck 1994) that have the potential to date the length of surface exposure of rocks and artifacts. Although the original concepts are far from new (e.g., Davis and Schaffer 1956), the advent of modern particle accelerator spectrometry now allows for the high-precision determinations necessary for application. These techniques measure the production of cosmogenic nuclides; in other words, new isotopes created by the collision of existing atoms and cosmic rays. The same process is responsible for the creation of ¹⁴C in the upper atmosphere, where cosmic ray flux is higher. The cosmogenic techniques measure generation of new isotopes due to cosmic ray influx in exposed surfaces at the ground, and are based on the assumption that cosmic ray flux is constant (not strictly true) and that the number of cosmogenic nuclides is proportional to the length of exposure (Cerling 1990; Kurz and Brook 1994).

Specific techniques in varying stages of development include ^{10}Be , ^{26}Al , ^{36}Cl , ^{14}C , ^{41}Ca , ^3He , and ^{21}Ne . These techniques can be divided into two classes: those that measure radionuclides and require an accelerator mass-spectrometer for measurement, and those that measure stable noble gas nuclides and can be measured with a noble gas mass spectrometer. Determinations based on noble gas nuclides are less complicated because they do not require adjustment for radioactive decay; they are also more problematic due to the potential for inherited isotopes. Table 5.3 illustrates the characteristics of each of the isotopes. Application of these methods to problems relevant to the Fort Bliss landscape has already begun (e.g., Wells et al. 1995).

Table 5.3.
Cosmogenic Nuclides Used for Quaternary Surface Exposure Dating
(after Kurz and Brook 1994)

Isotope	Half-Life (years)	Measurement Method	Procedural Comments	Approx. Production Rate (atoms/g/yr at sea level)	Approx. Age Range
Helium-3	Stable	Mass	Diffusive loss? High	160 (olivine)	1 ka to ca. 3 Ma
Beryllium-10	1.5×10^6	AMS	Production rate; lowest detection limit, inherited	6 (quartz)	3 ka to 4 Ma
Aluminum-26	7.16×10^5	AMS	He Atmospheric Contamination aluminum-27 interference	37 (quartz)	5 ka to 2 Ma
Chlorine-36	3.08×10^5	AMS	no mineral separates;	8 (basalt)	5 ka to 1 Ma
Neon-21	Stable	Mass Spectrometry	composition-dependent inherited neon	45 (olivine)	7 ka to 10 Ma
Carbon-14	5,730	AMS	shortest half-life;	20 (basalt)	1 ka to 18 ka
Calcium-40	1.03×10^5	AMS	Atmospheric contamination Useful half-life, difficult measurement	unknown	to 300 ka

Age determination requires measurement of the amount of the nuclide and determination of the rate of radioactive decay and the rate of production, which is dependent on altitude and latitude. When these factors are known, age can be determined by simply dividing the total amount of atoms of the nuclide in a given volume of sample by the net production rate, which is a function of production and decay. Complications arise when surface stability is not perfect, but corrections for slow surface erosion are possible (Kurz and Brook 1994).

Of the various methods, ^3He provides the most favorable combination of sample contexts, chronological resolution, and ease of measurement. This isotope is commonly used to date volcanic fields and flows of basaltic lava (Craig and Poreda 1986; Kurz et al. 1990), including the Potrillo volcanic field east of El Paso (Anthony and Poths 1992). It is possible that ground stone tools made of basalt could be dated using this method. However, given the complications with this method, cosmogenic isotope dating could only be used at Fort Bliss for artifacts known to have been continuously exposed on the surface of the site. Cosmogenic nuclide dating may also be of use to assess exposure histories of obsidian artifacts (Miller 1996: 34). However, there have been no applications or developments of this method for archaeological use at Fort Bliss. Based on the limited applications, potential expense, and measurement problems of the method, it is not recommended for use at Fort Bliss.

Cation-Ratio Dating

Another technique of dating surfaces in deserts is termed cation-ratio dating, which examines the ratio of soluble (potassium and calcium) versus insoluble (titanium) cations in desert varnish (e.g., Dorn and Oberlander 1982; Dorn et al. 1987). According to Dorn and his coauthors, this ratio decreases with time in a fashion that is regular enough to provide chronometric control once calibrated to an independent scale (typically through AMS radiocarbon dates on the varnish). However, several recent critics (e.g., Bierman and Gillespie 1994; Harry 1994) present compelling evidence that the uniformity necessary for use of the process as a chronometric dating technique does not exist. Therefore, the technique is not recommended for use at Fort Bliss at this time (Miller 1996: 35).

Chert Patination

Patination of chert is similar to obsidian hydration in that it involves progressive alteration of the surface of a freshly fractured artifact (Hurst and Kelley 1961). Several different types of patinas have been reported in the literature, including whitish patinas, brownish patinas, and glossy patinas. While white patinas are probably the most common and most likely represent a subtractive process (i.e., silica dissolution), the character of glossy and brown patinas may be either additive (e.g., staining by ferric or humic substances), subtractive, or indicative of in situ changes such as oxidation of extant components. A number of environmental and material-specific variables, including edaphic conditions, temperature, mineralogy, porosity, and permeability have been identified (VanNest 1985). Moreover, differential patination of different sides of artifacts is very common, suggesting at least a degree of photochemical control on patination rates. In short, little is understood about the various physical transformations commonly included under the rubric of patination (Frederick et al. 1994; VanNest 1985). Nevertheless, quantification of progressive patination has been proposed as a possible dating technique (e.g., Purdy and Clark 1987).

The utility of patination as a chronometric dating technique is limited by the many factors outlined above, coupled with uncertainties of burial inherent in a dynamic environment. In a study of patination of time-diagnostic chert artifacts on Fort Hood, Texas, Frederick and others (1994) found that while the maximum degree of patination across an artifact class appeared to be largely a function of age, the degree of patination of individual artifacts within that class could vary widely. Thus, once calibrated to an independent chronometric scale, patination appears potentially suitable for establishing a minimum age in that artifacts with a patina rind of thickness X can be no younger than the time necessary for that rind to develop; unfortunately, the presence of that rind in no way implies that the artifact is exactly that age. Moreover, a lack of patination has no implications for age whatsoever because many factors appear to be able to slow the rate of patina development. As a result, such studies are not recommended at Fort Bliss.

Amino Acid Racemization

Amino acid epimerization analysis involves the measurement of the ratio of the amino acid epimers D-alloisoleucine and L-isoleucine, referred to hereafter as the A/I ratio, in a carbonate matrix (McCoy 1987; Miller 1980). The method is typically applied to gastropod shells (e.g., Ellis and Goodfriend 1994; Goodfriend 1987), which are the focus of this discussion, but has also been applied to calcite speleothems (e.g., Lauritzen et al. 1994).

In modern specimens, essentially all amino acids are in the L-form, but over time they chemically convert (epimerize) to the D-form. The rate of conversion is a function of temperature, but is consistent enough that the A/I ratio can be used as a proxy measure of relative age, and can provide an approximation of absolute age when tied to an independently derived chronometric scale (Ellis and Goodfriend 1994; Goodfriend 1987). Although some moisture must be present

for the epimerization reaction to occur, the most important variable involved is heat, which governs the rate of conversion. Significantly, for archaeological studies, snails subjected to substantially elevated temperatures (e.g., in a fire) for short periods of time appear to rapidly epimerize during heating, resulting in ratios that resemble substantially older specimens.

Another factor that may affect the relationship between A/I and age is slope-aspect. One of the implicit assumptions of the A/I method is that the rate of reaction is equal in the spatial realm within the boundary of a given study area. In other words, while the rate of the reaction is recognized to vary temporally due to changes in climate, it is assumed to be equal at all locations within a limited geographic area at a given point in time. However, because elevation and aspect strongly influence soil temperature, snails from different topographic/edaphic settings may not be strictly comparable. Because of these types of factors, in the CRCP A/I method was recommended for use at Fort Bliss only in rock shelter excavations and for paleotemperature reconstruction (Miller 1996: 34).

Nevertheless, recent research (e.g., Ellis and Goodfriend 1994) suggests that amino acid racemization of land snails may provide relatively good chronometric data if interpreted carefully. Moreover, such research also has the potential to provide valuable information about the integrity of buried archaeological assemblages, and is relatively inexpensive to perform (Ellis et al. 1994).

Bone Fluoride Dating

Bone fluoride dating is a correlated age, relative dating method that has shown some promise for developing intrasite chronologies at complex sites with multiple features. The method is based on the premise that animal bone absorbs fluoride ions from surrounding soils and groundwater, and thus the fluoride content of a sample of bones from a specific location will increase with time (Johnsson 1997). If burial conditions are relatively similar and stable, older bones will have higher fluoride content than younger ones.

Fluoride dating works best when it is applied within a single site that has little variation in soil chemistry (Schurr 1989), a situation that characterizes the homogeneous eolian or alluvial depositional environments of most landforms at Fort Bliss. The method has been used to obtain fine-scale chronological resolution for human burial populations at Grasshopper Pueblo (Ezzo 1992). It has also been successfully used to differentiate occupational and trash disposal episodes at several complex sites by measuring fluoride content in animal bone (Schurr and Hally 1999). Of particular interest in the application of the method to develop a fine-scale relative chronological ordering of dozens of house structures and other facilities at the early agricultural Los Pozos Site in the Tucson Basin (Gregory and Schurr 2000; Schurr and Gregory 2002).

Conceivably, it would be possible to measure fluoride content in rabbit bone from one or more prehistoric sites at Fort Bliss. The drawbacks to the method are that, as a correlated age method, it requires paired radiocarbon dates to determine a local fluoride absorption rate and develop a calibration curve. An additionally restrictive aspect is that, given potentially variable soil conditions across the base, the scale or extent to which a particular fluoride absorption rate or calibration curve developed at one site could be applied to other sites remains unknown. It is possible that fluoride absorption rates are valid only at local scales. Therefore, the method may only be feasible at a single complex, multicomponent site with several well-dated occupations or group of such sites in proximity to each other.

Nevertheless, the method may help in determining occupational histories at complex pit house and pueblo sites with multiple house structures and pits. The bone fluoride dating method is very inexpensive and multiple samples may be analyzed for the equivalent cost of a single radiocarbon age estimate. If evidence of numerous pits, household clusters, and room blocks are revealed

through excavation at one or more major residential sites, it is recommended that an experimental pilot study of relative bone fluoride dating be undertaken.

RELATIVE AND CORRELATIVE DATING TECHNIQUES

This final suite of methods consists of interpretive techniques that can be used to obtain qualitative estimates of age. They are typically the first suite of chronometric tools applied at a given site, and usually dictate whether other, more precise methods will be applied.

Geomorphic Relative and Correlative Age Estimates

Soil Development: Because soil development is a time-dependent process, the degree of alteration that has affected a sedimentary unit is in large part a function of the duration of pedogenesis. For this reason, examination of the development of various soil attributes can be used to construct a soil chronosequence, which provides a rough indication of the age of different soils formed in similar parent materials under equivalent topographic, climatic, and biotic influences (e.g., Harden 1982; Singer and Janitzky 1986). Such a method can be applied relatively loosely by simply making field observations, which is probably most common, or it can be applied rigorously using precise laboratory measurement of various criteria. Although the latter approach can increase the precision of the estimate considerably and will even allow a rough numerical estimate of age in some cases, the large number of variables suggests that the technique is still best treated as a relative dating method.

Almost any type of pedogenic modification can be used as a rough indicator of age. At the less rigorous end of the scale, characteristics observed in the field (e.g., horizon sequence, degree of horizonation, soil thickness, soil texture, soil structure and consistency, organic matter accumulation, clay accumulation, degree of carbonate leaching, amount and morphology of carbonate accumulation, visibility of primary strata, rubification, degree of bioturbation) are typically used to assign the soil, and by implication the surface that the soil is developed in, to broad age categories (e.g., recent, Late Holocene, Early-Middle Holocene, Late Pleistocene-Early Holocene, etc.; Birkeland 1984). If laboratory characterizations (e.g., carbonate, iron, texture, organic matter, and pH) are used to characterize dated soils, then the estimated age of soils can frequently be refined (Singer and Janitzky 1986). In addition, similar techniques can be used to roughly estimate the length of depositional hiatuses represented by buried paleosols intercalated in stratigraphic sequences. However, because climate plays such a dominant role in the rate of soil formation, the expression of surface soils formed primarily under previous climatic conditions can be almost identical to contemporaneous soils that were subsequently buried, even though the two soils experienced very different soil-forming intervals (Birkeland 1984).

Geomorphic Position: Geomorphic position can be used to provide relative dating of archaeological sites in some cases because the architectural relationships between different landscape elements are frequently dictated by the sequence of formation; thus, in situ archaeological sites associated with a landform can be no older than the landform that they occupy. Thus, an archaeological site interstratified within an older terrace can be assumed to predate another site interstratified in a younger, inset terrace. In contrast, an archaeological site resting on top of the older terrace may be of any age younger than the age at which the terrace stabilized. Care must be taken in addressing shallowly buried sites in such a context also, because slow, incremental deposition can still occur on an effectively abandoned surface syncontemporaneously with aggradation of the inset fill; thus, a shallowly buried site may be significantly younger than the landform on which it rests. Reworking is also a problem to be considered because an older site can be eroded from its original context and incorporated into a younger fill.

Archaeological Relative and Correlative Age Estimation Methods

Stratigraphy and Superposition: Stratigraphy is one of the most heavily relied upon methods of determining age relationships between components at an archaeological site. The law of superposition states that in undisturbed sediments or rocks, each stratum is older than all strata above it and younger than all strata beneath it (Bates and Jackson 1984). Therefore, any excavation should encounter increasingly old deposits and associated artifacts with depth. However, the latter implication is not necessarily true, because while the age of the strata will follow the law, objects contained in the strata can be reworked through erosion or excavation, and thus may not rest in their original context. In one extreme form, archaeological sediments can exhibit reverse stratigraphy, where the age of artifacts actually decreases with depth (Schiffer 1987). This type of stratigraphy can be formed by earthmoving, or by the successive erosion and downslope redeposition of a thick archaeological sequence. A more common and insidious type of problem is presented by stratigraphic complexity. Although there is a marked tendency to treat archaeological sites as if they have layer-cake stratigraphy testing, and to correlate recovery in terms of depth below surface, particularly during interpretation of small, noncontiguous units excavated during testing, it is probably accurate to state that most stratigraphic situations do not conform to this ideal picture. Rather, local variations in rate and process in vertically aggrading systems, variability and localization of erosional processes, and the influence of laterally aggrading systems (e.g., point bars, migrating sand dunes) combine to complicate the picture. Usually, such effects can be eliminated by careful recording of the stratigraphy, but occasionally the pedogenic overprint is so pronounced that the original stratigraphic boundaries cannot be reliably identified.

Although stratigraphy in a strict sense is usually restricted to examination of individual sites, similar concepts can often be applied at a regional scale through the construction of a broadly applicable soil-stratigraphic framework. Such a framework utilizes sedimentological properties, soil criteria, topographic criteria, and/or architectural relationships between depositional units to devise a model of stratigraphy that can be used for rough age interpretation at a variety of sites (e.g., Blum et al. 1992; Ferring 1986; Frederick 1993; Mandel 1987; Nordt 1992). The general frameworks for eolian and alluvial fan deposits in the Tularosa Basin and Hueco Bolson (Doleman and Blair 1991; Gile et al. 1981; Monger 1993e) are local examples of such a framework. One important aspect of such frameworks is that they should be considered evolving entities and revised as additional data becomes available.

Archaeological stratigraphy is an underutilized method at Fort Bliss and the Jornada region. The neglect of stratigraphic studies is largely due to the predominance of archaeological work in the central basins. The absence of stratification among Holocene depositional units in basin landforms has led to a tacit assumption that temporally or occupationally stratified deposits are rare to non-existent in the Jornada region. However, within aggrading landforms such as alluvial fans and possibly playa lakeshores, archaeological features and occupational surfaces are often intergraded with natural deposits, thus resulting in stratified cultural deposits. For example, much of the Archaic period settlement on alluvial fan landforms lies buried at depths of 50 cm or more within deposits of Organ alluvium. Equally important, the combination of relatively fast sedimentation rates on alluvial fans and more intensive occupations characteristic of Formative period settlement often resulted in the formation of stratified cultural deposits. These offer a productive context for the study of site formation at Mesilla, Early Doña Ana, and Late Doña Ana phase pit house settlements. The potential of natural and cultural stratigraphic investigations are reviewed in greater detail in Chapter 10.

Artifact Seriation and Cross Dating: Together with stratigraphic superposition, artifact seriation and cross dating are the oldest methods of relative dating employed in archaeology. Seriation is a process where attributes of an artifact class are ordered chronologically. It is based on the

assumption that artifact attributes (particularly stylistic attributes, such as shape and decorative motifs) come into and go out of fashion. In the process of seriation, artifacts representing the same cultural tradition are arranged to trace these stylistic changes through time; thus specific artifacts can be determined to be "time-diagnostic: relative to that tradition. Cross dating refers to the common assumption that a diagnostic artifact found at undated locality B will represent a similar time period as the same type of diagnostic artifact found at dated locality A, and that the assemblage at locality B is therefore roughly the same age as the assemblage at A (Champion 1980). Although there are many potential problems with these approaches (not the least of which is reuse of found "heirloom" artifacts by later peoples), they have proven very useful and are used widely in North American archaeology, particularly for projectile points and ceramics.

Problems and prospects with projectile point and ceramic correlation dating are reviewed in greater depth in the Fort Bliss CRCP report (Miller 1996). The projectile point study identified several problems with use of these artifacts as a relative dating technique, although we suspect that this practice will continue, as it is nearly a tradition within the field of archaeology. Projectile point dating can be a useful technique for assigning sites to broad time intervals or cultural-historical periods, as long as a wide range of assumptions are met.

For example, the use of various projectile point types as a relative dating technique in the Fort Bliss region is hampered by the overlapping presence of a variety of different stylistic traditions. A fundamental problem with projectile point classification in the Jornada region is that there is *no* Jornada sequence. The regional projectile point "typology" is an inconsistent amalgamation of sequences and traditions adopted from other regions. These include typologies developed in Trans-Pecos and Central Texas (Mallouf 1985; Marmaduke 1978; Suhm and Jelks 1962; Turner and Hester 1985), the Cochise Tradition of southern Arizona (Sayles 1983), the Oshara Tradition of northern and central New Mexico (Irwin-Williams 1973; Thoms 1977), and sometimes even more distant locales. Each of these sequences has several styles that overlap with other sequences but are designated by different names - and are often assigned widely variable age ranges. Within the Jornada, most point types are poorly dated, as there have been few excavations with sufficient sample sizes, stratigraphy, or associated chronometric dates.

In addition, reworking or retouching of Jornada projectile points was an extremely common practice. It is generally believed that the particular lithic raw material characteristics of the Jornada region, combined with high levels of mobility and site reoccupation, each contributed to the high incidence of point reworking. The scarcity of raw materials in central basin topographic zones where the majority of point specimens were obtained, the generally poor quality of many local lithic materials, and the small nodule sizes available in alluvial fan deposits or along the margins of the Rio Grande Valley each served to place several constraints on the manufacture, size, and use of projectile point technologies. A close examination of the 1,233 point specimens examined during the CRCP found an overall 39 percent incidence of reworking. The most common locations included blade margins, basal edges, and shoulders or haft elements. The continual retouching in these locations tends to blur distinctions between types.

The point typology outlined in Table 5.4 is based primarily on the work of MacNeish (1993) at Todson Cave, and his summaries of the Fresnal and La Cueva material, work at Fresnal shelter reported by Jones (1990), and surface collection data reported by O'Hara and Elyea (1985), O'Hara (1988), and Carmichael (1986a). These data sources are supplemented by general overviews supplied by MacNeish and Beckett (1987), Beckes (1977b), Gossett (1985), Sayles and Antevs (1941), Suhm and Jelks (1962), Turner and Hester (1985), Mallouf (1985) and most recently Justice (2002).

Table 5.4.
Common Projectile Point Types and Their Probable Date Ranges for the Jornada Region.

Type Name	Probable Age Range	Reference	Revised Age Range (Justice 2002)	
Clovis	+11,000 - 9000 B.C.	MacNeish 1993; O'Hara 1988	+12,000 - 9000 B.C.	(Clovis Cluster)
Folsom	9000 - 8000 B.C.	Amick 1994a; MacNeish 1993; O'Hara 1988;	9000 - 8300 B.C.	(Folsom Cluster)
Angostura	8000 - 7000 B.C.	MacNeish 1993; O'Hara 1988		
Jay	6000 - 4000+ B.C.	Jones 1990; MacNeish 1993; O'Hara 1988	9000 - 6000 B.C.	(Lake Mojave Cluster)
Bajada	6000 - 4000+ B.C.	Jones 1990; MacNeish 1993; O'Hara 1988	6000 - 3300 B.C.	(Bajada Cluster)
Lerma	7000 - 4000+ B.C.	MacNeish 1993; O'Hara 1988		
Amargosa/Pinto	4500 - 2500 B.C.	MacNeish 1993	6000 - 3000 B.C.	(Pinto Cluster)
Augustin	4000 - 1000 B.C.	Jones 1990; MacNeish 1993; O'Hara 1988	2000 - 800 B.C.	(Gypsum Cluster)
Todson	3500 - 2000 B.C.	MacNeish 1993		
San Jose	+2500 - 1000 B.C.	Jones 1990; MacNeish 1993; O'Hara 1988	4500 - 1500 B.C.	(San Jose Cluster)
Chiricahua	+2500 - 1000 B.C.	Jones 1990; MacNeish 1993; O'Hara 1988	3500 - 1800 B.C.	(Ventana Cluster)
Maljamar	2500 - 1000 B.C.	MacNeish 1993	1000 B.C. - A.D. 100	(Maljamar Cluster)
Fresnal	2500 - 1000 B.C.	Jones 1990; MacNeish 1993	1450 - 900 B.C.	(Datil Cluster)
Hueco	1000 B.C. - A.D. 500	MacNeish 1993	1500 B.C. - A.D. 300	(San Pedro Cluster)
Pendejo	1000 B.C. - A.D. 500	MacNeish 1993		
San Pedro	1000 - 0+ B.C.	Jones 1990; MacNeish 1993; O'Hara 1988	1500 B.C. - A.D. 300	(San Pedro Cluster)
Coahuila	1500 - 1000 B.C.	Jones 1990		
Scallion	A.D. 500 - 1400+	MacNeish 1993; O'Hara 1988		
Toyah	A.D. 1000 - 1400+	MacNeish 1993	A.D. 1400 - 1700	
Harrell	A.D. 1000 - 1500+	MacNeish 1993; O'Hara 1988	A.D. 1250-1900	(Awatovi Side-Notched: Pueblo Side-Notched Cluster)

A "+" on either end of the date range indicates that there are reports of the point type dating either earlier or later than the assigned date. Priority for probable date ranges is given to the local area rather than the original description of the type. Waters and Stafford (2007), for example estimate Clovis dates between 11,800 and 11,050 B.P. in contrast to the estimates of Justice (2002), MacNeish (1993, or O'Hara (1988) shown above. These ages are based on radiocarbon dating of contexts associated with Clovis materials and are likely more accurate than previous age estimates. Drawings and metric descriptions are available for most types in MacNeish (1993), Jones (1990), O'Hara (1988), and Justice (2002). More recently, Seymour (2002, 2003) has proposed that several arrow point types represent Protohistoric and early Historic occupations.

An alternative approach to projectile point typological dating is to use general morphological trends such as those illustrated in Justice (2002) and Miller and Kenmotsu (2004). General trends in projectile design, particularly among hafting elements such as contracting or expanding stems, are broadly correlated with Paleo-Indian, Archaic, and Formative temporal periods within the Jornada region (Miller and Kenmotsu 2004) as well as throughout much of the western United States and northern Mexico (Justice 2002). For example, contracting stem dart points – typed under such names as Augustin, Pelona, and Gypsum – are typical of Middle Archaic occupations throughout southern New Mexico, Trans-Pecos Texas, northwest Mexico, and the Great Basin. The use of such general morphological categories may generally be more reliable, albeit less precise, than age assignments based on typological assignments. The Justice typology works acceptably well if restricted to the higher-order taxonomy – the point “clusters” that have broad morphological similarities and temporal ranges across the southwest and western United States and northern Mexico. Researchers might consider using the point “clusters” at a general level and - if very secure identifications can be made – the specific type names.

Imported ceramic wares and types are presented in Table 5.5. These are generally better dated than their projectile point counterparts are, especially outside the Jornada area as in several cases they are associated with tree-ring dates (see Anyon et al. 1981; Breternitz 1966; Carlson 1970; Crown 1994; Dean and Ravesloot 1993; Smiley 1977). The Mimbres sequence, with the tripartite style distinction primarily on ceramic bowls (Anyon et al. 1981; Shafer and Brewington 1995; Shafer and Taylor 1986), is one sequence that approaches a classic frequency seriation in that it appears to rely primarily on stylistic attribute changes. White Mountain Redware (St. John's Polychrome, Pinedale, Fourmile Polychrome, and other types) and Salado Polychromes (recently renamed as Roosevelt Redware and including Pinto, Gila, Tonto, and Cliff polychrome) are also generally classified based on design variations, although some types are strongly associated with a particular vessel form. Chihuahuan Viejo and Medio Period types are differentiated on the basis of designs and the presence of texturing.

The three Mimbres styles have been further subdivided into early and late variants (Shafer and Brewington 1995). This seriation is based on examination of design fields on whole vessels. While it has proven difficult to apply the seriation to the small sherds of these types typically recovered from Jornada sites, large body and rim sherds may occasionally be assigned to these subtypes (Miller et al. 1997).

For purposes of accurate ceramic cross dating, it is critical to maintain a distinction between ware and type. Imported ceramic sherds are usually recovered as small fragments in Jornada sites and in low numbers. Often these fragments are not large enough to allow for classification beyond the level of ware. That is, while a small bowl sherd with an interior black design painted over a red slip may be identified as a Red Mountain Redware, the sherd may be too small to determine whether white-painted interior and/or exterior designs were present on the original vessel. Therefore, further classification at the type level - e.g., Wingate Black-on-red, St. John's Polychrome, Pinedale Polychrome, or Fourmile Polychrome - should be approached with caution.

This is especially important since the production and distribution of these types effectively spans the Late Doña Ana and El Paso phases.

The local ceramic sequence, minimally consisting of El Paso Brown, El Paso Bichrome, and El Paso Polychrome, is dated by association with radiocarbon dates and cross dating with other types outside of the region (Hard et al. 1994; Miller 1996; Perttula et al. 1995; Whalen 1981).

Table 5.5.
Common Imported Ceramic Types and Their Probable Date Ranges for the Jornada Region

Ceramic Ware and Type	Production Dates	Reference
Mimbres Whiteware		
Mimbres Black-on-white Style I	A.D. 800-900	Anyon et al. 1981; Shafer and Taylor 1986;
Mimbres Black-on-white Style II	A.D. 850/900-1010	Shafer and Brewington 1995;
Mimbres Black-on-white Style III	A.D. 1000-1140	Shafer 2003 (references apply to all three styles)
Chihuahuan Wares		
Villa Ahumada Polychrome	A.D. 1200 - late 1400s	Dean and Ravesloot 1993; Rakita and Raymond 2003
Ramos Polychrome	A.D. 1300 - late 1400s	Dean and Ravesloot 1993; Rakita and Raymond 2003
Carretas Polychrome	A.D. 1200 - late 1400s	Dean and Ravesloot 1993; Rakita and Raymond 2003
Babicora Polychrome	A.D. 1200 - late 1400s-	Dean and Ravesloot 1993; Rakita and Raymond 2003
Playas Red	A.D. 1200 - late 1400s	Dean and Ravesloot 1993; Rakita and Raymond 2003
Miscellaneous Imported Wares		
Chupadero Black-on-white	A.D. 1100/1150-1500+	Smiley 1977; Wiseman 1982
Gila Polychrome	A.D. 1300-1450	Crown 1994
Tucson Polychrome	A.D. 1250/1300-1350	Lindsay 1992
Lincoln Black-on-red	A.D. 1200-1400	Breternitz 1966; Smiley 1977
San Andres Red-on-terracotta	A.D. 1000-1300	Breternitz 1966; Smiley 1977
Three-Rivers Red-on-terracotta	A.D. 1150-1300	Breternitz 1966; Smiley 1977
St. John's Polychrome	A.D. 1150-1300	Breternitz 1966; Carlson 1970

Table 5.6 lists the various production dates proposed for these types. From the various age ranges listed in this table, it is evident that defining the El Paso brownware chronological sequence remains a rather elusive pursuit. Production spans suggested by Perttula and others (1995) and Miller (1996) were conservatively based on preliminary reviews of radiocarbon and contextual data. Shafer and others (2001a) took issue with the exceptionally long maximal production span suggested for El Paso Bichrome, proposing instead that both El Paso Bichrome and early El Paso Polychrome were not produced prior to A.D. 1100 based on the presence of these wares in post-A.D. 1100 contexts at the NAN Ranch Site in the Mimbres Valley.

The inception date for El Paso Brown and ceramic production in general also remain unknown. Several instances of early (pre-A.D. 300) radiocarbon or thermoluminescence dates associated with brownware ceramics have recently been identified in the western Tularosa Basin and eastern

Hueco Bolson (Tim Church, personal communication 2006; Miller 2007a; Ward et al. 2008). Yet, it is interesting that in each case neutron activation analysis (NAA) geochemical data for the dated ceramics from these sites does not match regional El Paso brownware ceramic signatures, but rather indicates that the ceramics were produced in the western Mogollon region. Thus, the question of whether ceramic production occurred in the Jornada region prior to A.D. 400 remains unresolved.

The Late (or Classic) variant of El Paso Polychrome is rather securely dated through radiocarbon and archaeomagnetic dating of pueblo and pit house settlements securely associated with large quantities of this ceramic type (Miller 2005c). The end date of A.D. 1450 for El Paso Polychrome also signifies the termination date of the El Paso brownware ceramic tradition in the region.

Table 5.6.
Chronology of El Paso Brownware Types

Ceramic Ware and Type	Production Dates	Reference
El Paso Brown, Early and Late rim variants	A.D. 200/600-1000/1150	Miller 1996;
	A.D. 200/400-1150	Perttula et al. 1995 This report
El Paso Bichrome	A.D. 800/1000-1100/1250	Miller 1996;
	Post A.D. 1100-end date not specified	Perttula et al. 1995 Shafer et al. 2001a
	A.D. 1050/1100-1275/1300	This report
El Paso Polychrome, Early and Transitional variants	A.D. 1000/1100-1200/1250	Miller 1996;
	Post A.D. 1100-end date not specified	Perttula et al. 1995 Shafer et al. 2001a
	A.D. 1100-1275/1300	This report
El Paso Polychrome, Late [Classic] variant	A.D. 1200/1250-1400/1450	Miller 1996;
	A.D. 1275/1300-1450	Perttula et al. 1995 This report

The remaining beginning and ending production dates for local brownware types, including El Paso Brown, El Paso Bichrome, and the early variant of El Paso Polychrome, are all rather imprecise. Several chronometric and stratigraphic or cross dating seriation studies have been undertaken in an effort to refine the production dates for these types (Miller 1990, 1996; Miller and Kenmotsu 2004; Perttula et al. 1995; Shafer et al. 2001a). A consistent problem is that no pure El Paso Bichrome or early El Paso Polychrome assemblage has been identified. Rather, El Paso Brown, Bichrome, and early Polychrome are usually associated with each other in various proportions. Chronological trends are evident among these associations as well as with well-dated imported ceramic types: greater proportions of El Paso Polychrome correlate with greater quantities of Chupadero Black-on-white; higher proportions of El Paso Brown (late rim variant) and El Paso Bichrome correlate with greater proportions of Mimbres Style III. Nevertheless, there is no distinctive break in the sequence. In other words, the production dates for these El Paso brownware types do not necessarily correspond to the boundary dates of the revised Jornada Mogollon phase sequence (Miller 2005c) nor do they match the production dates of imported ceramic types. Rather, it appears that the production of some El Paso brownware types,

especially Bichrome and early variant Polychrome, span two or more divisions of both local and regional phase and/or ceramic sequences. Therefore, given the low resolution afforded by radiocarbon dating, assigning specific dates to these El Paso brownware types is not feasible at the present time and the age ranges listed in Table 5.6 (see Table 5.6) represent reasonable approximations.

Finally, several researchers have noted patterned variability in rim form attributes within the local ceramic sequence that seem to vary with time. Lehmer (1948: 94) first observed differences between El Paso Brownware rims, which were often pinched, and El Paso Polychrome rims, which are thickened and everted. Beginning in the late 1970s, a number of researchers attempted to develop a seriation of rim attributes based on these changes in rim form (see Whalen 1978; West 1982; Carmichael 1986a). Whalen (1978: 58-70, 1980) suggested that within the long Mesilla phase, the El Paso brownware ceramic sequence could be subdivided into early and late periods based on the degree of tapering in rims, with early rim lips being "tapered" and later rims having a more flattened profile.

West (1982) attempted to quantify aspects of the thickening of rims with the Rim Sherd Index (RSI), based on standardized measures of thickness at 2 cm and 15 cm below the lip of a rim. Carmichael (1986a) used the RSI to assign sites to phases, demonstrating that the mean RSI increases between sites assigned to the Mesilla, Doña Ana, and El Paso phases. While questions exist regarding changing vessel shapes (see Hard et al. 1994; Seaman and Mills 1988), these studies suggest that RSI may be useful at a phase level. Whalen (1978, 1980, and 1993) and Miller (1996) have conducted a variety of within-phase studies of rim form changes. In the most recent study, Whalen (1993) used rim sherds from dated contexts at the site of Turquoise Ridge to consider the potential of rim form changes within the Mesilla phase. Using RSI values, Whalen notes that, while there is no significant difference expressed in such values through time, there is a "tendency" for RSI values to increase after about A.D. 900. He also demonstrates that flattened rim forms are somewhat more common later in time. Unfortunately, changes in both of these measures are minimal, thus obviating most uses of such data for intra-phase assignment (see Whalen 1993: 484-485). Recently, Miller (1996: 77) developed a modification of the ratio RSI value by subtracting the 15 mm measure from the 2 mm measure. This was to deflect the fact that in the former calculation, the ratio was highly affected by the overall thickness of the sherds. With the new procedure, a general trend in RSI values can be seen through time. During the Mesilla phase RSI values range between -1.0 and -3.0; during the El Paso phase RSI values range between +1.0 and +2.0. During the period between A.D. 1000 and A.D. 1150, measurements range from 0.0 and -0.5, while from A.D. 1150 and A.D. 1250, RSI values range from 0.0 and +1.0.

Developing a useful seriation for assigning sites based on rim form variation is hampered, then, by a lack of strong intraphase changes in rim attributes and problems with variations in vessel form that may have been functional rather than stylistic. While these data support Lehmer's original characterizations of rim form change, additional research is necessary before RSI may be used to assign sites or components to phase or intraphase periods.

RECOMMENDED CHRONOMETRIC METHODS FOR USE AT FORT BLISS

The suite of dating methods outlined in this chapter is clearly not equally applicable to all archaeological contexts and problems on Fort Bliss. Although they are reliable, the timeframes addressed by many of the methods (e.g., Uranium series and lead isotope) are either too old or too young to be applicable to most archaeological questions on Fort Bliss; however, these methods have been included because they could potentially prove useful to investigation of Protohistoric/early Historic or "pre-Clovis" components. Other quantitative methods, notably the various forms of luminescence dating, have tremendous potential for addressing the Fort Bliss archaeological record, but are handicapped by their experimental nature, lack of wide availability,

and frequently long turn-around time. The quasi-chronometric techniques (e.g., obsidian hydration, chert patination, amino acid racemization, and cation-ratio dating) are less reliable than the chronometric techniques and are not recommended at this time. Dendrochronology has good potential, but is strongly handicapped by the paucity of preserved wood in sites on Fort Bliss and, as demonstrated by the situation at Madera Quemada Pueblo; even large collections of well-preserved wood beams will often be difficult to cross-date. Archaeomagnetism also has good potential but requires fired clay-rich sediment. Radiocarbon dating is clearly the single preferred method for dating Holocene archaeological phenomena. However, as the preceding discussion has demonstrated, the radiocarbon method needs to be applied and interpreted with care. Finally, because not every aspect of an individual site or the broader landscape can be sent to a laboratory for dating, the relative and correlative techniques need to be applied rigorously and systematically, building on the framework provided by absolute dating methods.

Table 5.7 illustrates the current status of the chronometric methods discussed in this section. The relative utility and range of applications of each method is described in the left-hand side of the table. The three categories denote whether a particular dating method can be applied to a wide range of contexts and sample materials common at Fort Bliss or if appropriate sample materials and contexts are rarely present among the typical archaeological sites encountered at the base. Three categories describing the developmental status of the chronometric methods are listed at the top of the table. These categories indicate whether a particular method is fully established and standardized, remains the subject of ongoing experimentation and refinement, or has been determined to be excessively problematic and generally been proven incapable of providing consistently accurate and precise age estimates.

Table 5.7
Status of Chronometric Methods and Recommendations for Use

Utility and Application of Method	Developmental Status of Chronometric Method		
	Established	Experimental	Problematic
Wide range of applications, samples, and contexts present at Fort Bliss	Radiocarbon	Ceramic luminescence OSL	Oxidizable carbon ratio Obsidian hydration FCR/BC TL
Sample contexts and applications occasionally encountered at Fort Bliss	Archaeomagnetism	¹³⁷ Cs	Electron spin resonance Bone fluoride
Sample contexts and applications rarely encountered at Fort Bliss	Dendrochronology	²¹⁰ Pb Amino acid racemization	Cosmogenic isotopes Fission track Cation ratio Chert patination

Boldface – significant advance in method or application to archaeological research since 1996 *Significance Standards* and CRCP Project reports

Recommended for routine use during archaeological investigations at Fort Bliss: radiocarbon and archaeomagnetism

Recommended for expanded archaeological and geomorphic application at Fort Bliss: ceramic luminescence and OSL

Recommended for occasional studies of coppice dune dating and evaluation of bioturbation: ¹³⁷Cs dating

Dating methods that have been the subject of significant advances in measurement, sample processing, or analytical technique, or have seen a significant application to archaeological research in the Jornada region since the 1996 publication of the *Significance Standards* and CRCP report, are indicated in boldface type. The fact that six of the chronometric methods are thus indicated serves to illustrate the advancement and enhanced status that chronometric research has achieved at Fort Bliss during the past decade.

Recommendations for chronometric methods have been developed by taking into consideration the combined factors of the utility of the method and its developmental status. The results are not overly surprising. Radiocarbon and archaeomagnetic dating methods are recommended for routine use during archaeological investigations at Fort Bliss. The most noteworthy is the recommendation for expanded applications of luminescence dating to both archaeological and geomorphic research problems. The use of ^{137}Cs dating is recommended for very specialized studies involving the age of coppice dune formations and for potentially evaluating the extent of bioturbation among soil profiles.

It should be emphasized that these recommendations are for routine archaeological use and expanded experimental use at Fort Bliss. As such, these recommendations do not preclude further experimentation with certain methods. Further controlled experimentation with bone fluoride dating and luminescence dating of burned rock and caliche materials should be considered under appropriate circumstances. Of course, should wood beams and structural elements of appropriate wood species for tree-ring dating be encountered at a site, all such samples should be collected and submitted for tree-ring dating. The history of poor results with this method should not discourage future attempts to obtain highly precise tree-ring dates.

Chronometric Design, Sampling, Analysis, and Data Presentation

The following discussion presents several guidelines to assist archaeological researchers, contractors, and managers in the design and conduct of chronometric research at Fort Bliss. The guidelines are intended to ensure that appropriate sample counts are obtained, selection of samples are uniform, analyses (statistical and graphical) are appropriate, and that the data resulting from the studies and analyses are presented in the proper manner.

Reporting and presentation procedures for chronometric data have been much improved since the 1996 *Significance Standards*. Laboratory reports issued by chronometric laboratories such as Beta Analytic, Inc. are routinely included as appendices to archaeological reports, allowing for independent evaluation of dates and full information to be compiled in databases. Radiocarbon data are frequently presented in both tabular and graphic formats, including useful displays of calibrated age ranges using the OxCal program (Bronk-Ramsey 1994, 1995, 2001).

Another favorable development is that multiple radiocarbon dates are now routinely submitted from archaeological sites. It is not uncommon for twenty or thirty radiocarbon dates to be obtained from a single large or complex site. Unfortunately, the information potential of large arrays of dates is sometimes not fully explored and realized. Fort Bliss researchers should focus on greater use of statistical contemporaneity and clustering methods to evaluate groups of dates (Shennan 1988; Ward and Wilson 1978; Wilson and Ward 1981) and Bayesian methods for reducing radiocarbon age ranges and for defining the boundaries of various archaeological phenomena (see Buck et al. 1991, 1992, 1994).

However, it should also be recognized that large numbers of dates are not always particularly useful nor a judicious use of project funds. Due to several shape peculiarities of dendrochronological calibration curves, calibration of radiocarbon dates will result in particularly precise calibrated age ranges during certain time periods while other time intervals will have very large and imprecise age ranges (Bowman 1990; McCormac and Baillie 1993; Miller 1996). A

particularly vexing local example pertains to the El Paso phase, where the calibrated age of any radiocarbon date will be a minimum of 100-120 years, despite the precision of the original date. Statistical averaging of multiple dates from an El Paso phase pueblo will result in a negligible improvement in chronometric precision over the information provided by a small number of dates. Chronometric research at Fort Bliss would also benefit from a broader acknowledgement of the distinction between the *dated event* and *target event* as defined by Dean (1978):

The target event is the date archeologists are seeking, such as the prehistoric abandonment of a pithouse or the use of a hearth; the dated event is what is actually dated by a particular chronometric method. For example, the radiocarbon method dates the time when a plant ceased metabolism (death) and incorporation of ^{13}C from the atmosphere. The “old wood” problem is a classic example of an age discrepancy between the target and dated event.

CHRONOMETRIC DATA POTENTIAL AND CHRONOMETRIC RESEARCH

As noted at the beginning of this section, chronometrics and chronology is not considered as a research issue *per se*. We already know that people lived in the Jornada Mogollon for the past 11,000 years. Dating more hearths or burned caliche features just because they contain sample material suitable for dating will not improve on that basic bit of information. However, the presence of chronometric materials at a site, whether they are based on relative, sidereal, or isotopic methods, is an important threshold in the evaluation of the site’s eligibility for inclusion in the NRHP.

Simply stated, in order for any site to empirically address any research question the site must have something that allows researchers to place it in a temporal framework. However, passing that threshold is not sufficient in and of itself to make the site eligible for inclusion in the NRHP. In addition to having chronometric potential, the site must also retain some level of geoarchaeological integrity and, even more importantly, have the type of data that will inform on a research issue relevant to the prehistory of Fort Bliss and the greater Jornada Mogollon region.

On the other hand, certain sites at Fort Bliss may present opportunities to conduct experimental research on chronometric methods. For example, archaeomagnetic dating has been underutilized in the Jornada region and the VGP curves are subject to continual refinement. Thus, a research topic for the region is: “Are fired features amenable to archaeomagnetic dating, and do the results agree with other lines of chronometric information?” Undertaking a study to address this question could result in an improvement of the VGP curves and allow researchers to better understand sites that do not have radiometric materials. Sites that could be used to address the question would need to contain features fired in clay-rich sediments, geomorphic integrity, and chronological data potential for corroborative radiocarbon dating. If they do, then such sites would meet the requirements for chronometric data potential as part of the NRHP eligibility review process, although geomorphic integrity and archaeological data potential would still have to be demonstrated for the sites to be recommended as eligible for inclusion in the NRHP (see Chapter 14 for a discussion of NRHP evaluation procedures).

The ambiguities in incorporating chronometric research questions into the process of evaluating NRHP eligibility need to be resolved. The research questions in this section are designed to determine whether a given site has the data potential to address various chronometric research questions (e.g., can ceramic luminescence dating be used successfully?). However, these questions are difficult to incorporate into an NRHP eligibility evaluation process because, if a given site has potential to conduct experimental research on chronometric methods and address one or more chronometric research questions, then the site clearly has substantial chronometric and chronological data potential. For example, Research Question 4-6 of the 1996 *Significance*

Standards inquires “Are fired features amenable to archaeomagnetic dating, and do the results agree with other lines of chronometric information?” In order to empirically address this research question, it is clear that a given site and its constituent features must retain some degree of chronological potential for both archaeomagnetic and corroborative radiocarbon dating. The distinction between chronometrics as a research domain and chronometric integrity and potential as an intrinsic site characteristic must be made explicit and the specific criteria for each need to be clarified.

So how should chronometric data potential be defined in terms of evaluating NRHP eligibility? For purposes of NRHP evaluations at Fort Bliss, the basic definition is that chronometric data potential refers to *the presence of one or more interpretable associations of datable archaeological contexts and items*. Under this definition, it becomes clear that chronometric data potential does not apply to isolated hearth features that can be dated but are otherwise not associated with other contexts or material culture that establish an interpretable association. While the hearth may contain organic material that can be radiocarbon dated, it lacks any association with other contexts or “items” of material culture that establish an interpretable relationship.

Moreover, this definition establishes a higher evidentiary threshold for establishing chronological potential based on the presence of small numbers of chronologically diagnostic artifacts. The mere presence of a single projectile point or ceramic sherd should not be routinely used to establish a dateable context or association. A more critical appraisal of the association or relationship between such items and other contexts, aspects of assemblage content, and corroborative chronometric or chronological data must be presented.

Chronometric Research Issues

As stated in the introduction to this section, while chronometric research and chronology are broadly considered to be intrinsic site attributes, the recommendations in this section do not necessarily imply that chronometric research is no longer necessary. Continued experimentation and refinement of chronometric methods for use at Fort Bliss is still encouraged. The following questions outline basic fundamental applications of the previously described techniques to archaeological problems at Fort Bliss. This represents a much-reduced range of questions than was set forth in the 1996 *Significance Standards* document. Many of the chronometric research questions in that document have been effectively resolved or annulled through the chronometric research sponsored by Fort Bliss during the past decade. The current series of research issues represents a much more focused and targeted research program for the coming decade.

Some of the issues may be best addressed through special funding avenues such as the Legacy program. Others issues are important enough that they should be addressed during routine archaeological work at Fort Bliss. The results of some of these studies should be compiled and synthesized as part of Fort Bliss’ annual program. It may also be possible to incorporate the less common studies, such as archaeomagnetic dating and ceramic luminescence, incrementally into individual projects as they occur. Finally, Fort Bliss should incorporate chronometric studies into Request for Proposals and Scopes of Work whenever appropriate contexts or situations are encountered.

Research Issue 5-1

Can the interpretation and precision of groups of radiocarbon dates be refined through statistical methods and stratigraphic analysis?

Radiocarbon dating is a well-developed and standardized chronometric technique that is applicable to most archaeological contexts at Fort Bliss. However, it suffers from poor resolution

and precision, particularly when attempting to partition Formative period occupations of less than 50-year or 100-year duration. The use of statistical contemporaneity tests, pooled date averages, and Bayesian models to a stratigraphically and horizontally distributed series of radiocarbon dates may offer a means to refine final age ranges for interpretation.

Research Issue 5-2

Can luminescence-dating techniques yield consistently accurate and precise age estimates and can they be expanded to a broader range of materials and contexts?

Ceramic luminescence dating is the foremost priority for this research issue. If TL, OSL, or IRSL techniques can provide consistently accurate and precise age estimates for ceramics, many previously questionable contexts (i.e., early incidences of ceramic production, Protohistoric occupations) may be effectively dated and identified. Moreover, while the precision of ceramic luminescence dates is dependent upon the measurement of the environmental radiation dose and internal luminescence signal and therefore is highly variable, ceramic TL dates occasionally offer significantly greater precision than radiocarbon dates. The application of luminescence dating to the eolian deposits on Fort Bliss has been significantly expanded over the past five years. There remains some question whether other deposits (e.g., playa, alluvial fan) can also yield reliable ages. Additionally, the potential effects of bioturbation on OSL dating remain to be fully explored. Finally, the issue of whether fire-cracked rock, burned caliche, or lithic artifacts and architectural features (walls, floors) exposed to fire can be dated through TL should be investigated.

Research Issue 5-3

Can the use of archaeomagnetic dating be expanded and can recent statistical refinements enhance the interpretive potential of this method?

Are other fired features and surfaces at Fort Bliss beyond collared floor hearths in formal architectural structures amenable to archaeomagnetic dating? Can the recent refinement of the Southwestern archaeomagnetic curve be correlated with other chronometric data? Recent developments in statistical averaging and contemporaneity tests have the potential to yield chronometric data of similar quality and utility to radiocarbon dating.

Research Issue 5-4

Can bone fluoride dating be used to develop high-resolution chronological sequences at complex sites?

As reviewed in Chapter 10, questions of site formation, site structure, and community plan are among the most important of current research domains at Fort Bliss. Lacking precise tree-ring dates, site specific chronologies must depend on radiocarbon, archaeomagnetic, and possibly luminescence dating, none of which currently provide dates of sufficient precision to partition occupational events of less than 50 or 100 years, even under the best of circumstances. Bone-fluoride dating offers a potential means of developing site-specific relative chronologies. However, the reliability, accuracy, and geographic extent of the method remain unknown. Should mitigation excavations be proposed at a complex, multi-component residential site having suitable quantities of faunal bone, the development of a bone fluoride chronology should be considered.

Research Issue 5-5

How can the soil-stratigraphic framework of the region be used to yield more accurate estimates of age? Can alluvial and cultural stratigraphy be consistently identified in alluvial fan landforms?

As will be discussed in the following section on geomorphology, one of the critical issues involves the identification and dating of different components of the Holocene Q3/Organ depositional unit. Monger's (1993a) definition of three components (Organ I, II, and III) has been questioned on geomorphic and chronological grounds. Others (e.g., Smith 2005) have identified strata based on soil and carbonate morphology. If these units can be related to a consistent chronological framework, their identification in the field can assist in the dating of associated cultural remains. Likewise, prehistoric sites in alluvial fans often have stratified deposits that may help in dating, analysis of site formation processes, and seriation studies of ceramics and other material culture.

Research Issue 5-6

Can the regional sequence of diagnostic artifacts be expanded and refined to allow for more common or accurate age estimates?

Notable advances have been made over the past 20 years in dating the local El Paso brownware ceramic sequence, but the current sequence continues to have a troublesome degree of imprecision. Likewise, the regional projectile point chronology is beset by numerous problems. While significant advances in ceramic or projectile point correlation dating are likely to be few and far between, research should continue to refine the sequences whenever appropriate contexts are encountered.

CHAPTER 6. GEOMORPHOLOGY AND GEOARCHAEOLOGY

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The following section develops discussions of geoarchaeological issues relevant to Fort Bliss. Five basic issues are addressed: eolian processes and landforms, alluvial fan processes and landforms, slope processes and landforms, arid lacustrine processes and playas, and soils. Each of the first four sections includes background discussions of relevant processes, characteristic landforms, climatic and geoarchaeological implications of the processes and landforms, and research questions arising from the discussion. The soils section addresses pedogenic processes and the implications of those soil-forming processes for landscape reconstruction and site disturbance. The chapter concludes with reviews of current problem areas, recommendations for future research, and a brief discussion of the relevance of context to archaeological investigations on Fort Bliss.

In the 1996 *Significance Standards* document, the combined topics of geomorphology and geoarchaeology were considered one of the seven research domains. Geomorphology and geoarchaeology have been placed in Part II of the current document, as we believe these topics more accurately represent intrinsic site attributes rather than a major research domain. However, as stated in the introduction to the previous section dealing with chronometrics, this change in status does not necessarily imply that geomorphic and geoarchaeological research is no longer necessary. Continued efforts are needed to clarify and refine the dating of Holocene and Late Pleistocene eolian depositional units in the central basins. These efforts include further evaluation of age discrepancies between dates provided by optically stimulated luminescence dating of eolian deposits and those provided by radiocarbon dating of soil carbonates. The effects of eolian erosional and depositional processes on the surface visibility and content of artifact distributions and sites remains a particularly vexing issue. These issues will surely continue to be addressed during the coming years. Geomorphic characterization and evaluation of sediments is now a standard practice during archaeological survey, testing, and mitigation projects at Fort Bliss and archaeological consulting firms are contractually required to have a geomorphologist on staff.

The majority of this section retains Abbott's original 1996 discussions. In light of the issues described above, major additions include discussions of playas and lacustrine processes, geochronology of eolian depositional unit, and geoarchaeology and contextual integrity. The latter sections contain new subsections dealing with the geochronology and nomenclature of the Quaternary stratigraphy at Fort Bliss. Perhaps the most significant development since 1996 is that a number of dedicated efforts to refine the dating of the Quaternary stratigraphic sequence have been undertaken. The results and implications of these studies are reviewed in detail. Finally, a section on research issues and data needs has been added to discuss issues of site visibility, preservation, and integrity.

EOLIAN PROCESSES AND LANDFORMS

Eolian processes represent one of the most important and pervasive mechanisms of Holocene landscape change in the study area, and thus have tremendous import to questions of site formation, integrity, and visibility. This section summarizes essential background information on generalized eolian processes and bedforms, climatic implications of eolian deposits, and

generalized geoarchaeological considerations pertinent to archaeological sites in eolian settings. The following section applies this information to a discussion of the eolian deposits of Fort Bliss, and then discusses implications for the archaeological record.

Eolian Processes

Like water, moving air is a fluid, and behaves much the same in its ability to entrain, transport, and deposit sediment. The two principal differences between air and water as mediums of sediment transport are differences in density and in the uniformity of flow (Summerfield 1994). Air is, of course, much less dense than water; as a result, the size of eolian clasts is limited by mass restrictions to grains the size of sand or smaller, while alluvial clasts can weigh many tons (Lancaster and Nickling 1994). A more subtle but equally important distinction is that eolian processes are not strictly controlled by preexisting topography; thus, while the vector of transport in alluvial systems is relatively constant (i.e., downhill), eolian systems are subject to strongly variable flow vectors, and thus do not exhibit nearly the same degree of topographic control.

Eolian transport is accomplished when the tractive forces imposed by wind on surficial sediment grains exceed the net resistance to movement imposed by grain mass and shape, friction, packing, and interparticle cohesion. These tractive forces include two force vectors, termed lift (the vertical component) and drag (the horizontal component) (Greeley and Iversen 1985). As wind speed exceeds the necessary threshold velocity, resistance is overcome and the particle begins to move. Eolian particles can move in any of three forms: as suspended load, held in the air column by turbulence; as saltating load, alternately lifted into the air column and returning to the earth; and as traction load, rolling and sliding at the air/ground interface in a process termed surface creep. In any given system, the coarsest particles undergoing transport (typically very coarse sand-sized or below) are in the traction load (also commonly termed surface creep), intermediately sized (typically medium to fine sand-sized or below) particles are in the saltating load, and fine particles (typically silt-sized and below) are in the suspended load. While suspended sediment grains can be carried hundreds or thousands of feet into the air column, and thus move considerable distances before returning to earth, saltating particles only rise a few feet off the ground and move a few feet forward with each "hop."

Saltation is the primary mechanism of movement in most sandy systems (Bagnold 1941). As the threshold wind velocity is exceeded, the grain detaches from the surface and rises almost vertically for a short period until the pull of gravity takes over, returning the particle to earth in a parabolic arc, and striking the surface at a relatively low angle (typically between 10° and 16°) (Bagnold 1941). As the grain returns to earth, it impacts other particles, imparting energy that can stimulate those particles to move. This subsequent movement either can be a minor shift caused by the force of the impact alone in a process termed *reptation* (Ungar and Haff 1987), or can provide the necessary impetus to initiate saltation of the impacted grain; the impacting grain, too, tends to rebound and thus continue saltating. As a result of this additional energy, wind velocity can fall below the initial threshold speed without causing transport to cease. Thus, two threshold wind speeds, termed the fluid threshold (which must be exceeded to initiate movement) and the impact threshold (which wind speed must drop below in order for movement to cease), are unique to eolian systems. Empirical observations have demonstrated that the fluid threshold is lowest for particles in the fine-to-very-fine sand size range; particles of larger size are increasingly inhibited by mass, while smaller particles are inhibited by interparticular attraction (Bagnold 1941). However, once saltation of sand grains is initiated, saltation impacts can dislodge finer particles, initiating their entrainment (Lancaster and Nickling 1994).

Eolian transport and deposition require that several prerequisite conditions be met. First, there must be a source of suitable sediment. As stated above, sand-sized particles are much more prone to eolian entrainment than silt and clay particles because of intrinsic differences in interparticular

cohesion. However, the inherent resistance to abrasive entrainment by saltating particles of a sediment is a function of the relative proportion of different sized particles; just as the addition of gravel to cement to form concrete increases its resilience, the inclusion of moderate amounts of sand increases the resistance of dominantly fine-grained sediments to eolian entrainment (Chepil and Woodruff 1963).

Further, eolian transport typically requires that the source sediment is dry and noncohesive. Even in sands, relatively low moisture contents can significantly inhibit necessary threshold velocities, which typically show an exponential increase in resistance to entrainment with increasing moisture content (Azizov 1977). Other factors contributing to differences in internal cohesion include the relative content of bonding agents, including silt and clay, organic matter, and soluble salts. Even in sediments where internal cohesion is low, entrainment can be inhibited through the formation of surface crusts by raindrop impacts, algae and fungi growth, or salt precipitation (Lancaster and Nickling 1994). In these cases, disruption of the surface crust by grazing animals or off-road vehicles can result in rapid deflation. On the other hand, drying and salt precipitation can also lead to the disruption of surface crusts, facilitating entrainment.

Finally, surface roughness conditions must be conducive to entrainment. On a perfectly smooth surface, friction between the moving air and the surface, and the resulting shear stress imposed, is distributed evenly, which causes a logarithmic reduction in wind speed in the boundary layer. However, in the case of rough surfaces, shear stress is distributed unevenly, with higher elements of the surface experiencing relatively greater stress. This effect is enhanced by increased turbulence in the boundary layer as air flow is distorted by surface obstacles, decreasing fluid competence. The degree of inhibition is a function of the size, arrangement, character, and spacing of surface obstacles. Thus, because of this disruption of flow in the boundary layer, effective surface armoring by plants and/or gravelly lag deposits does not require continuous coverage of the erodible substrate.

Eolian Landforms

Landforms resulting from the action of eolian processes can be divided into two broad classes: erosional forms, which resulted from the net removal of material through eolian entrainment (deflation) or from mechanical abrasion of the surface by (typically sandy) material in transport, and depositional forms, which resulted from the net accumulation of transported material.

Erosional Eolian Landform

A large number of erosional eolian landforms are known, but only a subset of these occurs within the region occupied by Fort Bliss. Several of the more exotic erosional forms, including yardangs (humpbacked, streamlined erosional forms typically formed in nonindurated, fine-grained sediments) and well-developed *ventifacts* (faceted stones that have been abraded and polished by wind-borne grit) have not been reported, to our knowledge, in the Fort Bliss region.

The most widespread type of feature on Fort Bliss that is commonly cited as evidence of eolian erosion is the abundant fan surfaces mantled with a relatively continuous carpet of coarse gravel. This phenomenon occurs in many arid environments, and is termed *desert pavement* in North America, *reg* in northwest Africa, *serir* in northeast Africa, and *gibber* in Australia (Dixon 1994; Whittow 1984). *Hamada* is a related Arabic term, which refers to bare rock surfaces mantled with coarse debris presumably left over after all the fines have been winnowed away. Although the classic model of desert pavement development focuses on eolian winnowing of alluvial deposits, resulting in a concentrated deflation lag of coarse clasts (Cooke 1970; Dan et al. 1982; Whittow 1984), this model has been challenged recently (e.g., Dixon 1994; McFadden et al. 1987; Wells et al. 1995). Dixon (1994) identifies five processes that have been cited as mechanisms of pavement formation: (1) winnowing of surface fines by eolian deflation; (2)

winnowing of surface fines by overland wash processes; (3) upward migration of stones due to expansion/contraction associated with wetting and drying or freeze-thaw cycles; (4) deposition and infiltration of eolian sand and dust on an existing pavement, coupled with slow downslope transport of the pavement, resulting in eolian accumulation beneath the stones; and (5) more rapid subsurface weathering, resulting in breakdown of coarse clasts below the surface. In addition to these five models, turbation by burrowing rodents is an additional mechanism of gravel introduction that can contribute to the surficial gravel mantle. While none of these models is probably the sole mechanism of pavement formation, it seems clear that eolian deflation is not the only mechanism operating to create desert pavements.

Playas, or ephemeral lake basins, are also frequently identified as geomorphic features that develop largely through eolian deflation; however, this model too remains somewhat controversial, and other mechanisms have been proposed.

Blowouts are phenomena characteristic of areas where stabilized, erodible sediments are disrupted, causing wind erosion (Figure 6.1). Blowouts are commonly associated with removal of protective vegetation, but can also occur where any type of surface disruption destroys an erosion resistant layer, such as a calcareous or fine-grained surface crust, an algal or fungal mat, or an armor of gravel clasts. Marston (1986) has documented that deflation is a common result of maneuver activity on Fort Bliss, particularly on the bolson floor. If deflation progresses, blowout depressions can form small, internally drained basins that cause laminated, fine-grained sediments to accrete.

Depositional Eolian Landforms

As sand accumulates, relief features termed eolian bedforms develop. A three-stage size hierarchy of superimposed forms is generally recognized in classic sandy eolian bedforms (Lancaster 1994; Summerfield 1994; Wilson 1972). The smallest bedforms are termed ripples, which range in wavelength from approximately 1 cm to 5 m and in amplitude from 0.1-50 cm. Dunes represent the intermediate stage, with wavelengths of 50- 300 m and heights of 5-30 m. Megadunes or *draas* represent the largest class, with heights of up to 400 m and wavelengths of up to 4 km. No megadunes occur on Fort Bliss; for this reason, the following discussion is limited to ripples and dunes.

Ripples are the smallest type of eolian bedform. They typically exhibit asymmetric profiles, with relatively gently inclined (8-10°), slightly convex slopes on the stoss side and steeper (20-30°), straight to gently concave slopes on the lee side. Wind ripples develop perpendicular to the vector of transporting winds, and always show a concentration of relatively coarse, resistant grains near the crest. The size of equilibrium ripples appears to be almost entirely a function of particle size and sorting with larger clasts forming larger ripples, while ripple wavelength represents a balance between sediment size and sorting and wind speed with higher winds resulting in longer wavelengths. Originally, Bagnold (1941) hypothesized that the mean length of the saltation path governed the wavelength of ripple formation, but subsequent investigators (e.g., Anderson 1987; Sharp 1963) have demonstrated that it is the mean distance of grain impact movements (reptations) rather than saltation hops that govern the spacing of wind ripples. As ripples are established, the low angle of incident saltating grains couples with the relatively steep lee face of ripples to create a "shadow" behind each ripple where grain impacts do not occur, and deposition and erosion are concentrated on the stoss faces.

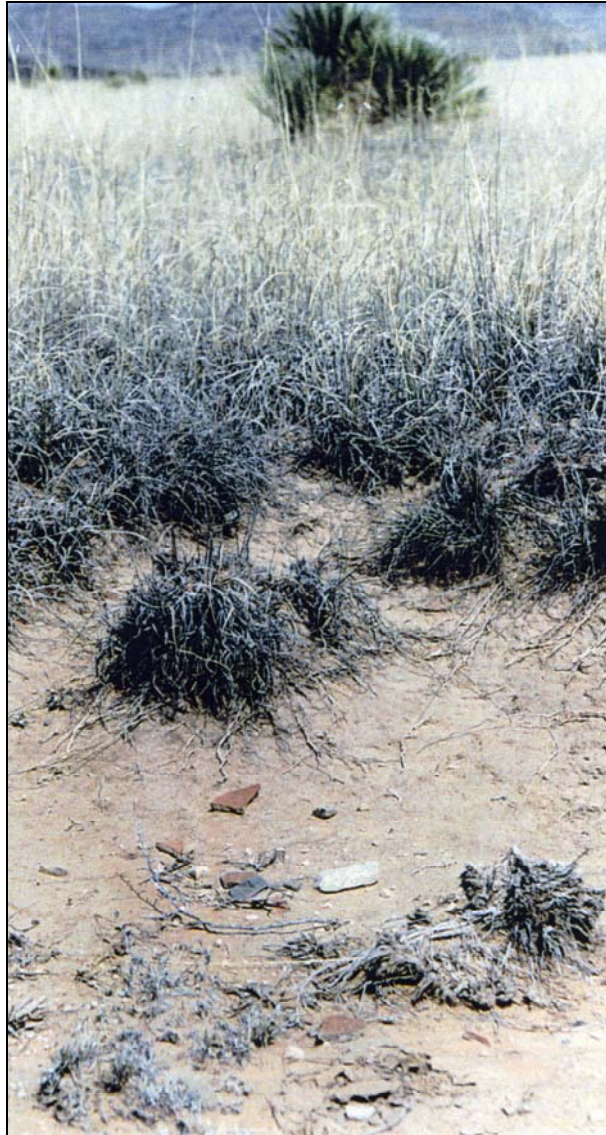


Figure 6.1. Detail of a blowout depression associated with a road on Otero Mesa containing a lag of ceramics and chipped stone.

(Note that no artifacts are apparent on surrounding undeflated surface, suggesting that they are buried by eolian deposits)

Ripples migrate downwind because sand tends to be deposited on the upper lee face, just beyond the ripple crest. This increases the length and height of the stoss face and oversteepens the lee face. As the inclination of the lee face exceeds a critical value, termed the angle of repose, the crest of the ripple collapses, and sediments slide down the lee face in a process termed avalanching, forming sheets termed foreset laminae (Reineck and Singh 1980). These laminae develop a slightly gentler angle, termed the angle of rest (Carrigy 1970), that represents the angle at which the sediments stabilize. These angles vary slightly with grain size, shape, and moisture conditions, but the angle of repose is approximately 35° in most eolian sands, while the angle of rest is roughly $31\text{-}32^{\circ}$ (Carrigy 1970; Reineck and Singh 1980). Because avalanching is typically an intermittent process except in conditions of very high sediment supply, finer-grained laminae deposited from suspension frequently alternate with coarser-grained avalanche laminae in ripple foresets.

While a great number of dune forms are known, most dunes can be classified as variant on a few basic forms. Most sedimentology focuses on a class of dunes, termed free dunes (Summerfield 1994), that develop spontaneously in unrestricted environments as a result of variations in sediment supply, sediment character, wind speed, and wind direction. Major types of free dunes include linear (or longitudinal) dunes, transverse dunes, barchan dunes, star dunes, reversing dunes, and dome dunes. Illustrations of the major classes of free dunes are common in geomorphology texts (e.g., Chorley et al. 1984; Summerfield 1994). A second major class, termed impeded dunes, subsumes bedforms influenced by local topography and vegetation as well as sediment supply and character, wind direction, and speed (Summerfield 1994). Major classes of impeded dunes include parabolic dunes, coppice dunes, lee dunes, climbing dunes, falling dunes, echo dunes, and lunettes. The major distinction between free and impeded dunes is that free dunes can actively migrate across the landscape, whereas impeded dunes are restricted by the obstacle with which they are associated; while sediment can usually freely enter and leave impeded dunes, the dune itself is not subject to migration.

Like ripples, free dunes typically have a gentler stoss face where erosion is facilitated and a steeper lee face where deposition predominates. The stoss face of dunes is typically mantled with superimposed ripples that are the result of the downwind migration of sediment over the dune. As in ripples, downwind migration tends to oversteepen the lee face of the dune, resulting in periodic avalanching down the lee face as the angle of repose is exceeded. Typically, only a part of the lee face will avalanche at any particular time, resulting in thin, interlocking lobes of avalanche deposits that are often partially reworked by turbulent eddies in the lee of the dune. In this manner, the bedform migrates downwind.

Transverse dunes represent elongated dunes oriented perpendicular to the prevailing winds, and thus represent a larger analog to ripples. Straight-crested transverse dunes are very rare; typically, microtopographic variations stimulate the development of heliocoidal flow vortices that result in a sinuous ridge crest termed barchanoid ridges. In conditions of moderately-high-to-high sediment supply, closely spaced barchanoid ridges result in a distinctive "fish scale" pattern of bedforms termed *akle* dunes.

If sand supply is decreased, the same processes result in the formation of individual barchan dunes, which are characterized by a crescentic form with a slipface along the concave portion and "horns" that point downwind. Barchans typically occur as isolated or widely spaced bedforms, but can grow to considerable size.

Dome dunes represent mounded accumulations of sand that lack obvious slipfaces, and are characteristic of areas with relatively high sediment supplies. At White Sands, dome dunes are developed closest to the sediment source, where the influx of sediment is greatest (McKee 1966). Reversing dunes arise in areas with opposed winds, and are characterized by slipfaces that alternately form and are destroyed on opposite sides of the bedform. Star dunes represent complex forms that result from strongly alternating wind directions.

Linear (or longitudinal) dunes, including sinuous seif dunes, represent elongated, crested sand bodies oriented roughly parallel to the prevailing wind direction. They are a form of reversing dune, in that they have slip faces that alternately form on either side of the dune, resulting in very complex internal stratigraphy. Linear dunes typically do not migrate laterally; rather they expand downwind and are cannibalized upwind. Older models of linear dune formation (e.g., Folk 1970; Glennie 1970; Wilson 1972) propose that they form when opposing heliocoidal (corkscrew) vortices are established along the line of air flow, sweeping sand from the interdunal areas to the dunes. More recent models (e.g., Fryberger et al. 1979; Greeley and Iversen 1985; Lancaster 1994) suggest that longitudinal dunes probably result from unopposed, bidirectional winds (usually from the same quadrant) that result in a relatively constant vector of net sand movement;

while heliocoidal flow patterns can sometimes be observed in such dunefields (Tseo 1990), it is probably a result of the influence of tall, linear dunes on air flow patterns, rather than a spontaneous phenomenon responsible for their formation.

At present, no active free dunefields occur in the boundary of Fort Bliss. However, some relict, partially stabilized free dune forms (including transverse and barchan dunefields) have been noted within the reservation boundary (Budd et al. 1979), and extensive dunefields are preserved farther north in the Tularosa Basin at White Sands (McKee 1966; McKee and Moiola 1975). McKee has demonstrated that these gypsum dunes reflect essentially unidirectional, southwesterly winds, and exhibit a progression of forms (domed, transverse, barchan, parabolic) with increasing distance from the sediment source, implying that the major control on dune form is sediment supply. Although the sediments comprising dunes on Fort Bliss are dominantly siliceous rather than evaporitic, the relict dunes of Fort Bliss are the product of similar wind regimes, and should reflect similar erosional and transport processes and depositional morphologies. However, because gypsum dunes tend to become consolidated and ultimately destroyed by wetting, the distance that they will travel is somewhat reduced.

While free dunes are scarce, impeded dunes are ubiquitous on many parts of Fort Bliss. Impeded dunes represent the interaction between eolian processes and other elements of the landscape, such as vegetation or topographic features, and thus do not migrate freely across the landscape. The single most common type of dune on Fort Bliss is the coppice dune, which number in the tens of thousands on the bolson floor (Figure 6.2). Coppice dunes (also termed shrub-coppice dunes [Melton 1940] and coppice mounds in North America, and nebkha and dikaka in North Africa and the Arabian peninsula [Glennie and Evamy 1968]) consist of small mounds of eolian material stabilized around desert shrubs. On Fort Bliss, coppice dunes are typically associated with mesquite (*Prosopis glandulosa*) on the lower fans and bolson floor, and can attain heights of several meters.

Parabolic dunes are crescentic dunes that face the opposite direction from barchans (i.e., with the horns pointing upwind). They typically represent dunes fringing the downwind side of blowouts, but can migrate considerable distances downwind, leaving long trailing "arms" partially stabilized by vegetation. At White Sands, McKee (1966) has demonstrated that parabolic dunes are typical of the most distal, sediment-starved areas of the dunefield, where vegetation can best become established.

Fore dunes and lee dunes represent sand accumulations formed in front of and behind obstacles, respectively. These obstacles interrupt wind flow, decreasing velocity and increasing turbulence, and causing a drop in competence that results in sediment deposition. Almost any obstacle can stimulate deposition of fore and lee dunes, including vegetation, topographic irregularities, and cultural features. Fencelines, in particular, are frequently the site of considerable deposition in susceptible areas. In addition, fore and lee dunes can develop in association with other dunes, and are a common secondary component of the large coppice dunefields on Fort Bliss.

Climbing and falling dunes represent dunes associated with a topographic obstacle, such as a hill or entrenched arroyo. Climbing dunes represent sand moving upslope on the downwind side of the obstacle (Figure 6.3), while falling dunes represent sand moving downslope off the lee side of the obstacle. If the topographic obstacle is large, extensive, and relatively abrupt, echo dunes can develop at distance from the scarp base. In this situation, dune development is separated from the scarp by a large roller vortex, resulting in a dune that stands away from but parallels the scarp.



Figure 6.2. Oblique aerial photograph of the bolson floor, illustrating the character of mesquite coppice dunefields.

Lunettes are dunes associated with playa lakes. Desiccation and salt crystal growth in the playa pans can lead to cracking and subsequent deflation of the fine-grained material in the playa, which frequently results in accumulation of curved lunette dunes on the lee side of the playa. Because the playa sediments are typically silt and clay-sized particles, this erosion typically involves sand-sized aggregates of finer particles. Subsequent wetting of these aggregates tends to cause them to break down and meld, forming relatively cohesive landforms termed clay dunes. Because these features are composed of cohesive sediments, they do not behave like sand dunes. Rather, they tend to accrete in the upwind direction and are not prone to migrate downwind. For this reason, the steeper face tends to occur on the upwind side, and can occasionally become significantly oversteepened by expansion of the playa.



Figure 6.3. Large climbing dune containing archaeological strata developed on the margin of a fan-channel arroyo, McGregor Range.

Sand sheets and gozes represent two additional types of eolian deposits that lack dune morphology. Sand sheets consist of small to very large areas of laminated and planar bedded sands, occasionally containing interbedded pebbles. Gozes are large areas of gently undulatory sand developed in the presence of sparse desert vegetation, and frequently lack clear internal bedding because deposition is accomplished by complex vortices in the boundary layer caused by growing grass (Bagnold 1941; Reineck and Singh 1980). In general, development of sand sheets and gozes occurs when conditions for dune formation are unfavorable (Kocurek and Nielsen 1986). Dune formation may be inhibited by a number of factors, including a high regional water table, periodic flooding or sheetwash inundation, surface cementation, coarse-textured sediments, and vegetation cover. Sand sheets can also occur in interdune areas, as can finer-grained, laminated paludal sediments and truncated bases of previous dunes (McKee 1966).

The internal structure of eolian bedforms is a function of the processes of deposition, bedform size and morphology, rate of transport, sediment texture, and sediment supply (Reineck and Singh 1980). The majority of preserved bedding planes in most migrating dunes consist of crossbedded tangential foresets, which are curved surfaces that represent former positions of the lee face. If sediment influx exceeds sediment loss on the stoss face, then ripple migration up the stoss face results in thin, laminated, gently inclined beds on the stoss face; these beds are rarely preserved because subsequent migration typically destroys them. Bagnold (1941) terms these two types of beds encroachment deposits and accretion deposits, respectively. Finally, massive or laminated horizontal bedding can develop in interdune areas and on lower parts of the dune.

Bounding surfaces are planar or curved contacts between beds. A three-part hierarchy of bounding surfaces between bedforms is typically recognized (Brookfield 1977; Kocurek 1981).

First order-bounding surfaces are extensive, relatively smooth, subhorizontal bedding contacts. They are generally interpreted as surfaces created by the migration of very large eolian bedforms.

Second-order bounding surfaces separate two sets of crossbedded strata with different bedding directions and/or inclinations, and are indicative of superposed bedforms in a migrating dunefield. Third-order bounding surfaces are divisions between subparallel packets of planar or ripple laminae within a coset of crossbeds, and are indicative of fluctuations in wind energy or direction in a single migrating bedform.

Paleoclimatic Implications of Eolian Deposits

As stated previously, eolian entrainment and transport requires several basic conditions: (1) wind of sufficient strength; (2) suitable sediments; and (3) a paucity of anchoring vegetation. It follows that long-term climatic variation should have an effect on the magnitude of eolian activity, and evidence of episodic activity has been observed in a great many eolian environments around the world (Lancaster 1994). Although frequently true, it would be a mistake to assume that eolian activity will necessarily coincide with periods of maximum aridity. Temperature shifts, changes in the magnitude and character of prevailing winds, and shifts in the periodicity and timing of annual precipitation can also initiate or limit eolian activity (Lowe and Walker 1984). More importantly, changes in the amount of available sediment can also exert strong control (Tchakerian 1994). Although shifts between arid and humid climatic regimes should facilitate and inhibit eolian activity, respectively, smaller-scale shifts between slightly less arid and more arid conditions would not necessarily have the same effect; indeed, a shift to slightly moister conditions in an arid environment could result in increased eolian activity by increasing the delivery of relatively high volumes of fresh, erodible sediment by alluvial systems. A linkage between eolian and alluvial processes is implied for Fort Bliss by Monger (1993e), who tentatively correlates eolian deposits in the basin with episodes of activity on the alluvial fans. Thus, initiation and abatement of eolian activity may be at least partly a secondary function of changes in alluvial fan activity, which are themselves linked to climate in a less than straightforward fashion (Bull 1991). In other words, the response of eolian systems to climatic shifts is apt to be complex, and is interrelated with dynamics of other geomorphic and biotic subsystems.

Geoarchaeological Implications of Eolian Processes and Deposits

Eolian processes and deposits have a number of profound implications for the preservation and visibility of archaeological sites. Many of these implications are so fundamental as to seem almost trite; nevertheless, they are frequently ignored in archaeological investigations, and particularly in regional analyses of settlement distributions. In general, the following seven implications pertain to archaeological sites in eolian settings.

Eolian Setting Implication 1

If the archaeological remains of interest are postdated by active eolian activity, then they are likely to be either deflated (if located in a locus of net erosion), buried by eolian sands (if located in a locus of eolian deposition), or both (Figure 6.4). Thus, the character and magnitude of eolian activity and the extent, depth, and morphology of eolian deposits condition the visibility and integrity of archaeological sites that predate that activity. Moreover, because loci of eolian erosion and eolian deposition are typically closely related, deflation and collapse of previously existing archaeological stratigraphy is likely in any situation where older, stratified deposits are present. Any artifacts in this general context, whether deflated or *in situ*, should typically rest on a higher-order bounding surface (e.g., first or second-order) unless displaced by bioturbation.

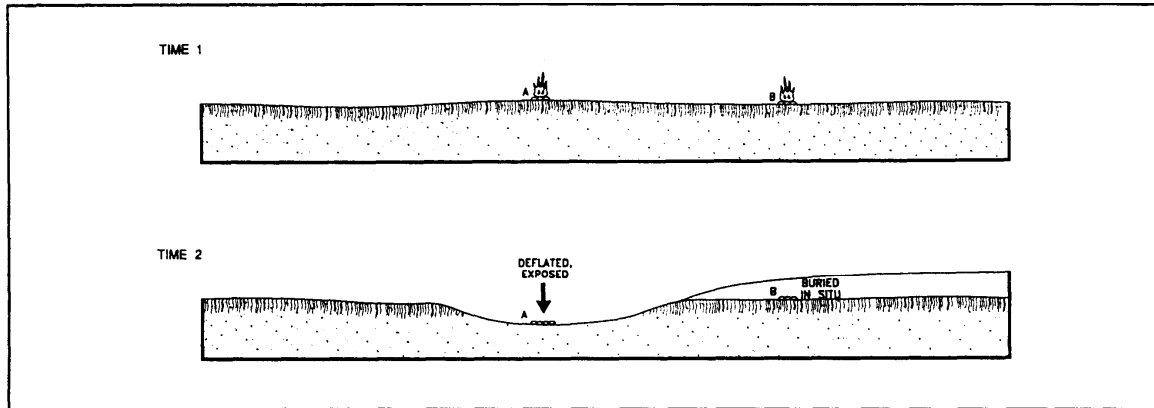


Figure 6.4. Generalized model of the effects of subsequent eolian activity on archaeological sites.

An alternative model has been proposed by Burgett (1994). Burgett observes that artifacts in the Hueco Bolson are often recovered from the upper sand mantle in sediments that are generally considered historic in age, and argues that artifacts may float on top of or within accumulating packets of eolian sand. Although this proposal runs counter to the models of artifact behavior in eolian contexts presented previously and while there are some problems with the physical aspects of Burgett's model, a similar revolutionary hypothesis has recently been convincingly advanced for the formation of desert pavements (McFadden et al. 1987). The processes and timescales proposed by McFadden and others are not precisely comparable, but the basic phenomenon of floating clasts is similar, and Burgett's proposal should not be dismissed out of hand. However, if the phenomenon identified by Burgett is real, and older artifacts are common in younger sand bodies on Fort Bliss, a viable physical mechanism remains to be proposed.

Eolian Setting Implication 2

If the occupation occurred at the same time that eolian deflation, transport, and deposition was ongoing, then archaeological materials associated with that occupation will also probably be buried. These deposits too are subject to displacement by eolian processes. Because most artifacts exceed the size necessary for effective eolian transport, they are primarily subject to gravity-driven displacement as the sand around them is entrained and transported (see Implication 5 below).

Barring displacement by turbation processes, artifacts deposited in a dune environment should rest on or between third-order bounding surfaces if the artifact is associated with the original bedform or if the surface aggrades sufficiently before passage of any subsequent bedforms. If, however, the eolian matrix is removed by deflation, the material should rest on higher-order (typically second order) bounding surfaces, and may be either exposed or buried. If sediment supply is sparse, deflation is a virtual certainty, because the magnitude of erosion will outpace the rate of burial. However, even if the sediment supply is high and the surface is actively aggrading, artifacts deposited on higher parts of the landscape are still subject to deflation before burial (Figure 6.5).

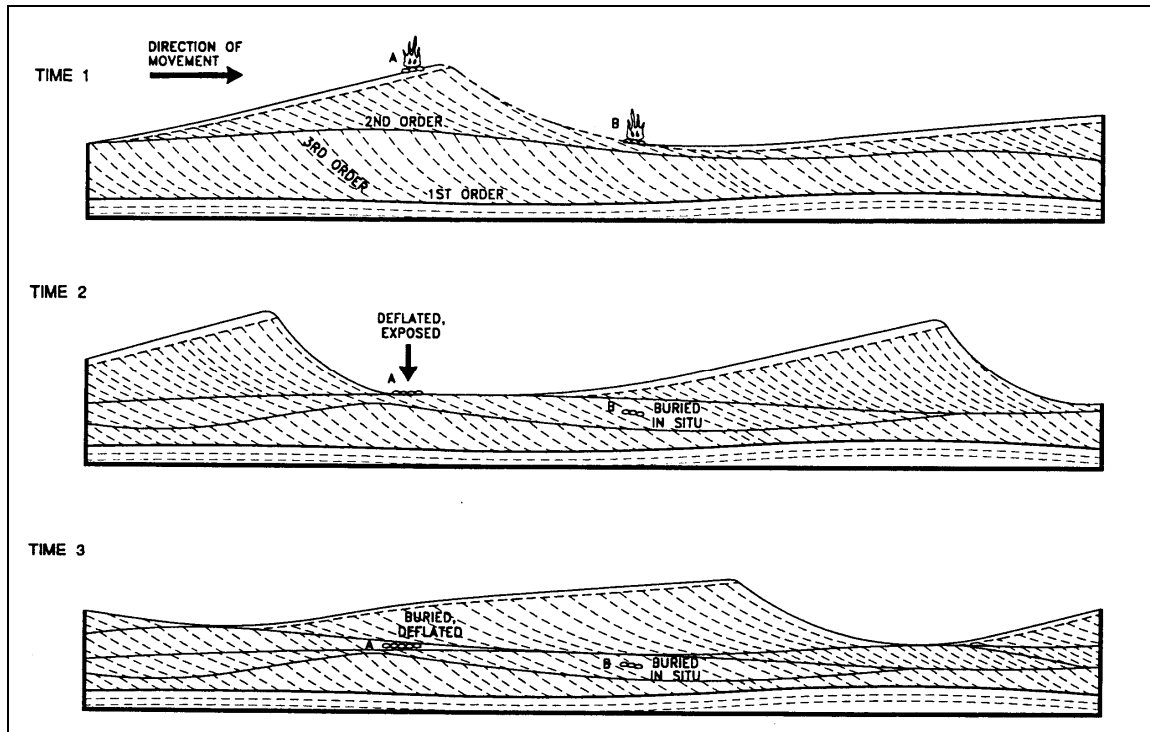


Figure 6.5. Generalized model of the effect of dune migration on preservation of archaeological sites formed in an active eolian environment.

Eolian Setting Implication 3

If the archaeological remains of interest postdate all eolian activity (i.e., occur on bedforms stabilized by vegetation), then they should rest on top of eolian landforms and be visible on the surface unless buried by other, subsequent processes (e.g., sheet or rill erosion and deposition, rainsplash, soil creep).

Eolian Setting Implication 4

If the occupation occurred during a period of stability that was bracketed by episodes of increased eolian activity, then the artifacts should be associated with buried paleosols in the eolian complex. Because the resilience of desert epipedons is usually not great unless the surface is stabilized by vegetation, artifacts that occur in association with a preserved A horizon typically imply site formation during that period of stability. In this case, bioturbation associated with pedogenesis can be expected to have obliterated associated third-order bounding surfaces, should any have originally existed. If renewed eolian activity results in erosion, then the soil can be expected to be deflated down to portions of the solum rendered more resistant by clay or carbonate accumulation. Any artifacts should rest on a second-order (or, occasionally, a first-order) bounding surface defined by this process of truncation (Figure 6.6). If the duration of pedogenesis was short, and the degree of alteration in the resultant soil was relatively low, all evidence of the soil could easily be destroyed by deflation, and the depositional setting could be indistinguishable from the previously described situations (i.e., Implications 1 and 2).

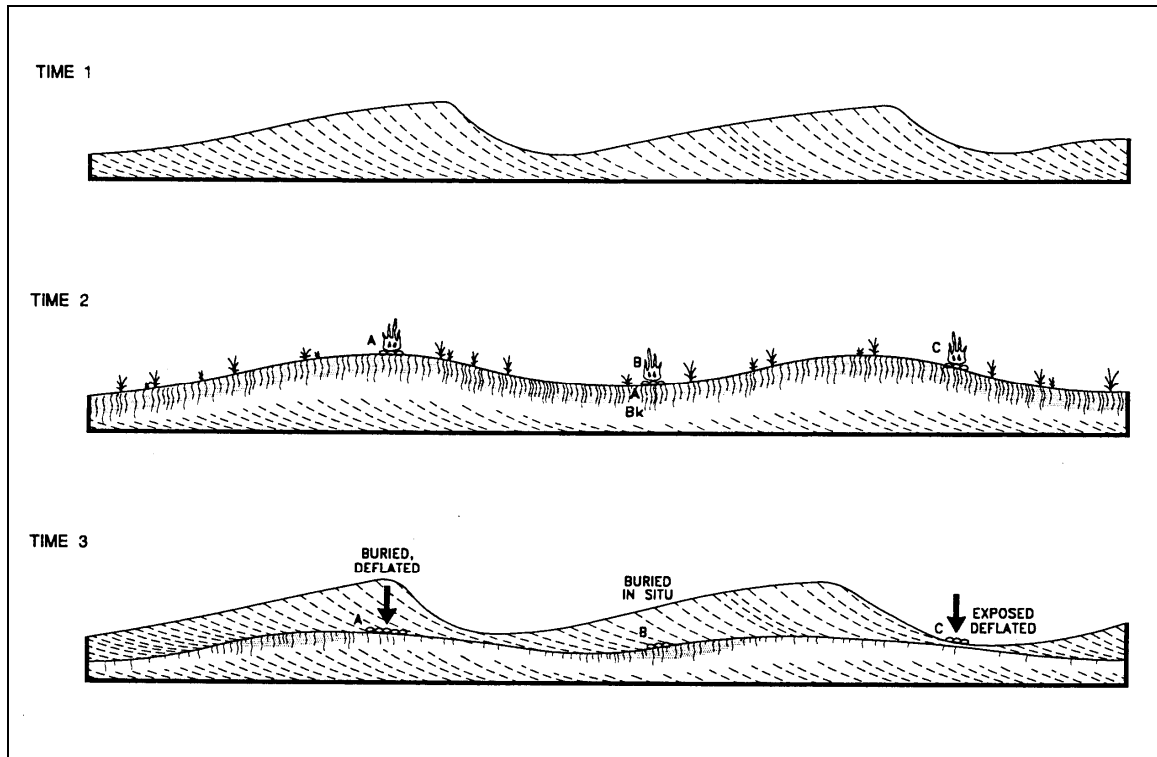


Figure 6.6. Generalized model of the effect of renewed eolian activity on archaeological sites formed in a stabilized eolian environment.

Eolian Setting Implication 5

In all cases, the spatial integrity of archaeological materials interstratified in eolian contexts should be considered suspect. As several studies of the effect of eolian processes on archaeological materials (e.g., Beckett 1980; Shelley and Nials 1983; Simms 1984; Wandsnider 1988) have shown, eolian processes are capable of laterally displacing artifacts on the surface, either directly in the traction load (either directly by wind action or, in the case of small artifacts like thinning flakes, by grain impacts) or through undermining of supporting strata, which stimulates gravity-driven movement. Wandsnider (1988: 20) also identifies, but does not fully explain, a third mechanism she says is capable of moving artifacts: "transport artifacts indirectly (sizes unknown) by forming small obstruction dunes behind the artifact, which then "plow" the artifact along."

It seems that Wandsnider envisions a process where a foredune formed on the windward side of an artifact expands or migrates downwind, pushing the artifact in front of it. Part of the considerable ambiguity of this proposed process concerns Wandsnider's use of the adjective "behind," which appears to refer to the upwind side of the artifact; while this location apparently describes position relative to the vector of travel, it is utterly confusing when used in the context of a discussion of eolian transport and deposition, where "behind" is synonymous with "downwind." However, no matter what the intended orientation of "behind," the proposed process is not viable. If the dune envisioned is a fore dune, then formation of the dune would cause flow separation and flow detachment around the obstacle, decreasing tractive force; although the dune might expand downwind, burying the obstacle, it would not be capable of pushing the obstacle in front of it. If instead, the bedform Wandsnider envisions were actually a

lee dune, any movement of the object would be due to wind friction and would be inhibited, rather than facilitated, by a mound of sand on the lee side.

The ability of wind to displace surface artifacts is a function of many interrelated variables, including artifact size, shape, mass, and orientation; macro-and microtopographic setting; slope; vegetation character, density, and placement; surface roughness; and surface hardness or compaction. Clearly, displacement of individual artifacts within a scatter will vary as a function of these variables. Moreover, manmade artifacts are frequently more subject to transport than natural clasts because of their shape. While a natural clast is typically rounded by transport, and thus exhibits a small surface area to mass ratio, manufactured artifacts like lithic debitage and potsherds typically exhibit relatively large surface areas relative to their mass, and are thus much more susceptible to movement by gusts of wind.

As Shelley and Nials (1983) demonstrate, direct transport of relatively large objects can occur (e.g., potsherds can be displaced upslope for short distances). However, it is fallacious to extrapolate long-term estimates of artifact movement from short-term data. One reason for this is that artifacts deposited on an eolian surface appear to undergo an initial "settling in" period of a few months to a few years, during which time they are in strong disequilibrium with the environment, and thus most prone to movement (Wandsnider 1988). More importantly, long-term artifact behavior cannot be extrapolated from short-term observation because the absolute distance that a given artifact will move is constrained by local topography and depositional setting. For example, while it is not unreasonable to expect a meter or more of movement by an individual sherd in a blowout depression during a short period of observation (or even a single strong windstorm), it is very unlikely that such an artifact will ever "climb out" of the blowout, which would be required for long-distance displacement.

While direct transport can be a significant factor, artifacts deposited in a dune system will probably be more strongly impacted by gravity-driven movements as the sand around them is exhumed by eolian processes. In a typical migrating dune, it can be expected that heavy artifacts deposited on the stoss face will gradually tend to migrate downslope (upwind) as surrounding sands on the windward face of the dune are progressively eroded. While artifacts deposited on the steeper lee slope can also move downslope, they are much more prone to rapid burial; note that these artifacts too can emerge on the stoss face as the dune migrates laterally. Once an artifact reaches the interdune area, there is little impetus for movement provided by gravity and most movement should be a function of direct traction transport. The movement of artifacts in sand sheets should also be primarily a function of direct traction transport due to the lack of relief, although the formation of deflation hollows can provide local sloping surfaces that facilitate gravity movements.

Given that the potential for displacement of artifacts is high in an eolian environment, lack of integrity should typically be assumed unless evidence that the material is *in situ* exists. Such evidence could include strong patterning in artifacts of different sizes in a manner that would not easily result from natural processes (e.g., a half-moon scatter of lithic debitage surrounding a chipping station) or discovery of intact features. Even so, evidence that a particular portion of a site is undeflated should not be taken as evidence that the entire site is unaffected.

Eolian Setting Implication 6

In most cases, and particularly where archaeological materials rest on higher-order bounding surfaces, the stratigraphic integrity of recovered materials must also be considered suspect. Deflation is universally recognized as a significant process in eolian environments. Direct deflation of an archaeological assemblage resting on or stratified in an eolian dune can result in collapse of the strata as the heavy artifacts are left behind as a lag. Typically, this process is

accompanied by lateral dispersion because the artifacts will tend to anchor the sands upon which they rest, causing surrounding sands to erode faster, and creating a temporary topographic high from which the artifacts can roll or slide (Figure 6.7).

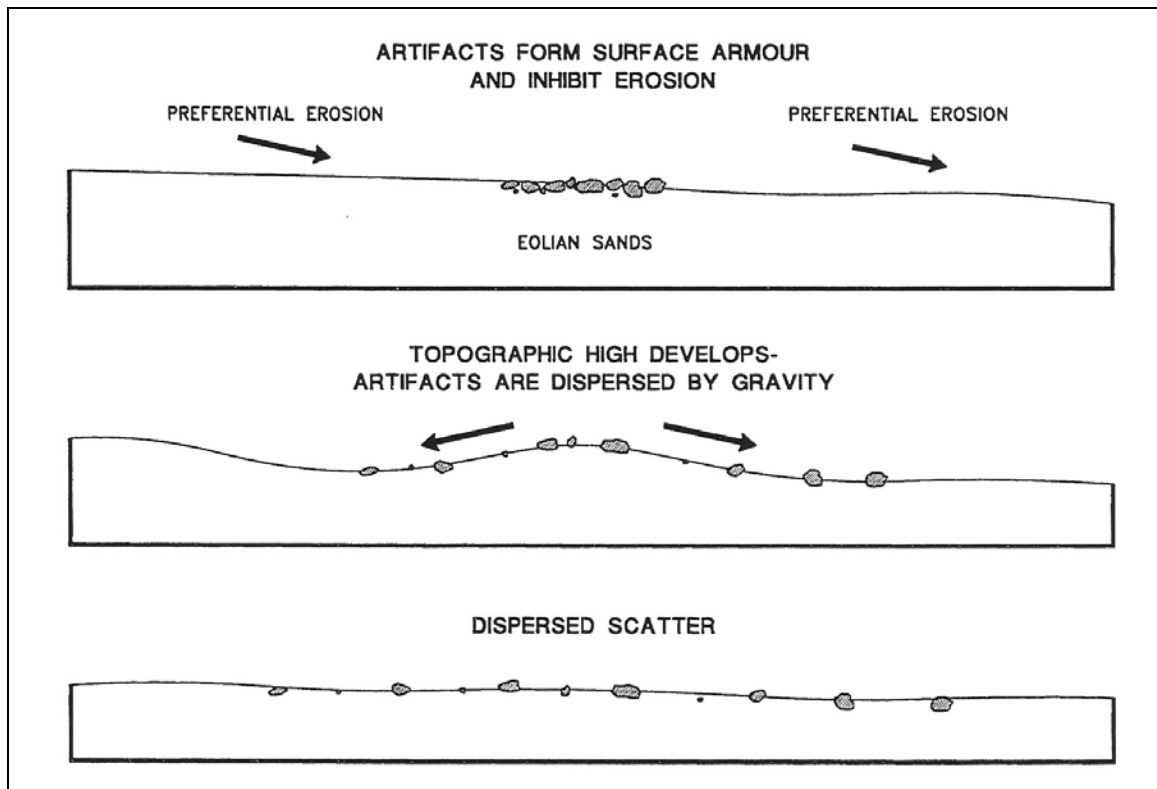


Figure 6.7. Generalized model of artifact dispersion by eolian activity.

However, if artifacts are displaced by lateral expansion of a blowout, it is possible that they could roll or slide down the inclined margin of the deflation hollow and come to rest on or in a thin sheet of sand mantling the floor of the blowout (Figure 6.8). Thus, dispersed materials can also become concentrated into false clusters. This type of process is also likely to result in size sorting of the remains because smaller artifacts are likely to move farther and more readily than larger, heavier artifacts.

Finally, it is possible for this process to displace an archaeological feature vertically without significant lateral dispersion. Thus, a cluster of hearth stones could theoretically be deflated significantly without destroying the spatial relationships that allow identification of the cluster as a hearth. However, such a feature should be completely devoid of charcoal and/or stained or oxidized sand. While the presence of charcoal should suggest relative integrity, because an *in situ* feature that has not undergone significant deflation could also lack this evidence given many different conditions and burial histories, the lack of charcoal and staining cannot be considered firm evidence for deflation.

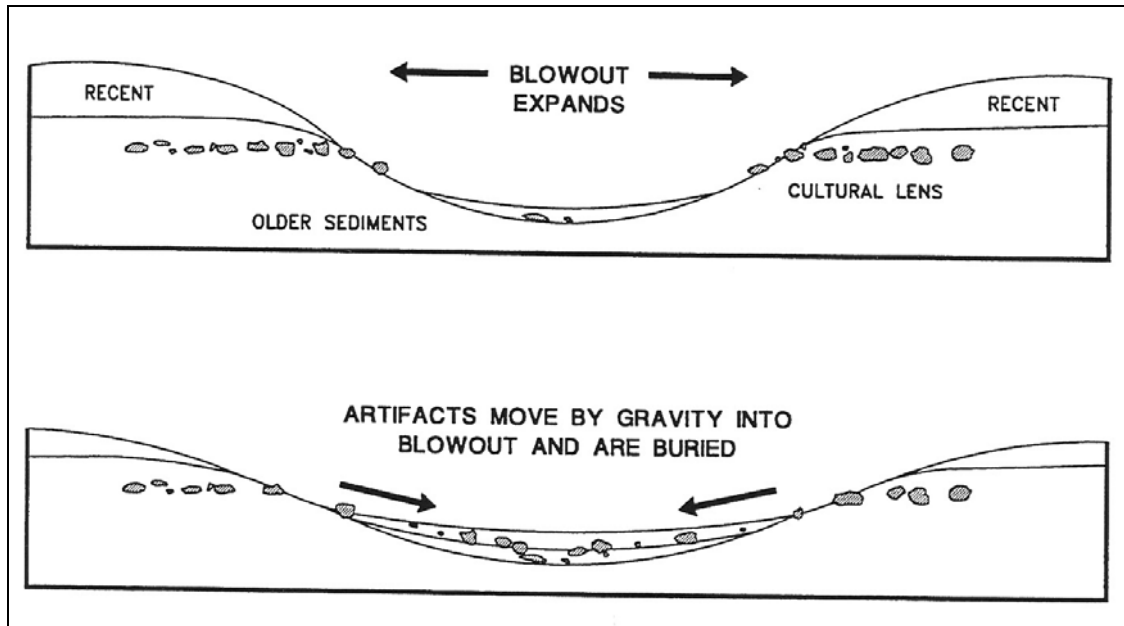


Figure 6.8. Generalized model of artifact concentration by eolian activity.

Eolian Setting Implication 7

In eolian environments where loci of deposition alternate with loci of erosion, visibility of the archaeological record, and particularly the spatial patterning of sites, will be conditioned not only by human activity but also by the size and frequency of erosional "windows" through the sand mantle. Thus, considerations of intersite patterning are not viable unless the biases imposed by differences in the potential for site visibility are accounted for.

ALLUVIAL FAN PROCESSES AND LANDFORMS

Alluvial fans represent deposits formed as streams undergo a reduction in gradient and a loss of confinement, such as typically occurs when a channel issues from a mountain front into an open valley. Typically, alluvial fans exhibit a wedge-shaped to semicircular plan morphology, a straight to gently concave, upward longitudinal (radial) profile, and a plano-convex transverse profile (Blair and McPherson 1994; Bull 1977; Nilsen 1985). Although alluvial fans occur in many different climatic settings, desert fans are among the most common and visible, and are clearly the most intensively studied type (Blair and McPherson 1994). This is particularly true in the basin and range province, where the characteristic steep ranges and alternating open graben valleys provide the perfect setting for their development.

The slope of alluvial fans varies from less than 1° to more than 25°, but most are inclined less than 10° (Bull 1977). Very steep, small fans are transitional between the typical fan and steep mass movement deposits termed talus cones, and are sometimes termed alluvial cones (Bull 1968). Where multiple fans emerge along a mountain front, they typically coalesce laterally, forming an alluvial *bajada*. Occasionally, broadly similar features are formed along mountain fronts that do not exhibit the point-source character and radial symmetry of fans; these features are commonly termed alluvial slopes or alluvial aprons. Similar ramplike morphologies can also arise from eolian transport in the valley system, which can build large climbing dunes termed eolian sandsheet ramps at the valley margin (where they often overlie older fan systems) (Blair and McPherson 1994).

Finally, pediments represent gently dipping erosional landforms in similar landscape contexts; while they are very different from fans and bajadas in terms of composition and genesis, they can appear very similar to thick alluvial bajadas in terms of their surface expression, particularly if mantled with a thin sheet of alluvium (Twidale 1981; Dohrenwend 1994). Collectively, these landforms make up the zone typically referred to as a mountain piedmont, which is transitional between highland and lowland areas.

Figure 6.9 presents a schematic view of an isolated alluvial fan system formed along a mountain front. All alluvial fan systems include two basic components: (1) a drainage basin, which consists of a coalescing dendritic drainage net and is the zone of net degradation (sediment loss), and (2) the fan itself, which consists of a constantly evolving, distributary drainage net and is a zone of net aggradation (sediment gain). Characteristic features of a fan system include the feeder channel, apex (or fan head), incised channel, intersection point, active depositional lobe, fossil (inactive) depositional lobes, and headward cutting gullies.

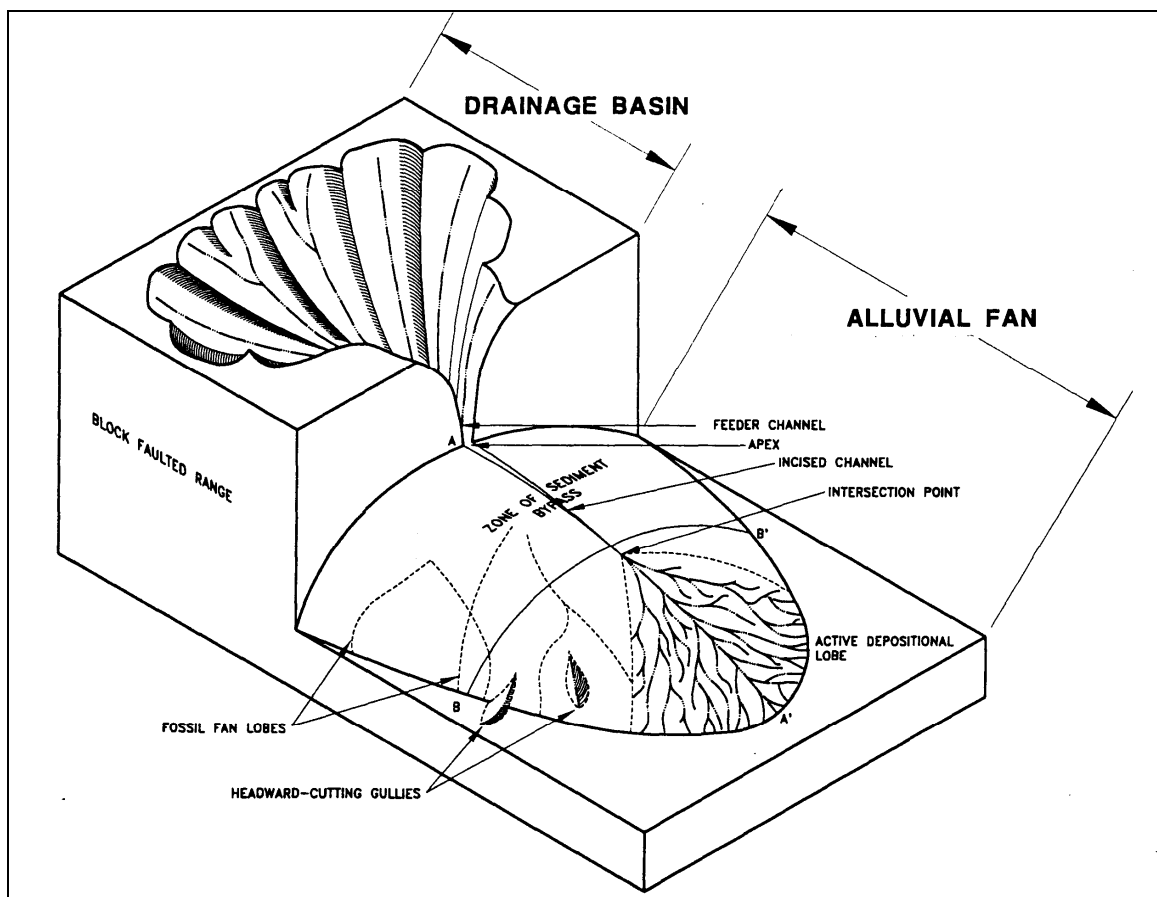


Figure 6.9. Illustration of an idealized alluvial fan.

The feeder channel is the principal channel supplying sediment to the system. The point where the feeder channel emerges from the confining valley at the mountain front, initiating flow expansion and deposition, is termed the fan apex or fan head. In many cases, particularly on older, well-developed fans, an incised channel extends from the fan apex to a point farther down-fan, or occasionally completely across the fan. Typically, the slope of this channel is less than the

slope of the fan surface, so that the channel becomes progressively shallower with distance from the apex, finally merging with the surrounding fan surface at a location termed the intersection point. Here, the flow expands laterally, forming a series of smaller, shifting distributary channels and dropping most of its sediment load. This results in the formation of a smaller, superimposed, fan-shaped area termed a fan lobe. The presence of an incised channel serves to shift deposition away from the mountain front, and facilitates basinward growth of the fan system.

With time, the active depositional lobe tends to shift laterally, or even be cut off completely, as the channel network evolves in response to complex interactions between morphology and sediment supply. Frequently, older lobes cut off from fresh sediment delivery by the fan-channel system may be dissected by headward-cutting gullies. If these gullies progress far enough up-fan, they can intersect and pirate the active channel system, causing the active lobe to be cut off. While the incised channel, fossil depositional lobes, and headward cutting gullies may be absent on many fans, the apex, intersection point, active depositional lobe, and some type of feeder channel is always present on active fans.

In terms of a short-term sediment budget, fan systems can be subdivided into three parts: (1) a zone of net degradation, which is situated in the drainage basin upstream from where the feeder channel enters the fan apex; (2) a zone of sediment bypassing, which is situated between the apex and the intersection point; and (3) a zone of net deposition, which is situated downfan from the intersection point. At a longer scale, all areas upstream from the apex are zones of erosion and all areas downfan are zones of deposition. Occasionally, an aggrading fan can build up to such an extent that the apex shifts upstream into the mountain front, decreasing the size of the drainage basin (Dohrwend 1994).

Alluvial Fan Processes

Deposition on alluvial fans can occur by several basic processes: streamflow, debris/mud flow, and sheetwash. Streamflow processes involve movement of sediment by water of appreciable depth, which generally occurs in a channelized situation (at a variety of scales, ranging from rills with depths of a centimeter or less to axial channels several meters deep). Like air, water is a Newtonian fluid, and transports sediment in traction, saltation, and suspension. Unlike air, water can also transport sediments as solutes in the dissolved load. Other major differences between transport by water and transport by air include: (1) greater restrictions on the variability of flow direction in water transport, which is more strongly controlled by topography and essentially unidirectional (e.g., downslope); (2) increased competence due to the much greater density of water as a transport medium, resulting in the effective movement of much larger clasts; (3) less-effective size sorting of particles due to increased fluid density; and (4) increased importance of traction and suspension transport, and corresponding decreased importance of saltation.

Debris flow and mudflow processes involve movement of sediment in muddy slurry that is considerably denser than water and behaves very differently, creating distinctive deposits. Debris flows represent a transition between unconsolidated mass movements (landslides, mudslides) and true streamflow, and vary considerably in character depending on water content. Unlike flows in air and water, debris flows are moderately to highly viscous, and often exhibit many properties of plastic, non-Newtonian flow (Nilsen 1985). The character of flows varies considerably, however, and spans the range from sediment-rich, plastic flows to water-rich, quasi-Newtonian flow. Due to the high density of the fluid flow, cobbles and even large boulders can be carried in suspension, and settling is minimal within the fluid column, resulting in moderately poor size sorting to a total lack of size sorting in the deposits. Generally, relatively "wet" flows show some degree of internal sorting, normal or inverse grading, and uniform clast orientation, while more viscous flows tend to yield unsorted deposits with randomly oriented clasts. Frequently, debris flows begin as a sudden mass movement on a saturated, unconsolidated slope, shifting from an

internally cohesive slip or slide to a viscous flow as speed increases. Debris-flow deposits are commonly associated with flash flooding in the arid west of North America (Blissenbach 1954).

Sheetflow processes involve thin, aerially extensive sheets of water with little appreciable depth (about a few millimeters or less) and tend to transport only very fine particles. Typically, sheetflow moving over the surface rapidly begins to organize itself into threads of weaving, channelized flow that diverge and converge in response to topographic irregularities and vegetation, such that distinguishing between true sheetflow (which is characterized by laminar flow, where the water molecules slide across each other in sheets, with no vertical mixing) and small-scale channelized flow (which is typically turbulent, and involves vertical and horizontal movement of individual molecules in the stream) is difficult. Thus, sheetflow often includes interspersed areas where laminar, turbulent, and transitional flow states exist. The term sheetwash is generally applied to the deposits of this suite of small-scale processes, regardless of the actual hydraulic behavior. Sheetflow is distinctly secondary to larger scale channelized flow and debris flow as an agent of fan deposition, and is probably most important as an agent of winnowing in alluvial fan deposits. With time, organization of the overland flow into streamlets can concentrate erosional energy, creating a network of small channels termed rills.

Deposition on alluvial fan surfaces is due to abrupt drops in flow competence resulting from changes in channel slope, channel confinement, and loss of water into the gravelly, permeable body of the fan. As the gradient decreases and flow expands the depth of flow decreases, surface area increases, and velocity drops off. As a result, competence is reduced and deposition occurs. Blissenbach (1954) identifies three modes of deposition on arid alluvial fans: (1) flash-flood deposits, resulting from high-volume, sediment-laden flows of short duration; (2) stream deposits, which occur within and proximal to distributary channels; and (3) stream-flood deposits, which occur through flow expansion across the fan surface.

Alluvial Fan Deposits

Most researchers subdivide alluvial fan deposits into two types: (1) unsorted debris flow deposits; and (2) poorly to moderately sorted, water-laid deposits (Bull 1977; Reineck and Singh 1980). Debris flows are capable of transporting very large clasts for long distances over relatively gentle slopes. They generally result in the deposition of thin, broad sheets or lobes a few decimeters thick. Internally, these sediment bodies consist of unoriented, matrix-supported coarse clasts in a muddy matrix, and can exhibit a pseudovesicular structure due to the inclusion of trapped air (Reineck and Singh 1980). Based on replicative laboratory fans, Hooke (1967) suggests that most debris-flow deposition occurs in the upper part of the fan, while water-laid deposits predominate downslope of the intersection point.

A variety of water-laid deposits occurs within fans. Reineck and Singh (1980) identify three basic types of water-laid sediments: (1) stream channel deposits; (2) sheet flood deposits; and (3) sieve deposits. Stream-channel deposits and sheet-flood deposits are analogous to deposits formed by alluvial rivers, while sieve deposits are unique to the fan environment. Stream channel deposits result from confined flow within incised channels on the fan surface, and thus are typical of the higher portion of fans (i.e., above the intersection point). They are typically composed of coarse to mixed load sediments, and may develop complex architectural relationships because of lateral shifts associated with aggradational and incisional episodes (Figure 6.10). Most channels are truncated, and consist of lenticular beds of poorly sorted gravel and sand, often exhibiting a gravelly lag at the base of individual scour fills. Cross-bedded sands may occur. The geometry of deposition varies considerably, but bars and multiple, ephemeral thalwegs are common within the boundary of the channel trench (Bull 1977; Reineck and Singh 1980).

Sheet-flood deposits result from flow expansion, typically downfan of the intersection point, where a network of bars and shallow distributary channels typically develops. They are typified by broad and thin sheet like and broad lenticular deposits of moderately sorted to well-sorted sand and gravel. Crossbedding and parallel bedding are common, and gravels are typically well imbricated. Scour and fill structures do occur, but are much less common and more poorly developed than in the confined channels upfan (Bull 1977; Reineck and Singh 1980). Similar, thin deposits can occur away from the active depositional lobe due to poorly organized flow across the fan surface (Wells and Dohrenwend 1985).



Figure 6.10. Complex fan-channel deposits exposed in an arroyo on McGregor Range.

Sieve deposits (also frequently termed sieve lobes due to their morphology) represent coarse deposits formed when water carrying primarily coarse clasts sinks abruptly into a porous substrate, causing the gravels to be deposited (Hooke 1967). Typically, sieve deposits are relatively well sorted, poorly imbricated, and commonly occur immediately down-fan of the intersection point. Subsequent infiltration of fine-grained deposits (e.g., fine sands and silts) is common, resulting in a bimodal grain size distribution and a fabric of randomly oriented, clast-supported coarse gravels in a fine-grained matrix (Reineck and Singh 1980).

At a larger scale, alluvial fans typically exhibit a sequence of depositional facies that fine with depth, because as a fan grows, coarse material is shunted farther and farther into the basin (Rust 1979). The proximal part of semiarid and arid fans is typically dominated by poorly sorted, matrix-supported, debris-flow conglomerates. Although debris flows may also occur, midfans are dominated by water-laid deposits, including normally and inverse graded clast-supported conglomerates and lenticular sand bodies. Distal fans are dominated by sandy to silty sheet flow deposits that exhibit parallel bedding and gently inclined planar crossbedding, and tend to grade subtly into basin facies. However, gravels may occur locally (Reineck and Singh 1980; Rust 1979).

The surface of alluvial fans in arid regions typically develops a characteristic surface armor of coarse clasts termed desert pavement. Typically, this gravelly surface is underlain by finer-grained sediments. For many years, this pavement was typically interpreted as an erosional lag of coarse clasts produced by eolian and/or sheetwash winnowing of gravelly sands and silts (e.g., Bates and Jackson 1984; Cooke and Warren 1973; Ritter 1986), although some authors (e.g., Dan et al. 1982; Mabbutt 1977;) argued that they were the result of upward migration of coarse clasts due to shrink-swell processes. Because development by either of these processes implies that deposition on the surface has ceased, desert pavement surfaces are generally considered stable. However, recent work has cast doubt on these interpretations (Dixon 1994; McFadden et al. 1987). In fact, work by McFadden and others (1987) documents at least one case where the pavement had to be formed by incremental additions of fine-grained material through eolian influx and *in situ* weathering, which served to raise detached surface clasts on a lava flow from the underlying bedrock. In other words, fine-grained material infiltrates into the gravels on the surface, lifting them up until a lens of fine-grained allocthonous sediment lies between the intact basalt and the armor of basaltic surface clasts. This led McFadden and others (1987) to conclude that "desert pavements are born and maintained at the surface," and propose a mechanism involving (1) colluvial movement of clasts into depressions filled with eolian sediment, and (2) detachment and uplifting of clasts from bedrock as salt-rich eolian fines accumulate in fractures, expand and contract with moisture variations, and force loose clasts upward. While it is debatable how widespread this phenomenon of aggradational pavements is (cf. Dixon 1994; Hooke 1990; Wells et al. 1990; Williams and Zimbleman 1994), it does indicate that the presence of a desert pavement surface does not necessarily imply that the surface is inactive.

A related question concerns the evolution of alluvial fan surfaces, which are typified by a channel and bar topography resulting from vectors of flow on the depositional lobe when active but tend to "flatten" into a relatively smooth surface with the development of a mature pavement surface (Hooke 1990). This proves is related to weathering of the surface gravels, redistribution by colluvial movement, localized eolian deposition, and (disputably) creep processes. Whatever the process, this time-progressive decrease in microrelief can provide a valuable tool for determining the relative age of various portions of a fan (McFadden et al. 1989). Equally important, it is possible that many of these processes of surface evolution can bury archaeological materials, particularly those deposited in low spots on the irregular distributary surface, long after principal deposition of the surface has ceased.

Climatic Implications of Alluvial Fan Activity and Quiescence

Because they are typically the result of structural controls, alluvial fans may form under any climatic regime. However, studies of individual fans have demonstrated rough regional synchronicity in episodes of alluvial fan activity, which has led a number of investigators to identify changes in activity in deserts (e.g., Bull 1977, 1991; Dorn 1994; Gile et al. 1981; Wells et al. 1987). Although the majority of authors cite climate change as the underlying mechanism stimulating fan activity, there is little agreement on the character of that change. Dorn (1994) identifies four climatic models of fan development: a transition-to-drier-climate model, a paraglacial model, a humid aggradation model, and a periglacial model.

The transition-to-drier-climate model is probably the most commonly invoked (e.g., Blair et al. 1990a; Dorn 1988; Gile et al. 1981; Mayer et al. 1984; Monger 1993a). It assumes that a shift toward drier conditions results in a reduction in vegetation cover, which leads to increased sediment production as hillslopes become more vulnerable to erosion. Because vegetation response to climate change is not instantaneous, this implies that a lag period must exist between the onset of drier conditions and the geomorphic response. It also implies that the preceding, moist period was conducive to weathering and the maintenance of a mantle of weathered regolith

on the slopes of the drainage basin. This model is generally espoused in the Fort Bliss region (Blair et al. 1990a; Gile et al. 1981; Monger 1993a).

In contrast, the humid-period-aggradation model argues that moisture that is more effective results in more efficient delivery of sediment, leading to the aggradation of fans during the wetter time periods (Barsch and Royse 1972; Lustig 1965; Mulhern 1982; Ponti 1985). Although not generally espoused in southern New Mexico, this relationship has equal theoretical viability and cannot be dismissed out of hand. In contrast, the paraglacial and periglacial models argue for the production of abundant sediment in the source basin by glacial processes and by cryoweathering processes, respectively. All extant paleoenvironmental data suggest that neither of these latter models is applicable to Fort Bliss, particularly during the culturally relevant timespan.

One additional model that Dorn (1994) does not address in any detail is the argument that episodes of alluvial fan activity can be stimulated by changes in the intensity or annual timing of precipitation, which does not necessarily require major shifts in vegetation density. Given that the climate of the Fort Bliss region appears to have been relatively arid throughout the Holocene, and thus should have supported discontinuous grass cover at best, it can be argued that variability in sediment production could as easily be a function of the frequency of individual intense storms, which would control the rate of sediment delivery, rather than the density of erosion inhibiting vegetation.

In addition, there is another school of thought that holds that external stimuli are not necessarily required to initiate change in arid fluvial systems (e.g., Patton and Schumm 1975, 1981; Schumm 1977). This model argues that because sustained flow is not present, sediment is shunted through the system in short "hops," such that loci of erosion and deposition shift constantly under relatively uniform conditions. To cite one example, initiation of a headward-cutting gully on the surface of a fan will cause sediment to be deposited at its mouth, because flow will not be sufficiently sustained to flush the sediment out of the system. This process will result in a distributary lobe at the mouth of the gully that may aggrade sufficiently to bury the lower reaches. Thus, the gully may expand headward while at the same time burying itself with freshly exhumed sediment at its lower end, thus essentially migrating up the fan. Similarly, aggradation and downcutting may alternate systematically within the main incised channel of a fan, occasionally burying the channel completely and resulting in renewed distributary deposition on the upper fan surface. A related issue is the concept of complex response, which proposes that a single stimulus (such as a change in climate) can initiate a number of successive changes in geomorphic behavior as the system adjusts to reach equilibrium with the new conditions (Schumm 1973).

In sum, the linkage between climate change and geomorphic response of alluvial fan systems is complex, and it is unlikely that a satisfactory process-response model of fan systems that is simple and universally applicable will ever be formulated. Rather, the response of arid fans is complex and dependent on the magnitude, direction, and rapidity of climate change as well as the preexisting state of many system variables; the resulting stratigraphic sequence is the combined result of both extrinsic controls (including climate change) and intrinsic processes. Thus, aggradation or erosion of fan channels may result from either shifts toward moister or drier conditions, changes in the intensity or timing of precipitation, or intrinsic systemic adjustments. Although the initiation of Organ fan deposition around 7 ka clearly seems to be related to a shift in aridity, the stratigraphic breaks between Organ I/Organ II (2.1 ka) and Organ II/Organ III (1.1 ka) are more tenuous, and should not be attributed *a priori* to increased aridity.

Geoarchaeological Implications of the Alluvial Fan Environment

The alluvial fans of Fort Bliss are extensive and represent an important component of the overall landscape. Thus, archaeological sites should be expected in the alluvial fan context, and extant surveys (e.g., Beckes et al. 1977; Skelton et al. 1981) reveal that archaeological sites are indeed

prevalent on the fans of Fort Bliss. Thus, interpretation of these sites requires an appreciation for the biases imposed by the geomorphic environment.

There are five geoarchaeological implications of alluvial fan formation processes. First, because loci of deposition are localized on an alluvial fan and tend to shift with time, the stratigraphic sequence should be highly variable; stratigraphic correlation of time-equivalent deposits across the broader fan environment is complex and may not be possible using purely architectural relationships. Several alternate lines of evidence, including soil stratigraphic, archaeological, and (less confidently) lithostratigraphic evidence, can be used to facilitate correlation, but chronometric data are an absolute necessity to establish a reliable sequence. It is important to realize that various archaeological components of the same age may be simultaneously exposed at the surface and buried at a variety of depths on different parts of the same alluvial fan.

Second, the character of deposition in entrenched and unentrenched portions of the active portion of an alluvial fan is profoundly different, and has varying potential to seal and preserve archaeological materials. Deposits formed within the casement valley of an incised arroyo channel can represent considerable tractive force, and any archaeological deposits contained therein can therefore represent highly reworked material. On the other hand, deposition here can also occur rapidly, and some components can be buried in near-pristine context. In contrast, archaeological materials associated with distributary, sheet flood deposits are less likely to be deeply buried, experience-generally less-tractive force, and are thus less likely to be strongly reworked than material in the channels. However, they are still subject to considerable lateral disturbance during burial and are more subject to vertical disturbance by pedogenic processes, including bioturbation.

Third, even after the cessation of primary deposition on any given portion of an alluvial fan, secondary processes (including eolian, slope wash, colluvial, expansion-contraction, pedologic, and bioturbation processes) continue to modify the sediment. Low magnitude channelized flow associated with precipitation falling on the fan surface (as opposed to in the drainage catchment) can also result in reworking and burial of archaeological components on "inactive" portions of the fan. Thus, it is possible that sites may be formed and subsequently buried on a relict lobe of a fan, particularly if they are situated within a topographic low. The presence of a surficial gravel lag, or desert pavement, does not preclude the possibility that archaeological components may be buried at depth.

Fourth, the locus of water delivery on an alluvial fan shifts through time as the drainage net evolves, both laterally due to changes in distributary channels and axially as the intersection point shifts up- and down-fan in response to channel aggradation and incision. Thus, currently observable areas of water delivery on a given fan can be expected to be different than they were in the past. This is particularly important if one is looking for evidence of dryland agricultural fields designed to exploit infrequent summer runoff. Although the extent of prehistoric agriculture practiced in the bolson is unclear, at least some agriculture was practiced during the Mesilla and (particularly) El Paso phases, and it is likely that intentional modifications of the landscape to provide for opportunistic irrigation of these fields were practiced. However, the small number of water control structures claimed to have been identified in the region (Hubbard 1987; Leach et al. 1993) have not been confirmed and such structures are conspicuously absent in the larger surveys (e.g., Beckes et al. 1977; Skelton et al. 1981). Better understanding of the areas experiencing active runoff during this time period could potentially allow more such structures, and possibly associated habitation sites, to be identified.

Last, if desert pavement on an alluvial fan surface has formed by sheetwash and/or eolian winnowing or by clast heave, then gravels should be present in the subsurface. If, instead, the pavement is formed by the "born at the surface" model of McFadden and others (1987; Wells et

al. 1995), then the sediment beneath the gravel armor should be exclusively eolian dust. In either case, the potential for buried archaeological sites beneath the pavement is not high.

Alluvial Fans on Fort Bliss

Alluvial fans are a very important and extensive environment on Fort Bliss. The margins of the graben basin are marked by a series of large alluvial fans of different ages that have coalesced into *bajadas* that extend kilometers away from the mountain front. Monger (1993b) has correlated these fans with similar features identified in the desert project area (Gile et al. 1981). Another sequence of fans, largely unstudied, is preserved on Otero Mesa. It is unclear how these spatially discrete fans are related to the larger fans in the basin. The following discussion outlines the basic morphostratigraphic and soil stratigraphic framework of alluvial fans in the bolson.

Jornada I fans are the oldest, highest-elevation fans in the project area, and represent the oldest post-Camp Rice sediments in the study area. Typically, they dip fairly steeply into the basin, and are exposed near the mountain front and buried basinward. Gile and others (1981) date Jornada I fans in the desert project area to between 250 and 400 ka. Jornada I fans are characterized by Stage IV carbonate morphology and, occasionally, strong argillic horizon development (although the solum of these old features is typically absent due to erosive truncation). In some cases, fine-grained facies exhibit Stage III carbonate morphology. Monger (1993b) maps Jornada I fans around the margin of the Hueco, Jarilla, Franklin, and Organ mountains.

Jornada II fans are younger fans that are inset into Jornada I fans near the mountain front and tend to bury the more steeply dipping Jornada I fans basinward. Gile (1987b) estimates the age of Jornada II deposition as 150 to 25 ka. Diagnostic pedofeatures include intermediate carbonate development, ranging from Stage III or incipient Stage IV morphology in gravelly sediments and from strong Stage II to Stage III morphology in fine sediments, and a relatively strongly-rubified argillic horizon (when preserved, which is not common). Monger (1993b) maps Jornada II fans around the base of the Organ Mountains; they are absent on the Hueco and Jarilla fan-piedmonts.

Isaack's Ranch fans are in turn inset into the Jornada II. This surface dates to approximately 15 to 8 ka, and is mapped only around the Organ Mountains (Monger 1993b). It is characterized by Stage II carbonate morphology in fines and in gravels, and a sparsely preserved, weak argillic horizon (Gile et al. 1981; Monger 1993a).

Organ Fans are the lowest alluvial surface preserved on Fort Bliss, and date to between 7000 and 100 B.P. (Gile et al. 1981). In medial fan reaches, the surface of the Organ unit often preserves the primary channel-and-bar topography that is largely eradicated on the older fans (although a secondary network of small channels can often be developed in a thin, surficial mantle of more recent sediments on these surfaces). Basinward, the organ alluvium becomes fine grained and grades almost imperceptibly into the basin floor; like the basin, the distal fan surfaces are often mantled with recent dunes. Organ sediments are characterized by Stage I carbonate morphology or a lack of pedogenic carbonate, very weakly argillic to cambic B-horizons, and (occasionally) a faint reddish-brown color.

Arroyos are common on the fans, and typically expose complex stratigraphic sequences that suggest that the incised channels have experienced a complex history of aggradation, incision, lateral migration, and avulsion. Little is known about the relatively thick late Quaternary stratigraphic record preserved in the incised reaches of the fan channels, and what is known is based on research in the Desert project field area.

Similarly, limited investigations on the fan piedmonts commonly indicate multiple generations of thin, stacked deposits with variable amounts of truncation (e.g., see Monger 1993a, soil pedon descriptions). The older fan surfaces, in particular, frequently are capped by a veneer of sediment of considerably younger age, and it is not unusual to find areas where the fan surface was

truncated to calcrete prior to deposition of a 1 to 2 m veneer of younger sediment (Abbott 1997; Monger 1993a). Thus, large-scale mapping of morphostratigraphic surfaces alone is insufficient to eliminate the possibility that buried archaeological materials exist.

Desert-pavement surfaces in the region are typically poorly developed in comparison to intensely studied pavements elsewhere (e.g., the Mojave Desert). Desert varnish is weakly developed, if at all. The packing of surface clasts is also typically relatively loose, with fine-grained sediment exposed in the interstices, which would render them vulnerable to attack by sheetwash. One common feature is apparent disturbance of the armored surface, indicated by irregular orientation of carbonate pendants on the clasts. These carbonate pendants are one of the first forms of pedogenic carbonate development in gravelly materials (Gile et al. 1966; Machette 1985), and appear to have developed *in situ*. However, the fact that up to 25 percent of the clasts frequently have pendants that are oriented up suggests that disturbance of the pavement is widespread. Although the mechanism of this disturbance is unknown, it may be due to either reworking by sheetwash (which has strong implications for the potential for site burial) or livestock trampling (which does not), or both.

Another area of interest that remains relatively unexploited concerns the fans on Otero Mesa. These fans, too, exhibit surfaces and fills of various ages. At present, very little is known about these fans, and, it is unclear how they correlate with the larger fans in the bolson.

UPLAND AND SLOPE ENVIRONMENTS

The third major geomorphic environment on Fort Bliss consists of the slopes of the mountains surrounding the bolson. Here, broad erosional facets interdigitate with smaller, depositional areas. The slopes are also the location of rock shelters, which can provide highly detailed cultural and paleoenvironmental records.

Slope Processes

Geomorphic activity on the slopes is typically dominated by gravity-driven processes termed mass movements, with the activity of water playing a distinctly secondary role as an agent of transport. Mass movements can be divided into categories on the basis of several characteristics, including the type of material undergoing movement, the integrity of the moving mass, the speed of movement, the character of the shear zone, the dominant vector of movement (i.e., either vertical or horizontal), and the degree of moisture or lubrication involved (Carson and Kirkby 1972; Chorley et al. 1984; Selby 1982).

Materials involved in mass movement may be rock, sediment, soil, or combinations of the above. Frequently, other materials (including vegetation, unfortunate people or animals, and, most relevant to this discussion, artifacts) are also incorporated into the moving mass and redeposited. One important factor that differentiates between various types of mass movement is the integrity of the moving mass. Consolidated mass movements consist of translation of intact or nearly intact blocks of rock or sediment, while unconsolidated mass movements do not maintain their internal integrity during movement. Frequently, a mass movement may start out consolidated (e.g., a rotational slump) and disintegrate into an unconsolidated movement (e.g., a flow) as the failure continues.

Speed is another important factor in differentiating between mass movements. Rapid mass movements occur in timeframes short enough to be perceptible to a casual observer, ranging from near instantaneous (e.g., a rock falling off a cliff) to a span of a few days (e.g., a slow-moving mudflow). Incremental mass movements, in contrast, occur gradually over longer spans of time, ranging from weeks to tens or hundreds of years.

With the exception of creep processes, all mass movements require some type of shear zone, where the material undergoing movement detaches from the underlying substrate. This shear zone can be related to surface-weathering phenomena, inherent zones of weakness in the bedrock or sediment (e.g., bedding planes or joints), or simply loci of maximum stress within a relatively homogeneous body. In addition, they may be either planar or curved, and can occur as discrete shear planes or as broader zones of failure.

The direction of translational movement is another factor to consider. Some mass movements are nearly vertical, while others also involve considerable horizontal movement. Finally, the degree of moisture or lubrication involved in failure and movement is a major factor distinguishing various forms of mass movement. This lubrication is often provided by water, but can also be provided by ice or snow. Once a rapid mass movement is initiated, trapped air can also provide hydraulic support, and is an important factor in decreasing friction in large, catastrophic slides and flows, allowing them to sometimes travel great distances and "ride over" topographic irregularities in their path. Table 6.1 illustrates the major classes of mass movements that can occur in a warm desert environment like south central New Mexico.

Mass movements occur when the shear stress imposed by gravity exceeds the shear strength of the material, which is a function of friction in unconsolidated material and mass strength in consolidated materials. Many factors can cause shear stress to exceed shear strength, either by increasing the former or reducing the latter.

Factors that can increase shear stress include the removal of lateral support (e.g., by lateral erosion), removal of underlying support (e.g., by stream undercutting or another mass movement), slope loading (through the accumulated weight of infiltrating water, vegetation, and/or accumulated debris), lateral pressure (e.g., freeze-thaw, shrink-swell, pressure release), and transient stresses (e.g., earthquakes, wind blowing on trees). Factors that can reduce shear strength include progressive weathering, structural changes or development, changes in pore water pressure, changes in interparticular cohesion due to wetting, or organic effects like animal burrowing or root decay (Summerfield 1994).

Other active processes on slopes can include slopewash, rill erosion, and rainsplash. Slopewash can involve sheet flow and small-scale, poorly organized channelized flow, which can erode small channels termed rills that serve to increase organization in runoff patterns. Rainsplash refers to the detachment of particles by the energy of raindrop impacts; because sediment thrown downslope tends to travel farther than sediment thrown upslope, over the long term, this process tends to result in net downslope sediment movement. Finally, solution processes form an important part of slope development. Solution is responsible for the development of most caves and rock shelters, which form an aerially insignificant but culturally important part of the slope environment. Most surface water and ground water is actually a weak solution of carbonic acid, which forms through the reaction of water and carbon dioxide. Although the character of the reaction is complex, the net result is that this solution is able to attack and dissolve calcite, which is the primary constituent of limestone.

Solution weathering occurs as water moving through cracks and fissures in bedrock dissolves the surrounding rock, eventually forming large voids (caves). Solution can be particularly efficient at seeps and springs where the groundwater emerges, which is the most common mechanism of rock shelter formation (although loss of support by solution of underlying strata can lead to collapse of shelter and cave walls and roofs, adding to the process). Solution can also attack surface rocks and sediments, carrying components of the slope away as water flows off the surface or through a sedimentary cover.

Table 6.1.
Classification of Mass Movements Typical of Warm Deserts.

Primary Mechanism	Type	Materials	Moisture Content	Rate of Movement	Description	Potential for Preservation of Archeological Content	
Lateral Movement Predominant	Creep	Rock Creep	plastic rocks (e.g. clays, shales)	low	very slow	slow plastic deformation of soft rock under gravity	n/a
		Continuous Creep	soil/sediment	low	very slow	slow plastic deformation of sediment under gravity	high
		Dry Flow	sand or silt	very low (air lubrication)	very rapid	funneled flow down steep slopes of noncohesive sediments	very low
		Debris/Rock Avalanche	rock/ice	low (air lubrication)	very rapid	catastrophic, long-distance, low-friction movement of large volumes of rock and ice; can override significant topographic features	very low
	Flow	Slow Earthflow	soil/sediment	low	slow	confined elongated flow	low
		Mud Flow	soil/sediment	very high	slow	confined elongated flow	low
		Rapid Earthflow	soil/sediment	very high	very rapid	rapid collapse and lateral spreading of soil/sediment	very low
	Translational Slide	Debris Flow	rock/soil/sediment	high/very high	very rapid	dense rapid flow usually confined in preexisting drainage routes	very low
		Rock Slide	coherent rock mass	low (air lubrication)	very slow to very rapid	shallow slide along fracture plane	low/moderate
		Block Slide	fractured rock mass	low (air lubrication)	moderate	shallow slide along fracture plane	low/moderate
		Debris/Earth Slide	rock debris/soil/sediment	low/moderate (air lubrication)	very slow to rapid	shallow slide of deformed or undeformed soil/sediment masses along failure plane	low/moderate
		Slump	rock, rock debris, or soil	low to moderate	slow	rotational movement along concave up failure plane	moderate
	Heave	Soil Creep	soil/sediment	low	very slow	widespread, noncoherent, incremental downslope movement of soil particles	moderate/high
		Talus Creep	rock debris	low	very slow	widespread, noncoherent, incremental downslope movement of rock particles	moderate
Rock Fall/Topple		coherent rock mass	low	very rapid	detachment and fall of blocks from vertical faces	low	
Vertical Movement Predominant	Fall	Earth Fall/Topple	coherent sediment mass	low	very rapid	toppling of cohesive masses from near-vertical faces of earth (e.g. stream cutbanks)	low
		Cavity Collapse	rock, soil, or sediment	low	very rapid	collapse of rock or soil into underground cavities (e.g. dolines)	low
Subsidence	Setting	soil/sediment	low	slow	lowering of surface due to ground compaction, usually as a result of ground water withdrawal	high	

modified from Summerfield 1991.

Slope Landforms

Slope morphology is typically described by subdividing a complex hillslope into segments (or facets) that have relatively simple geometric shapes (e.g., convex, straight, or concave) in each of two axes (e.g., parallel with and perpendicular to the slope); thus, nine basic slope facet forms can be identified (which can nonetheless vary considerably with inclination and degree of curvature) (Figure 6.11). Typically, slopes can be divided into a convex erosional upper slope, a straight middle slope, where transport is dominant, and a concave depositional lower slope. However, the dimensions of these various segments can vary considerably, and geologic controls can cause the development of a complex sequence of segments to form. The depositional lower slope can also be absent if an efficient transport agent (e.g., a stream) is present to remove accumulating debris.

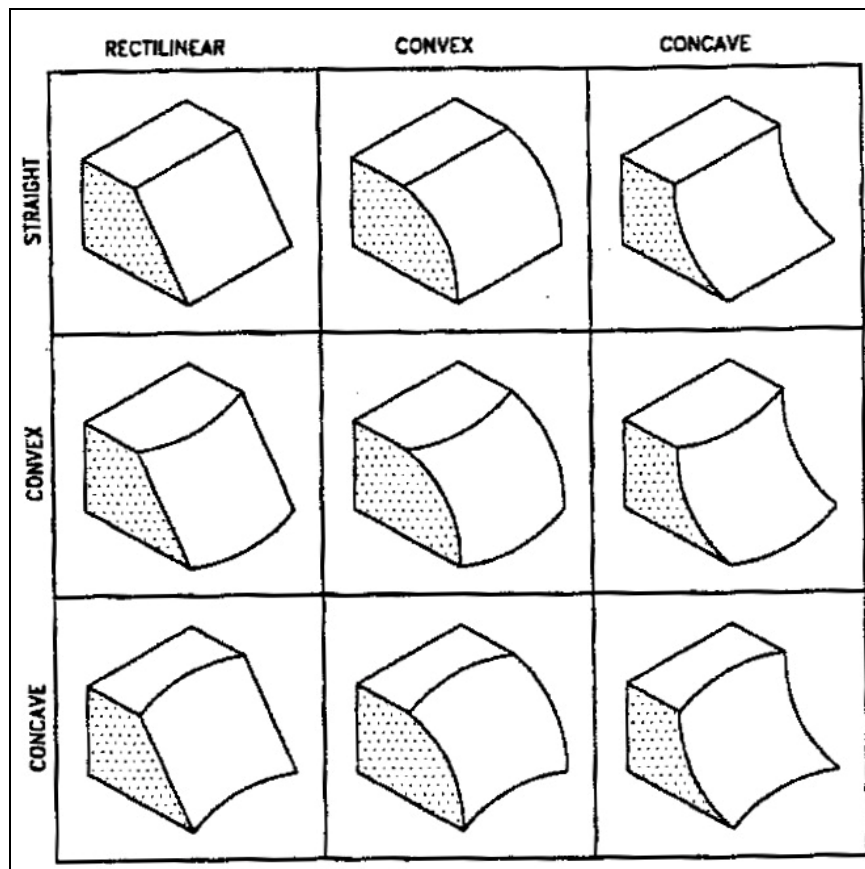


Figure 6.11. The nine possible shapes of three-dimensional hillslope facets. (after Parson 1988).

In humid environments, the rate of weathering typically outpaces the rate of denudation, and relatively- smooth, sediment-mantled slopes are typical. Rocks in arid environments, in contrast, weather relatively slowly and typically yield irregular slope profiles with facets that are more distinct and slope breaks. One common attribute of arid zone slopes are relatively steeply inclined bare rock faces, termed free faces, where the rate of retreat is entirely a function of the ability of weathering to detach rock for transport. The following discussion, in general, is only applicable to arid environments where the rate of chemical weathering is relatively low.

Deposition on slopes creates sedimentary bodies that are collectively termed colluvium, although the term is sometimes restricted to masses of poorly sorted coarse- and fine-grained material. As rock detaches from a free face, it falls to the base of the slope, where it accumulates in the form of a coarse wedge of rock termed talus or scree. Talus slopes are typically steep because the rock accumulates until it rests at an angle of repose determined by the size, shape, and frictional properties of constituent clasts. Additional weathering can lead to further downslope movement and the formation of mixed coarse and fine material (colluvium) that typically lies at a gentler inclination than talus. If surface wash processes are sufficient to further transport the fine material, relatively thick wedges of dominantly, fine-grained sediment, termed slopewash, can accumulate.

The mode of slope evolution under arid conditions can be either downwearing or backwearing. If an agent of transport is available to remove the accumulating material at the base of the slope, then long-term, essentially parallel, retreat of the steep free-face can result in the development of a gently inclined bedrock surface termed a pediment. If, instead, the material at the foot of the slope is allowed to accumulate, the overall slope angle will decline through time as the steeper slopes are gradually replaced by gentler slopes and the height of the free face declines, resulting in a debris slope that tends to decrease in gradient through time (Figure 6.12).

The model presented above is overly simplistic, because the interactions between slope processes are more complex than indicated in this brief summary (cf. Abrahams et al. 1994; Carson and Kirkby 1972; Parson 1988; Selby 1982; for in-depth treatment). Rates and processes are governed by conditions that change through time as climate undergoes shifts; thus, efficiency of weathering and of transport will vary both spatially through time (Abrahams et al. 1994; Schmidt 1994). Moreover, differing thresholds may cause various aspects of weathering and different transport agents to vary independently, so that both of the generalized models presented above may have acted on a given slope at various points in time.

Vegetation can also play a role in the rate of weathering, the types of weathering products produced, and the speed of sediment removal from the system (Francis 1994). Finally, the character of slopes is also strongly conditioned by the characteristics of the bedrock. For example, a free face will typically only develop in relatively hard rock, while pediment-like forms may develop at least partially through downwasting and deep weathering (Moss 1977). Vertical changes in rock characteristics (e.g., due to stratified sedimentary rocks) can cause complex slope forms with many different segments to form, greatly complicating the many factors that must be understood.

Climatic Implications of Slope Activity

In general, because formation is dictated by the rate of weathering of rock underlying the slope, hillslopes are relatively resistant to climate change in comparison with other types of landforms. At the same time, this resistance implies that any climatically determined characteristics imposed on a hillslope system are more likely to be preserved through subsequent shifts in external conditions; thus, hillslopes are more likely to retain vestiges of attributes arising from long-past climatic conditions (Schmidt 1994).

Nevertheless, climatic influences are frequently apparent in slope morphology and slope sediment characteristics. In particular, when climatic changes influence rates of groundwater discharge at springs, activity levels on underlying slopes should vary with rates of discharge. Increased groundwater discharge not only increases the potential for slopewash erosion to occur, but can also stimulate mass movements by increasing the weight of sediments on the slope and decreasing interparticulate friction.

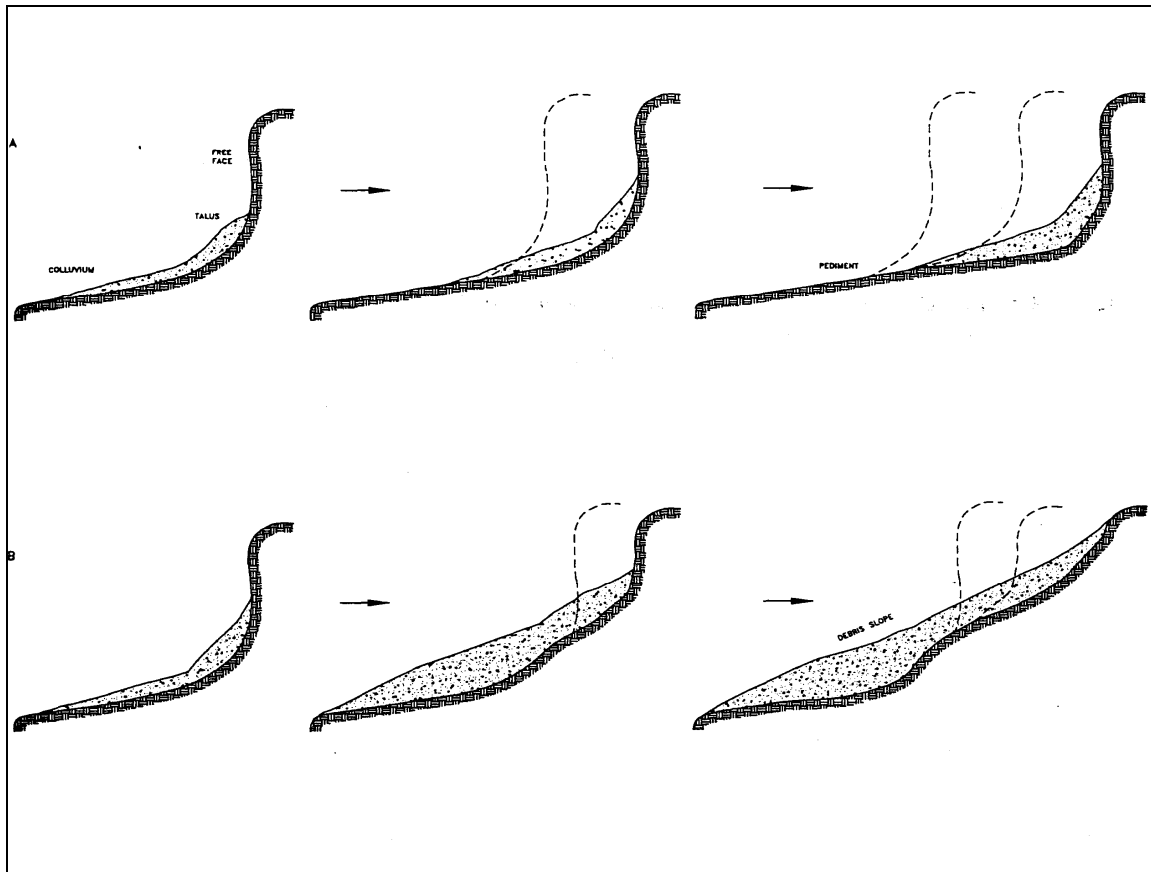


Figure 6.12. Two generalized simplified models of arid zone slope retreat. ([a] parallel retreat and pediment formation resulting from efficient removal of colluvial sediments from base of slope and [b] slope replacement and debris slope formation resulting from inefficient removal of colluvium from base of slope).

Discharge may also stimulate groundwater sapping, as water emerging at an aquiclude (e.g., a contact between overlying permeable sandstone and an underlying, impermeable mudstone) erodes the support of overlying beds, resulting in mass failure. Conversely, depending on the initial system state and the magnitude of the change in discharge, increased groundwater outflow can also lead to better development of anchoring vegetation, inhibiting slope activity.

Temperature changes also play a role. In particular, the frequency of freezing temperatures may strongly influence the rate of physical weathering of rock, and jointed rock in particular. Over the long-term, temperature and precipitation changes also dictate the rate of chemical weathering, in many cases profoundly influencing the stability of the slope.

Thus, the net effect of successive climatic perturbations can be a sequence of colluvial deposits that reflect former climates both in the rate of sedimentation represented and in the textural and chemical properties of the resulting sediment. Such sediments have been viewed as a proxy record of climate change (e.g., Devereaux 1982; Franschetti 1962). Nor are such controls limited to the slope system as a whole; similar trends in temperature and precipitation have been identified as important controls on the rate of rock shelter evolution (e.g., Laville 1976; Laville et al. 1980).

Geoarchaeological Implications of Slope Environments

Because hillslope processes and process rates are so variable, archaeological implications of geomorphic activity on hillslopes are particularly problematic to generalize. On the one hand, large, rapid mass movements can fundamentally alter the character of a hillslope in a matter of seconds, while on the other hand, many hillslopes evolve so slowly they can be essentially viewed as constants within the relevant time range in North American archaeology. Nevertheless, there are a number of broadly applicable geoarchaeological implications of hillslopes and hillslope deposits.

First, archaeological components developed on slope sediments that undergo rapid or slow progressive failure through mass movement and surface wash will be transported and redeposited along with those slope sediments; consequently, behaviorally significant spatial and stratigraphic context will generally be lost except in very broad terms. Second, archaeological components buried by rapid mass movements will also generally be disturbed to such an extent that spatial context is lost; however, stratigraphic context will typically be preserved. Third, archaeological components buried by incremental mass movements and slopewash will tend to operate as a slope sediment until buried; consequently, spatial context will typically once again be lost, but in some cases may be preserved. Stratigraphic integrity in such a context should be moderate to high in most cases. Fourth, the potential for preservation of spatial and stratigraphic context will decrease markedly with increasing slope angle. Fifth, the potential for burial will be highest on concave slope segments. Thick accumulations of sediments should occur only at the base of the slope and at points where the colluvial material encounters a distinct reduction in slope, such as on bedrock-controlled benches. Sixth, the sequence of colluvial sediments should reflect changes in sedimentation rates that mirror the degree of slope activity through time and may reflect climatic changes stimulating that activity. Shallow caves and rock shelters, too, should evince some cyclicity due to climatic changes. In particular, production of coarse debris should correlate with higher incidences of freezing temperatures, while production of finer materials should correlate with more pervasive chemical weathering. Seventh and last, in some cases, incremental erosion of a stratified archaeological hillslope deposit can lead to stratigraphic reversal, as increasingly old components are transported downslope and deposited on top of younger components.

Slope Environments on Fort Bliss

Very little attention has been focused on the slope environment on Fort Bliss. Most of the slopes are developed on stratified sedimentary rocks, and have therefore developed complex morphologies. Other slopes are developed on intrusive igneous rocks, particularly in the Organ and Jarilla mountains. Most slopes on the bolson margin are moderate to very steep; gentler inclines are typically underlain by alluvial fan deposits. The presence of ancient woodrat middens implies that, in general, the slopes are relatively stable; however, evidence of slide events is common, implying that the slopes fail catastrophically on a localized basis. The character of the colluvial record, and the extent that this record may contain paleoenvironmental information, are at present unknown.

LACUSTRINE PROCESSES AND PLAYAS

Playas are ephemeral lake basins formed in arid areas with internal drainage (Reineck and Singh 1980), and are abundant in the Tularosa Basin and Hueco Bolson. They typically consist of level, smooth surfaces underlain by fine-grained sediment. Playa environments are an extremely important component of the overall Fort Bliss landscape. The role of playas in prehistoric subsistence and land use has long been accepted as reflected in the original *Significance*

Standards. What was lacking in that discussion was the recognition, let alone an appreciation, for the variability hidden under the general term “playa.” Since 1996, the nature of macro-topographic features such as playas, swales, and *bajos* has received increasing interest (Church 2002; Miller 2004b). Much of the following discussions have been adapted from these two studies. The result has been a first attempt at defining the variation in these features and relating the features and their variability to subsistence, land use, and paleoenvironmental data potential.

From a paleoenvironmental perspective, playas and similar topographic depressions are significant in that they can contain fine-grained, laminated sediments capable of preserving a variety of types of climatic and biotic data. Another significance of these sediments is that they represent some of the few exposed clay sediments occurring in the bolson with sufficient clay content to permit cohesion for puddled adobe. Coupled with the fact that they are also the only real source of the water needed for adobe manufacture, it follows that playas would have been important resources for construction material during the latter prehistoric period.

Innumerable playas are distributed across the Tularosa Basin and Hueco Bolson. The distribution of depressions on Doña Ana Range, most of which are assumed to be playas, is presented in Figure 6.13. They range in size from shallow depressions a few hundred square meters in size to the over 20 square miles of playa basin comprising Lake Lucero. Local archaeologists have long assumed that these playas and topographic depressions of the desert basins of southern New Mexico and west Texas were essential oases for prehistoric populations. Visions of placid pools of water attracting game and surrounded by lush vegetation are often alluded to in the literature. This presentation takes a critical look at that model by examining the hydrology and water quality of playas and the characteristics of biomass, productivity, and resource availability of playas in the northern Chihuahuan Desert. The results provide evidence that the oasis model needs to be reconsidered and that the role of playa resources in local prehistoric subsistence systems is far more complex than initially thought.

Definition and Classification of Playas

Varieties of topographic depressions have been subsumed under the rubric “playa” by archaeologists, biologists, and geomorphologists. Yet it has become clear that this generalization masks a great deal of complexity. For purposes of this discussion swales/*bajos*, arroyo mouth ponds, and playas will be differentiated. The former two terms, swale/*bajo* and arroyo-mouth ponds, describe essentially the same type of water catchment: a depression that collects rainfall run-off water and nutrients from the surrounding landforms.

Playas

Playas are broadly defined as the flat, lower portions of arid basins with intermittent drainage that periodically flood and accumulate sediment (Neal 1975). While there is still a great deal of debate over specific definitions of playas (see Barth 2001; Briere 2000; Shaw and Thomson 1989), Briere’s definition (based on Rosen’s [1994] earlier definition) is used here. Briere (2000: 2) states that playas are “intercontinental arid zone basin[s] with a negative water balance for over half of each year, dry for over 75 percent of the time, with capillary fringes close enough to the surface such that evaporation will cause water to discharge, usually resulting in evaporites.”

Hydrologically, there are two varieties of playas: 1) those that are hydrologically closed and referred to as discharge playas; and, 2) those that are hydrologically open, termed through-flow playas (Rosen 1994). The latter are playas that are filled by ground water fluctuations; the former are filled by rainfall and runoff.

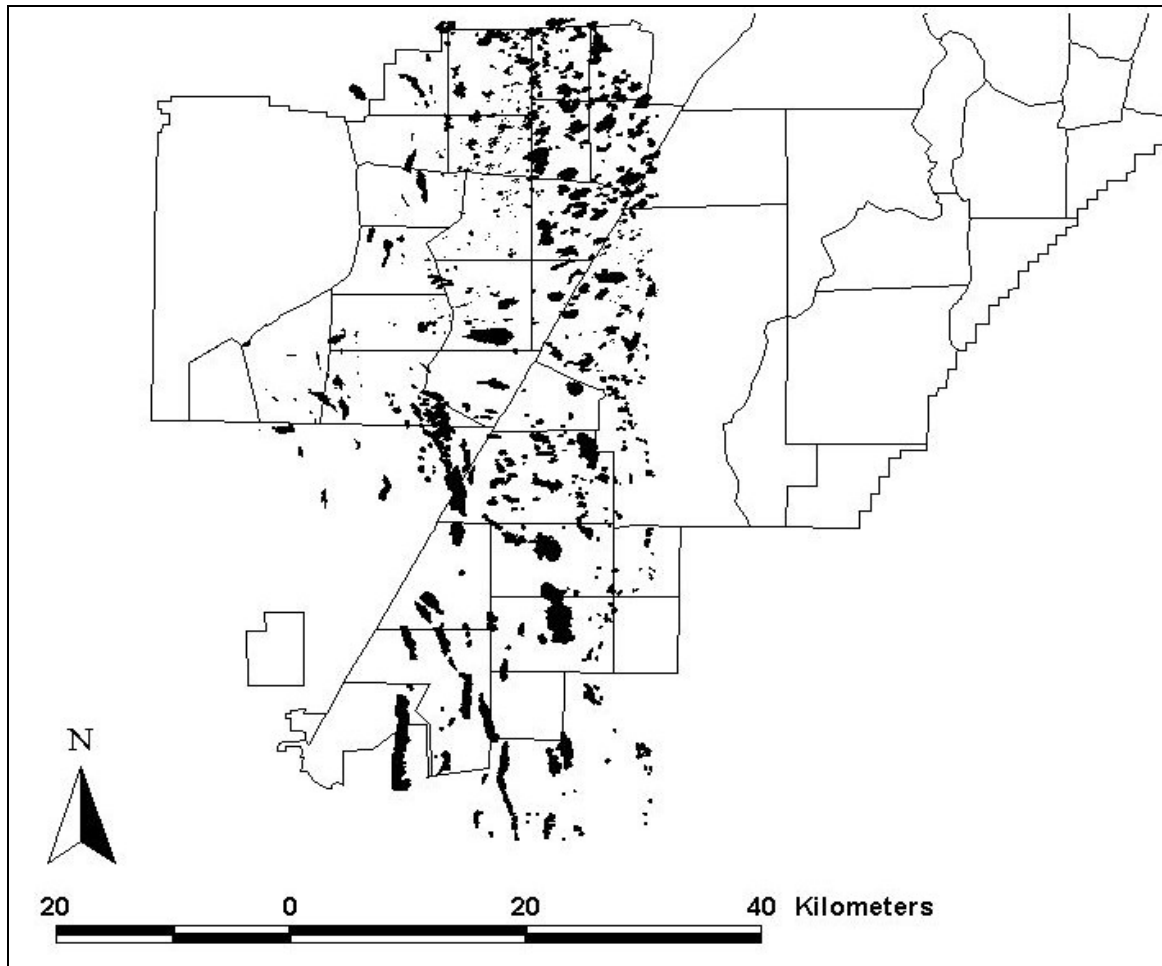


Figure 6.13. Distribution of playas on Doña Ana Range

Arroyo Mouth Ponds

Arroyo-mouth ponds (or fan-margin playas as the 1996 *Significance Standards* termed them) are discharge playas located on the edges of fans and fed by rainfall running off the fans. Blair and others (1990a) commented on, and delineated what they termed “Arroyo-mouth ponds” during geomorphic investigations on the flanks of the Jarilla Mountains. Blair and others (1990a: 175) describes them in the following passage: “The arroyos terminate on the basin-floor at topographic lows between eolian deposits, where irregular-shaped, ephemeral, arroyo-mouth ponds (varying from 10 to 500 m across) are formed.” These authors suggest that these ponding areas have been present at least since the late Pleistocene. Figure 6.14 shows an arroyo mouth pond at the base of the Jarilla Mountains.

Swales and Dunal Depressions

A swale is generally defined as, “a slight depression, sometimes swampy, in the midst of generally level land” (Bates and Jackson 1984). Don Johnson (1997: 76) defines dunal depressions as “any dunal depression that temporarily ponds water; [and is] extremely ephemeral”. Church (2002) used soils to define playas and swales/dunal depressions. These are defined as topographic depressions with Pendaro Fine soil type. While swales are an unlikely water source for humans to drink from, they do act as a nutrient sink that may result in increased natural vegetation growth, and could possibly have been exploited for horticultural use.

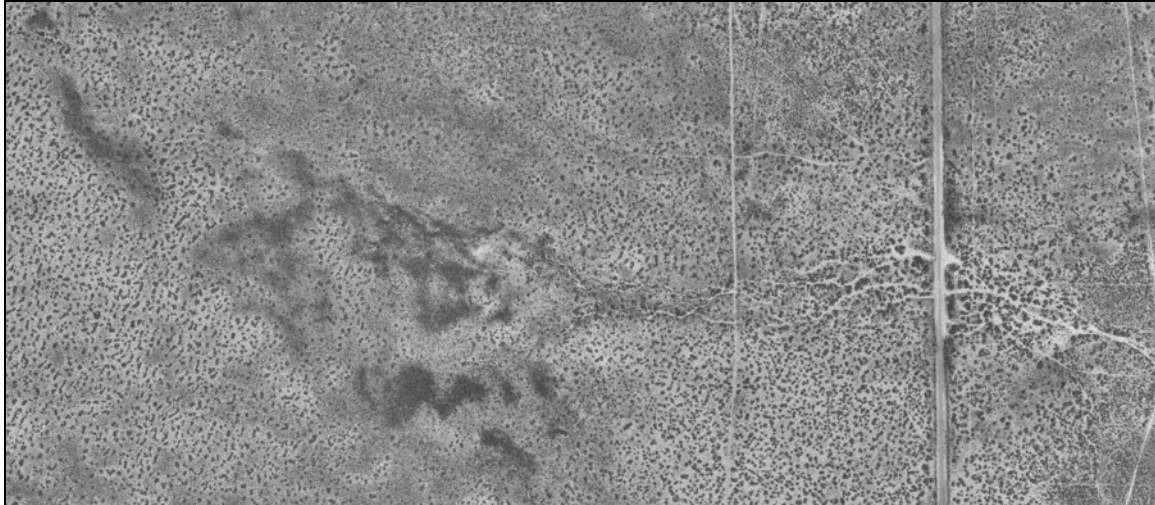


Figure 6.14. Aerial photograph of an arroyo mouth pond at the base of the Jarilla Mountains.

While classification of current topographic depressions helps in our understanding of the diversity and dynamics of these landforms, it must be recognized that prehistoric environmental conditions were probably different, perhaps significantly, and what are now discharge playas may have been through-flow playas in prehistory.

Formation Mechanisms of Playas

Several models describing the formation of playas and similar topographic depressions have been advanced in the geomorphic literature. Much of the literature uses the term “playa” rather than “topographic depression”; thus, the reader should understand that the processes of formation extend to more than just playas. In the eolian model, which is probably the most widely accepted, seasonal drying of the poorly vegetated, fine-grained playa surface results in desiccation, cracking, and subsequent deflation of the playa sediments and deepens the depression. This mechanism certainly occurs, as evidenced by the frequent presence of lunette dunes downwind.

However, other mechanisms cited as contributors to the formation process include (1) loss of volume in the sediments beneath the playa through solution of carbonates and other soluble salts in the near subsurface; (2) gain in volume (and accompanying elevation of the surface) of sediments outside the playa through the displacive growth of carbonate horizons that are inhibited in the playa by increased soil moisture; (3) faulting of basin-floor sediments due to regional tectonic processes; and, (4) faulting due to solution collapse of evaporite beds at depth in the subsurface (Gustayson 1986; Woodruff et al. 1979). Most of the playas on Fort Bliss appear to be related to faulting in the basin (Monger 1993b), although other mechanisms may have played a role in their subsequent growth. Notably, the eolian model and the first two alternate models presented above cannot account for the initial formation of a playa, only for its growth after establishment, and none of the models are necessarily mutually exclusive.

No matter what their formative mechanisms, these depressions represent areas where precipitation and/or runoff collects and evaporates. Infiltration also occurs, but is typically inhibited by the fine-grained, low-porosity character of deposits in the depression. Deposits in the depressions consist of both clastic sediments (typically silts and clays) contained in the water, and evaporitic minerals (e.g., gypsum, halite), formed as mineral-rich water evaporates. The size of the depressions is a direct function of the amount of precipitation and the rapidity of evaporation. One of the most common attributes of playa surfaces is the formation of polygonal desiccation cracks, which can range up to 300 m across and 5 m deep (Chorley et al. 1984), but

are typically much smaller. Motts (1970) distinguishes between fine-grained playas, which are typified by relatively smooth surfaces, and coarse-grained playas, which are characterized by "puffy" surfaces formed through the capillary rise of water as evaporation progresses. One of the mechanisms that appear to smooth the surfaces of playas is wind action on shallow, broad sheets of standing water in the playas (Motts 1970).

Sedimentological studies suggest that most playas consist of irregularly bedded laminae of silt, clay, and evaporites (primarily gypsum) cut with desiccation cracks. Glennie (1970) attributes the irregular bedding to the aggradation of adhesion ripples (a distinctive type of upwind-expanding, asymmetric ripple formed as blowing sand is trapped on a moist surface), but at least some of the irregularity in playa stratigraphy is clearly due to displacive growth of evaporite lenses. The relative amount of clastic and evaporitic material in a depression playa pan is largely a function of the mechanisms of water supply; those playas arroyo mouth ponds situated on the margin of a flat that are fed by runoff from adjacent fan systems will be relatively clastic-rich, while basin-central playas that are fed primarily by laterally-moving soil water tend to be evaporite rich, and can develop into salt pans consisting of a continuous crust of gypsum and evaporitic minerals. One such saltpan, formed by the contraction of pluvial Lake Otero, is the source of gypsum comprising the dunes at White Sands National Monument.

Sedimentological studies are divided on whether playas are aggrading or degrading features (e.g., Blackwelder 1931; Gustayson 1986; Stone 1956; Woodruff et al. 1979), and there are indications that different processes may be occurring in different situations. For example, Motts (1965) suggests that Mojave Desert playas are generally degradational features, while playas in southern New Mexico and western Texas are slowly aggrading.

Locally, playas may have been formed through at least two different factors. One factor promoting playa formation seems to be faulting. Donald Johnson (1997: 77), in his report of the geomorphology of McGregor Range, briefly mentions the playas on Doña Ana Range, noting that those in the southwest part of the range are linear and are probably related to faulting. The later geomorphic work in the Hueco Bolson by Buck and others (1998) suggests that now buried playas associated with fault troughs could have been water sources for Paleo-Indian populations.

Climatic Implications of Playas

Because playas ultimately represent the interplay between precipitation and evaporation, it follows that variations in playa size should be largely a function of climate change. The rate of sedimentation in topographic depressions should also reflect precipitation, increasing proportionately to the volume of sediment-laden water delivered. In fact, topographic depression dynamics should reflect a balance between sediment influx (either by alluvial processes or by trapping of eolian sediments by a moist surface) and sediment erosion (due to eolian activity), both of which are directly related to climate.

If the rate of influx exceeds the rate of erosion on an annual basis, then the playa depression should aggrade, while degradation would be promoted by more efficient wind erosion. Given that both of these factors are related to climate and may have varied in relative importance through time, examination and dating of erosional unconformities in a section through a depression pan fill could conceivably provide a proxy record of climatic conditions. However, localized effects (e.g., variations in sediment delivery due to shifts in the fan system feeding the depression and temporary eolian obstruction of the feeder system or burial of the depression) would have to be understood before such a record could be extracted. One of the most important variables in understanding the behavior of arroyo mouth ponds is the behavior of the drainage net on the distal fan, which can be expected to shift both in response to climate change and in an

autocyclic manner. This factor alone could be responsible for the growth and abandonment of many arroyo mouth ponds.

The ultimate impact of minor shifts in precipitation intensity and timing on activity in a playa system is difficult to predict, and probably differs between individual playas, even in relatively localized areas. If the balance between aggradation and deflation is strongly tipped in one direction or the other, then alternation between intermediate-term aggradation and degradation should not occur as a result of these minor shifts; the net effect would be either changes in the rate of sedimentation or in the rate of deflation, and the types of climatically driven sequences in playa sediments proposed above would not occur. However, if the two processes are in rough equilibrium, such that minor changes could tip the balance back and forth across a threshold, a sequence of deposits containing significant unconformities could be expected. However, the process-response relationships associated with such changes are still unclear. For example, does relatively sustained flow resulting from longer-lasting, less-intense storms introduce more sediment into the playa because the overall volume of flow is increased, or do shorter, more intense storms result in more highly sediment-charged water that counteracts this tendency?

Does more frequent, low-intensity wetting of the playa surface promote eolian erosion by generating more surface cracking, or is more thorough, widely timed wetting more effective in freeing sediment for entrainment? Although no answers to these questions currently exist, and indeed may not be possible except on a case-by-case basis that allows for consideration of other important variables (e.g., texture and mineralogy of delivered sediments, size and character of sediment supply routes), it can be argued that playa and other topographic depression behavior is controlled by climate, and thus there is potential for greater understanding of paleoclimatic conditions and climatic change through examination of the sedimentological record preserved in playas. Moreover, there is also strong potential for paleoenvironmental information through the examination of inclusions (e.g., pollen, diatoms, and ostracodes) in the fill (see Chapter 7).

Geoarchaeological Implications of Playas

There are four geoarchaeological implications relevant to the environment of playas and similar depressions. First, playas formed by faulting of basin floor sediments should exhibit-elongate shapes and roughly linear spatial relationships that reflect this origin, while purely deflation playas should be more randomly shaped and oriented. Monger (1993b) notes that both deflation and tectonic playas exist on Fort Bliss. Fault-basin playas should also be asymmetric in cross-section, with the thickest sediments on the downthrown side of the fault, while purely deflation playas should be much more regular in cross-section, with the thickest sediments situated near the middle of the playa. Although both types could potentially exhibit groundwater/soil water discharge, stratigraphic offsetting of strata or soil horizons behaving as aquicludes would be more likely to result in such discharge in tectonic playa basins, suggesting that they may have been slightly more reliable water sources in the prehistoric past.

Second, appreciable sedimentation in all depressions should only occur if the rate of sediment influx outpaces the rate of deflation over the long term. If a playa in the basin develops only through eolian deflation, thick sediments should not develop, and the playa should be floored with the sediments filling the broader basin. However, if the playa develops through tectonic processes, carbonate solution, or carbonate inhibition, thick playa sedimentation could still occur. Thus, useful paleoclimatic records are more likely to be associated with playas formed by processes other than simple eolian deflation.

Third, depression size should be a function of (a) effective precipitation; (b) effective evaporation; and (c) efficiency of the water/sediment delivery system. Thus, arroyo mouth ponds, which are subject to the vagaries of flow on the distal fans, should exhibit relatively complex, asynchronous histories, while basin-central playas should exhibit histories that are more

comparable. There should also be a tendency for arroyo mouth ponds to be better sources of water because of larger source areas.

Fourth, archaeological sites should be rare in active playas but common on the playa periphery. Thus, archaeological sites situated to exploit playa environments should reflect temporal periods when the particular playa was active, and ephemeral sites should coincide with annual peaks in precipitation (in this case, summer occupation). In most cases, extensive archaeological sites are not expected to be interstratified in playa sediments, although the remains of ephemeral sites may be common. However, the integrity of any such assemblage should be high unless strongly affected by pedogenesis or salt-crystal growth.

Playa Age and Formation at Fort Bliss

The timing of playa development in the Tularosa Basin is ambiguous, but it is assumed that at least some of these ponding features have been present for several thousand years. Pleistocene age playas are associated with the Petts tank geomorphic surface, while Holocene-age playas are associated with the Lake Tank surface (Gile et al. 1981; Monger 1993b). Reeves (1971) suggests that some of the numerous depressions across the region are a reflection of caliche dissolution or ancient dune swales. Playas may also be remnants of Pleistocene lakes that once occupied large portions of the Hueco Bolson and Tularosa Basin (Hawley 1993; Kirkpatrick and Weber 1996; Wilkins 1997; Wilkins and Currey 1997).

Church (2002), in an effort to define these two types of playas on Fort Bliss, reviewed the soil types present on known examples of these two types of playas. The true playas that fill and hold water for a period of time on the order of several weeks are defined as topographic depressions associated with the Malargo soil type. These types of playas may be relatively recent as Donald Johnson (1997: A18) using land snail shells dated the lowest part of Snail Playa at 790 B.P.

The second type of playas, fault trough playas, are defined as topographic depressions associated with the Wessly-Copia soil type, and formed by vertical structural displacement. These fault trough playas have been suggested to be older than the other types of playas. Radiocarbon dating of sediments from two of these playas indicates that they were in-filled with eolian sand between 4500-7000 years B.P. (Buck et al 1998: 83).

In addition to Buck's dating of a fault trough playa and D. Johnson's (1997: A18) dating of Snail Playa using land snail shells, Steve Hall recently dated playa sediments at Old Coe Lake Playa on Fort Bliss. Backhoe trenching of lake sediments revealed a massive clay deposit extending to a depth of 95 cm below the current ground surface. Radiocarbon bulk humate dates obtained from soil samples collected at depths of 28-33 cm and 80-85 cm yielded age estimates of 840 B.P. and 2740 B.P., respectively.

Caution is required in the interpretation of these dates. The dating of playa sediments has a mixed record. Cupper (2006: 2594) points out that:

Sedimentary sequences from playa lakes provide detailed records of hydrological change. They are also important sources of paleoecological information, rare settings in arid landscapes for the preservation of botanical and faunal microfossils. Often, however, chronological control of such sequences is poor. This is because playa systems are rarely geochemically closed, making the conventional radiocarbon technique typically applied to these deposits particularly vulnerable to contamination. Sediments usually have very low organic contents and small amounts of younger or older carbon have the potential to markedly influence age determinations.

Cupper's chronological study of Australian playa lakes provided an "essential chronology" for sedimentation, but the results of the paired AMS ^{14}C and OSL dates did not always correlate.

Locally, Hall suggested that some playa sediments (Lake Tank Playa to be specific) were so pollen rich that standard or AMS ^{14}C dating of pollen might be used (D. Johnson 1997). Future research on Fort Bliss should attempt to date a playa sedimentation sequence using both radiocarbon and OSL techniques. Even with the problems Cupper points out, such data will be valuable in beginning a chronological framework for local playa formation.

Playa Hydrology

Timing, Frequency, and Predictability of Playa Flooding

Previous investigators in the Tularosa Basin assumed playas provided potable water for prehistoric populations. “Because of the water source, these locations [playas] could be occupied by a relatively large population with foraging parties venturing out to exploit plant and animal resources” (Hard and Mauldin 1986: 22). Elsewhere, D. Johnson (1997: 68, 78-83) provides a variety of oral histories and other anecdotal evidence acquired from local ranchers demonstrating how playas throughout McGregor Range and other areas of Fort Bliss contained ponded water during periods of heavy rains. The majority of the oral histories tend to recollect an exceptional period of rainfall during the 1940s, during which time several sources recall certain playas containing water for periods of several years. Noting that historical precipitation records show that the high rainfall recorded during these years was actually exceeded at times over the past 150 years, D. Johnson (1977: 69-71) further states, “Based on these historic records one could reasonably infer that many or most playas [on McGregor Range and the Fort Bliss maneuver areas] held water, at least some water, repeatedly for one or several years since 1850. Projected back through the Holocene, this rainfall pattern.....suggests an environment that would clearly have attracted humans and other animals for sustained periods. [brackets added]”

While this is undoubtedly an accurate interpretation, it conveys only a partial and perhaps somewhat oversimplified perspective. Whether playas held water in historic times and, by extension, prehistoric times is not the central issue. Rather, the issues critical to understanding prehistoric exploitation of this unique environmental zone involve the timing, extent, frequency, and duration of ponding episodes within playas, as well as ecological, edaphic (soil-related), and water quality issues that would have constrained human adaptive and agricultural pursuits focused on playa and playa-margin landforms. These issues became increasingly important as agricultural production and more sedentary settlements developed through time.

Assessing, at some level or another, the hydrology of local playas thus becomes a critical path of inquiry. Lamentably, few such studies are available. Lichvar and others (2002: 9) conducted an extensive literature review and ultimately found “...no previous literature that has attempted to establish duration and frequency of ponding on playas in the arid Southwest.” It should be noted that by this statement Lichvar and his colleagues imply that they could find no studies of a systematic, quantitative, and long-term nature. Otherwise, instances of playa flooding and ponding events have occasionally been documented in the ecological and biological literature (Brostoff et al. 2001). Kubly (1982) monitored flooding events at 45 playas in California over a period of three years from 1978 to 1980. He reports that 65 percent of the playas held water during the first year of the study, but only 45 percent and 30 percent flooded during the following two years. Kubly also notes that the extent of flooding ranged from numerous small, shallow ponds scattered across the playa basin to floods that covered up to 90 percent of the playa surface. Two flooding events have been recorded at Rogers Playa in the Mojave Desert of south central California. Blodgett and Williams (1990) observed ponded water resulting from a single 1-inch rainfall in 1983 drained into the subsurface within a period of 24 hours. In another case, a similar 1-inch rainfall in 1996 resulted in ponded water of depths between 1-3 ft that evaporated over a period of one month (Dinehart and MacPherson 1998). Neal (1965) describes a flood event at

Silver Lake Playa in California that lasted for a period of 18 months after an interval of particularly heavy rains in 1938.

In one of the few long-term and quantitative studies of playa hydrology, Lichvar and others (2002, 2004) compare 59 years of rainfall records against 20 years of satellite imagery of three playas in the western Mojave Desert of California. Ponding was found to have occurred at the playas approximately half of the years under study. The average duration of the ponding events was 16 days, and ranged between 1-32 weeks. The authors also observed a linear relationship between the amount of precipitation and the duration of the ponding. Overall, the authors conclude that the wide range of values for the duration and timing of playa inundation reflects the uneven spatial and temporal nature of precipitation in the region.

Through-flow playas on the other hand are more predictable as groundwater rising and falling is linked with the overall precipitation patterns of the area, rather than specific rainfall events. Studies at a through-flow playa in Utah concluded that:

This large mountain [Pilot Peak] provides a nearly continuous source of groundwater, keeping the water table of the playa quite close to the surface, and flooding the playa each winter. The presence of the subsurface gradient was evident in the water table across the playa. By late summer, the water table on the side of the playa away from the mountain was almost 50 cm lower than the edge adjacent to the mountain. Indeed, fresh water springs are common most years along the western edge of the playa (Malek et al. 1990: 31).

In addition, through-flow playas sometimes have “pipes” that serve as natural conduits for the groundwater (Osterkamp and Wood 1987).

The predictability of the water ponding in playas throughout Fort Bliss and the Jornada region is dependent upon several factors. Studies done at a playa at the Jornada Long Term Ecological Research (LTER) station near Las Cruces, New Mexico, indicate that:

In all but the largest storms, runoff from the upland portions of the watershed is greatly or completely diminished before it reaches the channel outlet. Therefore, in most cases, runoff reaching the playa basin must originate lower on the fan piedmont or on the basin floor (Van Vactor 1989: 66).

Van Vactor (1989: 74) found that direct rainfall of specific intensity and duration must fall on or near the playa basin for flooding to occur. Runoff water from surrounding slopes contributes very little water (Van Vactor 1989). Thus, for a playa to fill, rainfall of sufficient intensity must fall either on or in the immediate area of the playa.

Rainfall occurs in the Chihuahuan Desert as brief, intense localized thunderstorms (bursts) typical of convective storms that generally travel southwest to northeast (Bell 1979). Based on historic weather records, Kunkel and others (1988) report an average of 42 thunderstorms per year for the area. Rainstorm cells in arid areas are often randomly distributed spatially, although linear arrangements of cells are possible (Bell 1979: 375). Patrick and Stephenson (1990: 679-680) state: “The pattern of rainfall intensities from real rainfall events over their duration varies radically, both with time and space.” Rainstorm cells in arid areas are typically only 1 or 2 square km in diameter initially, growing rapidly to 5 then 10 km in diameter. Spacing between cells is usually between 40 to 60 km (Bell 1979: 374-375). This results in very localized rainfall, with one area receiving heavy rainfall and another area only a few hundred meters away remaining dry. Meinzer and Hare (1915: 89), speaking of the Tularosa Basin, state:

The precipitation is irregularly distributed in space as well as in time. It is on average much greater on the high mountains than on the low plain, and for a given season, it

may be much greater in one locality than in another similarly situated. The fall and winter rains and snows are likely to be more or less general, but many of the sudden summer showers are local.

Given the above discussion, prehistoric use of discharge playas as water sources, assuming a precipitation pattern in the past similar to current conditions, would have been difficult. Groups would have had to move to areas that they could visually see were getting rainfall and hope that it was sufficient to pond water - a risky situation in a desert environment.

Duration of Standing Water

One of the long-standing beliefs about playas in the central basin is that the caliche substrate would act as a cap, inhibiting water infiltration and extending the life of surface water. This belief, however, appears questionable. Studies of the hydraulic properties of caliche “suggest that a calcic horizon would not greatly impede water movement, but drain rapidly instead. Ground water recharge from draining surface basins (playa lakes or unsealed water treatment lagoons) would not be hindered” (Baumhardt and Lascano 1993: 368). Rather than caliche, it is the presence of clays that seals the playa, essentially stopping water infiltration. Depending upon the wind, air temperature, soil conditions, depth of standing water, and recharge rates, the duration of standing water can vary dramatically.

Because the central basin playas are discharge playas (at least in modern times), subject to a single flooding event without recharge from groundwater, the duration of any standing water is minimal. Unfortunately, little quantitative or historical data exists on the frequency and duration of ponding water in playas within the Jornada Mogollon region, and much of the information is anecdotal. Van Vactor (1989) monitored rainfall and ponding events at a playa near the Doña Ana Mountains north of the Las Cruces, New Mexico. One of the more noteworthy findings of this study is that, in order for this playa to pond water, a relatively substantial rainfall must fall directly on or near the playa basin. Otherwise, several anecdotal observations have been documented. Interestingly, several of the accounts tend to contradict each other. Pigott (1977: 210-211) notes that playas on Doña Ana Range, including Old Coe Lake Playa, “retained surface water a few centimeters in depth for only a matter of hours following a locally intense rain” while Wondzell and others (1990) observed that ponded waters within a playa on the Jornada Experimental Range quickly evaporated and receded until only small water holes remained after a period of three weeks. Newman (1987), studying the biology of desert ponds in the Big Bend area of Texas, recorded pond duration over the course of three years. Their duration ranged from three to 13 days, with an average of 8.1 days.

In contrast to the studies above that report relatively ephemeral ponding events, Vernon Brook (1979a) observed ponded water of depths up to 12 cm for a period of three weeks at a playa in the central Hueco Bolson. As one of the few relatively long-term studies, MacKay and others (1990) recorded the presence of ponded water in a playa on the Jornada Experimental Range for a period of six months from May to October, a period subsuming the areas summer monsoon season. Ponded water was observed in the playa during four intervals, including a 16-day period in May, 14 days in August, and two periods of 3 and 11 days in October. Noticeably absent was any evidence of ponding during the months of July and September that, along with August, on average comprise the wettest period of the year.

The free surface evaporation of a playa near Las Cruces was calculated as 634.1 mm (24.96 inches) per year, with spring evaporation the highest (Wondzell et al. 1990), perhaps due to the effects of spring winds (Torgersen 1984). At these rates of loss, coupled with infiltration, a central basin playa filled with water to a depth of 2 cm (0.78 inches) would have a duration of only a week or two as Pigott suggests. Observations at playas in West Texas report water loss of

15.24 cm (6 inches) per week with cloudy conditions and minimal wind and light showers (Reed 1930). Water loss in Australian playa lakes range from 3-10 mm (0.12-0.39 inches) per day, with periods of loss up to 30 mm (1.81 inches) per day (Torgersen 1984).

Recently, GMI field crews conducting excavations at LA 91220 on the eastern margin of Old Coe Lake Playa observed that virtually no water collected within the playa, despite cumulative rainfall amounts that exceeded two inches during July of 2004. In contrast, the record rainfalls of August of 2006 filled a large portion of the playa for a period of three months. Robert Hard (personal communication 2006), while working at the Conejo Site to the west of Old Coe Lake Playa notes that water remained in the playa for a period of four months following a period of high late fall precipitation. Personal observations of LMAS field crew at Shrimp and Snail playas near Three Buttes on McGregor Range have documented a duration of at least two months (Church 2002), although it is unknown if any post-flooding rainfall refreshed the playas, extending the duration.

Playa Water Quality

Because of the hydrologic characteristics of soils in the Chihuahuan Desert, standing water in many of these playas is likely to contain high amounts of minerals and salts, making them unsuitable for drinking; particularly as the playas are reduced through evaporation and the chemicals become more concentrated (Hendrickson 1978). Studies in the Sahara indicate that maximum mineral content of water suitable for human consumption is about 2.7g/liter (Damon 1975). Meinzer and Hare (1915) state that humans can consume water with up to 2,500 parts per million (ppm) of dissolved salts; concentrations of 3,300 ppm can only be drunk only by those accustomed to that level. While the quantity of salt an individual needs depends on the climate where one lives, the amount of physical labor one performs, and the foods one eats (Bricklin and Claessens 1981: 55), concentrations of 5,000 ppm or greater would endanger human health if routinely ingested. Chlorine limits are less than 300 ppm for good drinking water; 300-600 ppm is poor, but drinkable; 600-1,000 ppm is suitable occasionally, and any water containing more than 1,000 ppm is unsuitable for human consumption. Water containing more than 750 ppm of chloride is considered salt water (Knowles and Kennedy 1956), and water containing over 5,000 ppm of total solids is considered unsuitable. Sulphate rich waters can be consumed, but in some cases (depending upon the type of sulphate) act as a laxative (Meizner and Hare 1915).

Generally, through-flow playas, or saline playas, are most likely to accumulate salts (Duffy and Al-Hassan 1988). The water quality in playas in the Hueco Bolson may suffer from high levels of salts and other minerals, making them undrinkable; particularly as the water in the playa diminishes through evaporation and the chemicals become more concentrated. Potable water from playas, therefore, may have been available only for the first days or weeks after filling. Geographic and temporal variation in hydrochemistry undoubtedly occurred; but the scale of that variation has not been investigated. A conservative assumption would be that many of the playas would not have been sources of potable water, or would have provided drinkable water only for a brief period after filling.

The flooding of Shrimp Playa on McGregor Range in the summer of 2000 offered an opportunity to observe the life cycle of a desert playa and take samples. Three water samples were collected over the course of two months by LMAS. (Church 2002). Analysis of these samples by the Water Testing Laboratory at New Mexico State University indicates that the water quality, in terms of the chemicals analyzed, was good, and stayed good until the playa had been almost totally reduced (Figure 6.15). The water contained low amounts of calcium and magnesium, making it "soft" water in the vernacular. Sulfate, and chloride were low also, but alkalinity was elevated. Overall, the water was potable, and appeared to stay potable for almost the entire duration of the standing water. There are, however, two caveats. First, there may be other

chemical compounds, or ingredients that were not tested that could inhibit human consumption. Second, the results of water testing from Shrimp Playa may not apply to all other basin playas. Indeed, studies of groundwater at Lake Lucero Playa have found that the waters are highly saline.

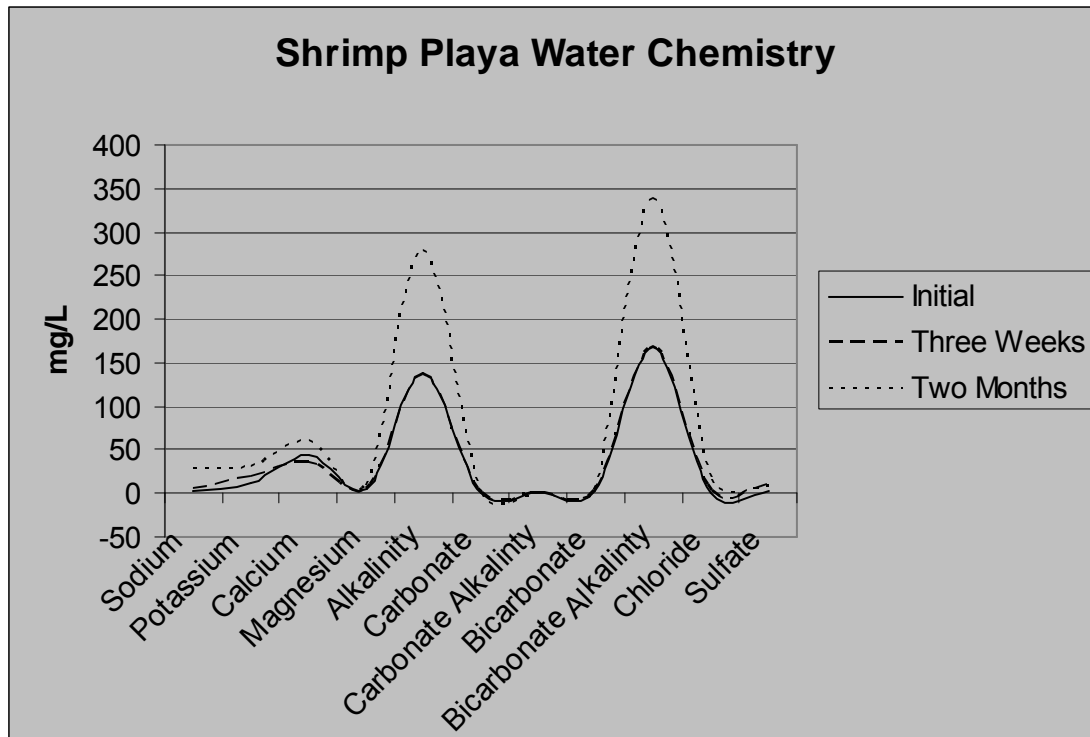


Figure 6.15. Graph showing chemical content of water at Shrimp Playa during the summer of 2000.

The issue of water and soil salinity deserves greater attention. The presence of salts in soil and water is one of the primary factors affecting the agricultural potential and sustainability of a particular location and the productivity of agricultural yields for various crops. Preliminary studies of several playas in the western United States and other arid regions of the world, including Lake Lucero as a local example, have consistently observed saline soils in association with desiccated playas. Evaporation of water ponded in playas results in increasing concentrations of soluble salts and minerals, and thus playa waters become increasingly saline through time. Freshwater recharge events dilute the concentrations of salts and serve to leach salts from underlying soils and groundwater reservoirs. If sufficient freshwater is deposited the ponded water can be both potable and useful for irrigation for a period of time.

Salinity affects the physiology and maturation of plants in several ways. Of importance for understanding both historic and prehistoric agricultural practices is the effect of salinity on crop yields. Crop yields will not be affected until salinity reaches a threshold value, after which yields will consistently decline to zero when salt concentrations reach a level that cannot be tolerated by a plant during germination and/or growth. Of critical importance for modeling and evaluating prehistoric agricultural strategies is the fact that the three major cultigens common to the prehistoric Southwest – corn (*Zea mays*), bean (*Phaseolus* sp.), and squash (*Cucurbita* sp.) – are among the most sensitive of the cultivated plants to saline soil and water conditions.

Almendinger and Titus (1973) provide a useful example of local groundwater salinity from Lake Lucero, located on White Sands Missile Range north of Fort Bliss. Lake Lucero is by far the largest fan-margin basin playa in the Tularosa Basin and Mesilla Bolson, effectively draining a large segment of the San Andres Mountains. Almendinger and Titus (1973) documented salinity of the groundwater in Lake Lucero after two freshwater recharge events of sufficient magnitude to fill a major portion of the central ponding area of the playa. The results of their study found that salinity increased dramatically over a period of 50 days (Figure 6.16). Salinity levels immediately after rainfall recharge are only marginally acceptable for agriculture. After this period, groundwater salinity is unsuitable for irrigation purposes, as the saline concentrations in the water after just 10 days would result in complete crop failure for all three cultigens. However, Lake Lucero is a truly saline playa and thus represents an extreme case. During the GMI investigation of LA 91220 in 2004, salinity tests were conducted on ponded waters at Old Coe Lake Playa (Miller and Graves 2006). Samples were collected during intervals of one day, seven days, and 21 days after a rainfall recharge event. The samples were submitted to the Soil, Water, and Air Testing Laboratory at New Mexico State University. In contrast to Lake Lucero, ponded water within Old Coe Lake Playa had very low salinity levels and could be used for both human consumption and agricultural irrigation (see Figure 6.16).

Playa Hydrology and Cultural Ecology of Prehistoric Systems

Understanding the dynamics of playas is essential to advancing the understanding of prehistoric land use and subsistence organization. In the past, the focus has been playas representing a source of water. This focus is too narrow. The focus should be on the spectrum of resources that are associated with a playa, water being one of many. Several important aspects of water availability relevant to modeling prehistoric settlement and agricultural potential can be integrated from a closer consideration of these studies. First, as suggested by Van Vactor (1989), for water to pond within many isolated playas and *bajos*, rainfall must be localized and fall directly within the immediate drainage basin of the playa. For fan-margin playas, rainfall falling on distal or terminal alluvial fan tributaries may contribute to ponding, but direct rainfall will provide the main source of water. Second, rainfall must be of a rather substantial amount to result in the infilling of playas. Third, the duration and extent of water ponding will be highly variable, depending on the amount and duration of precipitation, evaporation rates resulting from seasonal and climatic variations in temperature and wind velocities, the nature of soil substrates, along with several as yet undefined parameters and conditions.

Finally, a fourth issue is that water quality, in terms of chemical content and salinity, may vary among playas. It appears that the water quality of most playas may be acceptable. However, certain saline playas such as Lake Lucero may contain ponded water that is too saline for human consumption and agricultural use. Additionally, the water may not have been suitable for drinking by animals, thus further negating the common view of playas as focal points for game hunting. On the whole, it is evident that the presence of water within a given playa or *bajo* is a highly variable natural phenomenon that has numerous implications for modeling prehistoric land use by agriculturalists and hunter-gatherer groups.

SOIL PROCESSES AND SOIL MORPHOLOGY

Soil formation, or pedogenesis, consists of a suite of physical, chemical, and biological processes that act upon and transform rocks and sediments at the earth's surface. The morphology of a given soil represents the interaction of five basic soil-forming factors, first identified by Jenny (1941): climate, organisms, relief, parent material, and the duration of subaerial weathering

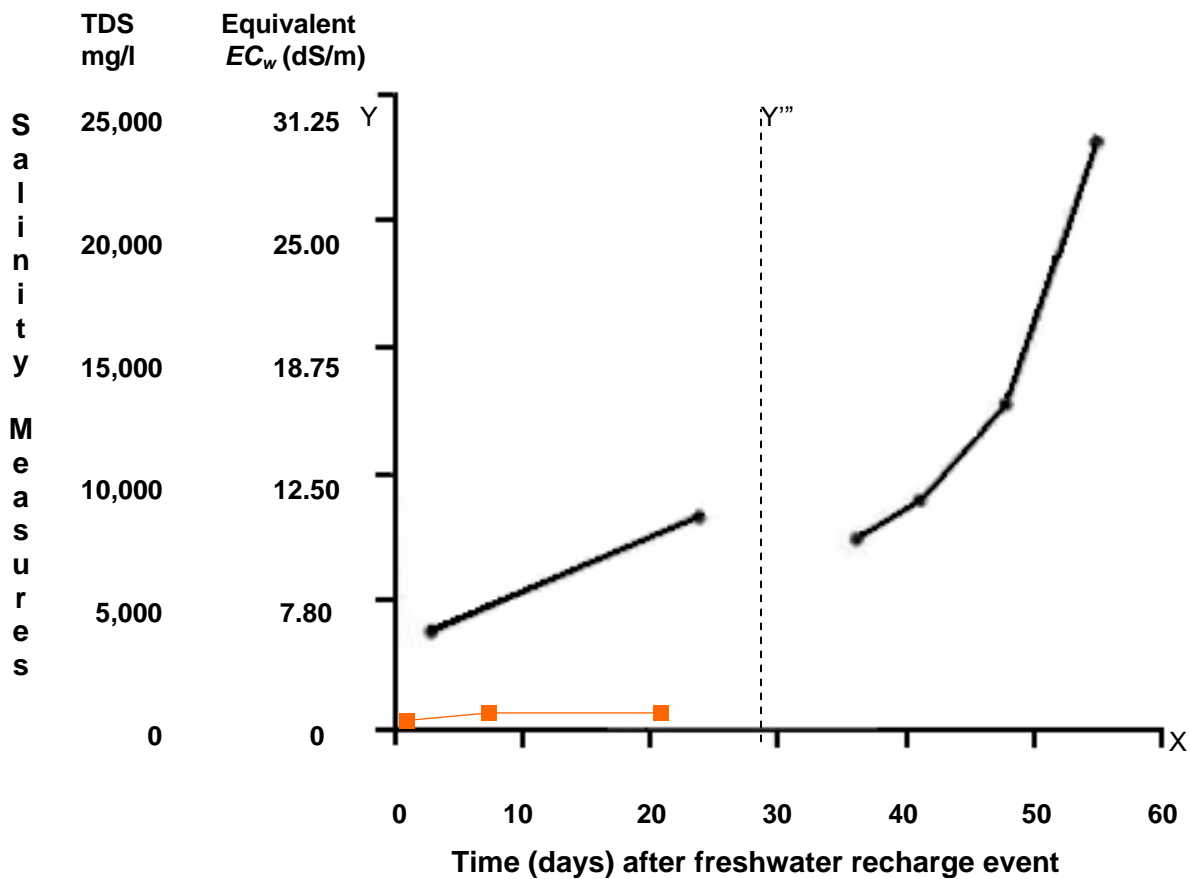


Figure 6.16. Graph illustrating increasing salinity of ponded water at Old Coe Lake Playa (red symbols and lines) and groundwater in Lake Lucero Playa (black symbols and lines) after freshwater recharge event (modified from Almendinger and Titus 1973) (Electrical conductivity/salinity measurements have been added for clarity using mathematical formula in Grattan [2002] to convert salinity values expressed as Total Dissolved Solids [TDS] to electrical conductivity values for irrigation water [EC_w dS/m]. Note low salinity levels at Old Coe Lake Playa).

(time). Soils have tremendous utility to questions of Quaternary landscape development and, by extension, to archaeology. The principal benefit to archaeological studies is essentially two-fold. First, soil geomorphology and soil stratigraphy can provide a mechanism for estimating the age of landforms and sediments, and thus provide constraints on the age of associated sites (Birkeland 1984, 1990; Morrison 1967). Second, understanding of the character of pedogenic transformations of the sediment matrix provides a means to address post depositional disturbance of archaeological strata (Butzer 1982; Schiffer 1987).

Climate is one of the most important soil-forming factors, in that it governs the types and rates of almost every pedogenic process. Variations in precipitation and temperature affect the rate of chemical and physical weathering, the types and abundance of vegetation and soil organisms, and the rate and character of soil-constituent translocation within the soil. Although there is a spatial component to the variability of climatic parameters (e.g., the mountainous areas on Fort Bliss receive more moisture and generally experience slightly lower temperatures than the bolson floor), for all intensive purposes, climate can be treated as a constant in consideration of the

contemporary soil landscape. It does play a role, however, in the types of properties that develop in soils of different ages under varying climatic regimes, as relatively minor changes in annual precipitation can have significant influence on rates of pedogenesis.

Organisms in the vicinity of Fort Bliss are conditioned by climate. In addition to contributing organic material to the soil, both plants and animals are significant factors in the turbation of soil profiles. Thus, from an archaeological perspective, the influence of soil organisms is of considerable interest in the preservation of archaeological sites. Plant cover is also an important control on the rate of surface erosion, which can frequently outpace pedogenesis if the sediment is not anchored by vegetation. Thus, soil thickness and horizon development are frequently governed by vegetation characteristics.

Relief primarily refers to the slope of a locality and its surroundings, but also includes slope-aspect and surface smoothness (microrelief). Collectively, these characteristics, coupled with soil texture and vegetation cover, control the potential for moisture to infiltrate or run off. Infiltration provides the moisture that supports (or limits) the biotic assemblage, allows chemical weathering to occur, and translocates soil constituents. Thus, when other factors are held constant, increasing relief results in successively thinner and less-developed soil profiles.

Parent material is the matrix that soil develops in, and can consist of either bedrock or sediment. Parent material exercises considerable control on soil development because it governs mineral content, weatherability, textural characteristics, and soil chemistry, and affects the depth and speed of infiltration, the character of relief development, and the nature of the biotic assemblage.

Finally, time exerts considerable control on soil morphology because almost all pedogenic processes are time-dependent and show increasing alteration of the parent material and spatial rearrangement of constituents with longer duration of subaerial weathering. This characteristic allows for the construction of soil chronosequences that can be used to obtain rough estimates of the length of exposure for both extant and buried surfaces. Although the rates of development of different properties can vary by several orders of magnitude, and eventually tend to reach equilibrium (Figure 6.17), variation in the expression of different soil properties (e.g., organic matter, extractable iron, manganese, clay, and carbonate content and morphology; soluble salt, phosphate, nitrate, and potassium content; mottling; rubification; pH; soil structure; soil consistence; horizon differentiation) can provide excellent criteria to correlate geomorphic surfaces and obtain relative ages of landforms and sediments.

Soil-Forming Processes

Although there are many processes involved in pedogenesis, this discussion will be limited to the most important processes operating in the general vicinity of Fort Bliss: organic matter accumulation, weathering, carbonate translocation and accumulation, clay translocation and accumulation, salt accumulation, and processes of turbation.

Organic Matter

Organic matter accumulation is typically the first detectable component of pedogenesis. However, biomass in the Fort Bliss region is low, and the rate of organic matter destruction by oxidation is high. Consequently, the accumulation of organic matter is a slow process and tends to reach rough equilibrium at relatively low concentrations (approximately 1-3 percent organic carbon). Thick, dark, A horizons typical of areas that are more humid do not develop; rather, well-developed soils exhibit pale-colored surface horizons termed ochric epipedons (Soil Survey Staff 1990). However, older soils can contain considerably more organic carbon than younger soils due to the bonding of organics by clays in argillic horizons.

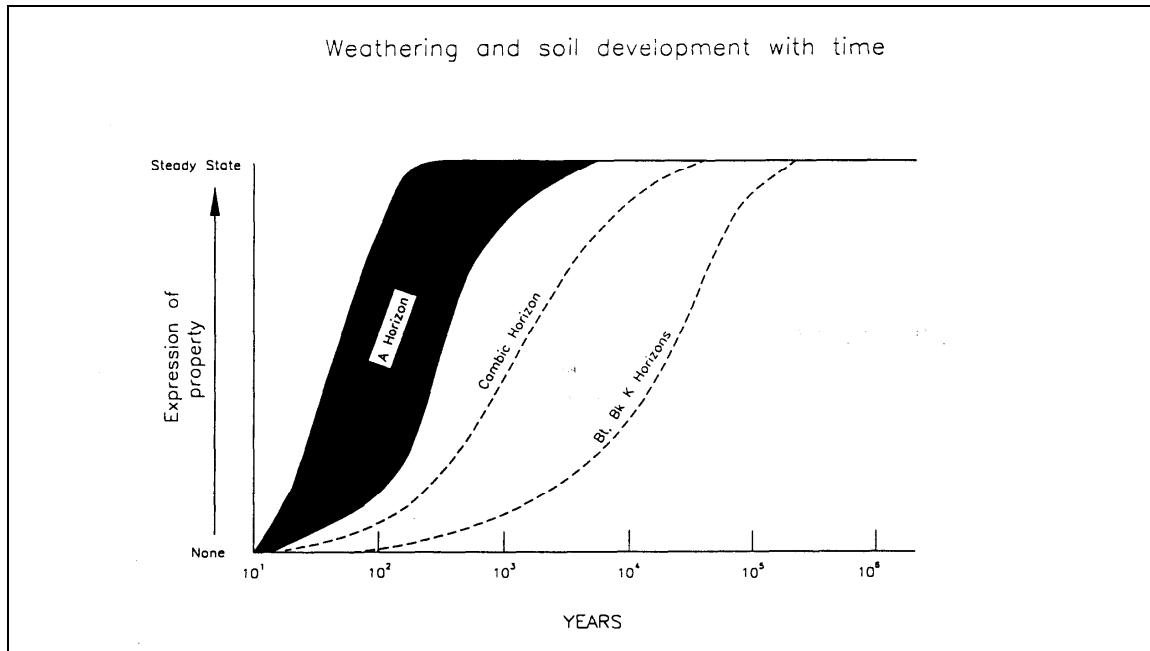


Figure 6.17. Illustration of the time necessary to reach steady state for various soil properties. (after Birkeland 1984).

Weathering

Weathering is typically subdivided into two suites of processes termed physical weathering and chemical weathering. Physical weathering subsumes processes that break rock apart, producing smaller and smaller particles composed of the same constituent minerals. Processes involved in physical weathering include freeze thaw, salt-crystal growth, unloading, mechanical abrasion (e.g., sandblasting), and (arguably) diurnal expansion and contraction (Birkeland 1984; Chorley et al. 1984).

Chemical weathering subsumes a suite of reactions, including solution, hydration, hydrolysis, oxidation, reduction, and chelation, that attack and alter constituent minerals. The products of these reactions are frequently intermediate minerals that are themselves subject to continued weathering. The ultimate products of weathering, including various base-poor clay minerals and aluminum and iron oxides, are relatively stable under surface conditions (Birkeland 1984). They rarely develop in arid environments because insufficient moisture exists to flush soluble bases out of the system; thus, most clay minerals are expandable, base-rich varieties (e.g., montmorillonite), although more stable varieties (e.g., kaolinite) also occur. Chemical weathering liberates soil constituents, allowing them to be translocated in the profile. Typically, constituents are removed from the upper solum in a process termed eluviation, translocated down through the profile, and deposited or precipitated deeper in the soil in a process termed illuviation. However, in some cases, constituents (particularly soluble salts) can be brought up through the profile by capillary rise, often forming a crust at the surface as the water evaporates.

Carbonate Translocation and Accumulation

Carbonate accumulation in the subsoil is probably the best single time-diagnostic feature of soil profiles in semiarid and arid climates. Zones of carbonate accumulation are termed Bk horizons when authigenic carbonate is dispersed through the matrix and K horizons when authigenic carbonate engulfs more than 90 percent primary fabric grains (Birkeland 1984; Gile et al. 1981). A commonly used alternative classification, still favored by the Soil Conservation Service (Soil

Survey Staff 1990), does not include the K horizon definition. Rather, all zones of carbonate accumulation are termed Bk horizons, with the term Bkm used for indurated horizons (also termed calcretes). Carbonate accumulations in general, and calcretes in particular, are commonly referred to by the term caliche.

Gile and others (1966) presented models of pedogenic carbonate accumulation in fine-grained and coarse-grained parent materials. Four stages of carbonate accumulation were recognized. This initial classification has been modified several times (e.g., Gile and others (1966 and six stages are now recognized (Stages V and VI represent subdivisions of the original Stage IV morphology; Stages I-III are essentially unchanged). The following summary description of diagnostic carbonate stages follows these modifications to the original system of Gile and others (1966), even though the original classification was used in the desert project in the Las Cruces area (Gile and Grossman 1979; Gile et al. 1981).

Stage I accumulations consist of thin, partial, or complete coatings in gravelly parent material and filaments and/or grain coatings in fine material. Due to the mechanics of water movement down through the profile, carbonate coatings in gravelly parent material typically develop on the bottom of clasts first (so-called meniscus carbonates, pendant carbonates, or gravity rinds), growing gradually upward around the clasts with time until the entire surface is covered with a fine carbonate coat that is thickest on the bottom of the clast.

Similar grain-coats may occur in fine-grained material, but more common are carbonate films (diffuse coats on ped faces), filaments (very fine, linear accumulations commonly associated with fine plant roots or fungal mycelia), and threads (similar to filaments, but thicker). Phreatic zone (groundwater) carbonates are usually distinguishable because the meniscus thickening on the underside of clasts does not occur; such coats are said to be isopachous.

Stage II accumulations consist of thicker, more continuous clast coats with at least some interclast bridges or fillings in the interstices in coarse materials and the formation of carbonate nodules in fine material. In many cases, the nodules may be surrounded by low carbonate matrix, but clouds of soft matrix carbonate, overall matrix whitening, and thicker filamental carbonates may also be present. With increasing development, the size of nodules and the amount of internodular matrix carbonate increases. Occasionally, nodules may not develop; rather filaments increase to the point that overall volume of carbonate is similar to nodular horizons, and the designator *IIf* is used (Birkeland 1984).

Stage III accumulations in both gravels and fines are represented by abundant carbonate throughout the horizon that may be soft and chalky, but frequently becomes indurated and very hard. In latter Stage III accumulations, the horizon becomes plugged with carbonate, drastically decreasing permeability. Typically, Stage III carbonate accumulation occurs much more rapidly in gravels because so much of the matrix is occupied by rock. In both cases, carbonate matrix growth may begin to force primary fabric grains apart.

Another common feature of Stage III morphology (and higher) are rhizoliths, which consist of thin to relatively thick, tubular nodules accreted around plant roots. They frequently occur below the plugging horizon where the root allows deeper water penetration, and eventually seal off and kill the root.

Stage IV accumulations in both coarse and fine sediments consist of -a thin, weakly expressed laminar layer composed of almost pure cemented carbonate (>75 percent) overlying a plugged horizon. Lamination develops as infiltrating water is stopped at plugged horizon and begins to flow laterally, dissolving and reprecipitating carbonate as it goes. Carbonate growth in the plugged horizon is usually sufficient to result in noticeable separation of framework clasts.

Stage V accumulations are characterized by thick laminar crusts, incipient brecciation (where the calcrete fractures and is recemented), and the initial development of pisoliths (irregular, concentric laminae of carbonate around a nucleus, which is typically a framework clast or a brecciated calcrete fragment). Deep cracks through the indurated horizon may develop, and the sides of these cracks often develop laminae of their own. As the laminated coating in these cracks grows, they can exert lateral pressure, causing the calcrete hardpan to fracture further.

Stage VI accumulations are characterized by thick laminar crusts, strongly or repeatedly brecciated and recemented K horizons, and strongly developed pisoliths. They usually indicate considerable antiquity.

The six stages of carbonate accumulation are illustrated in Figure 6.18. In general, Late Holocene deposits in arid climates exhibit Stage I morphology, while early Holocene and Late Pleistocene deposits exhibit advanced Stage I or early Stage II morphology. However, capillary groundwater rise can result in rapid precipitation of phreatic carbonate that can appear similar to Stage III pedogenic carbonates at a macro scale, although they can be clearly differentiated microscopically (Goudie 1983).

Development of post-Stage III morphology is also time-dependent; however, radiocarbon ages on strongly developed calcretes tend to be unreliable indicators of actual age because of carbon exchanges during frequent dissolution/precipitation, and adjacent parts of the same horizon can yield dramatically different ages (cf. Gile et al. 1981, Table 22; Monger 1993d, Table VIII-2). This suggests that caution should also be employed in interpretation of stable carbon isotope signatures from pedogenic carbonates (see Chapter 7).

Although calcrete formation can be facilitated by the presence of calcareous parent material, carbonate horizons tend to develop in all profiles with time; even in calcareous materials, the amount of carbonate deposited in the Bk and K horizons usually exceeds the amount leached from the upper solum. This suggests that calcareous dust delivery is a very important mechanism in the formation of calcretes.

Clay Translocation and Accumulation

Clay accumulation in the lower solum results in the formation of an argillic horizon that becomes thicker and more clay-rich with time. Argillic horizon development is also a slow process and occurs on a roughly similar timescale as carbonate horizon development. As pedogenesis progresses, arid soils go through an intermediate stage where a cambic B horizon develops. Cambic horizons are subsurface horizons that evince significant alteration from the parent material through obliteration of primary depositional structures, development of incipient soil structure, slight-to-moderate rubification (reddening), some leaching of carbonates, and slight accumulation of translocated clay. Gile (1966b) estimates that distinct cambic horizons can develop in 5,000 years in the vicinity of Fort Bliss, although some aspects (e.g., obliteration of primary structure) can clearly occur more rapidly.

With time, an argillic horizon gradually develops, as clay accumulates to such an extent that a noticeable clay bulge is apparent in a plot of the clay content of each horizon. Clay comprising this bulge can be derived from a number of sources: it can be inherited from the parent material, neoformed in the B horizon through the weathering of silicate minerals, neoformed in the overlying eluvial horizon and translocated down through the profile, translocated from inherited clay in the eluvial horizon, or introduced aerosolically to the soil and translocated to the B horizon. In order to be considered a true argillic horizon, a significant portion of this clay must have been translocated into or within the horizon (Soil Survey Staff 1990).

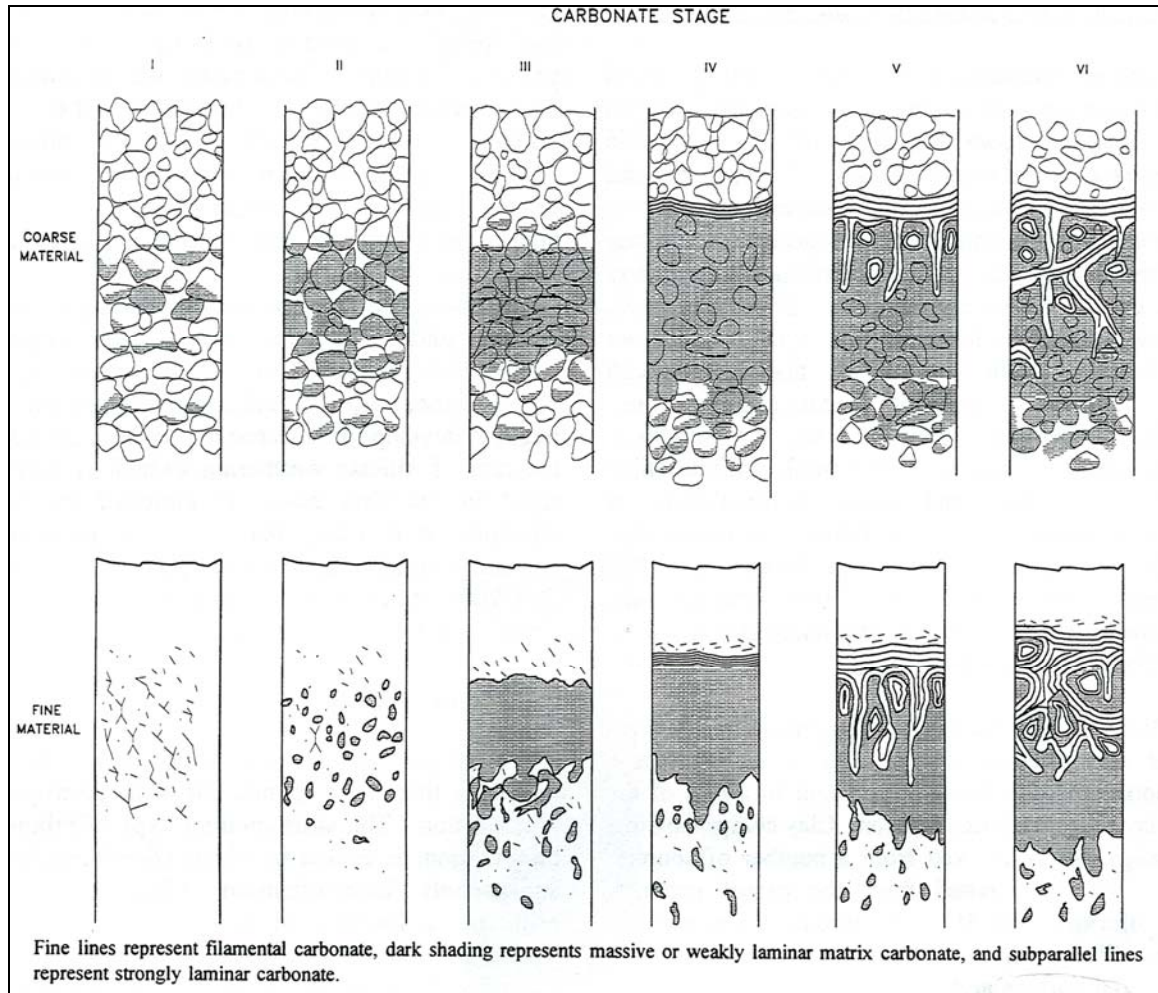


Figure 6.18. Illustration of Carbonate Stage Morphology sequence.
(based on figures in Gile et al. 1966 and description in Birkeland 1984).

Translocated clay is indicated by grain coats, intergrain bridges, and laminae of oriented clay in pores and between peds. Argillic horizon development is usually accompanied by increasingly strong development of soil structure as the clay accumulates. In all cases, the argillic horizon develops above the associated carbonate horizon because illuvial clay is typically carried in suspension while carbonate is carried in solution. However, very strong argillic horizon development can "plug" the horizon, resulting in carbonate precipitation and/or bleaching of sediments above the horizon as infiltration is blocked. Most argillic horizons in semiarid and arid climates are reddened (7.5YR-2.5YR hues) due to oxidation of associated iron and many may be relict remnants of more humid Pleistocene climates (Nettleton et al. 1975).

In all cases, the development of a strong argillic horizon, like a strong - carbonate horizon, implies considerable antiquity (i.e., Pleistocene age). Nevertheless, incipient argillic horizons can clearly begin to develop in Holocene timescales. Because the rate of silicate weathering (which is hardly rapid in the first place) is inhibited by low moisture, it is likely that the most important control on argillic-horizon development rates in the Fort Bliss region is the rapidity at which eolian processes introduce aerosolic clay.

Turbation

Turbation (or pedoturbation) refers to a suite of processes that serve to mix the soil, destroying horizonation. The most common type of mixing, bioturbation, is caused by plants (floralturbation) and animals (faunalturbation). Floralturbation is primarily a function of sediment displacement caused by root growth, although other processes (e.g., tree throw, which occurs when a rooted plant is upended, carrying sediment adhering to the roots up to the surface) can have a local effect. Faunalturbation is primarily a function of burrowing animals (e.g., rodents, insects, earthworms), although mixing of soft surface strata by large animals (e.g., cattle) is also probably significant, particularly in eolian sands. Other mechanisms include argilliturbation (due to heave processes resulting from clay expansion and contraction), cryoturbation (due to heave associated with freezing and thawing), and salturbation (resulting from growth and dissolution of soluble salt crystals). Although it is a recent phenomenon, another very important source of disturbance on Fort Bliss is vehicularurbation and other forms of disturbance by people.

Turbation processes are particularly important to archaeology because mixing of the soil results in disturbance of cultural strata contained within that soil. The degree of disturbance is a function of the type(s) and depths ofurbation processes, and may serve to segregate various size fractions of artifacts; for example,urbation by ants may well result in displacement of small flakes but is less likely to disturb hearthstones significantly, whileurbation by large burrowing rodents can wreak havoc on buried features.

The processes and rates ofurbation are one of the least-understood aspects of soil development in southern New Mexico. At the same time, they are one of the most important aspects from a geoarchaeological perspective because they represent a major influence on the structure and integrity of buried sites. Although poorly documented, one of the most importanturbation processes appears to be mixing by burrowing insects, particularly termites (Gile 1975b; Abbott 1997), but also ants and cicadas. Termites in the area are subterranean and do not form mounds, but do create dense networks of underground passages (Gile 1975b). Abbott (1997) observed that trenches exposing eolian Organ sediments in the bolson frequently appear massive when freshly cut but reveal very dense networks of small insect krotovina when allowed to weather for several days. This fact alone may largely account for the lack of primary stratification typically apparent in Organ-age sediments in the bolson. On the other hand, there is little clear evidence that eolian sediments in the bolson ever contained clear primary strata. If eolian deposition occurred in grassy conditions, disruption of air flow by grasses would tend to inhibit formation of bedding planes. If that is the case, then intensiveurbation does not necessarily need to be invoked to explain the lack of primary stratification in deposits of Organ age and older. However, the disturbance and mixing of soft sediments and associated artifacts from an archaeological site on a sand sheet are to be anticipated. It is perhaps better to expect that disturbance has occurred and look for evidence that it has not instead of the other way around.

Other insects also cause bioturbation. For example, cicada insect nymphs spend 13- and 17-year cycles underground feeding on juices from plant roots, emerging for only a few weeks as adults. Their burrows are 10-20 cm in depth and are characterized by crescent-shaped backfilling. Over time, 100 percent of a sediment column can be displaced by cicadas (Hall and Goble 2006). Cicada insect burrowing is more subtle and in fact may be invisible in the cases where the small burrow fills have the same color as that of the sediment in which the burrows occur. In the field, excavations left open for a week or more may be sand blasted in which case cicada burrow fills will show in faint micro-relief due to small differences in carbonate cementation of the fills and surrounding sediment.

In some cases, features such as stone-lined hearths will appear to be in place. However, cicada insects burrow around the stones. While the stones are still more or less in their original position, the sediment surrounding the stones may be entirely disturbed by small amounts. This phenomenon must be taken into account when sampling sediment columns for textural, radiocarbon, pollen, macrobotanical, isotope, and geochemical analysis. Small artifacts, such as retouch flakes, may also be displaced laterally and vertically by cicadas. While ant burrows do not disturb sediments as much as other burrowing animals, they bring to the surface small pebbles that can accumulate in large numbers on the ground surface. In a study in southeastern New Mexico, it was found that ants contribute 84g/m² of pebbles per year to the surface (Whitford et al. 1986). Most of the pebbles were of caliche and 3-6 mm in diameter. If uniform, this equals 37 tons per acre per century. Upon deflation, the small caliche pebbles that were deposited by ants would be a major component of the stone pavement.

Larger burrowing animals leave large krotovina that are occasionally observable in section. If termite burrowing is ubiquitous, then larger burrows should be preserved for only limited spans of time. Large burrows are significant in that they are a possible source of calcrete fragments that occasionally litter the surface of relatively recent eolian deposits and may also displace large buried artifacts. Monger noted that calcrete fragments tend to occur where the calcrete hardpan is within approximately 40 cm of the surface, and postulated that increased wetting and root penetration causes the calcrete hardpan to break up, and that fragments then "begin an upward migration to the land surface" (Monger 1993c: 35). The mechanism envisioned for this upward migration is not specified, but appears to be some type of heave process. This is somewhat problematic because the clay content of Organ eolian sediments does not appear high enough to explain such a significant incidence of soil heave, nor are freezes intense enough to cause intense cryoturbation. Nevertheless, if such a heave process is active (or has been intermittently active during the Holocene) then the implications for buried sites are profound.

A possible alternative explanation is that burrowing rodents are responsible for the breakup and delivery to the surface of calcrete fragments, and evidence of such large burrows is gradually erased by burrowing insects. If the latter scenario is accurate, then wholesale disturbance of large clasts in the matrix (including those associated with buried archaeological features) should be more localized, while disturbance of small clasts by termite activity should be ubiquitous.

Bioturbation by carnivores is perhaps the most severe. In the Tularosa Basin and Hueco Bolson, coyotes (*Canus latrans*) and badgers (*Taxidea taxus*) cause the most damage to the natural stratigraphy, even digging through calcic soils on the trail of rodents. As a result of their foraging for pocket gophers, kangaroo rats, and other rodents, they can produce a tremendous amount of disturbance. Johnson (1997: 149-151; Johnson and Johnson 2004) observed large areas on the McGregor Range where badgers had plowed through the sediments, leaving behind a mixture of sediment and caliche in a biomantle (Figure 6.19).

The black tailed prairie dog (*Cynomys ludovicianus*) is also found in south central New Mexico (Findley et al. 1975). The burrowing by prairie dogs, today and in the recent past, has caused serious bioturbation of the sedimentary record. Their burrows, funnel-shaped at the top, are generally 7-10 cm diameter and may descend 2-5 m before leveling off (Davis and Schmidly 1994).

The Family Geomyidae or pocket gophers are well represented in the Tularosa Basin and Hueco Bolson by burrowers, especially Botta's pocket gopher (*Thomomys bottae*), desert pocket gopher (*Geomys arenarius*), Plains pocket mouse (*Perognathus flavescens*), desert pocket mouse (*Chaetodipus penicillatus*), Ord's kangaroo rat (*Dipodomys ordii*), and Merriam's kangaroo rat (*D. merriami*) (Findley et al. 1975). All produce burrows. The burrow systems of Botta's pocket gopher:



Figure 6.19. Alluvial gravels disturbed by badger, McGregor Range, New Mexico. (identified by D. L. Johnson, photo 1997).

are often complicated structures consisting of two or more main galleries and several side chambers. A partly excavated burrow extended more than 30 m in length, had four main ‘forks,’ and averaged 6 cm beneath the surface, although the tunnel leading to the next descended to a depth of more than 60 cm. Tunnel systems more than 150 m in length are not rare (Davis and Schmidly 1994: 121).

The role of Botta’s pocket gopher in the development of a soil biomantle in California has been discussed by Don Johnson (1989).

Overall, bioturbation by large burrowing animals such as badgers may be difficult to identify when the entire upper meter of sediment has been churned into a biomantle (Figure 6.20). Rodent burrows are more easily recognizable: their round tube-like burrows are generally filled with different sediment, and such burrow fills can be avoided when extracting samples in archaeological sites.

Deflation, or eolian erosion, is another process that dominates the present-day landscape in the general area of Fort Bliss. During deflation, sand-size particles are removed and pebbles are concentrated on the eroded surface. Local sheet erosion from runoff during intense rainstorms can magnify the removal of sand as well as transport small pebbles. If an archaeological site is present, deflation, and local sheet erosion, results in the concentration and mixture of pebbles and artifacts on the surface. If the surface becomes buried by younger fresh sediments, the stone-artifact pavement or stone line could be mistaken for an *in situ* archaeological site (Figure 6.21).

Soil Geomorphology

Soil geomorphology represents an integration of pedology and geomorphology (Birkeland 1974; 1984; 1990; McFadden and Knuepfer 1990). In most cases, soil evidence is used to address geomorphic problems. Birkeland (1990) identifies four typical goals of soil geomorphic research: (1) development of a soil chronosequence framework to date surficial deposits; (2) as indicators of the duration of landscape stability; (3) to examine climate change through the pedogenic effect; and (4) to examine the relationship between soil development, surface hydrology, and hillslope erosion.

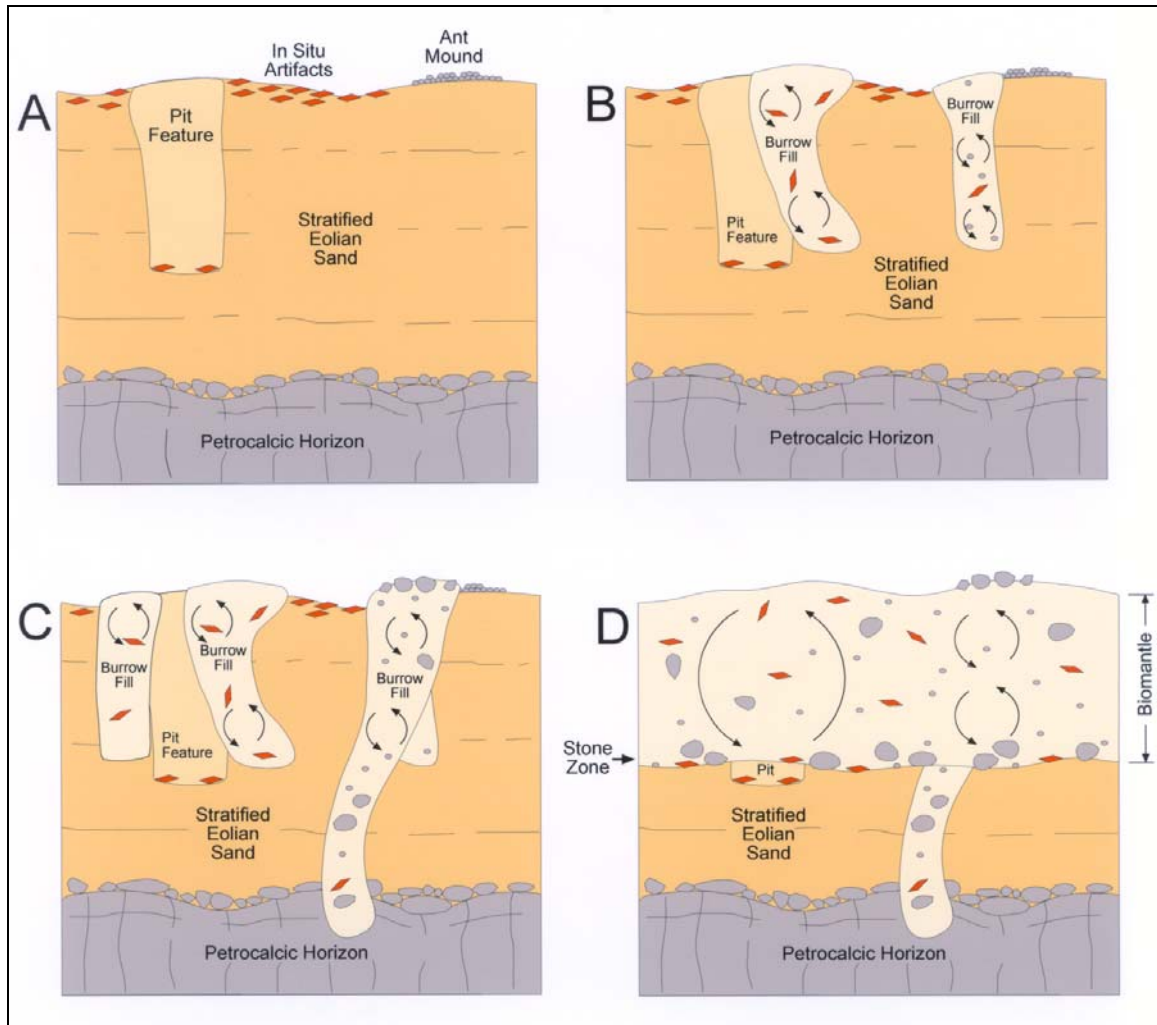


Figure 6.20. The development of a biomantle by repeated, continuing activity of burrowing animals.
 (Large stones tend to accumulate at the base of the biomantle forming a stone zone [modified from Hall 2002 and D. Johnson 1997]).

Although the disciplines of pedology and geomorphology have essentially developed independently since the early twentieth century, a great deal of convergence has occurred since the publication of Birkeland's landmark book, *Pedology, Weathering, and Geomorphological Research*, in 1974, as researchers have noted that many aspects of geomorphology and pedology are so interrelated that it is impossible to study one without at least some attention to the other (McFadden and Knuepfer 1990). This is well illustrated in the Fort Bliss region, where soils criteria are frequently the only basis for *a priori* estimation of sediment age (see Chapter 2, Figure 2.11).

There are four geoarchaeological implications of soils and paleosols. First, soil formation implies a measure of surface stability, particularly in the arid west where the rate of soil formation is strongly governed by the availability of moisture for chemical weathering, organic production, and constituent translocation. Therefore, the presence of a soil within a stratigraphic sequence implies that the surface was neither aggrading nor degrading significantly during the period of formation.

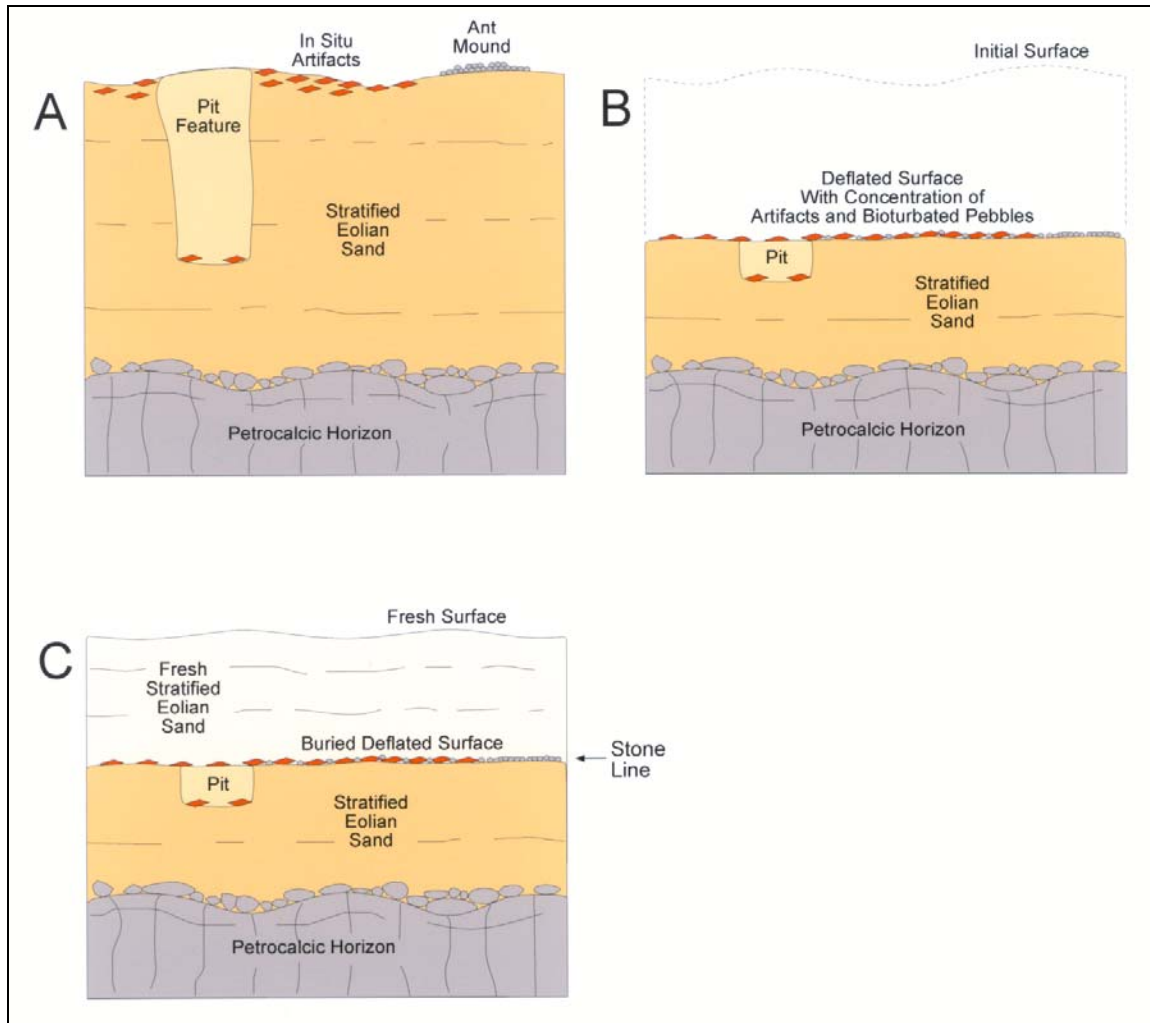


Figure 6.21. Deflation of sand sheet surface and archaeological site producing a stone line.
 (Deflation and stone-line development can occur on a biomantle where stones and artifacts have been disturbed and brought to the surface by coyotes and badgers. Upon burial by fresh eolian sand, the buried stone line and associated artifacts could be misinterpreted as an in situ archaeological site).

Archaeological components contained within that soil were thus probably exposed at the surface for long periods prior to burial, during which time many opportunities existed for disturbance processes to affect the spatial (horizontal) arrangements of artifacts within the assemblage. Moreover, because of the length of exposure, the opportunity for organisms to disturb the stratigraphic (vertical) relationships between artifacts in the matrix is also enhanced.

Second, a lack of soil development conversely implies that deposition occurred at a rate greater than pedogenesis, and that the degree of stratigraphic and spatial disturbance due to prolonged surface exposure and pedoturbation are likely to be relatively low. Of course, disturbance due to other factors, such as depositional energy, must be evaluated independently.

Third, where truncated soils are preserved (e.g., where the soil column was eroded to a relatively resistant argillic or calcic horizon), artifacts preserved at or immediately above the erosive contact are likely to be strongly displaced by the erosive energy involved in truncating the soil.

Fourth, where discrete geomorphic surfaces in a given area support similar soils developed in similar parent materials and exhibiting similar relief characteristics, the age of those landforms are likely to be roughly equivalent provided that both have been exposed for similar lengths of time; similarly, where one landform exhibits stronger soil development than another, it is likely to be older unless some factor attenuated pedogenesis on the apparently younger surface. Attenuating factors can include burial by other sediments, followed by exhumation: parent materials with differing resistance to erosion, moisture-delivery differences, and differences in soil moisture resulting from differing degrees of dissection (Gile 1975a; 1975b).

Soil and Eolian Geomorphology of Fort Bliss

With the exception of some soils at higher elevations in the Sacramento Mountains and on Otero Mesa, soils on Fort Bliss are essentially identical to soils described in the desert project (Gile and Grossman 1979; Gile et al. 1981). Chronosequences in these soils are well-established (Figure 6.22) and are quite useful for relative dating. Much of the soil sequence has been described previously in this document and will not be repeated here. Rather, the focus of this discussion is on aspects that remain relatively poorly understood, particularly on those aspects with high significance to archaeological studies.

Another phenomenon noted by Abbott (1997) in the Hueco Bolson is the presence of calcretes that appear to have been exhumed and mechanically abraded. At several alluvial fan sites southeast of Fort Bliss, Abbott noted plugged calcrete horizons developed on fan surfaces of probable Jornada I age that exhibited no upper laminae (as in Stage III morphology) but contained vertical cracks coated with thick laminae (typical of late Stage IV-early Stage V morphology). Because these features could not develop without corresponding development of upper laminae, the best explanation is that the calcrete was exhumed and stripped. Overlying sediments in this setting consisted of gravelly loams exhibiting a weak A-Bk profile, suggesting that this exhumation may have corresponded with the regional post-Isaac's Ranch erosion noted by Monger (1993b, 1993e).

The character of soils associated with the alluvial fans, and particularly with desert pavements, is poorly understood. In many cases, the loose pavement on alluvial fans displays evidence of surface disturbance; carbonate pendants, which should be uniformly oriented down and thus not visible, can often be observed on up to 50 percent of surface clasts. This implies that some mechanism has disturbed the pavements. If this phenomenon is related to Euro American activity in the bolson (i.e., due to large numbers of cattle introduced in the latter nineteenth century), then surface clasts should show simple pendant morphologies, despite their orientation. If it is due instead to longer-term natural processes, then carbonate coats should be more complex, containing multiple generations of discretely oriented pendants with varying degrees of preservation. In addition, the character of soils developed beneath the pavements should provide evidence of the possible applicability of the "born at the surface" model of pavement formation of McFadden and others (1987).

The degree of A-horizon preservation beneath coppice dunes is also relevant. If the coppice fields developed in relatively short order because of historic disturbance, then A horizons should be preserved beneath the larger, older coppice dunes. The elevation of these A horizons is also relevant; if the A horizon is preserved at or near the base of the dunes, the degree of interdunal deflation should be low, while if the A horizon is preserved high in the dunes, interdunal deflation would be high, and artifacts in the interdunes are probably reworked from their original contexts.

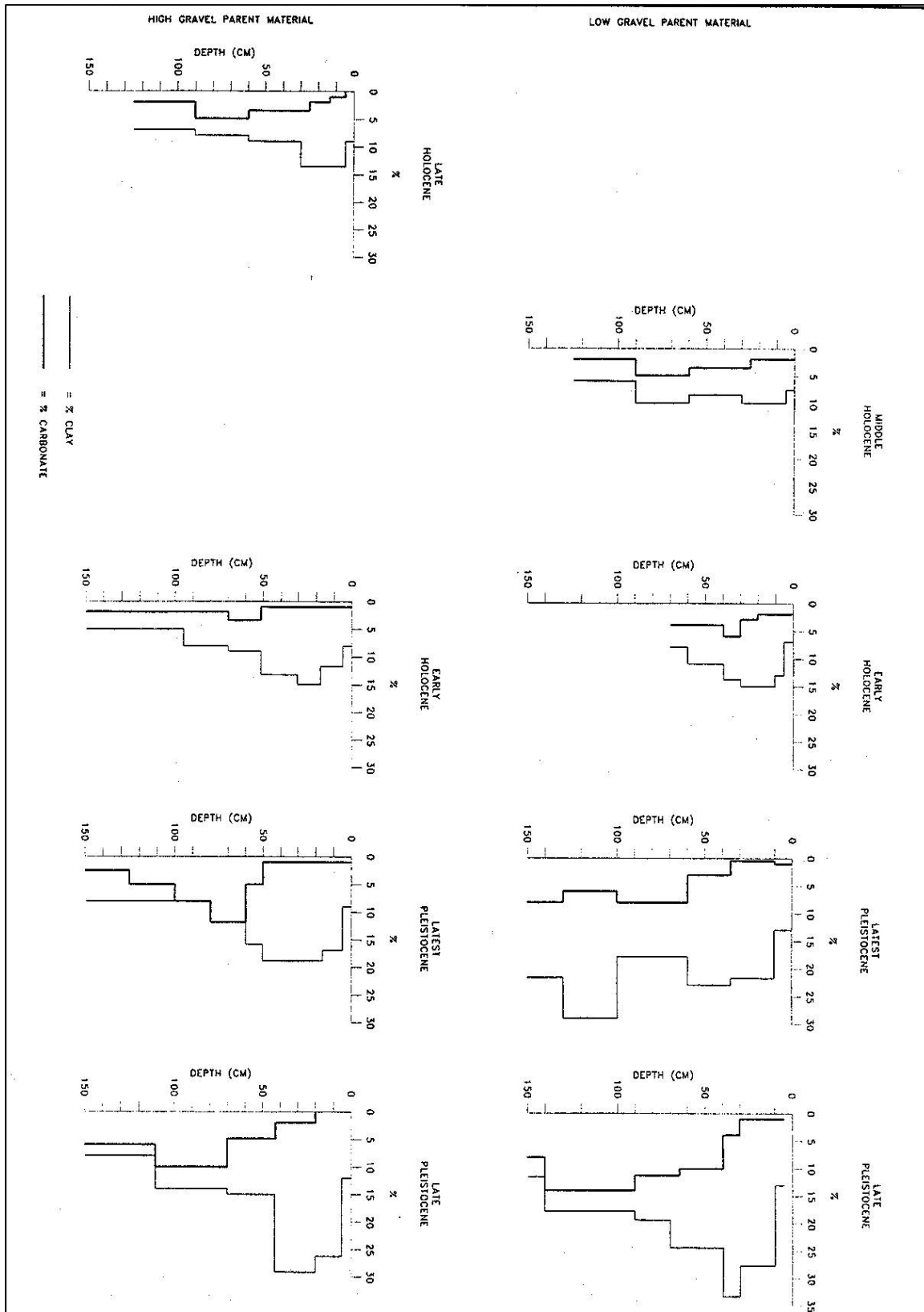


Figure 6.22. Trends in carbonate and clay content in alluvial soils of south central New Mexico. (after Gile et al. 1981).

The eolian record on Fort Bliss proper (i.e., exclusive of McGregor Range) has been examined by Monger (1993b; 1993e). The other major source drawn on for this summary is the work done on the western flank of the Jarilla Mountains immediately north of Fort Bliss in White Sands Missile Range (e.g., Blair et al. 1990a; 1990b; Doleman and Swift 1991). Collectively, these studies provide a good first approximation of the eolian record preserved on the basin floor, and serve as the basis of this synthesis. Although briefly noted by Pigott (1977), little information exists for eolian deposits elsewhere on the post, and on Otero Mesa in particular. Nevertheless, it is likely that the same types of controls operating on the basin floor were also operating in the higher portions of the base, and thus resulted in a broadly similar stratigraphic sequence; however, because the sediment supply was probably much more limited on Otero Mesa, the thickness of eolian deposits is liable to be lower, and erosional truncation may be more common. This tentative conclusion, however, requires further study.

The first model was developed by Blair and others (1990a, 1990b) for Late Quaternary sediments in the Tularosa Basin. Late Quaternary eolian sediments are arranged in a four-unit framework, designated Q1 through Q4. The Q1 unit was deposited between ca. 50,000-250,000 years ago and contains soils with Stage III to Stage IV carbonates (i.e., many carbonate nodules to laminar/plugged horizons) and Btk-K-Bk profiles. Unit Q2 is temporally analogous to the Isaack's Ranch unit (ca. 9000-15,000 years B.P.) and is characterized by Btk, Bk, or Btk-Bk horizons with Stage II carbonate nodules. The Q3 unit in the Tularosa Basin encompasses the Organ I-Organ III units and was deposited between ca. 100-7,300 years ago. Q3 soils are generally poorly developed and exhibit A-Bw-C or A-Bk-C profiles with Stage I carbonates. Finally, Q4 deposits are Historic in age and apply to eolian coppice dunes and sand sheets. They are temporally and morphologically analogous to the Historic Blowsand deposits of the Gile and others (1981) and Monger (1993a) terminology.

A second model was proposed by Monger (1993e) who tentatively identifies four episodes of Holocene eolian activity on the installation, which he equates with episodes of fan and arroyo activity previously identified in the Desert Project study area on the opposite side of the Organ Mountains (Gile and Grossman 1979; Gile et al. 1981). A broadly similar sequence, albeit with less resolution during the Holocene and extending farther back into the Pleistocene, is identified at White Sands Missile Range (Blair et al. 1990a; 1990b).

These episodes of eolian activity resulted in deposits that have experienced different degrees of pedogenesis, and thus can be correlated using soil development criteria. Unlike the model proposed by Blair and others (1990a), Monger subdivides the Holocene-aged Q3 unit into the Organ I-III sequence. Table 6.2 correlates the sequences and diagnostic features proposed by Blair and others (1990a, 1990b) and Monger (1993a).

With the exception of the historic sands, each of these eolian units appears to have accumulated over broad areas as relatively low relief sand sheets with some larger eolian ridges and mounds, but few large, active dunes. Transport appears to have occurred primarily through ripple drift and grain fall processes, probably in the presence of moderate amounts of vegetation (Blair et al. 1990b). For this reason, the stratigraphic units can frequently be found stacked in individual profiles. However, because in each case broad to relatively closely spaced areas of deposition alternate with comparable areas of erosion, not all units occur in every profile and the thickness of individual units varies considerably.

Overall thickness of the Late Pleistocene and Holocene units in the basins is unknown, but investigated parts of the sequence range between zero and approximately 3 m thick, although in most areas on the basin floor depth to calcrete is less than 1.5 m (Blair et al. 1990b; Monger 1993e).

As Table 6.2 illustrates (see Table 6.2), primary eolian stratification is typically only preserved in the most recent dunes. This lack of stratification is consistent with sand sheet deposition (Fryberger et al. 1979; Kocurek and Nielsen 1986) because extensive bioturbation frequently accompanies eolian aggradation in a vegetated environment (Pye 1983).

Table 6.2.
Correlation of Eolian Deposits on Fort Bliss and White Sands Missile Range.

Eolian Stratigraphy, Fort Bliss			Generalized Soil Stratigraphy, White Sands Missile Range		
Monger 1993a			Blair et al. 1990a; 1990b		
Unit	Diagnostic Feature	Tentative Age	Unit	Diagnostic Feature	Tentative Age
Historic Blowsand	Stratified eolian sediments	1850 A.D. to present	Q4	Loose single grain structure; primary sedimentary structures partially disrupted by bioturbation; weak, local vesicular A horizons; occasional faint Stage I filaments	>100 BP
Organ III	No eolian strata, No carbonate filaments	100 to 1100 BP	Q3	A-Bw-C or A-Bk-C profile (often truncated); soft to slightly hard dry consistence; single grain or weak to moderate subangular blocky structure; Stage I carbonate morphology or slight reddening and clay enrichment	100-7300 B.P.
Organ II	Faint Stage I filaments	1100 to 2100 BP			
Organ I	Prominent Stage I filaments, commonly 5 YR hues, faint clay skins	2100 to 7000 BP			
Isaack's Ranch	No eolian deposits of this age described, however, lag carbonate nodules indicating deflation of older strata are present	>7000 BP	Q2	Btk, Bk, or Btk-Bk profile; A horizon truncated; hard to very hard dry consistence; moderate angular-subangular blocky structure; Stage II carbonate morphology; distinct reddening and illuvial clay	9400-15,000 BP
Jornada II	No eolian deposits of this age described		Q1	Truncated; Btk-K-Bk profile; Stage III to Stage IV carbonate morphology	50,000-250,000 BP

Both Blair and others (1990b) and Monger (1993e) tentatively relate the formation of these eolian sand sheets with relatively arid intervals. Presumably, eolian activity was closely linked to increased activity on the fan-piedmont, resulting in the delivery of increased amounts of erodible sediments and a decrease in eolian-inhibiting vegetation on the basin floor. Conversely, cessation of eolian activity would have coincided with increasing slope stability, decreasing sediment

delivery, and more pervasive vegetation cover on the basin floor and on the mountain slopes. The sole exception is the modern environment, which is interpreted as the irreversible consequence of overgrazing on fragile, marginal grassland (Buffington and Herbel 1965; York and Dick-Peddie 1969).

Although this model is tenable, further work is needed to effectively relate the landscape response to a climatic stimulus. As outlined in Chapter 2, most paleoclimatic work from the region paints a unidirectional picture of decreasing effective moisture throughout the Holocene. Although the initiation of Organ/Q3 deposition around 7000-7300 B.P. does appear to follow the crossing of an environmental threshold about 8000 B.P. that marked the initial appearance of many of the modern Chihuahuan Desert species, much of the extant paleoenvironmental data suggests that grasslands persisted until around 4000 B.P., when they were superseded by desert scrub (Van Devender 1990).

Interestingly, no extant data suggests a change in eolian activity coincident with this shift in vegetation. Pollen data described by Freeman (1972) from the Gardner Springs site in the Desert Project study area suggests that grasses may have been replaced by scrub in the early Middle Holocene, only to flourish again for a short time during the early Late Holocene (approximately 4500-3500 B.P.) before being replaced again by desert scrub. Once again, no clear geomorphic response to these apparent vegetation shifts is preserved in the stratigraphic record.

Conversely, apart from the stratigraphic evidence, there is no real local corroboration for climatic forcing as a mechanism in the transition between Organ I-Organ II and Organ II-Organ III deposition at 2200 B.P. and 1000 B.P., respectively. However, there is clear geomorphic evidence of a sudden shift in climate around 1000 B.P. on the southern Plains (Hall 1990a), suggesting that the Organ II to Organ III transition may indeed have a climatic cause not reflected in the local biotic record.

One of the problems with Monger's (1993e) model is that the subdivision of the Organ eolian sequence into Organ I-III phases does not include the stable periods necessary for the formation of soils that define the units. In reality, this is a problem in resolution; the bulk of eolian activity probably would have occurred relatively early in the bracketing timescales, while relative stability, and concomitant soil development, would have dominated during the latter part of each episode. In addition, although the sequence is defined only at a temporal scale, there is good reason to expect spatial variability in the location of active eolian environments in the basin, which introduces additional complexity. For these reasons, there is a strong need for additional data to refine the eolian sequence to reflect periods of stability and instability in a spatiotemporal framework.

Monger (1993c) has identified and mapped several broad categories of eolian alteration within the Fort Bliss maneuver areas. These broad categories include a variety of subcategories, resulting in seven distinct mapping units:

- 1a. large dunes (generally more than 1 m in relief) with collapsed interdune strata;
- 1b. small dunes (generally less than 1 m in relief) with collapsed interdune strata;
- 1c. deflated nondune areas;
- 2a. large dunes with interdune sheet deposits;
- 2b. small dunes with interdune sheet deposits;
3. depositional areas comprised of sand sheet deposits; and
4. areas where soil strata are modified little by wind.

In Figure 6.23, Mapping Units 1a, 1b, and 1c are defined based on dune size and the presence of a surficial lag of carbonate nodules in the interdune areas. This nodular lag is equated with Isaack's Ranch soil development, and provides a clear indication that Holocene depositional units are not preserved in the interdune areas. Mapping Units 2a and 2b are also characterized by dunes, but lack the nodular lag in the interdunal swales, indicating that Holocene eolian deposits (e.g., Organ and/or Isaack's Ranch) may be preserved at depth. Mapping Unit 3 consists of sand sheet deposits that exhibit no surficial lag of carbonate nodules and no dunes; they also may contain preserved archaeological strata. Finally, Mapping Unit 4 consists of areas that do not exhibit evidence of substantial eolian truncation or additions, such as fan and playa surfaces.

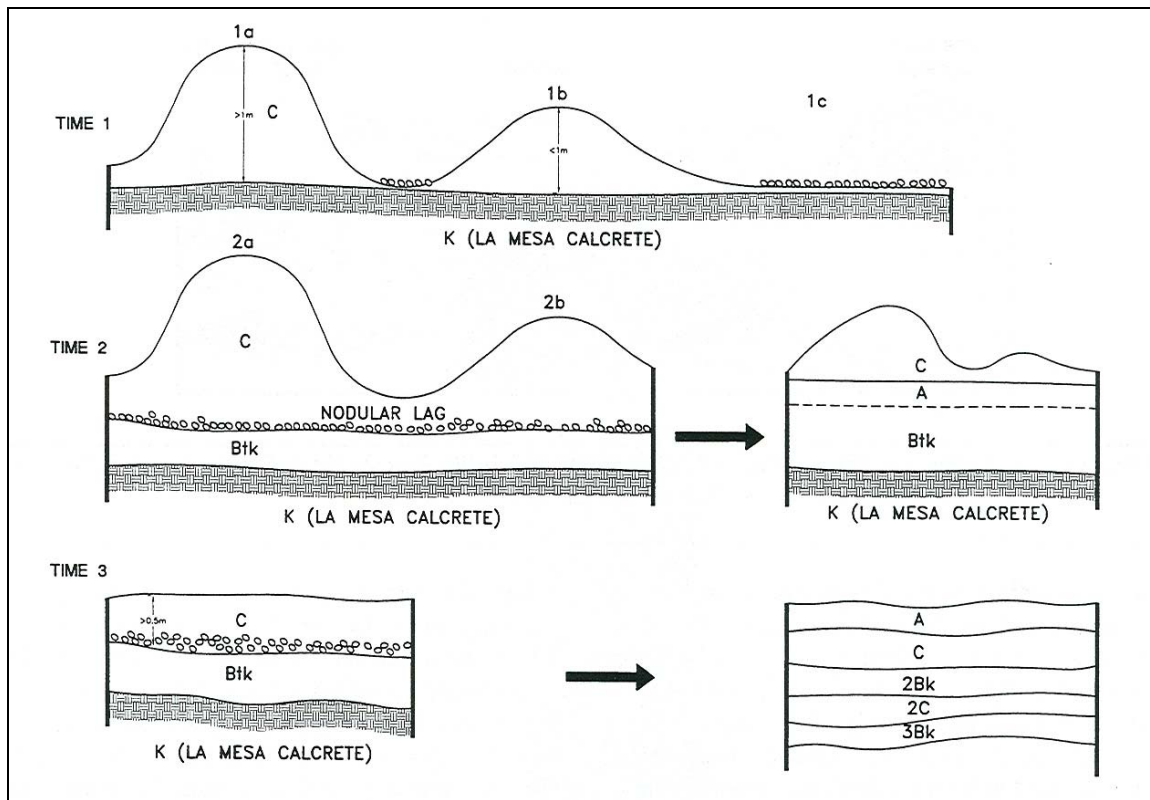


Figure 6.23. Illustration of Eolian Alteration Units.
(after Monger 1993c)

The profiles represented in Figure 6.23 (see Figure 6.23) represent only a few of the possible profiles underlying Monger's four mapping units. The character of soil profiles developed in eolian deposits will reflect the net result of the magnitude of localized erosional and depositional episodes through the late Quaternary. Preliminary work in the maneuver areas (Monger 1993a) and elsewhere in the bolson (Abbott 1997) demonstrate that the thickness and geometry of the Isaack's Ranch Unit and the various Organ units can vary considerably over short distances depending on the patterning of blowouts that develops on each successive paleosurface as it is erosional truncated during subsequent active episodes.

Figure 6.24 schematically illustrates lateral variability in depositional units documented at a series of sites in the northern Hueco Bolson, just southeast of Fort Bliss (Abbott 1997); similar relationships are suggested at the Tobin Wells and McNew Tank Pipeline localities on Fort Bliss (Monger 1993e). Although these studies provide only a few examples, they do demonstrate that

the internal stratigraphy of the eolian deposits can be very complex and exhibit strong lateral variability over relatively short distances.

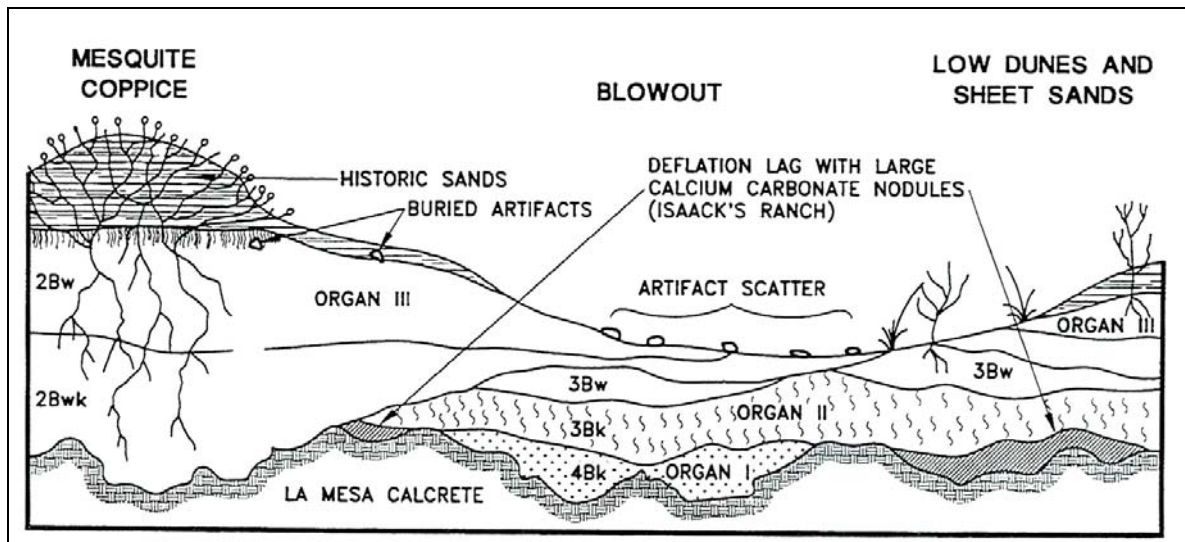


Figure 6.24. Schematic illustration of stratigraphic variability observed at a single archaeological site in the northern Hueco Bolson. (after Abbott 1997)

In particular, there is strong evidence (Abbott 1997; Gile 1966a) that A horizons of the last episode of landscape stability are frequently preserved in coppice dunes at elevations higher than the modern interdunal areas. This is not surprising, given the model for formation of the coppice fields. Presumably, the coppice dunes developed as a result of historic overgrazing, which resulted in both the destruction of the fragile grassland ecosystem and the wide distribution of mesquite beans in the dung of grazing stock. As the grass cover disappeared, eolian erosion began to occur. However, pockets of sand were rapidly trapped by young mesquites, armoring portions of the surface. As this process progressed, relief in the coppice dunefields increased as the interdunes were increasingly deflated and the mesquite plants grew, trapping more and more sand.

Four basic geoarchaeological implications that pertain to the eolian deposits on Fort Bliss can be derived from Monger's (1993e) model. First, significant eolian activity has occurred during the archaeologically relevant time span within the boundary of Fort Bliss. Therefore, it follows that much of the archaeological record is concealed by more recent eolian deposits, and the pattern of sites discovered by pedestrian survey and the apparent size of those sites, are a combined function of the actual distribution and size of sites and the pattern of potential visibility provided by the patterning of eolian deposits on the post.

In general, sites in Mapping Units 1a and 1b should be visible in interdunal areas, and thus apparent sizes should be a combined function of the actual size of the scatter and the distribution of erosional "windows"; sites in Mapping Unit 1c should be wholly visible; sites in Mapping Unit 3 should be buried and undetectable from surface survey; and sites in Mapping Unit 2 should be either limited by erosional windows (if the deflation hollows are deep enough to expose the cultural strata and fresh sands are not present in the interdunes) or undetectable (if the deflation hollows are not as deep as the cultural strata or fresh sheet sands are present in the interdunes).

The potential visibility of sites in Mapping Unit 4 is unrelated to eolian processes, and should be evaluated using other appropriate criteria.

Second, buried cultural strata could potentially be preserved anywhere in Mapping Units 2a, 2b, and 3, necessitating subsurface testing to determine their presence and distribution. Because the internal stratigraphy of the eolian cover can vary considerably within a short distance, this testing should be relatively intensive. In Mapping Units 1a and 1b, the potential for preserved cultural strata should typically be limited to the dunes; the interdune areas should have poor potential for any semblance of stratigraphic integrity. Similarly, Mapping Unit 1c should have poor subsurface potential and would not require testing. Once again, the potential of areas included in Mapping Unit 4 would have to be evaluated on the basis of other criteria.

Third, horizontal patterning of exposed artifacts in all mapping units should be carefully and critically evaluated for evidence of disturbance, and should probably be considered to lack culturally significant patterns unless evidence to the contrary is apparent. In particular, the artifacts in Mapping Units 1a, 1b, 2a, and 2b should be examined for size patterning or other evidence of sorting, and clustering of artifacts in interdunal areas should be examined critically before assigning any behavioral relevance to the pattern. Similarly, artifact scatters in Mapping Unit 1c should be examined carefully for evidence of possible dispersion or concentration.

Fourth, vertical patterning of materials in section should also be carefully evaluated for evidence of deflation and bioturbation. Buried materials associated with major bounding unconformities between units should be examined with particular care. In all cases, a concentration on evidence for collapse of multiple primary strata into secondary palimpsest assemblages, which would strongly limit the potential utility of the recovered assemblage, should be emphasized.

LATE QUATERNARY STRATIGRAPHIC NOMENCLATURE

Researchers in the Hueco Bolson and Tularosa Basin have utilized a number of different late Quaternary stratigraphic and geomorphic chronologies. Gile and others (1981) developed one stratigraphic and pedogenic chronosequence for alluvial fan/piedmont surfaces in the southern Tularosa Basin. The model was subsequently expanded by Monger and others (1993a) to include fan/piedmont and basin floor surfaces in both the Hueco Bolson and Tularosa Basin areas. Under the Gile and others (1981) and Monger (1993a) model, Holocene-aged deposits are assigned to the Isaack's Ranch, Organ I, II, III, and Historic Blowsand stratigraphic units. These units are in part differentiated on the basis of soil carbonates.

The Isaack's Ranch Unit is comprised of generally coarse-grained alluvial fan sediments that were deposited along the margins of the Hueco Bolson between ca. 15,000-8,000 years ago. The Organ Unit is comprised of eolian and alluvial sediments that were deposited in alluvial fan/piedmont, arroyo, and basin-floor settings between ca. 7000-150 years ago. The Organ deposits are subdivided into three members largely on the basis of soil carbonate morphology (Gile et al. 1981): (1) Organ I [7000-2100 years B.P.]; (2) Organ II [2100-1100 years B.P.]; and (3) Organ III [1100-150 years B.P.]; (Gile et al. 1981; Monger 1993a). The Historic Blowsand Unit is comprised of sand sheets and coppice (i.e., nabkha) dunes that were deposited by eolian processes within the last ca. 150 years.

An alternative model is that proposed by Blair and others (1990a, 1990b) for Late Quaternary sediments in the Tularosa Basin. The Tularosa Basin has a geomorphic history similar to the Hueco Bolson and is also covered in Holocene-aged eolian sandsheets and dunes. Blair and others (1990a) summarize this history and present a model similar to the ones established for the Hueco Bolson, although they do not subdivide Holocene-aged soils in a manner analogous to the Organ I-III sequence (refer to Table 6.2).

Hall (1999; 2003) argues that the Blair and others (1990a) Q1-Q4 model should be used when describing and interpreting surficial eolian deposits in the Hueco Bolson and Tularosa Basin. His decision to use the model proposed by Blair and others (1990a) is based on a number of conceptual geological problems recognized in the application of Gile and others (1981)/Monger (1993a) model to Late Quaternary eolian deposits in basin floor settings. The first of these is the problem of applying a soil chronosequence developed for dated alluvial fan sediments in a limited physiographic setting to eolian sand sediments in a totally different setting. The application of the Desert Project model to eolian basin-floor deposits assumes there is a time correlation between alluvial fan and eolian basin sediments.

Hall (1999: 43) argues first that no such time correlation has been demonstrated and also that soil chronosequences, like the one developed on the basis of soil carbonate development for the Desert Project alluvial fans, are generally regarded as relative and not absolute. Second, soil carbonate content is not just dependent on time, but also on texture, bedrock lithology, topography, and physiography (Hall 1999: 43). The soil chronosequence advocated specifically by Monger (1993a) defines Organ III soils as having a lack of secondary carbonates, Organ II as having a small amount of secondary carbonates, and Organ I as having a stronger degree of carbonates (Hall 1999: 44).

In addition, in some eolian sand sections, carbonates increase with greater depth, while in others the surface A horizon is interpreted as Organ III but the underlying Bk horizon is interpreted as Organ I. These identifications give the impression that eolian sands in basin floor settings represent separate deposits that correlate temporally with radiocarbon dated Organ alluvium on the other side of the Organ Mountains (Hall 1999: 44).

Hall (1999: 44) completes his argument with five additional reasons why application of the Desert Project model to eolian sands is conceptually unsound. These are:

1. the natural variability of pedogenesis and secondary carbonate accumulation;
2. the gradational increase of carbonates with depth in the generally thin sand mantle;
3. the absence of erosional unconformities in the eolian section;
4. the general absence of buried soils; and,
5. the mixing of sediment and soils by burrowing animals.

Hall's arguments are shared by Lukowski and others (2003), who have proposed and utilized a geochronologic scheme that relies on a subdivision of the Q3 unit of Blair and others (1990a). Lukowski and others (2003) argue against using the Organ I-III model in eolian basin floor settings and say that a subdivision of the Q3 unit is possible on the basis of soil morphology, stratigraphy, and radiocarbon dating. The Q3a unit is estimated to be between 7300-2400 years B.P. in age and is characterized by Stage I carbonates (Lukowski et al. 2003: 39). The Q3b unit dates from ca. 2400-100 B.P. and is comprised of a weakly developed Bw-Bk soil horizon profile with common buried A horizons. Three radiocarbon dates on bulk soil organic matter provided the temporal framework for this model. The soil samples were collected during archaeological and geomorphic field work in the Nations East Well – Hueco Mountains Archaeological Project Area (Lukowski et al. 2003). While the soil humate dates contain a potential source of error, which the authors acknowledge, they do also effectively demonstrate that the proposed Q3a and Q3b units represent distinct episodes of deposition. It is important to note, however, that the unconformable contact between the Q3a and the Q3b units in the Nations East Well area happens to correspond to the boundary between Bw and Bk soil horizons exposed in backhoe trench walls. The boundary also separates what the authors identify as the Organ I (Bk) and Organ III (Bw) units of the Gile and others (1981) and Monger (1993a) model.

As Hall (1999) correctly points out, the correlation of stratigraphic unit designation with soil horizon differences based on pedogenic carbonate development is, in itself, not in keeping with accepted stratigraphic nomenclature. Time-stratigraphic, or geochronologic units are individual bodies of sediment that were deposited within a specific depositional environment during a specific period of time (cf. NACOSN 1983; Waters 1992: 85). Soil horizons, in contrast, represent vertical subdivisions within a soil profile based on specific, measurable physical and chemical characteristics resulting from soil formation processes (Soil Survey Staff 1975; Waters 1992: 51). Soil formation can be limited to individual stratigraphic units, but can also imprint adjacent units within a given locality if sufficient periods of landscape stability occur subsequent to unit aggradation. The tendency to equate named lithostratigraphic units (i.e. Organ I, III) with soil horizons characterized by differing carbonate content (i.e., Bw and Bk) is a common practice in the Fort Bliss area; but it is one that blurs the distinction between time-stratigraphic units and soil horizons developed within a single stratigraphic unit through time (Hall 1999: 44). This, in turn can lead to problems in archaeological interpretation, as Waters (1992: 76) paraphrases from Holliday (1990):

Horizons should not be confused with geologic layering, because soil horizons have no relationship to geologic deposition. It cannot be overstressed that the color, textural, and structural characteristics of soil horizons bear little relationship to the original layering of sediments on which they developed. If two lithostratigraphic units of different ages are both exposed at the surface, pedogenesis will alter both units during a period of landscape stability and will create a laterally continuous soil profile. Consequently, artifacts of different ages buried in two different lithostratigraphic units may occur in the same soil horizon and lead to the erroneous conclusion that they are from the same time period.

In addition, Hall (1999) states that pedogenic carbonates themselves are not just dependent on time, but also on factors such as texture, topography, bedrock content, and physiography. Thus use of soil carbonates in the identification of Organ unit soils may require additional sources of information. Likewise, Kuehn (2004) observes that identification of Organ-aged soils, particularly Organ III, on the basis of a lack of carbonates may be problematic in some stratigraphic contexts. These include soil horizons that are currently exposed on the surface and horizons that appear to have been on the surface at one time but are now buried. Such surface exposures could result in the vertical translocation of formerly extant carbonates out of the soil profile by rainfall and water percolation. As a result, soils older than Organ III may exhibit a lack of carbonates due to surface/near-surface leaching rendering the lack of carbonates of little use in the estimation of age.

Cumulatively, the arguments presented by Hall (1999; 2003), Lukowski and others (2003), and Kuehn (2004) present a convincing case for re-thinking the applicability of the Organ unit model. Hall's discussions in particular stress the need to limit application of the Organ sequence to alluvial fan/piedmont environments in the Organ Mountain area. This is where the Organ model was originally developed and where the available data are the strongest. In other settings, particularly basin floor eolian environments, correlations to Organ unit deposits have yet to be convincingly demonstrated. In these settings, researchers are strongly encouraged to use the Q1-Q4 model developed by Blair and others (1990a). The Q3 unit of the Blair model, however, should be refined with the goal of establishing finer temporal resolution. The subdivision of the Q3 adopted by Lukowski and others (2003) is a good place to start. However significant dating efforts, such as those described under the following subheading, are needed in order to increase the reliability of subsequent correlation and need to be a component of all geoarchaeological efforts undertaken during excavation of sites in the basin.

Finally, a separate late Quaternary model, one that relies more on geomorphic mapping units, was developed by D. Johnson (1997) for the McGregor Range portion of Fort Bliss. In his research at McGregor, Johnson (1997) proposed a geomorphic landscape model that differs somewhat from the Desert Project model of Gile and others (1981) and Monger (1993a), as well as the Q1-Q4 model of Blair and others (1990a, 1990b) and Hall (1999, 2003). Johnson also decided not to use the Desert Project model in his study for a number of reasons. These are: (1) the expense and cost of obtaining meaningful correlations between the McGregor Range and Desert Model units and geomorphic surfaces would be prohibitive; (2) sediments in the Desert Project study area are derived from both carbonate and noncarbonate rocks, while sediments in the McGregor Range are derived almost exclusively from carbonate rocks; (3) biotic landscape disturbances, from plant and animal activity, have significantly impacted landforms on McGregor but similar disturbances have not been systematically documented in the Desert Project area; and (4) the Desert Project stressed soil/geomorphic relationships as the fundamental framework for subsequent interpretation, while Johnson's McGregor research stressed a soil evolution, biomantle, dynamic denudation process approach. These different frameworks yield different interpretations and different results, meaning that the two data sets would not be compatible (Johnson 1997: 4).

Johnson identified 15 major surface landform categories and geomorphic mapping units on McGregor Range, defined on the basis of morphology, sedimentology, stratigraphy, and soils (D. Johnson 1997). These landform/mapping units are: (1) Alluvium-Recent; (2) Alluvium-Relict; (3) Alluvium-Older Relict; (4) Bedrock; (5) Bolson Floor Complex; (6) Camp Rice (Rio Grande) Sediments; (7) Dune-Local; (8) Dune Pile; (9) Dune Sheet; (10) Dune Sheet-Coppiced; (11) Dune Sheet-Gypsiferous; (12) Fault; (13) Pediment; (14) Playa; and (15) Playa Lunette (D. Johnson 1997: 4). With the exception of the Camp Rice mapping unit, which is essentially the same as the Camp Rice Formation deposits of early to middle Pleistocene age (Gile et al. 1981), the remaining 14 landforms are not implicitly associated with temporal periods.

Landforms 1 through 3 (Alluvium Recent, Relict, and Older Relict) are comprised of fine to coarse-grained alluvium distributed in arroyos, gullies, and broad shallow alluvial channels (D. Johnson 1997: 5). These sediments are generally analogous to the Historic Arroyo, Organ, Isaack's Ranch, and Jornada I alluvial lithofacies as defined by Gile and others (1981) and Monger (1993a). The Bolson Floor Complex is a mapping area found exclusively on the floor of the Tularosa Basin and is a complicated assortment of sediments and geomorphic surfaces. These include Camp Rice gravels, playa lake sediments, coppice dunes, sand sheets, and toeslope deposits (D. Johnson 1997: 7). The Dune Local, Dune Pile, Dune Sheet, and Dune Sheet-Coppiced mapping units correspond to the eolian sand lithofacies of the Historic Blowsand and Organ stratigraphic units (Johnson 1997: 8-11). The Dune Sheet-Gypsiferous unit is more or less unique to the Tularosa Basin (i.e., not appreciably present in the Hueco Bolson) and consists of gypsiferous sands which originated on dried floor of intermittent Lake Jarilla, and possibly several smaller playas (D. Johnson 1997: 11). The Playa Lunette mapping unit is comprised of prominent to subdued crescentic dunes deposited by wind on the downwind side of playa lakes (D. Johnson 1997). They are both gypsum rich and calcite rich (D. Johnson 1997: 13). The Fault unit consists primarily of normal faults as indicated by visible landform features such as lineaments, offset bedrock and offset streams, scarps, linear depressions and truncated fans (D. Johnson 1997: 12). Pediments are defined as "solutional- and/or abrasional-bedrock surfaces generally overlain by a thin (1-3 m) veneer or mantle of soil or sediments" (D. Johnson 1997: 12). These occur along the periphery of mountain ranges, foothills, and bedrock outcrops. Finally, the Playa mapping unit is generally comprised of depressional lows that hold water permanently or intermittently. They are widespread on the floor of the Tularosa Basin and range in size from small, isolated depressions to large paleolake remnants (D. Johnson 1997: 12-13).

To recap, archaeologists, geomorphologists, and Quaternary geologists have recognized the usefulness of both the Organ I-III and Q1-Q4 stratigraphic models of Gile and others (1981) and Blair and others (1990a, 1990b), as well as Johnson's (1997) geomorphic-based model in the Fort Bliss area. Conceptual and correlation problems, however, have been recognized when attempting to rely solely on one of the above-mentioned approaches. Principal among these are: (1) difficulties in the correlation of fan/piedmont with basin floor deposits; (2) a blurred distinction between stratigraphic units and individual soil horizons; (3) problems assessing the age of stratigraphic units on the basis of soil carbonates; (4) limited temporal resolution; and, (5) the reliability of bulk soil radiocarbon ages when attempting to apply the Organ unit of the Desert Project and the Q3 unit of Blair and others to archaeological sites in the Fort Bliss area. This is the subject of the following discussion below.

GEOCHRONOLOGY OF QUATERNARY STRATIGRAPHY AND GEOMORPHIC FEATURES AT FORT BLISS

From 1957 to 1972, the Desert Soil-Geomorphology Project of the U. S. Soil Conservation Service was conducted. It encompassed an area of about 400 square miles on the west slope of the San Andres Mountains and on the adjacent Rio Grande Rift Valley north of Las Cruces in southern New Mexico. The objective of the project was "to delineate the kinds of land forms and soils in the area and to determine the nature of their origin within the physiographic history of the region" (Ruhe 1967: 2). From the project, numerous publications were produced on soils associated with alluvial fan deposits and their geomorphic surfaces (Gile et al. 1981; Gile et al. 1995; Ruhe 1967). One result of the investigations is a chronosequence of calcic soils that has been applied as a standard throughout the American Southwest. The lessons learned in the Desert Project also have been applied to the geomorphic condition in the Tularosa Basin and Hueco Bolson of Texas and New Mexico.

Radiocarbon Dating for Geochronological Investigations

Radiocarbon dating is the most mature method of geochronology applied worldwide to Late Quaternary materials and, since its discovery, has revolutionized our understanding of the recent geologic and archaeological records. Willard F. Libby pioneered the method while at the University of Chicago, producing the first radiocarbon age in 1949 (Arnold and Libby 1951). He was awarded the Nobel Prize in Chemistry in 1960 for his work in the development of radiocarbon dating. However, the first radiocarbon ages, determined on materials of known historical age, were off by several hundred years. It was realized that radiocarbon years and calendar years are not the same, requiring calibration (Libby 1955, 1963). Radiocarbon is the only dating method that produces ages in non-calendar years. A good summary of the application of radiocarbon dating can be found in Chapter 5 (see also Bowman 1990) and will not be repeated here. However, this section will provide some brief discussions of radiocarbon dating as they apply to the geochronology of the lands of Fort Bliss.

Most materials with organic carbon in them are suitable for radiocarbon dating, but the problems associated with obtaining and interpreting radiocarbon dates are many as discussed by Bowman (1990; see also Chapter 5). Nonetheless, in the Tularosa Basin and Hueco Bolson, radiocarbon dating has produced a valuable chronology for the archaeological record, and the data base of radiocarbon ages is an important resource for analysts.

One of the more persistent problems of radiocarbon dating in the desert is the presence of old wood and the possibility that pieces of old wood were used in prehistoric campfires. While mesquite and creosote wood are eventually consumed by desert termites, stems of old dead wood can be present on the surface for several hundred years. If gathered for a fire, the radiocarbon age of the hearth charcoal may be several hundred years too old. The problem can be solved by

identifying the wood or seeds. Long-lived species, such as mesquite, can be set aside and short-lived species, such as seeds from grasses or annual plants, chosen for dating. For example, 23 individual dead stems of creosote (*Larrea tridentata*) were collected from the sandy surface of the Mojave Desert in southern California and separately radiocarbon dated from 295 ± 150 to 730 ± 125 ^{14}C years B.P., while a single stem of manzanita wood (*Arctostaphylos patula*) from a granite outcrop was dated to 520 ± 100 ^{14}C years B.P. (Taylor 1975; Vasek 1980). As another example, a dead juniper stem (*Juniperus* sp.) from a limestone slope of Bishop Cap in Doña Ana County, New Mexico, was dated to 130 ± 30 ^{14}C years B.P. (Tx-8575; Hall, unpublished). These examples underscore the fact that the old wood problem will always be a factor in the interpretation of radiocarbon ages on wood charcoal from archaeological sites, especially in arid environments.

AMS radiocarbon dating, while more expensive than conventional dating, has improved local chronologies as it can produce ages on very small materials, such as a single grass seed. In addition, the AMS method results in smaller standard deviations than conventional dates. A conventional age that is 1000 ± 85 ^{14}C years B.P. can be 1000 ± 40 ^{14}C years B.P. by AMS.

Regardless of the radiocarbon method used, in every case the date should be corrected by the radiocarbon laboratory for $\delta^{13}\text{C}$ value. As noted in Chapter 5, different plants fractionate carbon in different ways during their growth, resulting in varying $\delta^{13}\text{C}$ values and, hence, different radiocarbon ages (Table 6.3). In order to get around the fractionation effect, radiocarbon ages are universally “corrected” by normalizing the age to $\delta^{13}\text{C} = -25.0\text{‰}$. It is critical that normalizing be done if the radiocarbon age is going to be calibrated by one of the dated tree-ring sequences. The calibrations of radiocarbon years to calendar years that have been developed by various laboratories around the world all use ^{13}C -corrected dates. As a bonus for spending extra funds on ^{13}C -corrections, the $\delta^{13}\text{C}$ values can provide useful information on plant ecology (Jones 1985; Whitford 2002).

Table 6.3.
Photosynthetic Pathways and ^{13}C Signature of Some Plant Species in Southern New Mexico.

Photosynthetic Pathways	Plants*	$\delta^{13}\text{C}$ (‰)
C4, warm-season grasses (5% plant biomass, 1% known species)	Maize, blue grama, black grama, buffalo grass, tobosa, little bluestem, big bluestem	-11.0 to -15.0
CAM, succulents (small number of species)	Cactus, agave	15.0 to -20.0
C3, cool-season grasses (95% plant biomass, 99% known species)	Mesquite, creosote, Indian ricegrass, western wheatgrass, sedges, common reed, cattail, most composites, most chenopods, juniper, pine, oak, most trees	-20.0 to -35.0

* From various sources including Dawson and others (2002) and Waller and Lewis (1979)

Another key factor in using radiocarbon dates is their presentation in publications. Radiocarbon dates consist of two laboratory measurements: the measured ^{14}C age and the $\delta^{13}\text{C}$ value. Both of these measured values and should be listed in a table of dates. The corrected age, derived from the $\delta^{13}\text{C}$ value, must be listed since it is the date that is used in calibration with a tree-ring curve. Subsequent to the first published tree-ring calibration by Suess (1970), a number of new calibrations have been produced by various laboratories around the world. Because there is more than one calibration curve in the literature, it is important that the table of radiocarbon dates includes a reference to the curve that is used to determine the calibrated age (Table 6.4).

Table 6.4.
Format for Presenting Radiocarbon Dates

Locality	Lab No.	Material Dated	Measured Radiocarbon Age	$\delta^{13}\text{C}$	Corrected Radiocarbon Age	2 Sigma Calibrated Age
Site 42 Feature 7	Beta-204718	Wood charcoal ¹	90 ± 40	-21.6	150 ± 40	A.D. 1666-1784 A.D. 1795-1892 A.D. 1908-1953
Feature 10	Beta-204719	Charred seed ²	240 ± 40	-17.0	370 ± 40	A.D. 1446-1530 A.D. 1539-1635
Feature 17c	Beta-240720	Organic detritus	2930 ± 60	-20.3	3010 ± 60	1411-1110 B.C. 1103-1073 B.C.

* AMS; Libby half-life

‡ CALIB 5.0.1; Reimer and others 2004; Stuiver and Reimer 1993

¹ mesquite (*Prosopis* sp.)

² cactus (*Opuntia* sp.)

A commonly used calibration curve is CALIB 5.0 that has been put together and recently updated by investigators at the Quaternary Isotopes Laboratory, University of Washington, Seattle (Reimer et al. 2004; Stuiver and Reimer 1993), and is available for downloading on the Internet (<http://depts.washington.edu/qil>). The CALIB 5.0 calibration curve now extends to about 26,000 calendar years B.P.

With this brief review of organic carbon, we now turn to inorganic carbon. Carbon is part of the elemental makeup of the minerals aragonite and calcite (CaCO_3); both minerals have the same chemical composition, but their atomic structures differ. The carbon in aragonite and calcite can be routinely radiocarbon dated, either by conventional or AMS methods, and it has been used to date mollusks and soil carbonates from archaeological and geoarchaeological contexts. While such dating has its advantages, neither process is without its shortcomings.

Mollusks precipitate aragonitic shells that have a pearly or nacreous luster. Snails and clams ingest “dead” or ^{14}C -depleted carbonate from the substrate or aquatic plants that has been used to provide relative dates to archaeological deposits. However, such dates will result in radiocarbon ages that are too old as shown in an interesting study in central Texas, a region with abundant limestone and calcic substrates. Shells of modern land snails (*Rabdotus dealbatus* and *Rabdotus alternatus*) formed before detonation of the first atomic bomb were obtained from museum collections and submitted for radiocarbon dating. Ten separate shell collections yielded ages ranging from 425-965 years B.P., averaging 690 ± 180 ^{14}C years B.P.. Given these results, about 700 years should be subtracted from radiocarbon dates on land snail shells before the ages are calibrated with a tree-ring curve (Goodfriend et al. 1999). The 700-year subtraction probably applies as well to land snails inhabiting the Tularosa Basin and Hueco Bolson where limestone and calcic substrates are common.

The radiocarbon dating of mollusk shell is further complicated by the geochemical condition that aragonite is less stable than calcite. After time and burial in sediments and in archaeological sites, the original aragonitic shell can recrystallize into calcite as part of normal diagenetic processes. Calcified fossil shells are recognized in the field because they have lost their pearly luster and, instead, are chalky white. The recrystallization process may incorporate additional ^{14}C -depleted carbon from old carbonates dissolved in soil-sediment moisture. Again, this results in radiocarbon ages that can be much older than the deposits in which the shells occur as fossils. In sum, calcified shells can yield finite radiocarbon dates, but the radiocarbon ages are of uncertain accuracy.

In contrast to mollusks, soil carbonates are exclusively calcite (CaCO_3) and can be routinely radiocarbon dated by both conventional and AMS methods. There are, however, three separate geologic-paleoecologic issues relating to the radiocarbon age of soil carbonates: (1) do the ^{14}C ages of the carbonates accurately represent the true radiocarbon age of the soil; (2) what is the relationship between the ^{14}C age of the soil carbonates, the age of the soil, and the age of the sediments in which the soil is developed; and (3) are the ^{14}C ages obtained from soil carbonates accurate, representing true absolute radiocarbon time? In other words, if a soil carbonate yields a ^{14}C age of 5000 ^{14}C years B.P., did that calcite actually precipitate 5,000 ^{14}C -years ago or did the calcite precipitate at some other time?

Turning first to the issue of the age of the soil and its parent material, it is important to note that soils form on stable surfaces. Concentrations of carbonates in soils are entirely secondary in origin, as they form in parent material that was deposited and present *before* soil development or pedogenesis occurred. Regardless of whether the parent material is Holocene, Pleistocene, or pre-Pleistocene, soil development *post-dates* the age of the deposits. The soil and its secondary carbonates are always younger (in absolute time) than its parent material, without exception. If the ^{14}C ages of soil carbonates were 100 percent accurate and absolute, the carbonate ages should always post-date the age of the sediments.

In order to assess the significance of ^{14}C ages of soil carbonates, then, it is necessary to consider where the carbonates come from and how they are incorporated into soils in south central New Mexico. Soil carbonates in arid regions in New Mexico and around the world are thought to originate from Ca^{2+} and CaCO_3 found in atmospheric dust and in rainfall (Birkeland 1999; Gile et al. 1981; Ruhe 1967). In south central New Mexico, seven dust-trap stations were collected for 5-10 years during the period 1962 to 1972, resulting in a range of 9.3 to 58.6 $\text{g/m}^2/\text{year}$ total dust averaged for each of the trapping stations. The carbonate content of the dust ranged from 1.3-5.7 percent (Gile et al. 1981: 63, 65). More recent trap studies of atmospheric dust related to soil development in southern California and Nevada indicate that modern deflation of dry playa surfaces are a major source of atmospheric carbonates that eventually end up in downwind soils. However, past shifts in Quaternary climate may also influence dust sources and the amounts of rainfall that in turn affect Pleistocene calcic soil development (Reheis et al. 1995, 2002). Calcium occurs in precipitation as well as in dust and, as pointed out by Gile and others (1981: 63), the Ca^{2+} in rainfall may produce two to three times the carbonate that originates from dry calcic dust.

In summary, it is generally accepted by earth scientists working in the arid Southwest that soil carbonates originate by influx of Ca^{2+} and CaCO_3 from both atmospheric dust and precipitation. The Ca^{2+} and HCO_3^- from precipitation and dissolved particulate CaCO_3 are carried in solution by rainwater moving downward in the soil profile until it is precipitated as calcite by decreasing CO_2 partial pressure, and loss of water through evapotranspiration. The chemistry of Ca^{2+} and CO_2 and how they form CaCO_3 in soils are discussed in more detail by Birkeland (1999). Recently, it has been suggested that bacteria may participate in the *in situ* carbonate precipitation in some soils (Loisy et al. 1999; Monger et al. 1991). However, the role of bacteria in soil carbonate production is yet to be determined, and the ^{14}C -age signature of bacteria-precipitated carbonate, if any, is unknown.

Numerous ^{14}C ages of soil carbonates are in the literature. From the beginning, however, many investigators worried that the carbonate ages were spurious. Working on the Desert Project near Las Cruces, New Mexico, Ruhe (1967: 60) concluded that radiocarbon dates from inorganic carbon in soils were unreliable. An early summary of paired organic-inorganic ^{14}C ages from arid land soils indicated that soil carbonate ages are about 3,600 years too old (Williams and Polach 1969). Additional studies in arid Australia indicate that, while inorganic carbon ages may be relatively in line, absolute ages on soil carbonate ages are 500-7,000 years too old (Williams and

Polach 1971). A summary of paired organic-inorganic carbon ages from paleosols in south central New Mexico shows that carbonate ages are 4,000-9,000 ¹⁴C years too old (Table 6.5).

Table 6.5.
Radiocarbon Ages of Paired Organic Carbon and Carbonate Samples from Calcic Paleosols,
South Central New Mexico

Organic-Carbon Age (¹⁴ C years B.P.)	Carbonate Age (¹⁴ C years B.P.)	Carbonate Age Too Old (¹⁴ C yrs)	Reference
4060 ± 70	10,300 ± 80	+6,240	Monger and Buck 1995: 31
4100 ± 90	10,190 ± 60	+6,090	Monger and Buck 1995: 31
4100 ± 70	10,620 ± 80	+6,520	Monger and Buck 1995: 31
11,000	15,000	+4,000	Gile et al. 1981: 77, 130*
21,000	29,000	+8,000	Gile et al. 1981: 77, 122**
21,000	30,000	+9,000	Gile et al. 1981: 77, 122**
9550 ± 300	13,850 ± 600	+4,300	Ruhe 1967: 60

* Picacho surface ("Late Pleistocene; 25,000 to 75,000 years")

** Upper La Mesa surface ("Middle Pleistocene; 250,000 to 900,000 years")

Ironically, while soil carbonate ¹⁴C ages are consistently older than associated organics, soil carbonate ¹⁴C ages from Pleistocene paleosols with Stage II-IV carbonate morphology are too young when compared with the geologic age of the paleosol (Table 6.6). Gile and others (1981: 110, 144) noted the discrepancy between the young ¹⁴C ages and old soils. Concerning their ¹⁴C dates from the Stage IV calcrete on the Jornada I surface, they (Gile et al. 1981: 110) state:

while these soils started their development in middle Pleistocene time, carbonate age in the K22m horizons is much younger. Occasional cracks in the petrocalcic horizons of these soils must have been well within reach of wetting during full-glacial times, and such wetting would result in a younger C-14 age.

A new investigation of paleosols in southern New Mexico also concluded that comparatively young carbonates are secondarily precipitated or "overprinted" on surfaces of older carbonates that are already present in the paleosol (Deutz et al. 2001, 2002).

Finite ¹⁴C ages from old calcic paleosols are not unique to southern New Mexico. The Caprock calcrete near Lubbock, Texas, regarded as Pliocene in age (Gustavson 1996), was sampled at 50 cm, 100 cm, 120 cm, and 310 cm depth below the surface, and yielded ¹⁴C ages on carbonates ranging from 18,500-32,000 ¹⁴C years B.P.; organic carbon was dated from 8,500-18,000 ¹⁴C years B.P. (Karlsson et al. 1996). In paired samples, the organic dates were always younger than the inorganic dates, similar to what has been documented in southern New Mexico. Nonetheless, the finite organic and inorganic ¹⁴C ages from the Caprock calcrete are a puzzle.

Are ¹⁴C ages of soil carbonates absolute, or are they "off" from true radiocarbon time? At present, the empirical record from southern New Mexico suggests that ¹⁴C dates on secondary carbonates do not produce reliable absolute ages. Additional advances in theoretical geochemistry are needed to show the way to useable radiocarbon dates from soil carbonates. The following three points summarize the current observations on carbonate ¹⁴C ages:

Table 6.6.
Finite Radiocarbon Ages from Secondary Carbonates in Geologically-Dated Paleosols, South Central New Mexico

Soil	Carbonate Age (^{14}C years B.P.)	Carbonate Sample (cm depth in soil profile)	Stage of Soil Carbonate Morphology	Reference
Organ alluvium (late to middle Holocene, 0.1 to 7 ka) **	3120 \pm 70	Filament (68 cm)	I	Deutz et al. 2001: 299
Isaacks' Ranch alluvium (earliest Holocene-latest Pleistocene, 7.5-22 ka) **	3710 \pm 70	Filament (45 cm)	I	Deutz et al. 2001: 299
	11,870 \pm 100	Interpebble (50 cm)	I	Deutz et al. 2001: 299
	9390 \pm 70	Interpebble (50 cm)	II	Deutz et al. 2001: 299
	2960 \pm 50	Interpebble (92 cm)	II	Deutz et al. 2001: 299
	14,980 \pm 80	Coating (95 cm)	II	Deutz et al. 2001: 299
	20,840 \pm 110	Matrix (120 cm)	II	Deutz et al. 2001: 299
Picacho surface (late Pleistocene, 25-75 ka) **	15,000	Laminar (30-34 cm)	IV	Gile et al. 1981: 128, 130
	29,990 +1400/-1200	Pebble coat (89-122 cm)	III	Gile et al. 1981: 102-103
Post-Jornada surface (ca. 75-250 ka) **	20,300 \pm 800	Nodule (64-135 cm)	III	Gile et al. 1981: 169
Jornada II (late Pleistocene, >150 ka) **	>30,000 ‡	Nodule (165-226 cm)	III	Gile et al. 1981: 169
	2260 \pm 70	Discrete nodule (60 cm)	II	Deutz et al. 2001: 299
	13,260 \pm 70	Discrete nodule (70 cm)	II	Deutz et al. 2001: 299
	23,030 \pm 120	Orthic nodule (135 cm)	II	Deutz et al. 2001: 299
Jornada I surface (late middle Pleistocene, 250-400 ka) **	24,530 \pm 460	Interpebble (207 cm)	II-III	Deutz et al. 2001: 299
	25,000	Pebble coat (43-64 cm) †	IV	Gile et al. 1981: 110
	20,000	Pebble coat †	IV	Gile et al. 1981: 110
	27,000	Matrix (231-262 cm)	IV	Gile et al. 1981: 144
	17,640 \pm 90	Discrete nodule (48 cm)	II	Deutz et al. 2001: 299
Lower La Mesa surface (730-900 ka) **	18,010 \pm 110	Discrete nodule (48 cm)	II	Deutz et al. 2001: 299
	11,720 \pm 160	Discrete nodule (48 cm)	II	Deutz et al. 2001: 300
	18,070 \pm 120	Discrete nodule (50 cm)	II	Deutz et al. 2001: 300
	9220 \pm 60	Orthic nodule (50 cm)	II	Deutz et al. 2001: 300
	4590 \pm 60	Orthic nodule (50 cm)	II	Deutz et al. 2001: 300
	5720 \pm 50	Orthic nodule (65 cm)	II	Deutz et al. 2001: 300
	11,020 \pm 120	Orthic nodule (80 cm)	II	Deutz et al. 2001: 300
	9700 \pm 70	Orthic nodule (82 cm)	II	Deutz et al. 2001: 300
	29,000	Laminar (48-74 cm) §	IV	Gile et al. 1981: 121-122
	30,000	Laminar (48-74 cm) §	IV	Gile et al. 1981: 121-122
Upper La Mesa surface (400-1500 ka) **	28,000	Pugged zone (74-102 cm)	IV	Gile et al. 1981: 121-122

‡ The only "dead" or ^{14}C -depleted sample in the Desert Project (Gile et al. 1981: 169)

† Carbonate coats on gravels below the laminar horizon

§ Upper and lower parts of strongly indurated zone in middle of laminar horizon

*Stage of carbonate morphology from Birkeland (1999) and Machette (1985); stage designation for these samples from Deutz and others (2001)

** Age of deposits and surfaces from Gile and others (1981: 38) and modified in Deutz and others (2001)

- Paired organic-carbonate ^{14}C ages show that carbonate ages are consistently older by 4,000-9,000 years.
- Carbonate from geologically old paleosols with Stage II-IV carbonate morphology yield finite ^{14}C ages ranging from 2,300-30,000 years B.P. While this must mean that secondary carbonates are migrating downward into calcrete profiles, the exact process has not been identified.
- The assumption that ^{14}C ages on secondary carbonates provide absolute ages in true radiocarbon years has not been validated by the empirical record or by any theoretical geochemical model.

Clearly, there are serious complications with radiocarbon dating of soil carbonates. It is evident that radiocarbon dating cannot provide true ages of calcic paleosols, nor can radiocarbon dating provide reliable ages for the sediments in which the soils are formed. In published records, Holocene deposits generally yield Holocene ^{14}C ages and late Pleistocene deposits generally yield late Pleistocene ages. While carbonates may yield ^{14}C ages that are in relative sequence, youngest to oldest, the absolute accuracy of soil carbonate ages has not been shown. At best, soil carbonate ages may be off by 3,000 years, or more, for Holocene deposits. Accordingly, soil carbonate ^{14}C ages themselves cannot be used as a reliable absolute chronology for associated sequences of stable isotopes. One can only conclude that carbonate ^{14}C ages are unreliable for dating sedimentary sequences and their contained archaeology in southern New Mexico.

OSL Dating Evidence and Revised Chronologies

Optically stimulated luminescence dating is also discussed in detail in Chapter 5. In this section it will only be discussed in relation to geomorphic research. OSL was developed in the 1980s as a variation of TL dating (Aitken 1998). In OSL dating, the sample is activated by a laser beam. Small samples can be analyzed, and numerous aliquots or subsamples can be run, resulting in accurate ages with narrow standard deviations. OSL dating can be applied routinely to sediments from 50-200,000 years old. OSL ages are in calendar years.

OSL dating has been successfully applied to the eolian sand deposits at Fort Bliss, and the specific information presented and discussed below is based on the results from new studies (Hall 2002, 2007). The material dated by OSL is quartz sand grains in the 90-150 micrometer (μm) size fraction, equivalent to upper very fine to lower fine sand on the Wentworth scale (Folk 1968), the predominant size of sand deposited by wind at Fort Bliss as well as worldwide. While quartz is the preferred mineral, OSL ages can also be obtained from potassium feldspar and zircon, using different laboratory techniques.

The OSL signal or age of quartz sand grains is a function of the amount of time the sand grains are buried and the amount of natural radioactivity in the sediments. When a sand grain is deposited and buried, it is bombarded by decay particles from radioactive minerals in surrounding sediments. At Fort Bliss, the eolian sand includes a component of 0.8-1.3 ppm of uranium and 4.4-6.0 ppm of thorium, both radioactive elements. During the radioactive decay of these elements, decay particles are produced that strike quartz grains, dislodging electrons that are then accumulated in traps or irregularities within the atomic structure of the quartz grains.

With the passage of time as the sedimentary deposit becomes older, more electrons become trapped. In the laboratory, the grains are bombarded with laser light, and a photon signal is released from the sample and measured; the larger the signal, the older the sample. Ideally, the sample is zeroed out before it was geologically deposited and thus any previous luminescence signal in the quartz grains was lost during exposure to sunlight; zeroing can occur in a few minutes.

Eolian deposits at two archaeological sites at Fort Bliss have been dated by OSL (Hall 2002, 2007). Both series of OSL ages have provided new interpretations as well as raising new questions concerning the late Quaternary eolian geomorphology and associated archaeological geology of the area.

El Arenal Site (FB 12650)

A series of eight OSL ages were obtained at the El Arenal Site (FB 12650) on eolian sand deposits that were identified as Q2 and Q3, using the Blair stratigraphic-geomorphic classification (Blair et al. 1990a, 1990b). The archaeological materials at the site are on the surface of the sand, but trenching exposed 152 cm of Q3 sand deposits resting directly on the Q1 calcrete. Historic coppice dunes (Q4) on the Q3 sand are common at the site. Artifacts and features occur on the present-day surface of the Q3 sand. The stratigraphy of the sand sheet at the site with OSL ages is shown in Figures 6.25 and 6.26.

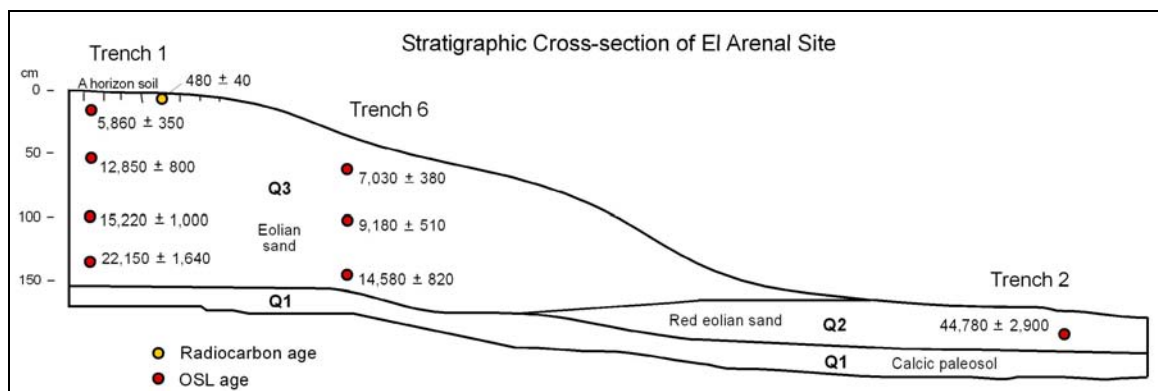


Figure 6.25. Sketch of Q2 and Q3 eolian sand with position of OSL ages. (The 480 ± 40 years B.P. age of the A horizon soil that caps the sand sheet is a radiocarbon date, the 44,780 ± 2900 years B.P. OSL age from the thin exposure of the reddish Q2 eolian sand may be a minimum age).

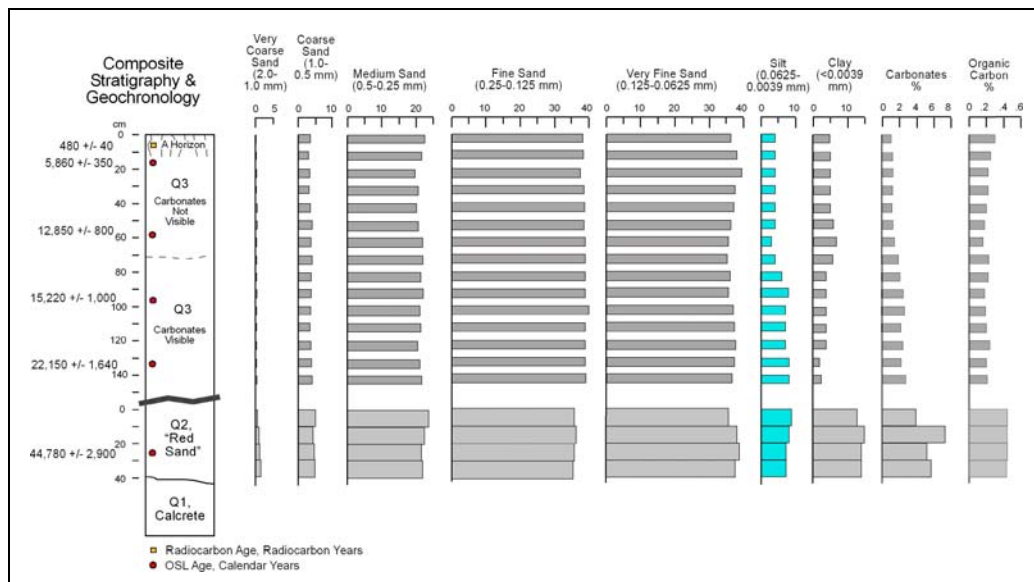


Figure 6.26. Composite stratigraphy, OSL ages, and sedimentology at El Arenal Site. (Higher percentages of silt may represent glacial-age atmospheric influx).

The OSL ages indicate that the Q3 eolian sand was deposited during the period 22,000-5,000 years B.P. (calendar years). The stratigraphic sequence from which the OSL ages were obtained shows no unconformity. Textural analysis of the sand also shows no discontinuity in eolian sedimentation (see Figure 6.26). The upper levels of the sequence have higher amounts of organic carbon associated with the A horizon soil. The entire sand column is calcareous and, below about 70 cm in depth, carbonate coats on sand grains give a whitened color to the sand. Higher percentages of silt below 80 cm depth may correspond to higher dust influx related to glacial-age winds and accompanying atmospheric dust and loess environment.

A slight clay bulge occurs at 50-80 cm depth. However, it is not clear if this is due to primary deposition or pedogenesis. If it is due to pedogenesis, there is no accompanying visible Bw horizon, and the slightly higher percentages of clay were not visible or discernable in the field.

A single OSL age from the red Q2 sand is $44,780 \pm 2900$ years B.P. The Q2 sand is not as well sorted as the Q3 sand and has more clays, carbonates, and organic carbon. The red color may be related to the presence of clay (13-15 percent) and iron oxalates (0.015-0.018 percent). The red Q2 sand is interpreted as an eroded Bt horizon of a Wisconsin-age paleosol. Based on this date, the age of the red Q2 sand is clearly too old for prehistoric sites unless they are intrusive into that unit.

Radiocarbon ages from the site range from 4030 ± 70 to 400 ± 40 ^{14}C years B.P., with the earliest age calibrated to no older than ca. 2800 B.C. The OSL age for the top of the sand sheet at 16 cm deep (at a location where the A horizon soil is intact, thereby avoiding disturbance of the sand as much as possible) is 5860 ± 350 years B.P. or ca. 3800 B.C. The OSL ages from the sand and the radiocarbon ages from the archaeological site are entirely consistent. The sand sheet has been quasi-stable since ca. 3800 B.C., and the prehistoric occupation of the site on the sand sheet began by ca. 2800 B.C. Indeed, since the sand sheet at this locality has been stable for 5,800 years, it has also been "available" as an occupation surface during all of that time. However, archaeological sites older than ca. 3800 B.C. would be buried in the sand sheet at this locality.

41EP5396

A second application of OSL dating has resulted in a series of four OSL ages from Q3 eolian sand and one age from the base of an historic coppice dune (Figure 6.27). The geochronology and sedimentology of 41EP5396 illustrate new aspects of the Q3 sand sheet as compared with the results from El Arenal.

The Q3 eolian sand at the site is about 70 cm thick and rests directly on the Q1 calcrete. The OSL ages range from 7690 ± 480 to 1390 ± 130 years B.P., significantly younger than the Q3 sand at El Arenal, although the earlier period of Q3 sand deposition simply may not have occurred here. However, the upper 30 cm of eolian sand at this locality is coarser textured, with higher amounts of medium sand, less very fine sand, less silt, less clay, and especially fewer carbonates than occurring below 30 cm depth (see Figure 6.27). This change in sediment does not appear in the field to be associated with an unconformity. At the outcrop, the stratigraphy appears uninterrupted. Coinciding with the sediment change, the two younger OSL ages may represent a second phase of slightly coarser Q3 eolian sand deposition in the past 4,000 years that was not present at El Arenal. At this stage of research, however, it is too early for more than idle observation on this topic.

Cesium-137 Age of Coppice Dunes

While coppice dunes are regarded as historic, little is known about the geographic sequence of dune formation during the twentieth century. Short-lived isotopes may be a way to get a handle on the age of the dunes. Cesium-137 is a short-lived (ca. 30 years) radioisotope found in nuclear

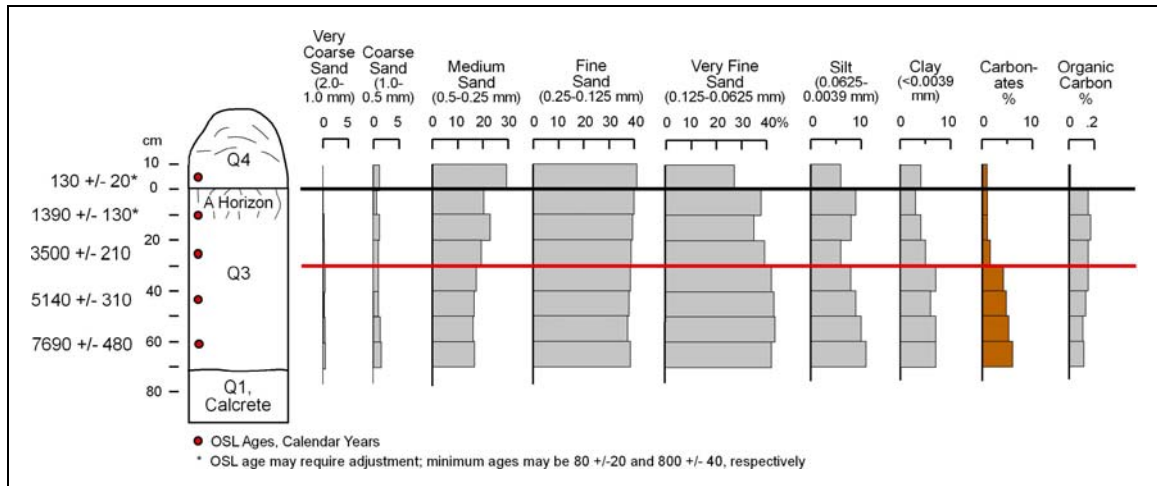


Figure 6.27. OSL ages, stratigraphy, and sedimentology at 41EP5396.

(The coarsening of the sediment at a 30-cm depth accompanied by a sharp decrease in carbonates indicates the presence of a local unconformity [red line] in the Q3 sand. The age of the sand above 30 cm is younger than the El Arenal sequences, possibly indicating a younger episode of local sand accumulation on the sand sheet. The coppice dune sand [Q4] above the black line is coarser than the older Q3 sand).

power plants and produced by atmospheric testing of atomic bombs. Beginning ca. 1954 and peaking in 1963, atmospheric testing produced ^{137}Cs that was dispersed worldwide and incorporated as fallout into recently forming sedimentary deposits (Jeter 2000).

At El Arenal, sand samples were taken from the excavated face of a coppice dune and analyzed for ^{137}Cs . The entire dune has ^{137}Cs , although in very small amounts at the margin of laboratory detection. It is tentatively concluded that the coppice dunes at El Arenal formed after 1954.

Another case study is a small 95-cm high coppice dune in the Mescalero Sands. The upper 22 cm of the dune contained ^{137}Cs , indicating that the upper part of the dune began accumulating since ca. 1954 and that the lower part predates 1954 (Hall 2002). Unfortunately, absolute ages from ^{137}Cs analysis are not possible, only pre- or post-1954 can be determined.

Comparison of OSL and Radiocarbon Dating

OSL has the potential to become one of the most important methods of Quaternary geochronology, sharing the spotlight with radiocarbon dating. At present, however, the only laboratories doing OSL are university labs. For many years, radiocarbon dating was also conducted entirely at university labs. The development of commercial laboratories for radiocarbon dating since the 1970s has been a boon for the science of archaeology. Hopefully, a reliable commercial OSL lab will go into operation soon.

With present technology, radiocarbon ages tend to have more precise ages. When the 1-sigma standard deviation of OSL and ^{14}C ages are compared, OSL ages tend to cluster around 6 percent while ^{14}C ages cluster at 2 percent although there is some overlap; young ages for both methods generally have higher sigma percents (Figure 6.28). On the other hand, OSL ages are in calendar years and do not require calibration. Radiocarbon years require calibration that, because of the meandering of the tree-ring curve, may double the sigma percents of some calibrated ^{14}C ages, although this is not universally the case. The tree-ring calibration curve since ca. 1500 A.D. is especially sinuous, however, resulting in ^{14}C ages with uncertain accuracy for the past 500 years. OSL is not plagued by the problem of a variable radiocarbon content of the atmosphere.

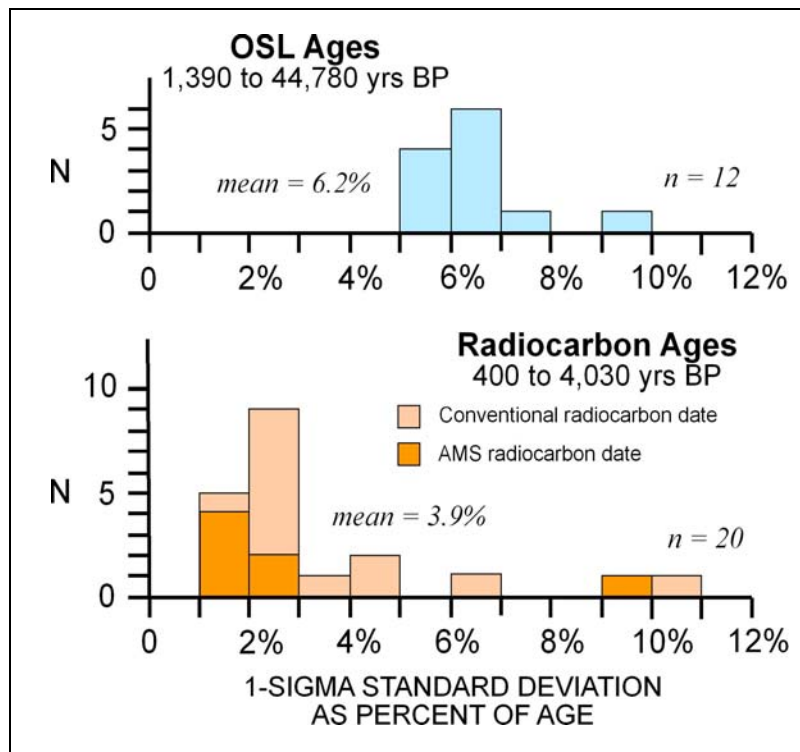


Figure 6.28. Comparison of 1-sigma standard deviation of OSL and radiocarbon ages as a percentage of the age in both cases. (OSL dates are from Figure 6.25 [excluding the Q4 date] and all radiocarbon dates from El Arenal Site [Miller 2007a]. Larger sigma percentages occur with youngest ages).

GEOMORPHOLOGY, GEOARCHAEOLOGY, AND CONTEXTUAL INTEGRITY

The lines of inquiry addressed in this chapter are all concerned with the context of archaeological phenomena in the sense employed by Butzer (1982). Butzer defines archaeological context as:

...a four-dimensional spatial-temporal matrix that comprises both a cultural environment and a noncultural environment and that can be applied either to a single artifact or to a constellation of sites (Butzer 1982: 4).

and argues for a contextual archaeology that:

...will transcend the traditional preoccupation with artifacts and sites in isolation, to arrive at a realistic appreciation of the environmental matrix and of its potential spatial, economic, and social interactions with the subsistence-settlement system (Butzer 1982: 12).

Obviously, the aspects of archaeological context addressed here are a subset of those subsumed under Butzer's definition. In particular, the geoarchaeological lines of inquiry proposed above are designed to address (1) landscape context, or the configuration of the landscape both at the time of site formation and subsequent to formation, including both the geomorphic configuration and the biotic matrix; (2) depositional context, or the character, depositional agents, and energy

conditions represented by sediments that the site is developed in; (3) temporal context of the site; and, (4) spatial and stratigraphic context of artifacts and features within the site matrix.

One of the most important aspects of this approach is evaluation of the integrity of an archaeological site; that is, the extent to which the three-dimensional distribution of artifacts within the site matrix reflects behavioral processes of the people responsible for that distribution. Artifact distributions are the sum consequence of cultural and natural processes acting on artifacts from the time of initial discard to the time that they are collected by an archaeologist. Schiffer (1983; 1987) employs the term *formation processes*, and differentiates between C-transforms (cultural processes) and N-transforms (natural processes).

Binford (1981) has taken strong issue with the concept of C-transforms, arguing that all cultural transforms are reflections of behavior, which is obviously true. Nevertheless, Schiffer's point is well taken; to cite an extreme example, examination of spatial relationships among artifacts in a bulldozed archaeological site is likely to tell you much more about the cultural process of bulldozing than the original behavior forming the site. If the goal of the investigation is to understand that original behavior, it follows that subsequent cultural disturbance must be viewed as a filter that does indeed distort the record of interest.

The preceding sections have focused on geological and pedological processes and deposits that affect and structure the archaeological record in the vicinity of Fort Bliss; they are essentially a summary of the most important N-transforms affecting the record. Understanding of these processes allows inference about the degree to which the archaeological record is distorted by postdepositional factors. The degree of contextual integrity is a very important component of the overall research potential of a site.

Determination of contextual integrity is not a simple yes-or-no matter. Rather, it is important to view integrity as a continuum that begins with a factors associated with the initial formation of the assemblage and proceeds through increasing levels of disorganization (disturbance) to total entropy. As the preceding discussions suggest, the likelihood that a purely behavioral assemblage will be preserved (the "Pompeii premise" of Ascher [1961]) is exceedingly small because postdepositional processes will always have some effect on the preservation and internal spatial relationships of an assemblage. However, the degree to which those processes have altered the spatial relationships between artifacts is highly variable. Thus, an archaeological site that has experienced minor spatial and stratigraphic disturbance has higher information content, and therefore should be considered more valuable than a site that has experienced significant disturbance or has been completely deflated. Yet even these sites have information potential and should be considered more valuable than a heavily bulldozed site or a deflated site whose tool assemblage now rests in a variety of coffee cans in the basements of local collectors.

Although stratigraphic and spatial integrity are desirable, some information can be recovered from sites where that integrity has been lost. However, if that loss of integrity results in the intermingling of more than one component into an inseparable palimpsest, the research potential of the site is sharply reduced.

Finally, it must be pointed out that simple site-by-site evaluation, coupled with overly strict adherence to integrity in site evaluations, can itself bias the archaeological record. Just as resources are patterned on the landscape, the character of geomorphic and sedimentary processes also vary spatially. Moreover, the distribution of resources is in large part governed by the distribution of different landforms and sedimentary environments.

Thus, many important aspects of an adaptive system may occur in local environments that are not particularly conducive to preservation, and slavish devotion to integrity as a necessary threshold for significance can lead to the neglect of those sites, skewing perception of the overall adaptive

system under study. However, if the evaluation process is structured around geomorphic landscape subdivisions, and integrity criteria applied to each individual site are gauged independently relative to the potential for preservation in each geomorphic environment, then much of this bias can be overcome.

Archaeological Significance of the New OSL Chronology of the Sand Sheet

The previous chronology of the Tularosa Basin and Hueco Bolson sand sheet was based largely on radiocarbon dates from archaeological sites. Geologists assumed that sites in the sand were contemporaneous with deposition of the sand sheet, not realizing that, for the most part, the sites were intrusive and that the sand largely pre-dated the archaeological record. This assumption was discussed by Hall (2002: 26-28) in a study of the Mescalero Sands in southeastern New Mexico and its correlation with the Tularosa Basin and Hueco Bolson sand sheet. The following is a revised discussion of the local geochronology that tries to correct that assumption.

Q1 Calcrete

Underlying the Tularosa Basin and Hueco Bolson sand sheet is a well-developed calcrete with Stage III-IV carbonate morphology. Blair and others (1990a, 1990b) conveniently referred to it as "Q1," the oldest of four Quaternary units they were investigating. They estimate its age as 50 to 250 ka, a reasonable guess, although its absolute age is yet to be determined.

Q2 Red Eolian Sand

The Q2 sand is generally less than 150-cm thick and is missing in many areas because it has been eroded away. This red sand unit is eolian in origin but has been weathered and is largely a Bt argillic soil with an underlying Stage II calcic horizon. The age of the Q2 sand was thought to be 15,000-9,400 years based on various lines of evidence. However, the age is too young for a strong argillic soil with Stage II carbonates to form. The single OSL from the Q2 unit has an age of $44,780 \pm 2900$ years B.P. which is more consistent with the advanced degree of soil development and the unit's geomorphic position in the landscape. Although the initial early Holocene-late Pleistocene age of the Q2 sediments left open the possibility that it might contain a prehistoric record, archaeological sites have not been reported from the Q2. The OSL age of the unit is clearly too old for prehistoric sites unless they are intrusive into that unit.

Q3 Eolian Sand

Although the Q3 is the main sand body on the sand sheets in the Tularosa Basin and Hueco Bolson, it is generally less than 100-cm thick and is missing in some areas. It is a massive unit of eolian sand that lacks soil development. Its age assignment, 7,300-400 years B.P., is based on radiocarbon dates of charcoal from archaeological sites as well as with correlation with radiocarbon-dated alluvium in the region. However, the OSL ages from the Q3 sand at the El Arenal Site are from ca. 22,000-5,000 years B.P. (Table 6.7 and Figure 6.29).

At El Arenal, the archaeological deposits date to a period younger than ca. 4,000 years and all site features are in the top of the sand sheet. At a second site, 41EP5396, a local occurrence of an additional 30 cm of eolian sand was deposited between ca. 4,000 and 1,200 years B.P. How representative these two studied areas are, and how the OSL-dated sand correlates across the sand sheet remains to be understood. Clearly however, all of the archaeological sites in the Tularosa Basin and Hueco Bolson are to be found either within or on top of the Q3 sand.

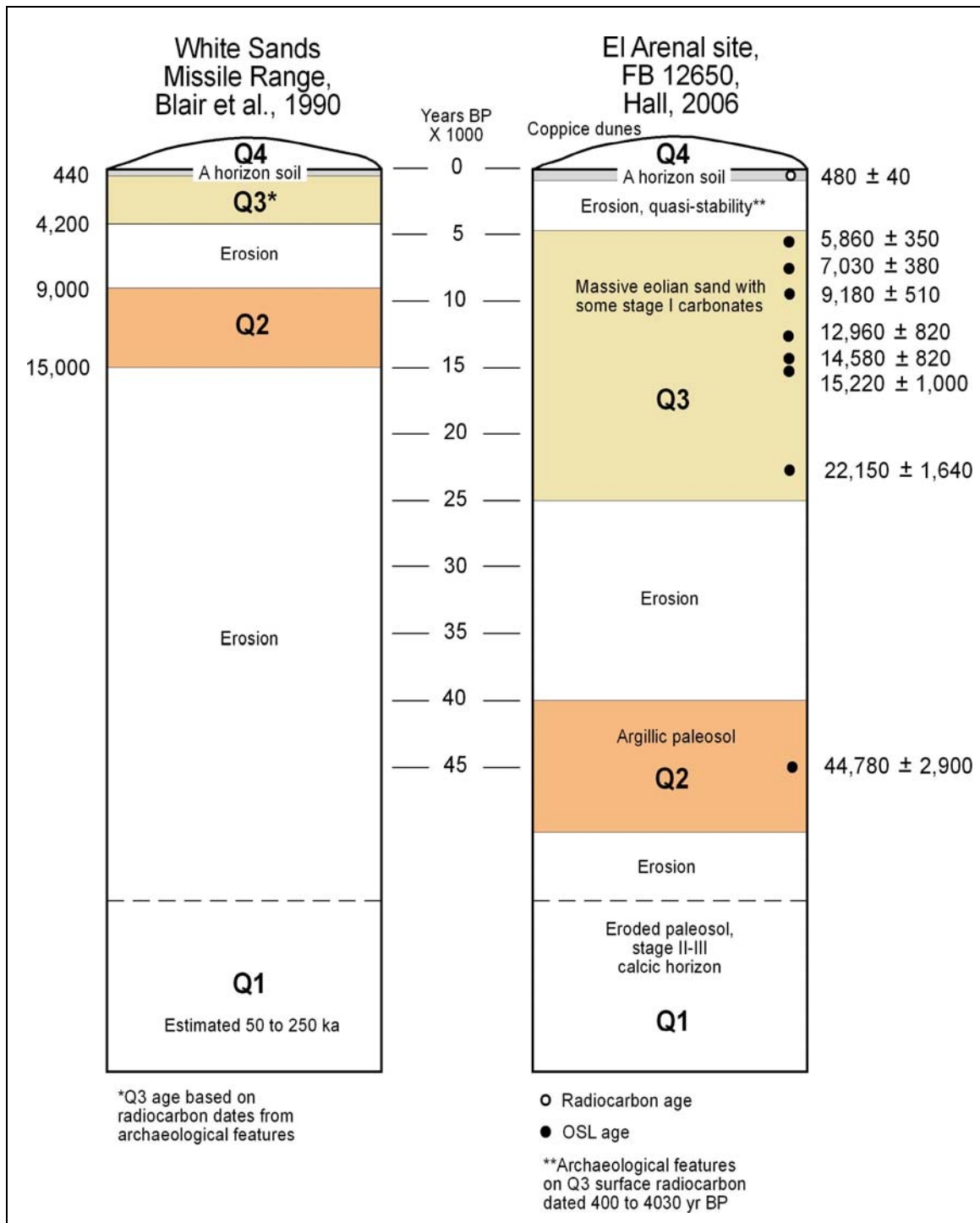


Figure 6.29. Correlation of OSL ages from El Arenal (Hall 2007) with radiocarbon-based chronology of the Q1-Q4 unit stratigraphy at White Sands Missile Range. (Blair et al. 1990a)

Table 6.7.
Summary of OSL Ages from Fort Bliss
(from Hall 2007 and unpublished data)

Lab No.	Site	Depth	Stratigraphic Unit	OSL Age* (calendar years, 1-sigma)
UNL-701	El Arenal, trench 1	16 cm †	Q3	5860 ± 350
UNL-700	El Arenal, trench 1	58 cm	Q3	12,850 ± 800
UNL-699	El Arenal, trench 1	96 cm	Q3	15,220 ± 1000
UNL-698	El Arenal, trench 1	134 cm	Q3	22,150 ± 1640
UNL-866	El Arenal, trench 6	20 cm	Q3	7030 ± 380
UNL-865	El Arenal, trench 6	55 cm	Q3	9180 ± 510
UNL-864	El Arenal, trench 6	95 cm	Q3	14,580 ± 820
UNL-867	El Arenal, trench 2	27 cm	Q3	44,780 ± 2900
UNL-1489	41EP5396, trench 1	base of dune	Q3	130 ± 20 60 ± 10 ‡
UNL-1485	41EP5396, trench 1	10 cm	Q3	1390 ± 130 800 ± 40 ‡
UNL-1486	41EP5396, trench 1	26 cm	Q3	3500 ± 210
UNL-1487	41EP5396, trench 1	43 cm	Q3	5140 ± 310
UNL-1488	41EP5396, trench 1	61 cm	Q3	7690 ± 480

* OSL ages are given in years before the year they were determined in the laboratory; there is no “zero” year for reference, such as the 1950 zero year in radiocarbon dating; OSL ages are automatically measured in calendar years

† The upper 10 cm of the section is the young A horizon soil; the OSL sample was collected 6 cm below the A horizon
‡ Partial bleaching or mixing in each of these two samples; a calculated minimum age may be more accurate burial age, using the minimum age model of Galbraith and others (1999, *Archaeometry*, v. 41: 339-364); the samples were processed and analyzed in 2006, hence a minimum OSL age of the base of the small coppice dune is A.D. 1946 ± 10 years.

Q3A, A Horizon Soil

A 10-20 cm thick, weak A horizon soil occurs at the top of the Q3 sand in the Tularosa Basin-Hueco Bolson, except where it has been removed by recent erosion. It probably formed on a stable surface protected by desert grasses. In the Blair and others (1990b) study, the A horizon was thought to be the top of the Q3 sand and an end of deposition and stability of the Q3 sand unit. Johnson (1997) reported the A horizon at the McGregor Range in the bolson as well. In another study, the A horizon was radiocarbon dated 160 ± 90 ^{14}C years B.P. (Swift 1991b).

At El Arenal, the same A horizon is dated 480 ± 40 ^{14}C years B.P. (Hall 2007). The A horizon soil has been observed on protected uneroded surfaces throughout southern New Mexico, especially in eolian sand. In the Mescalero Sands, the A horizon soil occurs in eolian sand, alluvium, and colluvium. It also rests directly on the eroded surface of the late Pleistocene red sand. In the Mescalero Sands, it is named the Loco Hills soil and is dated 370 ± 40 to 150 ± 40 ^{14}C years B.P. (Hall 2002; Hall and Goble 2006).

Q3A Soil and Anthrosols

The Q3A soil should not be confused with a site’s anthrosol. The accumulation of organic materials, especially charred particles, at archaeological sites can over time produce a dark gray zone with continued occupation. The resulting thick organic layer looks like an A horizon soil. It actually is an A horizon, after a fashion, although entirely cultural in origin. When a site is abandoned, the surface may be stabilized by grasses that will form a natural A horizon soil, such as the Q3A soil. When excavated, the anthrosol and Q3A soil may be indistinguishable. However, away from the site, the anthrosol quickly thins out and the younger, natural A horizon will continue across the landscape.

Historic Q4 Eolian Sand and Coppice Dunes

The surface of the Tularosa Basin and Hueco Bolson is characterized by coppice dunes. The dunes follow the geographic spread of mesquite. Land survey records indicate that the dunes appeared after ca. 1880 (Gile 1975a). A study of tree growth rings in a coppice dunefield in southern New Mexico indicates that 62 percent of the mesquite germinated during the period ca. 1931-1941 (Gadzia and Ludwig 1983). At the El Arenal Site, the Q4 eolian sand occurs as two facies, a lower massive sand with small pebbles with a thickness up to 75 cm overlain by the stratified coppice dune with a maximum thickness of about 65 cm. From a variety of evidence then, the coppice dunes are historic in age.

In the coppice dunes, the areas around the dunes are generally eroded, exposing artifacts and burned rock from archaeological sites. It is always thought that, beneath the dune, *in situ* features can be found. Based on observations by Hall (2002) in southern New Mexico and the adjacent Trans-Pecos region of Texas, sites that are eroded around a dune are likely eroded beneath the dune, too. In other words, the sites may have eroded before the coppice dune formed (Figure 6.30).

Sedimentation Rates

Three columns of OSL ages from the Q3 eolian sand (two from El Arenal and one from 41EP5396) have produced net sedimentation rates that are very low and at the same time consistent between the two sites. The net rates are 0.076 and 0.099 mm/year at El Arenal and 0.082 mm/year at 41EP5396. These net sedimentation rates are equivalent to 1 cm per 131 years, 1 cm per 102 years and 1 cm per 121 years, respectively (Figure 6.31). Not only are the net rates from the three sand columns very similar, but the correlation coefficients for depth versus age are strong, $r = 0.98-0.99$.

The sedimentation of the Q3 sand sheet was very slow and steady for 17,000 years until about 5,000 years ago when sediment accumulation halted. Evidence of soils or erosional unconformities or other indications of major stratigraphic breaks in sedimentation of the Q3 sand during this time are absent. Thus, the environment during the time of sand sheet accumulation must have been very different from the situation seen today. While today rapid deflation and accumulation of large coppice dunes occurs, these processes were evidently not occurring during the time the sand sheet was forming. The sand sheet may have accumulated in a quasi-stable state, with slow influx of fine-very fine sand to a surface protected by sagebrush grassland vegetation that dominated the region during the Wisconsin (Hall 2001, 2005).

If the top of the Q3 eolian sand sheet is ca. 5,000 years old, then archaeological sites older than 5,000 years may be buried in the sand. This is especially true at El Arenal, where the age of the eolian sand ranges from ca. 5,000-22,000 years B.P. Hence, since the age of the Clovis complex, for example, is about 13,000 cal years old (Waters and Stafford 2007), based on the net sedimentation rate at El Arenal, any extant Clovis occupation would occur at 71 or 83 cm in depth in the sand sheet (see Figure 6.31).

A site buried at that depth would be unlikely to have artifacts or materials showing at the surface unless severe bioturbation had occurred. Importantly, at site 41EP5396, the Q3 sand sheet record begins only ca. 8,000 years ago. If a Clovis-age site had been present at that locality, it would be resting on the eroded surface of Q1 calcrete and be buried by the eolian sand.

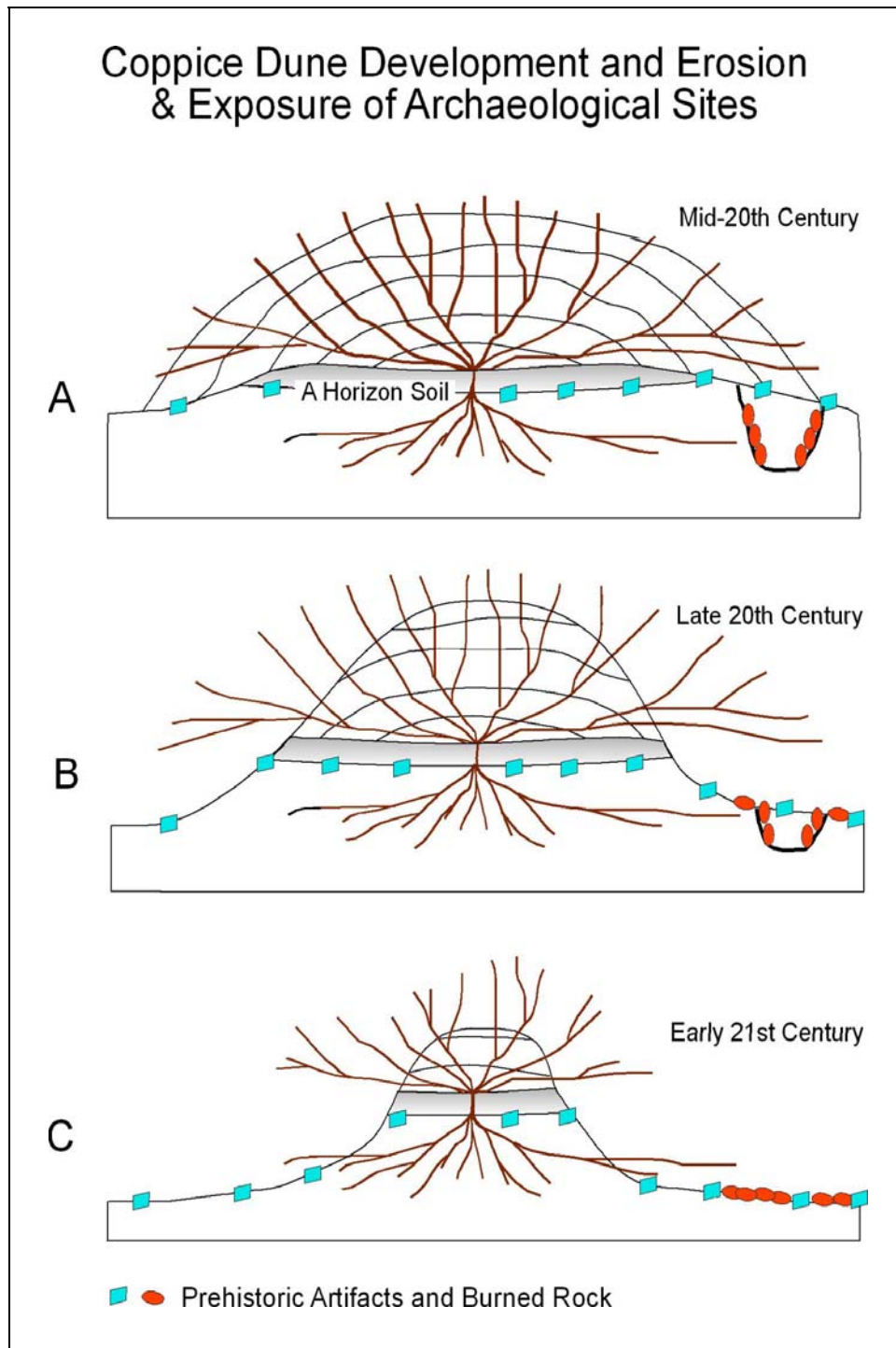


Figure 6.30. Deposition and erosion of mesquite coppice dunes, southern New Mexico. (modified from Hall and Goble 2006)

(In less than 130 years, Torrey mesquite and accompanying coppice dunes spread over the landscape; while many sites were already eroded, site erosion became exacerbated with the recent trend towards loss of the dunes. Note that during the erosional stage, prehistoric sites appear to be “in” the dunes; instead, the dune has evolved from a depositional to an erosional landform, forming a pedestal that includes older pre-dune sediments at the base that incorporate the sites).

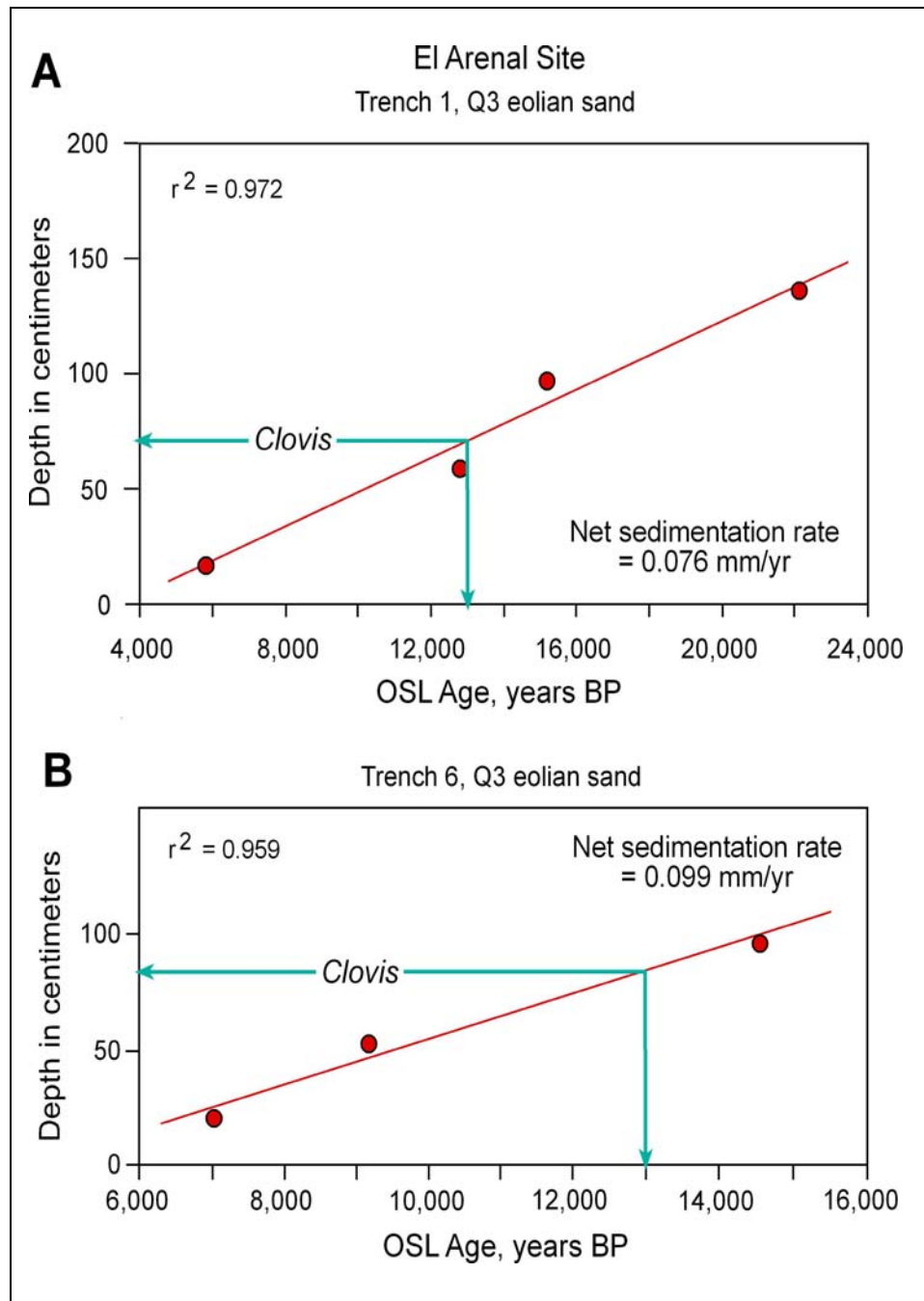


Figure 6.31. Sedimentation rates at El Arenal Site based on OSL ages versus depth at (A) Trench 1 and (B) Trench 6.

(The age of the Clovis Complex is about 13,000 cal years B.P. and is equivalent to 71 and 83 cm depth in the Q3 sand sheet at this locality, respectively; the extrapolated ages for the base and top (excluding 10 cm for the young A horizon soil) of Q3 sand at Trench 1 are 24,650 to 5070 years B.P.; extrapolated ages for the base and top of Q3 sand at Trench 6 are 16,300 to 5010 years B.P.)

The ultimate geomorphic and geoarchaeological implications of the revised chronology and sedimentation rates are that eolian depositional processes in the central basins may have been too slow and prolonged to result in the formation of vertically separated and stratified cultural deposits for archaeological components dating after 5000 B.P. This helps explain the rarity of isolatable stratigraphic contexts in basin landforms at Fort Bliss and surrounding areas.

More critically, it creates several implications for evaluating research potential and integrity of archaeological sites. If there was little or no vertical separation among prehistoric occupations and activity locations in the first place, then the issue of stratigraphic integrity is pointless for considerations of research potential and integrity. Instead, the common observation that features of different age are generally positioned at equivalent elevations suggests that the finding of preserved features equates with some degree of geomorphic integrity.

The implication of these differing models and perceptions of stratigraphic site formation is that archaeologists may have to focus more on elucidating patterns of *horizontal* integrity among distributions of prehistoric features and artifact distributions in the basin landforms. This would involve a fundamental reorientation of the concept of site structure, in that evaluations of research potential would be based on whether isolatable temporal and occupational components can be differentiated across the horizontal dimension of basin landscapes.

While this is by no means a simple proposition, a consequential effect is that a revised emphasis on the horizontal dimension of spatial integrity may actually help simplify the often difficult conceptual relationship between geomorphic (i.e., stratigraphic) integrity and chronometric potential. Both chronometric and geomorphic integrity may be demonstrated in tandem provided that a sufficient portion of the Q3 stratum is present to retain cultural features and remnants of features.

RECOMMENDATIONS AND FUTURE DIRECTIONS

During the roundtable discussion of the revised *Significance and Research Standards* held at Fort Bliss on January 26, 2006, cultural resource professionals agreed upon a number of future actions that would address the questions of stratigraphic terminology, chronology, as well as the problems in utilizing existing stratigraphic and geomorphic models reviewed in this section. These actions and recommendations are:

1. Archaeological, geomorphic, and geoarchaeological researchers in the Fort Bliss area should continue to utilize the Gile and others (1981) Organ-Isaack's Ranch model for the classification and study of Late Quaternary sediments and soils in fan/piedmont environments. The model was developed specifically for landforms in the fan/piedmont area and has proven to be of important research and interpretive value. Researchers, however, are cautioned about problems that may arise in the distinction between stratigraphic units and soil horizons, and in the identification of stratigraphic units on the basis of pedogenic carbonates, particularly when there is a lack of carbonates. In other geomorphic and topographic portions of Fort Bliss however, particularly in basin-floor settings, researchers are encouraged to utilize the Q1-Q4 model (Blair et al. 1990a, 1990b).
2. Use of the Q1-Q4 model, particularly application of Q3 to the classification and interpretation of sediments deposited between ca. 7000-100 years B.P. will require significant temporal refinement. A conceptual scheme that spans the latest 7000 year portion of the Holocene is of limited use to archaeologists and cultural resource managers who are framing research questions and questions of site significance in terms of hundreds and not thousands of years. A more tightly controlled geochronological

sequence is required for the Fort Bliss area. Such a sequence requires the procurement of a significant number of new chronometric dates (i.e., radiocarbon and OSL) from professionally-recorded stratigraphic sections.

3. Researchers should strive to combine the most well-documented and testable portions of both the Blair and others (1990a), Gile and others (1981); Hall (2002, 2007), and Monger (1993a) models for reconstruction of the geochronological and pedo-geomorphic, Late Quaternary history of the Fort Bliss region. At present this will require, to the extent possible, a refinement and redefinition of the Q3 lithostratigraphic unit and/or a strengthening of the temporal and pedogenic composition of the Organ I – Organ III units. The Q3a and Q3b subdivision proposed by Lukowski and others (2003) is a possible starting point for such a refinement if it can be demonstrated that the subunits reflect separated episodes of deposition and not merely soil horizon differences within a single identifiable unit. In any case, reliance on this subdivision is dependent on a much tighter temporal framework than is currently available.

Refined temporal contexts of Holocene-age sediments in the Fort Bliss area are expected to prove extremely valuable to archaeologists in locating and evaluating archaeological sites. Archaeologists and other researchers must also know how to reliably recognize and identify Holocene deposits in the field. As noted above, these deposits are assignable in the Fort Bliss region to the Q2, Q3, and Q4 units of the Blair and others (1990a) geochronologic model for eolian sediments in basin-floor settings. In fan/piedmont environments, sediments of similar age have been assigned to the Isaack's Ranch and Organ units of the Desert Project model (Gile et al. 1981; Monger 1993a). How to recognize these units in the field and how to describe them is outlined below.

The Q2-Q4 model was developed in order to classify Late Quaternary eolian sediments in the central Tularosa Basin (Blair et al. 1990a) and has proven to be a valuable, if somewhat coarse-grained, framework for archaeological and geoarchaeological research in basin-floor settings throughout Fort Bliss. The Blair and others (1990a) sequence, with cautions by Hall (2002, 2007) includes two stratigraphic units that fall, wholly or partially, within the Holocene epoch (i.e., the last ca. 10,000 years). These are: Q3 (100-22,000 B.P.) and Q4 (less than 100 B.P.)

As shown in Table 6.1 earlier in this chapter (see Table 6.1), Q2 sediments contain soils that exhibit Btk, Bk, or Btk-Bk profiles. Other soil characteristics include truncated A horizons, hard-to-very-hard dry consistency, moderate angular-subangular blocky structure; Stage II carbonate morphology; distinct reddening, and illuvial clay. Isaack's Ranch sediments are primarily alluvial fan deposits, corresponding to the Isaack's Ranch alluvial fan surface, which is geomorphically situated below the late Pleistocene Jornada II fan and the Holocene-aged Organ fan. Isaack's Ranch soils are characterized by Stage II carbonates in the form of continuous pebble coatings, some interpebble fillings (gravelly soil) and few to common nodules (nongravelly soil; Gile et al. 1966). In well-preserved contexts, soils often contain a reddish Bt argillic horizon (Gile et al. 1981; Monger 1993a: 28).

Q3 soils contain A-Bw-C or A-Bk-C profiles with A horizons often truncated. Additional soil characteristics include soft to slightly hard dry consistency, single grain or weak to moderate subangular blocky structure; Stage I carbonate morphology or slight reddening and clay enrichment (Blair et al. 1990a). Q3 is temporally analogous to Organ-aged sediments, which are subdivided into Organ I, II, and III. The time period associated with the Q3 period of aggradation and soil development corresponds with the Organ I, II, and III units, originally described as Holocene-aged alluvial fan sediments and later expanded by Monger (1993a) to include eolian deposits in basin-floor settings.

Organ I sediments were deposited and pedogenically altered between ca. 7,000-2,200 years ago. These soils contain Stage I carbonate filaments, often 5YR hues and faint clay skins. Organ I is stratigraphically situated below Historic and late Holocene eolian sands (i.e., Organ II, III, Historic Blowsand sediments) and, in basin-floor settings, above Pleistocene-aged indurated carbonates or caliche (Monger 1993a; Monger and Buck 1995). Organ II dates from ca. 2200-1100 years B.P. and Organ III from 1,100 to ca. 100 years B.P. (Gile et al. 1981; Monger 1993a; Monger and Buck 1995). Organ II soils contain faint Stage I carbonate filaments while Organ III soils do not generally contain visible carbonates.

Q4 deposits represent eolian sand sheet and coppice dune landforms of Historic-period age. Diagnostic features in Q4 include loose, single grain structure, primary sedimentary structures that have been partially disrupted by bioturbation; weak, local vesicular A horizons (uncommon); and faint, Stage I carbonate filaments. Q4 has an estimated temporal range of 0 to ca. 400 years B.P., which is identical to the Historic Blowsand unit as defined by Monger (1993a: 30). The Historic Blowsands are planar bedded to massive, eolian coppice dune and sand sheet sediments attributed to vegetative changes brought about by overgrazing during the late nineteenth century. The Q4/Historic Blowsand deposits are too young to have been significantly altered by soil formation processes. Consequently, C horizon designation is frequently applied to these sediments in the field. Q4 sediments are located at the top of the stratigraphic profile and overlie Q3, Q2, and/or Q1 deposits.

Methods of Field Identification

The diagnostic features associated with the Holocene deposits have proven valuable in the identification of these deposits in the field and therefore researchers are encouraged to use as many of these criteria as possible. Of the various units described, the Q4/Historic Blowsand and the Q1/La Mesa are the easiest to recognize in the field.

The Q4 and Historic Blowsand units contain loose, fine, and very fine sand in extant coppice dunes and eolian sand sheets that are visible on the surface. These sediments have planar laminated and occasionally, ripple cross-laminated, sedimentary structures but are frequently massive due to extensive bioturbation caused primarily by plant roots. The coppice dunes are anchored by predominately mesquite and creosote. The dunes are separated by interdunal areas that exhibit varying degrees of wind deflation. Lag gravels, including pieces of weathered caliche, are common on the surface of interdunal areas. Again, the Q4/Historic Blowsand sediments do not generally contain visible pedogenic carbonates.

At the bottom of the stratigraphic sequence, Q1/La Mesa deposits are easily recognized by the presence of late-stage pedogenic carbonates. These horizons are given K or Bkm horizon designation. The La Mesa geomorphic surface (Late Pleistocene) covers much of the basin floor and caps the Pleistocene-aged Camp Rice Formation (Gile et al. 1981; Monger 1993a; Seager et al. 1987). La Mesa is identifiable on the basis of Stage IV carbonate morphology (Monger 1993a: 13). Stage IV carbonates are characterized by the development of laminar CaCO₃ horizons. These generally form above plugged horizons containing thick, Stage V carbonate laminae and pisolites (Machette 1985; Monger 1993a: 13-19). The well-developed carbonates lie at various depths, ranging from the surface to over 2 m below the surface, depending on the thickness of the overlying sand sheets and coppice dunes. The Q1 unit can be recognized by the presence of Stage III carbonates, in which the carbonate is more or less continuous with plugged horizons forming in the lower portions of the horizon. In their Q1-Q4 Late Quaternary model, Blair and others (1990a) correlate the Q1 with the Jornada II of the Desert Project model. However Jornada II was named for alluvial fan surfaces along the flanks of the Organ Mountains and basin floor settings (Gile 1987b; Gile et al. 1981; Hawley et al. 1976). Jornada II has a temporal range of ca. 150,000-25,000 years B.P. (Gile 1987b; Monger 1993a: 19). Monger and

Buck (1995: 27) point out that non-gravelly Jornada II soils do have Stage III carbonates but in basin floor settings most K or Bkm horizons exhibit Stage IV morphology.

The Q3 unit, spanning over 22,000 years, is stratigraphically situated below the extant Q4 coppice dunes and sand sheets and above the late Pleistocene-early Holocene Q2 eolian sands. In areas with well-preserved stratigraphic sequences, this intermediate position is an adjunct to field identification. In areas where the Historic Q4 sands are absent, the Q3 sediments can be at the surface. In these instances, recognition of the Q3 is most reliably based on pedogenic characteristics, particularly soil horizon configuration (A-Bw-C or A-Bk-C), soil structure (weak to moderate subangular blocky or single grain), soil consistence (soft to slightly hard dry), and Stage I soil carbonates (see Table 6.1). In field situations where Q3 Bk horizons are at on, or very near, the surface, soil carbonate morphology, specifically the lack of carbonates or limited carbonate expressions, are not considered a reliable indicator of soil age due to the propensity of surface soils to be affected by carbonate leaching. As Kuehn (2004) points out: "surface exposures could result in the vertical translocation of formerly extant carbonates out of the soil profile by rainfall and water percolation. As a result, soils older than Organ III may exhibit a lack of carbonates due to surface/near-surface leaching rendering the lack of carbonates of little use in the estimation of age". This is a possible source of error when attempting to identify Q3 soils in the field.

Stratigraphic position is also a valuable tool in the identification of the late Pleistocene/early Holocene Q2 unit, which is situated below the Historic-aged Q4 and the Holocene Q3 sands and above the basal Q1 petrocalcic horizons. When stratigraphic position is ambiguous (i.e. when overlying units are eroded or completely absent), soil characteristics are the best avenue to field identification. Again, significant Q2 soil attributes include: Bk, Btk, or Btk-Bk horizon profiles; truncated A horizons; moderate angular-subangular blocky structure; hard to very hard dry consistency, Stage II carbonates, distinct reddening, and illuvial clay. The key difference here is that illuvial Bt and Btk horizons are not generally present in Q3 soils (Blair et al. 1990a). While this is an important field indicator, Q2 soils are frequently truncated and both A and Bt horizons can be missing from the soil profile. In addition, the Q2 soils tend to have reddish coloration while the Q3 soils do not, and the Q2 has Stage II carbonates (nodules and continuous pebble coatings) while the Q3 has Stage I filaments (Blair et al. 1990a). These are important differences that aid field identification. However, carbonate morphology is potentially problematic as noted above. For instance, Blair and others (1990a) correlate the Q2 with the Isaack's Ranch unit of Gile and others (1981) that both contain Stage II Bk horizons. As Monger and Buck (1995: 25) point out, however, soils older than Isaack's Ranch can also have Stage II carbonates if polygenetic profiles are present. In addition, carbonates in both the Isaack's Ranch and Q2 soils can be affected by leaching if subjected to surface conditions.

Archaeological Visibility and Integrity in Stable Eolian Settings

Questions of site visibility and site preservation in eolian environments have been areas of research in the Western United States for over two decades (cf. Shelley and Nials 1983; Simms 1984; Wandsnider 1988). This stems in part from the realization that eolian deposits form highly dynamic geomorphic landscapes, which affect both the discovery and integrity of archaeological sites (Wandsnider 1988: 18). Consequently archaeologists have increasingly been interested in investigating the relationship between eolian depositional environments, natural site formation processes, and the preservation of archaeological materials (Monger and Buck 1995; Shelley and Nials 1983; Wandsnider 1988)

In the Fort Bliss area of southern New Mexico and far west Texas, a number of researchers have addressed the topic of archaeological site visibility and integrity in eolian landscapes. At Fort Bliss, surface eolian landforms are dominated by Historic-period coppice dunes and sand sheets

assignable to the Historic Blowsand or Q4 units of the Blair and others (1990a), Gile and others (1981), and Monger (1993a). Surface eolian landforms also contain remnants of older sand sheet deposits that appear to correlate with the Q3/Organ I-III units (Blair et al. 1990a; Monger 1993a). In the original *Significance Standards*, the authors outlined a basic premise that, in settings where eolian landforms postdate prehistoric archaeological materials, these materials should either be buried by eolian sands or situated in exposed, deflated contexts. Research conducted since publication of the first *Significance Standards* has repeatedly demonstrated that this premise is largely accurate and that archaeological remains associated with the Formative and Archaic periods are in fact buried under coppice dunes and sand sheets or are exposed in interdunal deflationary areas. The most recent research, however, also demonstrates that the extent of intra-site burial, exposure, and preservation at the intrasite level is far more variable than first expected.

For example, there is increasing evidence that the highest levels of site preservation occur in flat-lying sand sheet environments, with sites often covered with thick grasses. Such preservation is generally absent in dunes and blowouts. In sand sheet settings, exposed artifacts are generally not as visible as they are in coppice dune landforms. While substantive temporal data are only now starting to become available, recent research tends to suggest that the sand sheets predate the Historic Blowsand/Q4 stratigraphic units and therefore may represent land surfaces that are more or less contemporaneous with one or more prehistoric cultural groups. As a result, relatively uneroded sand sheet landscapes offer researchers a very promising avenue of investigation. In the following discussion we will focus on some examples of recent geoarchaeological research in sand sheet settings. Although these investigations vary widely in scope and level of field investigation, they do serve to illustrate the growing attention being paid to sand sheet landforms.

During geoarchaeological research at 319 sites in the Hueco Mountains Archaeological Project area, TRC Associates, Inc., (Lukowski et al. 2003) studied the relationship between Formative and Archaic period sites and eolian depositional environments. As a result of the investigations, these researchers discuss site visibility and contextual integrity as they apply to coppice dunes, interdunal deflationary areas, and sand sheets, which they term “mini mesas”. While coppice dune exposures exhibit thick accumulation of Historic-aged sand, the soil underlying the dunes has typical Bw-Bk-La Mesa profiles. Buried A horizons at the top of the sub-dune soil profile are largely truncated and tend to be poorly developed. It is important to note, however, when buried A horizons are extant under the dune sands, they often appear associated with Formative-period cultural materials (Lukowski et al. 2003: 40). In the study, interdunal deflationary areas are the most eroded and therefore offer the least potential for buried, intact archaeological remains. Most interdunal areas are eroded to the Q3Bk horizon, with others eroded down to the Q3Bw horizon (Lukowski et al. 2003). In many cases the interdunal areas contain abundant caliche gravels, supporting the deflationary origin of these areas and also suggesting that vertical erosion has penetrated relatively close to Bkm horizons associated with the La Mesa geomorphic surface.

Sand sheets are flat-topped surfaces that lie 1-3 m above the surrounding interdunal zones (Lukowski et al. 2003: 41-42). Backhoe trench investigations in the “mini mesa” landforms revealed the “most complete” stratigraphic sequences. Important in these soil sequences are the preservation of buried A horizons (i.e., Q3b unit soil as described by Lukowski et al. 2003: 39-40). The Ab horizon overlies Bw (Q3b), Bk (Q3a), Btk (Q2) and K horizon (Q1) soils. Samples of the Ab horizon soils yielded bulk humate ages of 2428 ± 60 , 2451 ± 60 , and 3564 ± 60 B.P (Lukowski et al. 2003: 41). While these ages may be suspect due to the inherent problems associated with attempting to use bulk humates (Wang et al. 1996), the dates are food for thought with regard to the temporal context of the Q3b and Organ II-III sediments in basin floor settings at Fort Bliss.

In a classification of advanced coppice dune microtopography developed by Basabilvazo and Earl (1987), Lowry and others (2003) note that advanced dune microtopography is characterized by

steep-sided dunes that measure more than 2 m in height, severely eroded interdunal areas with only a thin layer of recent sands extant on the surface, and a paucity of significant sand sheets. While rare, it is the sand sheets, concentrated where two or three coppice dunes are located in close proximity to each other, that hold the greatest potential for buried, well preserved cultural features and remnant Q3 soils (Lowry et al. 2003). Lowry and others (2003) also note that in spite of a lack of adjacent blowouts, many artifacts and features in sand sheet settings will have some surface expressions. Because of these factors, Lowry and others (2003) recommend that sand sheet areas should be the main focus of subsurface backhoe trench programs during future investigations in similar topographic areas.

In the same research report, Lowry and others (2003) address the question of geoarchaeological integrity in sandy eolian settings. In their contextual overview, Lowry and others (2003) outline the following preservation scenarios:

1. Dunes have only limited surface artifact distribution and no archaeological potential;
2. Interdunal areas are highly deflated and have low archaeological potential;
3. Subsurface expressions in interdunal areas could provide fairly accurate impressions of site context;
4. Geoarchaeological integrity can be summarized by reference to a number of preservation contexts: (a) areas with thin deflated interdunal mantles of Q3 sands over Pleistocene Q1 sediments; (b) intrusive Q3 hearths cut into Q2 sediment; (c) buried Q3 remnants under dunes; and, (d) deeper Q3 sand sheet deposits with cultural features still preserved.

These preservation scenarios can be applied to areas on Fort Bliss. For example, in the Tobin Well project area, Lukowski and others (2006) summarize six prehistoric sites situated in grassland settings. They subdivide the Q3 unit of Blair and others (1990a) into two subunits: Q3a (ca. 7000-2400 years B.P.) and Q3b (ca. 2300-100 years B.P.; Lukowski et al. 2006: 292-293). In sand sheet portions of the study area, Lukowski and others (2006) identify two stratigraphic zones. The upper zone, Zone 1, contains a buried A horizon that is suggestive of what was a stable surface during the site occupation. Zone 2 is the portion of the soil where the majority of cultural materials are concentrated. All features encountered in the sand sheet environment were located in the upper portion of the Organ III/Q3b unit that dates from ca. 1170-650 years B.P., based on the procurement of 26 radiocarbon ages (bulk soil humates). In this context, preservation was excellent because of good geoarchaeological integrity.

Kuehn (2005) conducted intensive auger test investigations within a one-square kilometer study area in the Doña Ana Range. By examining the morphology, genetic origin, and thickness of Q1 through Q4 (La Mesa through Historic Blowsand) sediments, Kuehn was able to demonstrate that sand sheet landforms contain thick deposits of pre-Historic aged sediment in the project area and thus the greatest potential for intact, buried precontact cultural resources just as Lowry and others (2003) proposed. Other eolian landforms monitored during the study were coppice dunes, coppice dune slopes, and interdunal deflationary areas (Kuehn 2005: E-8). The average thickness of Q3 sand sheets in this area (to La Mesa calcrete) is 56.3 cm, as compared to heavily bioturbated sand dunes (92.8 cm), dune slopes (54.6 cm), and interdunal deflationary areas (31.4 cm). Because sand sheet environments are not generally associated with interdunal deflationary area, they are ranked the highest in terms of inherent research potential in eolian landscapes.

In summary, recent investigations at Fort Bliss reveal that eolian depositional environments offer interesting challenges to the interpretation of site density, site visibility, and site integrity. Researchers agree that coppice dune and blowout settings are a mixed blessing in that they contain high numbers of visible prehistoric artifacts and features due to the abundance of interdunal deflationary areas. These interdunal areas are where most cultural materials are located. Thus, as argued by Lowry and others (2003), most sites located in dune settings are

likely to have some surface manifestation which is an important adjunct to field identification. On the other hand, the processes of deflation that make eolian sites highly visible, also serve to destroy various aspects of archaeological integrity as deflation progresses. Downward displacement of size/weight sorted artifacts certainly can result in a loss of spatial context.

Recent field investigations show that the extent to which sites are impacted by wind deflation varies greatly. Wind deflation in interdunal areas can remove all soils in the stratigraphic sequence from Q1 (La Mesa) through Q2 (Isaack's Ranch), through Q3 (Organ I, II, III). On the other hand, while many deflationary areas are eroded down to La Mesa K/Bkm soils leaving virtually no intact archaeological potential, it is also true that interdunal areas eroded down to Q3a or Q3b (Organ I-Organ III) can, and often do, contain intact archaeological remains and features. The presence of intact features, for example, are good indicators of site preservation. In addition, sand dunes themselves have frequently served to protect underlying soils and sediments from erosion. As noted previously, the presence of generally weak Ab horizon soils at the base of extant coppice dunes are a good indicator of potential site integrity.

Finally, sand sheets have proven to be very promising areas for well preserved archaeological sites in eolian settings. Sand sheets can encompass most of the Q3 stratigraphic record and often contain buried soils that have the potential to contain datable materials and good proxy data on paleoenvironmental conditions. Because sand sheets are not associated with extreme wind deflation, archaeological sites there are also not as readily visible as they are in dunefields. Recognizing this fact, archaeologists at Fort Bliss are increasing their arsenal of subsurface investigative techniques when searching for sites in sand sheet areas. Currently used techniques include backhoe trenching, bucket augering, and core augering. These, and additional methods such as remote sensing, promise to expand the present knowledge of sand sheet environments, which appear quite well preserved in many basin-floor settings.

It is clear from the discussions above that the geomorphic and stratigraphic conditions within the Hueco Bolson and Tularosa Basin have the potential to play a large role in the identification of significant sites at Fort Bliss. However, the majority of our "windows" into the basin's Quaternary stratigraphy occurs in the context of individual sites identified by pedestrian survey. It could be argued that pedestrian survey, by its nature, tends to identify sites with the highest surface visibility of archaeological materials. Areas of high surface visibility often consist of the most-eroded locales and thus, some of the poorest areas for preserving the stratigraphic record within the basin. Given this situation, it is not surprising that geomorphic investigations associated with sites have not been able to sort out the issue of whether the stratigraphic systems of Blair and others (1990a, 1990b) or Monger (1993a) are suitable for basin-wide use or if a modified stratigraphic system should be adopted. Some geomorphic investigations focused entirely on finding well-preserved locales could be conducted on Fort Bliss (i.e., projects not focused solely on archaeological requirements) to resolve this issue.

Specific Fieldwork Recommendations

The following is a list of recommended tasks and a methodology for investigating the geology and paleoenvironments of the Tularosa Basin and Hueco Bolson during subsurface investigations.

Stratigraphy and Sedimentology:

- Describe the stratigraphy and sedimentology of a 1-m wide column through the deposits. Observe and describe primary as well as secondary properties of the sediment, especially noting lateral changes in stratigraphy. Describe the sedimentary deposits using the suggestions in Compton (1962, esp. Ch. 12, *Field Work with Sedimentary Rocks*, p. 208) and Kottowski (1975, esp. Ch. 6, *Description of Measured Sections*, p. 180) or a similar geology field guide.

- It is strongly recommended that, for the present, the stratigraphic categories of Q1, Q2, Q3, and Q4 introduced by Blair and others (1990a, 1990b) should be applied to eolian deposits and underlying calcrete in the bolson. The terms that have been applied by others to alluvium and alluvial fan deposits are inappropriate for the sand sheet.
- If a paleosol is present, describe it using the suggestions in Birkeland (1999, esp. Appendix 1, Describing Soil Properties, p. 347). There may be some overlap with the first recommendation.
- Sediment/soil samples should be collected at 5 or 10 cm intervals from the deposits being studied. The samples should be analyzed at a reputable geotechnical sediment lab. The important characteristics to be analyzed for are: (a) sand-silt-clay (silt and clay can be by hydrometer); (b) sand at standard description intervals (very coarse, coarse, medium, fine, very fine); (c) carbonates using the Chittick Method; and, (d) organic carbon using the B-W Method. Depending on the situation, an analysis of: (e) gravel; and (f) Fe-oxalates may need to be included.
- To facilitate a better understanding of the basin's Quaternary stratigraphy, it is proposed that a sampling scheme be developed that attempts to identify well-preserved locales throughout the basin. For example, there appears to be an association between creosote bush and locales with relatively well-preserved paleosols. This association is not helpful in alluvial fan areas where creosote bush is ubiquitous, but is an observation that does seem to have some merit within the eolian dunefields where creosote bush is rare. This association should be more systematically studied to determine if it has merit or is just a coincidence noticed in a small sampling of locales. It is recommended that aerial photographs be used to identify basin locales (i.e. not alluvial fans) that contain creosote bush. Then a sampling scheme could be developed to test some of those locales with backhoe trenches.

Radiocarbon dating:

- Select seeds from annual plants for radiocarbon dating when possible; the seeds should be identified to genus or species if possible.
- Wood charcoal is the next best choice for radiocarbon dating; the wood should be identified and reported along with the radiocarbon date.
- When introducing new radiocarbon dates, report: (a) measured ^{14}C age; (b) measured $\delta^{13}\text{C}$ value; (c) corrected ^{14}C age; and, (d) tree-ring calibrated age, citing the reference for which the calibration is made. A precise location of the dated sample and its radiocarbon laboratory number is also mandatory.
- Avoid radiocarbon dates on soil carbonates; they will always yield an age but are useless in establishing a chronology for deposits in the bolson. Indeed, when submitting samples for radiocarbon dating from the bolson, always specify that the sample should be pretreated to remove carbonates.
- Do not hesitate to use AMS dating; it costs more, but the results are invaluable. A solid series of ^{14}C ages is the foundation of archaeological research.

OSL Dating:

- It is strongly recommend that a practitioner in the field be brought in to do the locality selection and the sampling for OSL dating. At this beginning stage of OSL application to bolson stratigraphy it is vital to get high quality results. Poor or inexperienced sample

collection in the field can result in imprecise or inaccurate OSL dates. As an alternative, it is encouraged that staff representatives from Fort Bliss and its archaeological contractors be formally trained in OSL sample collection procedures.

- Multiple stratigraphic columns of paired OSL and radiocarbon dates are needed to evaluate systematic errors in the methods.

FIELD RESEARCH AND DOCUMENTATION QUESTIONS

The following questions apply to site-specific geomorphic and geoarchaeological research at Fort Bliss. They are all intimately related and represent the suite of questions that should be posed routinely at each site investigated within eolian, alluvial fan, and hill slope settings. Because the data needs for all of the procedures are relatively simple and largely identical, the questions are all posed first, followed by a single identification of data needs and an integrated discussion.

Eolian Contexts

- What is the character and timing of the eolian deposition? How many cycles of deposition are preserved at the site?
- What is the timing of erosional episodes?
- What is the timing of episodes of site stability?
- What is the character of depositional architecture at the site?
- Are stratified components present, or is all material at or just beneath the surface?
- What is the stratigraphic context of archaeological remains? How old are the encasing deposits?
- Do the sealed components appear to be in primary or secondary context?
- What evidence is there for horizontal disturbance? Vertical disturbance?
- Are the archaeological deposits contained within or stratified between depositional units?
- What is the likelihood that the archaeological remains represent more than one time period?
- What types and degrees of postdepositional modification of deposits are apparent?
- What is the source of the eolian sands? Does it appear to be locally derived, or has it been transported in considerable distances?
- What was the topography like at the time of deposition? Were dunes developed, or was the environment a sand sheet? If dunes were present, in what part of the environment was the site developed (e.g., stoss face, lee face, interdune)?
- To what extent is archaeological visibility inhibited by eolian sands?
- What does geometry and bedding suggest about the depositional environment?
- Is there any evidence that the artifacts have "floated" up through the profile during deposition? If so, what are the characteristics of those artifacts? Do all artifacts appear to move equally, or are there size/shape/mass relationships apparent?

Alluvial Fan Contexts

- What facies are represented at the site? What facies contain cultural material?
- What is the architecture of these facies?
- Is the deposition characteristic of confined (fan channel) or unconfined (distributary lobe) flow? What can be said about local microtopography at the time of deposition?
- What energy conditions are implied during deposition?
- Is there evidence of erosive truncation?
- Do the archaeological remains appear to be the same age as the encasing sediment, or are they older?

- What is the morphology of the present surface, and what are the implications of this morphology for the local dynamism of the environment?

Hill Slope Contexts

- What is the character and thickness of sediments on the site? What processes were involved in deposition?
- What age or ages are represented by the sediments? Do the archaeological inclusions exhibit clear evidence for normal or reversed stratigraphy? Does the material appear to be in semiprimary or secondary context?
- Are unconformities apparent in the colluvial sequence? What is the relationship between archaeological inclusions in the sediment and those unconformities? Do the artifacts appear to have been transported and redeposited with the sediment, or simply buried by sediment derived from upslope?

Data needs: For documentation of eolian stratigraphic contexts, extensive (mechanical) exposures of site stratigraphy and absolute and relative chronometric information are needed. For documentation of alluvial fan contexts, data needs include extensive mechanical exposures, aerial photo coverage, and chronometric data of alluvial fan depositional environments. As in the eolian environment, interpretation of sites in the alluvial fan environment requires sufficient "windows" into the subsurface to define lateral variability in sedimentary units and soil development. High-quality aerial stereopair photographs can provide an invaluable tool for mapping the distribution of different depositional units and facies variation within units, particularly when coupled with ground-based stratigraphic, sedimentologic, and pedologic data. Once again, chronometric data is a virtual necessity to understanding the interrelationships between site components and the role of the site in the larger landscape context. For documentation of hill slope contexts, extensive stratigraphic exposures, textural and chemical laboratory data to characterize site sediments and source sediments, and chronometric data are needed in colluvial depositional contexts.

Summary of Critical Research Issues

The following summary of critical research issues is derived from the preceding discussions. These issues represent the primary focus of investigation for the next five or ten years of geomorphic and geoarchaeological research at Fort Bliss. As such, they may be reviewed during the next planned revision to the *Significance and Research Standards*. Several of the research issues are broadly-phrased and incorporate one or more of the research questions of the original *Significance Standards* document.

These geoarchaeological and geomorphic research questions apply to larger areas or to Fort Bliss as a whole. However, the proper investigation and resolution of these issues requires multiple site-specific studies. These represent an interesting series of questions associated with Fort Bliss. They are not easy questions to answer, due to the sheer size of the post and the necessity to compile information from many different sites. However, they must be the focus of long-term research if the archaeological record in the basins and on Otero Mesa is ever to be understood within a regional landscape context.

These questions should all be addressed with the same types of data. The single most important requirement is extensive exposure; few of the issues can be addressed with only one or two trenches. While few of the issues can be conclusively answered with even a moderate level of subsurface effort, such expenditures will allow for strong tentative conclusions that are not possible without subsurface examination. In fact, it can be argued that because geomorphic processes impose such a strong filter on archaeological visibility, any type of reasonable site assessment in the eolian landscapes is impossible without subsurface testing. It follows that if

individual site assessments are impossible, regional interpretations of settlement and subsistence built on site distributions are also impossible, and any such models based on current pedestrian survey data from this environment represent models based on biased information and cannot be considered tenable.

Research Issues 6-1, 6-2, and 6-3 set forth fundamental issues regarding the terminology, age, and stratigraphic/temporal relationships of depositional units and geomorphic landforms in the Fort Bliss region. These issues involve the baseline terms and data upon which all subsequent geomorphic and geoarchaeological investigations are based.

Research Issue 6-1

Consensus on terminology and chronology of Late Quaternary sediments

A consensus view among geomorphologists and archaeologists working at Fort Bliss is that the Quaternary (Q) sequence nomenclature of Blair and others (1990a, 1990b) should be used for describing the eolian stratigraphy of interior basin contexts in preference to the Organ I-II-III nomenclature as applied by Monger (1993a). However, the Quaternary sequence is in need of further refinement, particularly in describing the stratigraphy and formation of the Holocene Q3 unit (e.g., Q3kw, Q3bk). Consistency of stratigraphic nomenclature is critical for consistent communication between archaeologists and resource managers. Additionally, investigations into the relationships between alluvial and eolian sequences in the Tularosa Basin and Hueco Bolson should continue to be pursued, and the relationships between episodes of erosion or deposition on alluvial fans and eolian activity in the central basin needs to be clarified. Moreover, efforts are needed to reconcile stratigraphic models and geomorphic mapping units. Overall, geomorphologists need to focus on formulating utilitarian models summarizing Late Quaternary landscape evolution across the major landforms of Fort Bliss.

Research Issue 6-2

Dating, age assignments, and relationships of Late Quaternary depositional units

The preceding discussions have reviewed new chronometric and stratigraphic data on the age and formation of the Q2, Q3, and Q4 stratigraphic units. These new chronological models have several implications for regional geomorphology, geoarchaeology, and cultural resources management. Yet, numerous questions and research topics still remain:

- Can basin-wide episodes of landscape stability be identified, or are episodes of stability and instability localized? In other words, what is the spatial variability in this temporal sequence?
- What is the sequence of Holocene aggradation and erosion represented in fan channels on Fort Bliss? To what extent are Holocene deposits preserved in these cut-and-fill sequences? How does this sequence relate to the overall sequence of fan activity?
- What is the variability in timing and magnitude of alluvial fan activity between the fans associated with the Organ Mountains, Jarilla Mountains, Sacramento Mountains, Franklin Mountains, Hueco Mountains, and the Otero Mesa scarp? In other words, do fans in various parts of Fort Bliss exhibit synchronous or asynchronous periods of formation?
- Are there deposits of Late Pleistocene to Early Holocene age (e.g., Jornada II/Isaack's Ranch) associated with the fans on the eastern side of the bolson, where associated morphogenetic surfaces are not mapped?
- Is there evidence for time-transgressive autocyclicity in the fan-channel temporal record, or do incision and aggradation appear to be synchronous along fan-channels and between fan systems?

- What is the magnitude of deposition associated with distributary distribution at the mouths of incised fan channels? How thick and extensive are these deposits, and how rapidly do they appear to shift locations on the fan?
- What is the magnitude and variability of deposition away from the active depositional lobe of alluvial fans? Is eolian influx important in this environment? Do the pavement surfaces represent long-term stability, or could archaeological materials be buried beneath them?
- What is the character of the colluvial sequence preserved on Fort Bliss? Are thick colluvial deposits present, and if so, to what extent do they appear to be of culturally relevant age? What processes appear to have predominated?
- How similar are colluvial deposits mantling the slopes of the various ranges flanking the basin? What does this similarity or lack thereof, imply about the importance of regional controls in general and climatic change in particular? What is implied about the variability of geomorphic processes involved in local slope evolution?
- How does the colluvial sequence (if any is apparent) correlate with other evidence of climatic change? What types of changes appear to "turn on" and "turn off" colluvial activity? How sensitive to change does the slope system appear to be?

Research Issue 6-3

What are the sources of the discrepancies between radiocarbon and OSL dates? How reliable are OSL dates from buried eolian sediments?

Chronometric age estimates provided by radiocarbon dating of soil carbonates and OSL dating of buried eolian sediments yield highly discordant age profiles for Holocene and Late Pleistocene depositional units. Problems with dating soil carbonates are well-known and have been reviewed in the preceding chapter. However, OSL dating is not free of issues involving sample integrity and contamination, field sample collection or laboratory measurement errors, and other problems. For example, Bateman and others (2007) observed that bioturbation can alter the exposure histories of sand particles in eolian deposits, thus affecting the timing of when the luminescence signal of a deposit was "zeroed" by exposure to sunlight. Continued research is required on this matter. A consensus decision of the *Significance Standards* geomorphology meeting at Fort Bliss was that paired sequences of tightly controlled radiocarbon and luminescence dates are required from several sites and contexts across the base.

Research Issues 6-4, 6-5, 6-6, and 6-7 have critical implications for the identification, management, and treatment of cultural resources at Fort Bliss. The modeling and interpretation of soil aggradation rates, locations of favorable preservation contexts and buried cultural landscapes, and the effects of bioturbation all have implications for the identification of cultural resources and the evaluation of their research potential and NRHP eligibility.

Research Issue 6-4

Implications of age and aggradation rates for Q3/Organ Unit and other units

Different age profiles for the Organ/Q3 depositional unit yield different aggradation rate models. The fast versus slow aggradation rates for formation of the Organ/Q3 unit has important implications for the context and integrity of archaeological features and deposits. The implication of differing aggradation rates on site formation is reviewed in greater depth in Chapter 10 of this document. If eolian aggradation rates were rapid, as indicated by the ages of the Q3/Organ unit proposed by Monger (1993a), then cultural features and deposits of differing ages emplaced within eolian units should be vertically (stratigraphically) separated.

In contrast, if aggradation rates were much slower, as suggested by recent OSL dates, then eolian depositional processes in the central basins would have been too slow to result in the formation of

vertically separated and stratified cultural deposits. This may explain the rarity of isolatable stratigraphic contexts in basin landforms at Fort Bliss and surrounding areas. More critically, it creates several implications for evaluating research potential and integrity of archaeological sites. If there was little or no vertical separation among prehistoric occupations and activity locations in the first place, then the issue of stratigraphic integrity is pointless for considerations of research potential and integrity.

Instead, the common observation that features of different age are generally positioned at equivalent elevations suggests that the finding of preserved features equates with some degree of geomorphic integrity. The ultimate implication of these differing models and perceptions of stratigraphic site formation is that archaeologists should focus more on elucidating patterns of *horizontal* integrity among distributions of prehistoric features and artifact distributions in the basin landform.

For older cultural remains and natural stratigraphic units, the issue of carbonate lag deposits is important. Monger (1993b; 1993e) has noted that Isaack's Ranch sediments are commonly represented by a lag of carbonate nodules, implying that a regional deflationary episode may have occurred in the early Holocene, prior to onset of Organ sedimentation about 7 ka. This is significant because it implies that all Paleo-Indian and much Early Archaic material may be out of context, and because it has strong implications for the habitability of the bolson during this time period.

If however, this deflation proves to be localized or the Organ/Q3 unit has much greater time depth as indicated by OSL dates, then such materials may be locally preserved and the likelihood for continuity of occupation is enhanced. Are fine-grained soils exhibiting moderate Stage II carbonate morphology and incipient argillic horizon development (i.e., Isaack's Ranch soils) preserved on the reservation, and if so, how widely? How widespread are lag strata of carbonate nodules?

Research Issue 6-5

Can favorable and unfavorable eolian contexts for preservation be systematically identified?

Various eolian contexts such as surface deposits, sheet sands, and dune formations have been classified and mapped (D. Johnson 1997; Monger 1993a). In addition, microtopographic landforms such as mini-mesas (Smith 2005) and various types of coppice dune/erosional landforms (Basabilvazo and Earl 1987) have been identified. Which of these contexts offer the best and worst environments for preserved cultural deposits? Can these be reliably and consistently identified and described in the field during survey and excavation projects?

Research Issue 6-6

Questions of archaeological visibility and integrity in stable landform settings

Plots of artifact and site distribution on aerial photographs or geomorphic maps often show a distinct pattern of reduced site and artifact densities in areas having relatively stable deposits of sediment, particularly sand sheets with sparse grass cover. In addition, in sand dune settings there appears to be a relative absence of materials in coppice dunes and an increase of materials in interdunal deflated areas. Are these patterns quantifiable, and if so, to what extent are they the result of cultural versus natural site formation processes? Given the anticipated expansion of training and maneuvers on Fort Bliss and McGregor Range, it is time to address this issue and suggest methods to evaluate the research potential of cultural deposits and artifact distributions in geomorphically-stable contexts. What field procedures can be developed to better address these topics?

Research Issue 6-7

What are the most important mechanisms ofurbation in eolian and alluvial fan contexts and how widespread are these processes? Are A horizons widely preserved beneath the coppice dunes, and does disturbance of A horizons appear to be a recent phenomenon attributable to livestock?

Based on the variety, extent, and disturbance potential of the bioturbation processes discussed in this section, it would appear that the existence of intact stratigraphic units and cultural deposits would be a remote possibility. This is counterintuitive, however, since intact hearth and structural features are common in the central basins and alluvial fans. Thus, the issues of which processes are most important in terms of stratigraphic integrity remain open for investigation. More importantly, both the vertical and horizontal extent of such disturbances needs to be monitored and quantified.

The only methods available to assess the degree of mixing of a soil profile are (1) detailed recording of trench profiles, (2) multiple OSL and radiocarbon dates, and (3) detailed, targeted analysis of chemical trends, particularly carbonate content, because insects can be expected to carry finely divided carbonate from the K horizon back up through the profile and leave it unevenly distributed in the profile. Identification of insect krotovina may only be possible if trench faces are allowed to weather for several days. Textural analysis and clay mineralogical studies should permit evaluation of the viability of long term heave due to wetting and drying and salt-crystal growth.

The widespread presence of preserved A horizons would support the hypothesis that the coppice fields are a product of livestock introduction, while an absence would argue against recent origin. If A horizons are preserved, their elevation within the coppice dunes would indicate how great the degree of localized interdunal deflation is. Moreover, the aggregate surface topology of the buried A horizons could indicate how level or rolling the previous landscape was. As explained above, the complexity of carbonate pendants on surficial clasts should give an indication of the time depth of surface disturbance on the fan surfaces; simple, randomly oriented pendants would support recent (i.e., livestock) disturbance, while complex, overlapping pendants or pendant remnants on individual clasts would indicate greater time depth. Textural and chemical data would provide a means to address the viability of heave processes, and detailed recording of exposures could assess the ubiquity of biotic disturbance, as described above. The presence of continuous, rock-free zones beneath the pavements would support the McFadden and others (1987) model of pavement formation, while gravelly sediments would support sheet erosion and deflation as formative mechanisms.

Research Issue 6-8

Playa hydrology, water quality, and landscape evolution

The final research issue in this section involves the hydrology, natural ecology, and prehistoric cultural ecology of playas, swales, and other topographic depressions. As previously stated, a prominent component of nearly all prehistoric settlement and land use models is that they refer to aspects of settlement that are focused around topographic depressions. Moreover, empirical support of the settlement focus of playas is provided by the common observation of increased site counts, site densities, and site sizes in proximity to topographic depressions. Yet, as noted above, there has been little systematic investigation of playa hydrology and ecology beyond a small number of recent studies (Church 2002; Miller 2004b). While issues involving the quality and salinity of ponded waters in large playas have been mostly settled through these studies, numerous environmental, ecological, and geomorphic factors have yet to be adequately addressed.

Too few playas have been investigated to provide conclusive insights into the potential of playa sediments for palynological studies. Johnson (1997) submitted core samples from Holocene sediments of Lake Tank Playa to Steven Hall for evaluation. Hall's summary of his cursory pollen study states that "... the potential pollen record from Lake Tank Playa will be the first good pollen data from the northern Chihuahuan Desert and be an important step at vegetation and paleoclimatic reconstruction in the region. I don't have to exaggerate the significance of this potential record". Unfortunately, the samples were not submitted for a full pollen analysis. Johnson also submitted pollen samples from Bassett Lake Playa to Dr. Linda Scott-Cummings. Dr. Scott-Cummings report concludes, "Certainly the pollen preservation and abundance in these samples indicates that an interpretable record exists at Bassett Lake in the upper 112 cm" (Scott-Cummings 1996). Finally, corn pollen has been reported from the Lost River Playa on Holloman Air Force Base north of Fort Bliss (Sale et al. 1996).

The playas present on Fort Bliss have likely changed over the millennia, but the extent that they have eroded, grown or decreased in size, or been in-filled and obscured, is unknown. Moreover, the relationship between playa formation and broader climatic and environmental processes remains unknown. Based on a regional geomorphic analysis, Pigott (1977: 210) suggested that torriaquent (playa soils) coverage has been reduced from 2.68 percent to 0.08 percent by the advancement of dunes. Based on the presence of Spike Rush seeds in flotation samples from the El Arenal Site, Miller (2007a) suggests that a small playa was once present at Nations East Well but has since been obscured by the encroachment of eolian coppice dunes and disturbances resulting from historic ranching and military vehicle maneuvers.

Topographic depressions contain soils that differ from those in surrounding alluvial and eolian landforms. Little is known of these soils in terms of their productivity and agricultural potential. Small, shallow, basin depressions tend to contain dense grassland plant communities and organic litter after periods of rainfall, while fan-margin playas contain sparse vegetation communities of salt-resistant shrubs typical of western playas, or lack vegetation entirely within the interior salt pans such as observed at Lake Lucero north of Fort Bliss and at Salt Flat Playa to the east.

Specific research topics for topographic depressions include:

- What are the frequency, duration, and timing of water ponding events in major topographic depressions on Fort Bliss such as Old Coe Lake, Lake Tank, and Shrimp playas? Do these hydrological attributes differ from those observed among the smaller swales, dunal depressions, and arroyo-mouth ponds?
- What are the qualities of soils in topographic depressions? What is the agricultural potential of soils in and around different forms of topographic depressions?
- Are topographic depressions associated with increased biomass?
- Are other forms of paleoenvironmental data (e.g., pollen, diatoms, ostracodes, stable isotopes on soil carbonate) obtainable from the stratigraphic sequences in playas?
- Can episodes of activity and inactivity be documented in fan-marginal playas? If so, how do they appear to relate to activity on the adjacent fan? What is the relationship between playas and eolian activity on the basin floor? Are there playas now buried by eolian sand?
- What is the character of the record preserved in playa-margin lunette dunes? Can they be used to document episodes of activity and inactivity in the playa?

CHAPTER 7. Paleoenvironments and Paleoenvironmental Research

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As outlined in Chapter 2, cumulative paleoclimatic evidence from the northern Chihuahuan Desert suggests an essentially unidirectional trend toward aridity throughout the Late Pleistocene and Holocene. However, there is little doubt that finer-grained fluctuations in climatic parameters, such as are suggested by the relatively short dendroclimatological record (Grissino-Mayer et al. 1997), were superimposed on this long-term trend throughout the Holocene. Beyond the 1,373 year period encompassed by the dendroclimatic study, the degree of resolution in the extant data are generally not sufficient to effectively reconstruct environmental changes at a resolution suitable to modeling cultural responses to fine-grained shifts in climate. It follows that more research is needed before the character of the Fort Bliss paleoenvironmental record can be identified at a resolution that fully facilitates interpretation of human adaptations to the environment throughout the Archaic and Paleo-Indian periods. Although this chapter is now within Part II (Intrinsic Site Attributes and Qualities) rather than within the Research Domains (Part III), this chapter has received only moderate revisions from the 1996 publication of the *Significance Standards*. Many of the revisions are found under the subheading *Cautionary Critique of Extant Data* and are based on recent studies.

The commonly accepted span of human occupation in North America in general, and of the Fort Bliss region in particular, is roughly the last 12,500 years (latest Pleistocene to the present); therefore, the focus of proposed research is on this period. However, not all scientists are agreed that this range is accurate, and Pendejo Cave has been proposed as evidence of Pleistocene occupation in North America (Appenzeller 1992; MacNeish and Libby 2004; however, see discussion in Chapter 3 of this report). For this reason, and because historical context is also important in understanding trajectories of environmental change, archaeologically sponsored paleoenvironmental research on Fort Bliss should not focus exclusively on the period beginning in Paleo-Indian times, but should instead embrace the whole of the Late Quaternary.

NATURE OF THE EVIDENCE

Four basic lines of evidence can be exploited to examine the environmental history of a region: historical data, circulation models, proxy evidence, and direct evidence.

Historical Evidence

The best, and at the same time most limited, source of data are historical records that document then-current climatic and environmental conditions. These records can provide direct data on climate (e.g., temperature, precipitation, winds, humidity) and on environmental conditions (e.g., vegetation observations, stream flow, channel incision and migration, dune formation), and may occur in the form of either written or photographic records. In general, the resolution provided by these types of data is far superior to that obtained from proxy sources; however, the time span covered is so limited that they are frequently good for little more than providing a comparable modern baseline.

Global Circulation Models

Global circulation models provide a type of information on climate change that is complimentary to empirical methods by conceptually addressing the root causes, rather than examining the effects, of shifts in temperature and precipitation patterns through time (Bryson et al. 1970; Kutzbach 1983; Kutzbach et al. 1993). Global circulation models can also provide additional types of data, such as characteristic wind speeds and directions at various times of year, which are very difficult or impossible to obtain from proxy evidence. These computer models simulate atmospheric behavior by considering the complex interaction of atmospheric, terrestrial, and oceanic processes. Boundary conditions for the models are in turn based on geological evidence for a variety of parameters such as sea-surface temperature, terrestrial and ocean ice volume, orographic influences imposed by topographic variability, and the composition of atmospheric aerosols and gasses (Kutzbach 1983; Kutzbach and Ruddiman 1993).

Proxy Evidence

Many lines of paleoenvironmental information involve proxy evidence, which allows indirect examination of one environmental variable through its effects on other variables (Caran 1998). Because they are dynamically interrelated, a single type of data can provide direct evidence about one aspect of the former environment (e.g., macrobotanical evidence of vegetation) and, simultaneously, indirect proxy evidence about another aspect (e.g., the climatic parameters indicated by the presence of those biotic taxa). Most proxy evidence bears on paleoclimatic questions through examination of other systems, such as vegetation or soils; however, proxy evidence can address issues other than climate (e.g., evidence of the composition of biota derived from stable isotope analysis of soil carbonate).

Few lines of proxy evidence have been exploited in detail in the Fort Bliss region, although some work has been done on most of the major categories. As a result, the paleoenvironmental picture is beginning to come into focus, but much work needs to be done before the remaining questions can be resolved. The major classes of proxy climatic evidence relevant to the Fort Bliss region, and examples of studies utilizing these data from southern New Mexico, west Texas, and surrounding regions, are presented in Table 7.1. The potential resolution and scale of these approaches differ markedly. For example, while tree rings can provide an extremely high-resolution record, their time depth is limited, and other methods such as geomorphic criteria, pollen, and isotope evidence can provide a much longer record but at a lower degree of temporal resolution.

Because proxy evidence represents environmental response to climatic shifts, interpretation requires compensation for the effects of the intervening physical and biological processes, variable lag times, and local versus regional effects. Consideration must also be given to the depth of abstraction; in other words, the distance of the evidence from the characteristic being considered. For example, in the example presented above where stable isotopes are used to address the composition of the biotic assemblage, it is then possible to infer climatic conditions from that assemblage. Although such applications are routinely pursued, they represent an additional layer of abstraction, with a whole other set of requisite assumptions, and require even greater caution in interpretation.

One of the principal problems inherent in the use of proxy data for paleoclimatic reconstruction is the concept of *equifinality* (i.e., the realization that a shift from condition A to condition B in a physical or biotic system can be stimulated by a variety of different environmental changes; Bull 1991; Caran 1998). For example, if a biotic change is noted at a certain time (e.g., piñon pine disappears from an area), it is not immediately clear whether it is due to a shift in precipitation or temperature because the interaction between these two variables controls the amount of moisture available for plant growth and changes in either or both may be responsible (Thompson et al.

1993). Similarly, a given geomorphic response (e.g., stream incision) can result from changes in annual precipitation, precipitation timing and/or intensity, or sediment yield (Schumm 1977).

Table 7.1.
Types of Proxy Data Bearing on Climate, with Representative Studies.

Category	Source	Relevant and Example Studies and Syntheses	
Biotic Evidence	Plants	Macrofossils Pollen Phytoliths Diatoms Dendroclimatology	Wells 1966; Van Devender et al. 1984; Van Devender 1990 Freeman 1972; Markgraf et al. 1984; Leopold et al. 1963; Hall 1990b; Gish 1993 Buck 1993; Scott-Cummings 1993 <i>Winsborough 1994*</i> ; <i>Bradbury 1984*</i> Mauldin 1995; Drew 1972; Dean and Robinson 1978
	Animals	Large fauna Microfauna Insects Gastropods Ostracods Isotope chemistry	<i>Dillehay 1972*</i> Harris 1989; 1990 Elias and Van Devender 1990; 1992 <i>Neck 1987*</i> <i>Delorme 1989*</i> Huebner 1991a
	Human	Isotope chemistry Coprolites Dentition and skeletal data	Huebner 1991b Bryant 1974; Bohrer 1981 Marks et al. 1985
Soil Evidence	Soils	Morphology and development Isotope chemistry	Monger et al. 1993; Gile et al 1979; 1981; Gile 1966 Monger et al. 1993; Rightmire 1967
Geological Evidence	Sediments	Alluvial stratigraphy and sedimentology Eolian stratigraphy Timing and character of slope activity Lake/playa sediments and shoreline features Tufa and speleothem formation	Ruhe 1964; 1967; Gile and Grossman 1979; Gile et al. 1981 Monger 1993a; Blair et al. 1990a <i>Bull 1991*</i> Khresat 1993; Reeves 1965 <i>Szabo 1990*</i>
Historical Records		Direct climate records Vegetation records	U.S. Weather Bureau Files Buffington and Herbel 1965; York and Dick-Peddie 1969

*Studies listed in italicized type have little or no local relevance and are included as illustrations of the method only.

Another problem with proxy evidence is that various physical and biotic systems have different levels of sensitivity to perturbations in climate. Thus, threshold conditions necessary to initiate change in the various systems may not be exceeded simultaneously, or at all. For example, a decrease in effective moisture may have the effect of reducing the density of groundcover to the extent that geomorphic changes are initiated without seriously affecting species composition in the vegetation community; thus, while the geomorphic system changes in a manner reflected in the stratigraphic record, evidence of vegetation change in the pollen and macrobotanical records may be absent. Lag times may also differ, such that a noticeable change in one system may occur much more quickly than in other, related systems.

Thus, uncritical interpretation of the timing and character of climatic change can be expected to differ depending on the evidence considered. In addition, a single environmental stimulus may initiate a sequence of successive, differing systemic adjustments to the new equilibrium conditions (Chorley and Kennedy 1971). For example, a change in moisture influx may cause an initial increase in sediment delivery to a stream ill equipped to transport it effectively, causing aggradations in the upper basin. With time, however, the stream will adjust its channel geometry and gradient in the upper basin to carry the increased load, incising into the newly formed deposits. However, this adjustment may increase delivery to the lower basin, causing it to aggrade in turn. Thus, a single impulse at time X may result in a sequence of successive, time-transgressive, aggradational and incisional events that affect various parts of the basin for decades or centuries that follow in a process termed complex response (Schumm 1973; 1977). Uncritical examination of such a record could easily lead to an erroneous interpretation that identifies a number of changes in climate, when in reality the sequence reflects successive adjustment to a single climatic stimulus.

Climatic changes may also be manifest in a number of different ways. While many treatments tend to simplify the relationship to questions of variability in temperature and moisture on an annual basis, climate changes can also occur as shifts in the timing and/or intensity of precipitation and in seasonal temperatures. These changes may strongly affect some systems without affecting others. For example, a shift from a dominance of gentle, winter precipitation toward intense summer precipitation could conceivably have a strong impact on vegetation without significantly affecting annual precipitation totals. If temperature remained constant, such a change would decrease effective soil moisture on an annual basis, moving the biotic community toward a more arid-adapted composition. Thus, a net systemic effect interpreted as a move toward aridity could arise without a change in annual precipitation totals. If instead, the aforementioned shift in precipitation timing was accompanied by changes in average summer or winter temperatures, then the net tendency toward increased arid adaptation in the biotic assemblage could be increased, ameliorated, or reversed, depending on the magnitude, direction, and timing of temperature shifts. However, geomorphic systems could still be expected to respond to the change in precipitation intensity and timing.

Another factor to consider in examination of the effects of climate change is the preexisting state of various physical systems. For example, depending on the density of vegetation cover at the time of a shift toward increased precipitation, the net result could be either a decrease in sediment production (as vegetation density increases under the influence of more effective moisture) or an increase in sediment production (as unprotected sediment on the slopes is subjected to more frequent or intense storms). To cite another example, there is good reason to believe that the historic changes in the character of the basin floor (e.g., replacement of grasses by scrub vegetation, formation of the coppice dunefields) occurred primarily because the former grassy ecosystem was already in a precarious, marginal state of equilibrium with the climate, and the historic disturbance probably would have had a far different effect if the system had been more stable (York and Dick-Peddie 1969).

In short, landscape responses to climatic changes are complex and reflect the interaction of a number of related biotic and physical systems. For this reason, paleoclimatic interpretations derived from proxy data are typically far from straightforward, and multiple lines of evidence are highly desirable.

Direct Evidence

Many lines of proxy evidence are also lines of direct evidence when considered in a different light. Many forms of paleovegetation information (e.g., macrobotanicals, pollen) can be considered direct evidence of vegetation presence, while simultaneously serving as proxy

evidence of climatic conditions. Other types of evidence (e.g., oxygen isotopes, lake levels, tree rings) are sometimes considered as direct evidence of climatic conditions. However, it is important to realize that even direct evidence is affected by various processes that filter the data, requiring considerable interpretation to arrive at paleoenvironmental significance. For example, while macrobotanicals and pollen do provide direct evidence that specific species were present, either locally (in the case of macrobotanicals) or within the range of aerosolic transport (in the case of pollen), they require many assumptions about and adjustments for natural filters that affect the data before a clear picture of the local paleovegetation assemblage can be obtained.

Similarly, while oxygen isotopes do reflect water temperature, it is not immediately clear whether trends reflect changes in mean annual temperature, changes in the seasonality of precipitation (winter precipitation is, naturally, colder than summer precipitation, and therefore should have a different isotopic signature), or changes in the moisture source (e.g., warm Gulf versus cold Pacific moisture) that are only tangentially related to actual temperature trends. Lake levels, too, may reflect either increases in precipitation or decreases in temperature (that reduce effective evapotranspiration), while the response of tree rings to regional climatic shifts is also strongly conditioned by microclimatic, edaphic, and biological factors.

The preceding examples are not a complete list of data types that could be considered direct lines of paleoenvironmental evidence. However, they do illustrate the salient point that no matter what the evidence is, at least some level of abstraction is necessary to arrive at meaningful interpretation of the data, and some of the assumptions and/or weightings given to various aspects of the filtering mechanisms are apt to be wrong. Thus, multiple lines of evidence are crucial to robust paleoenvironmental reconstruction.

DIRECT AND PROXY SOURCES OF PALEOENVIRONMENTAL INFORMATION

The following sections briefly summarize the most important individual lines of evidence that have the potential to provide information on the trajectory of climate change in the Fort Bliss region through the Late Quaternary. The emphasis of this discussion is on potential contributions; extant results are summarized in the following section.

Macrobotanical Information

Macrobotanicals consist of the remains of plant tissue. Because different plants have unique and distinctive cellular structures and produce distinctive seeds, microscopic and sometimes macroscopic examination can be used to document that a particular taxon was present; dating of the remains or associated materials allows for a statement of the time frame represented. Preservation of ancient plant tissues is usually a result of one of three processes: incomplete combustion, which carbonizes the remains, thus allowing them to resist decomposition; dessication, which inhibits microbial activity; and anaerobic saturation, which also limits microbial decomposition. Naturally, because of the arid climate, only the former two mechanisms should be expected to occur on Fort Bliss.

Because different plants have varying tolerances for extremes in temperature and precipitation, examination of representative plant assemblages can be used to reconstruct the character of the environment through the use of modern analogs. Unfortunately, the process is complicated and requires a number of assumptions be made before an environmental interpretation can be obtained. First, the modern range of the taxon must be known and the limiting environmental factors must be understood. Second, the taxon must be in equilibrium with its modern range. Third, the fossil remains must represent taxa that were also in equilibrium with environmental variables. Fourth, the modern range must be a reflection only of environmental tolerances; other

factors such as interspecies competition cannot be limiting factors. Finally, the ecological affinities of the taxon must not have changed with time.

In practice, it is impossible to know with any degree of certainty whether any of these assumptions are true. Further complicating matters, few interpretations can afford to focus on a single type of organism, nor should they. Different organisms living with the same modern range of environmental conditions are said to be sympatric. If the fossil remains reflect a sympatric assemblage, then interpretation is strengthened. Unfortunately, many fossil assemblages are disjunct, meaning that they are composed of various taxa that do not now occupy the same environment, which greatly complicates interpretation because no modern analog exists. Nevertheless, examination of biotic records provides one of the most powerful suites of tools for examination of the paleoenvironment.

The most comprehensive work in the Chihuahuan Desert region concerns examination of fossil packrat middens (and occasionally middens of other animals, such as porcupine), which have yielded macrobotanical, microfaunal, insect faunal, and occasionally pollen evidence of local environmental conditions through time (e.g., Elias and Van Devender 1990, 1992; Van Devender 1990; Van Devender and Spaulding 1979; Van Devender et al. 1984; Wells 1966). In addition to packrat middens, macrobotanical information can occasionally be obtained from archaeological sites, particularly if the plant tissue was partially carbonized in a fire. In this context, the recovered material typically represents something of economic value (e.g., foodstuff, fuel) that was intentionally carried to the site by people; it is entirely possible that the material is not at all representative of the local environment because people can and often do carry specific resources for long distances. Thus, while carefully interpreted macrobotanical assemblages from archaeological contexts can provide a tremendous amount of information about subsistence, seasonality, and (potentially) mobility and procurement patterns, they should usually be viewed with caution in characterization of the local environment.

Pollen and Phytoliths

Pollen, and to a lesser extent phytoliths, can also provide a picture of the vegetation assemblage in a given region at various points in time. Pollen grains are microscopic structures dispersed in great numbers by higher plants (angiosperms and gymnosperms) that carry male genetic material to other plants, enabling reproduction. While some taxa (primarily flowering plants) are dependent on insects to carry the pollen between plants, many plants simply produce and release great numbers of airborne pollen, literally casting their fate to the wind. Pollen grains of different plants are distinctive structures with characteristic shapes and features, and only one type of grain morphology is produced by an individual taxon; consequently, examination of pollen allows determinations of which parent plant taxa are represented.

Phytoliths are tiny siliceous structures formed by the precipitation of dissolved silica in and around cells in plants. They are most common in plant tissues where evapotranspiration is highest, particularly in leaves, and develop distinctive shapes that mirror the sites of deposition (e.g., internal cellular and intracellular casts). On death of the plant, phytoliths are released into the environment through decomposition, where they behave as any other similarly-sized sediment. Phytoliths range in size from less than 1 micron (coarse clay-sized) to more than 500 microns (medium sand-sized), with most identifiable types measuring less than 50 microns (silt sized) (Buck 1993). Because they are composed of opaline silica, phytoliths are very resistant to degradation under most surface conditions. Because different plant taxa have distinctively sized and shaped cells, phytoliths have the potential to allow identification of the parent plant, and thus allow for paleoenvironmental reconstruction (Rovner 1971). However, the fact that many different sizes and shapes of phytoliths can be generated by a single plant taxon—indeed, by a single plant—has greatly complicated classification and generation of phytolith taxonomies,

which are a necessary step if they are ever to be broadly applicable to paleoenvironmental problems.

At present, the applicability of pollen analysis is much greater than that of phytoliths for several reasons, including: (1) pollen grains produced by a given taxon are essentially identical, while phytoliths can exhibit extremely variable morphology; (2) pollen grains are much easier to extract in a sediment sample because they generally have different density characteristics than the sediment, while phytoliths do not; and (3) pollen taxonomy is much better developed than phytolith taxonomy. Nevertheless, phytolith studies have shown some promise, particularly in the identification of broad classes of relatively simple plants like C^3 and C^4 grasses (Scott-Cummings 1993; Twiss 1987).

Despite its advantage, pollen analysis is extremely complex and problematic. Deriving a representative picture of regional vegetation from a pollen sequence requires (1) preservation of pollen, which in itself is no mean feat in the harsh, oxidizing environment of the Fort Bliss region; (2) compensation for the effects of differential transport of various pollen grain taxa, some of which can be carried hundreds of miles by wind; (3) compensation for the effects of differential pollen production by various taxa; and (4) compensation for differential pollen preservation, which occurs because various pollen taxa have differing resistance to environmental corrosion.

Although some successful pollen research has been conducted in south-central New Mexico (e.g., Hall 1990b; Markgraf et al. 1984), pollen preservation is generally not good in the region. However, there is still some potential, particularly if sediments are preserved in the playa lakes (Oldfield and Schoenwetter 1975). Phytolith analysis (e.g., Buck 1993; Scott-Cummings 1993) is in its infancy and has yielded little informative data to this point. However, the resiliency of phytoliths in the environment is much better than pollen, and therefore merits continued attempts to refine their method and classification.

Tree Rings

The application of tree rings to paleoclimatic problems, termed dendroclimatology, is based on the fact that tree growth is frequently limited by climatic parameters. As a tree grows, annual cycles of growth are reflected by successive annuli of thin-celled, high growth-season wood, and dense, thick-celled, low growth-season wood. As early as the eighteenth century, it was recognized that tree rings could vary in width in response to annual levels of environmental stress, and thus represented a proxy record of climatic conditions (Bradley 1985). Subsequent work (e.g., Douglas 1919; Fritts 1976) has established that tree rings can indeed provide a sensitive, albeit complex, proxy record of paleoclimatic conditions.

The use of tree rings as paleoclimatic indicators is complicated by a number of factors. Trees are biotic organisms with complex responses to environmental stimuli. Many trees, especially ones that are able to exploit groundwater, are relatively immune to minor climatic perturbations, and exhibit relatively uniform widths (complacent tree rings) that have little relation to climate. However, the growth of other trees is strongly conditioned by climate (sensitive tree rings) and contains a clear climatic signal contained in the widths of annular rings.

Another complication is introduced by the fact that, as a tree grows and its girth increases, the width of individual rings decreases. Therefore, in order to obtain a climate record from an individual tree's rings, or to correlate between trees of different ages to extend a chronology back in time, it is first necessary to standardize tree ring widths by fitting them to a polynomial growth curve, which is a complex procedure and requires a number of assumptions (see Bradley 1985 and Fritts 1976). Once the record is standardized, it must then be calibrated to climatic parameters controlling growth before independent climatic statements can be made. This

procedure is even more complex, and is usually accomplished with multivariate regression statistics (Bradley 1985; Fritts 1962, 1976).

In addition to widths, density characteristics of wood composing individual rings are also somewhat dependent on climate and thus can provide a paleoclimatic signal (Schweingruber et al. 1979). Finally, isotopic analysis of oxygen ($^{18}\text{O}/^{16}\text{O}$) and hydrogen (deuterium/hydrogen) contained in cellulose of tree rings can provide a sensitive record of temperature variations (Bradley 1985), although other factors can also complicate this signal (Luckman and Gray 1990). The most sensitive and robust reconstructions combine width, density, and isotopic data, and can yield very sensitive records of paleoclimatic conditions (Bradley 1985).

Diatoms

Diatoms are a type of algae whose cellular contents are enclosed between two valves of framework silica that is preserved when the organism dies. Diatoms can occur in remarkable abundance (up to 4,000 living organisms per milliliter of water and up to 200 million per cubic centimeter of lake bottom sediment); rendering them relatively easy to come by in both extant and fossil lake deposits (Bradbury 1988). The paleoenvironmental significance of diatoms arises from the fact that different taxa have differing tolerances for extremes of temperature, salinity, water depth, water clarity, and lake eutrophy (nutrient concentration), and respond rapidly to changes in these factors.

The same types of problems inherent in pollen analysis are also present in diatoms. Different taxa are differentially susceptible to destruction and adverse chemical conditions can impose a taphonomic bias on the record. Diatoms are also highly subject to transport within water bodies and are readily reworked from older sediments that may reflect different climatic conditions. In addition, the controlling environmental parameters are sometimes problematic; although commonly interpreted as temperature indicators, some work (e.g., Brugham 1980) has suggested that many diatoms have wide temperature tolerance and are primarily sensitive to changes in water chemistry and lake eutrophy. Nevertheless, examination of trends in diatom taxa through time in lake-bottom sediments can provide a high resolution picture of changes in conditions resulting from shifts in water influx and evaporation rates, particularly when combined with other types of data (e.g., ostracodes, pollen) (Bradbury 1984, 1988).

Fauna

A variety of types of fauna can provide paleoenvironmental information. Like plants, different animal taxa are adapted to exploit specific environmental niches; thus, changes in climate and accompanying changes in environmental conditions dictate the geographic range in which the fauna will live. Thus, the presence of taxa with known modern environmental tolerances and geographic ranges can be used to infer the character of previous environmental conditions. However, as with plants, the interpretation of fossil animal assemblages also requires assumptions about the degree to which the ancient remains and the modern analogs are in environmental equilibrium and represent stable ecological preferences; taphonomic biases are also of considerable concern. Many of these assumptions are dangerous because the short life cycle of the smaller, more environmentally sensitive animals (particularly micromammals) renders them relatively well suited to rapid adjustment to different environmental conditions. Further, reconstruction of past climatic conditions is best accomplished with species that show relatively strong sensitivity to climatic parameters; many species are adapted to a wide range of environmental conditions and are therefore less useful indicators of past environments.

Nevertheless, animal remains can provide considerable paleoenvironmental information. Arthropods, for instance, have been utilized extensively. Many types of insects, arachnids, and chilopods have been found in Quaternary deposits in the Fort Bliss region. Elias and Van

Devender (1992) report that 101 taxa of insects, arachnids, and chilopods have been recovered from fossil contexts in the vicinity of Fort Bliss. These insects, and Coleoptera (beetles) in particular, have proven a valuable source of paleoenvironmental data in the Fort Bliss region.

Gastropods (particularly land snails) are another potential source of paleoenvironmental information that has yet to be exploited to any degree in south-central New Mexico. Like other small animals, gastropods have specific microenvironmental preferences and can provide a sensitive record of minor environmental shifts (Neck 1987). Identification of taxa is accomplished on the basis of shape and surface relief and is relatively straightforward in comparison to other types of invertebrate evidence because the number of different taxa in an area is usually limited and taxonomies are typically well developed (Lowe and Walker 1984).

Ostracods are tiny, aquatic arthropods composed of a hinged outer shell, or carapace, that protects the soft body parts inside. These carapaces are frequently preserved in alluvial and lacustrine sediments, and contain a wide variety of diagnostic features (e.g., frills and spines, muscle scars, pore canals) that allow species differentiation (Lowe and Walker 1984). Different taxa of ostracods are adapted to specific, frequently narrow extremes of water temperature and salinity; freshwater species are also strongly controlled by the character of the substrate. Because ostracods (as a class) can live under a wide range of temperature conditions, and in fresh to hypersaline water, the proportions of ostracod species are a direct reflection of water temperature and salinity; individual species are indicators of minimum and maximum temperatures (Delorme 1989). Thus, analysis of ostracod assemblages at a given locality, and their changes through time, can provide abundant information about local water conditions, and thus allow inferences about broader paleoenvironmental trends.

Although most vertebrates can also be used to provide paleoenvironmental information, investigation tends to focus on mammals, and particularly micromammals (e.g., shrews, voles, gophers) because they are typically the most highly specialized, and thus provide the tightest constraints on accompanying environmental conditions (Graham 1987; Lundelius 1986). Although the controls on small mammal distributions are often a direct consequence of climatic parameters, they sometimes reflect other characteristics of the environment. For example, Semken (1961) and Toomey (1993) document the disappearance of the plains pocket gopher (*Geomys bursarius*) from central and west-central Texas during the Holocene, and relate that disappearance with widespread soil erosion that essentially destroyed its habitat.

Although larger animals are generally more tolerant of extremes in temperature and precipitation, and thus provide less sensitive evidence about former conditions, they can also sometimes provide valuable evidence of environmental conditions. One important distinction is between browsers (e.g., deer), which are primarily dependent on leafy vegetation, and grazers (e.g., pronghorn), which depend primarily on grasses. Because of these differing diets, the relative frequency of browsing and grazing animals can be used as a rough proxy of the character of the biotic assemblage. Bison population changes are also commonly interpreted as evidence of environmental changes (Dillehay 1974), although various researchers have differed strongly on the climatic implications of these shifts (cf. Creel et al. 1990; Dillehay 1974; Hall 1982).

Stable Isotopes

Stable carbon isotopes provide another avenue of paleoenvironmental information. Isotopic investigation can provide clues to the character of vegetation, diet, and temperature in the prehistoric environment. Commonly investigated isotopes include ^{13}C , ^{18}O , and ^{15}N .

As rainwater passes through the solum of a soil, it takes on the isotopic character of soil CO_2 , which is a function of plants growing on the surface. Carbon occurs in three basic isotopic forms: ^{14}C , which is radioactive and forms the basis of radiocarbon dating, and ^{12}C and ^{13}C , which are

both isotopically stable. Roughly 98.9 percent of the carbon in circulation is ^{12}C , 1.1 percent is ^{13}C , and 1.18×10^{-10} percent is ^{14}C (Lowe and Walker 1984). However, biological processes tend to fractionate ^{12}C and ^{13}C such that the ratio between the two reflects the metabolic pathway of the organism that fixed the carbon into its structure. Three different metabolic pathways are recognized in plants: the Calvin-Benson pathway (CAL or C_3) pathway, which is typical of most plants (including almost all plants in the temperate regions) and has a typical fractionation of approximately -22 percent to -33 percent; the Hatch-Slack (HS or C_4) pathway, which is typical of tropical grasses (including some grain crops) and has a typical fractionation of -9 percent to -16 percent; and the crassulacean acid metabolism (CAM) pathway, which utilizes both of the other pathways depending on temperature and photoperiod, has intermediate fractionation values, and is typical of succulents like cactus (DeNiro 1987; van der Merwe 1982). Stable carbon isotope analysis of faunal (Schoeninger and DeNiro 1984) and human (DeNiro 1987; Huebner 1991a) remains has demonstrated that $\delta^{13}\text{C}$ values reflect the composition of paleodiet, with uniform shifts reflecting trophic level. In the southern Plains and Rockies, a great deal of attention rests on systematic variation in $\delta^{13}\text{C}$ of values that reflects climate-driven shifts in the relative abundance of C_3 and C_4 plants. In addition to studies of bone from animals feeding on the plant assemblage, this variability is reflected in the isotopic composition of soils and sediments supporting the vegetative community (e.g., Amundson et al. 1988; Nordt et al. 1994) and in pedogenic carbonates developed in those soils (Cerling 1984; Monger 1993d; Monger et al. 1993). Stable carbon isotopes have also been extracted from occluded carbon in opal phytoliths (e.g., Kelly et al. 1991), which provides a record of isotopic composition of individual plants that lived in the system.

Systematic, temperature-dependent variation in the fractionation of the $^{18}\text{O}/^{16}\text{O}$ isotopes of oxygen was initially recognized by Urey (1947), and was subsequently used to calculate variations in global temperature based on the isotopic composition of deep-ocean sediments (Emeliani 1955). However, subsequent workers (e.g., Dansgaard and Tauber 1969; Shackleton 1967; Shackleton and Opdyke 1973) have argued that most of the observed changes in oxygen isotope composition are due not to temperature changes *sensu stricto*, but rather to changes in global ice volume. The basic argument is that during evaporation of seawater, a natural fractionation occurs as the lighter ^{16}O isotope is preferentially evaporated, rendering atmospheric water vapor isotopically lighter than the water in the oceans. During glacial periods, this isotopically light water vapor is subsequently bound up in the continental ice sheets, resulting in progressive enrichment of the ocean reservoir in the heavier ^{18}O isotope, while deglaciation frees the trapped lighter isotopes, which are returned to the sea in meltwater.

In terrestrial situations, oxygen isotopes do have a direct, albeit complex, relationship to temperature variations. For the same reason that isotopically light water (molecules containing ^{16}O) is preferentially evaporated, the concentration of isotopically heavy water (molecules containing ^{18}O) in precipitation is a function of temperature. However, this record is far from straightforward, as the isotopic composition of an air mass is affected by a number of factors, including (1) the isotopic composition of the moisture source(s), (2) exchanges between water vapor and water droplets in the air, as well as with water on the ground, (3) the amount of moisture in the air relative to its original water content, (4) the kinematics of precipitation, (5) the temperature at the source, (6) distance from the source, and (7) the latitude of the source and study areas. Nevertheless, the $\delta^{18}\text{O}/^{16}\text{O}$ ratio terrestrial deposits have been successfully used to obtain analog records of paleoclimatic variation from a number of sources, including glacial ice (e.g., Epstein et al. 1970; Paterson et al. 1977), tufas and travertines (Pazdur et al. 1988), sedimentary and chemical lacustrine deposits (Abel et al. 1982; Muller and Wagner 1978;), pedogenic carbonates (Allan and Matthews 1982; Magaritz 1983), and cave speleothems (e.g., Harmon et al. 1977; Thompson et al. 1976). Biotic remains (e.g., wood, snail shell, bone) also contain an oxygen isotope record, but interpretation is very difficult because of the additional

complexities introduced by metabolic fractionation; nevertheless, such materials can also provide valuable paleoenvironmental information (e.g., Jacoby 1980; Gray and Thompson 1976).

Stable carbon isotopes such as $\delta^{13}\text{C}$ can provide another form of proxy estimate of past precipitation and related temperature variations (Freyer and Belacy 1983; Leavitt and Long 1989, 1991; Peng et al. 1983; Stuiver and Braziunas 1987). Large differences in $\delta^{13}\text{C}$ have been observed during the Pleistocene-Holocene glacial transition (Krishnamurthy and Epstein 1990; Leavitt and Danzer 1992) to warmer temperatures. There are several problems to be considered when using $\delta^{13}\text{C}$ measures for climatic reconstruction, including seasonal and topographic variations, genetic factors, and possible fractionation differences within different plant parts and plant species.

Finally, nitrogen isotopes can be used to differentiate between nitrogen-fixing plants (legumes) and other plants. While most plants can only obtain nitrogen from soil nitrates and ammonium, legumes (or rather, bacteria that live in a symbiotic relationship with legumes) are able to also extract N^2 directly from the atmosphere. Because the atmosphere is not enriched in ^{15}N , and soil nitrates and ammonium are, leguminous plants typically exhibit much lower $\delta^{15}\text{N}$ (approximately 1 part per thousand [ppt]), while nonlegumes are closer to 9 ppt (DeNiro 1987). As the plants are consumed and metabolized, $\delta^{15}\text{N}$ is enriched approximately 3 ppt for each trophic level (Bousman 1990). Another relatively poorly understood phenomenon is that the $\delta^{15}\text{N}$ in plants and animals also appears to increase in response to elevated aridity and salinity in the environment (Heaton 1987; Sealy et al. 1987), suggesting that systematic variation in $\delta^{15}\text{N}$ could be used as a proxy for patterns in precipitation.

Human Skeletal Remains and Coprolites

Human skeletal remains can provide a number of lines of evidence relevant to paleoenvironmental and subsistence questions. Bones and teeth can retain physical evidence of a variety of pathological conditions, many of which are linked to specific or generalized dietary deficiencies (Brothwell 1965; Buikstra and Ubelaker 1994). Isotopic studies (e.g., Sr/Ca, Ba/Sr, stable carbon, stable nitrogen) can provide considerable detail about dietary habits (Buikstra and Ubelaker 1994), which in turn has implications for the character of the available resource base. However, the use of skeletal remains for such purposes is complicated by a number of ethical and legal ramifications that are beyond the scope of this discussion. Human coprolites, which are desiccated feces, can also be used to address dietary questions in a uniquely direct, albeit short-term manner.

Soil Morphology

Soil criteria can provide valuable evidence of previous climatic conditions because the types and rates of pedogenic processes, and therefore the resulting thickness and morphology of soils, are strongly controlled by climate. As discussed in Chapter 6, there is good reason to believe that many of the more strongly developed soils in the Fort Bliss region are actually the result of previous climatic conditions and would not develop to such a degree under the present climate in any length of time. However, the character of soils is not a precise method to reconstruct paleoenvironments and is probably one of the least useful tools available to address extant paleoenvironmental problems in the Fort Bliss region.

Stratigraphy and Sedimentology

The character of sediments and landforms developed under particular climatic regimes is frequently a valuable tool for understanding the character of former environments. The types and morphologies of landforms themselves are in large part dictated by environmental characteristics (Biidel 1983; Bull 1991), and the types of sediments laid down are strongly indicative of their

environment (Reineck and Singh 1980). The climatic implications of various landforms and sediments in the Fort Bliss area have been addressed in Chapter 6; the reader is referred there and to references cited therein for detailed treatments on the climatic implications of sediments and landforms.

Tufa and Speleothems

Tufa and travertine deposits represent chemically precipitated calcium carbonate that form around springs, seeps, in stream channels, in caves, and occasionally on the margin of lakes. Because the deposits can sometimes accrete relatively rapidly, they have considerable potential utility for paleoenvironmental studies. Speleothems are travertine deposits that form in deep caves, where changes in ambient environmental conditions occur relatively slowly. Although they have distinct advantages over deposits formed in more open conditions, particularly for isotopic studies, accretion of speleothems is frequently too slow to provide a high-resolution Holocene record.

Travertine consists of dense, thin-laminated to microlaminated carbonate, while tufa typically has a spongy to vesicular structure (Bates and Jackson 1984). Much of the spongy structure of tufa appears to result from accretion in and around a mat of algae or bacteria, which can in fact chemically stimulate the precipitation of the carbonate. In rock shelters, the formation of tufa and travertine implies active groundwater discharge, and suggests that the rate of accretion should vary as a function of changes in regional precipitation. This general relationship has been confirmed by a number of researchers working at significantly longer time scales (e.g., Gordon et al. 1989; Harmon et al. 1977; Szabo 1990). Thus, changes in the rate of travertine accumulation may provide a sensitive indicator of changes in precipitation rates throughout the Holocene, providing that the travertine sequence can be dated.

Several other lines of paleoenvironmental information are also potentially obtainable from travertine deposits, including paleotemperature information provided by the analysis of the isotopic oxygen, and paleovegetation analysis provided by isotopic carbon and nitrogen. However, most authors (e.g., Bradley 1985, Lowe and Walker 1984) stress that temperature trends can only be obtained from flowstones if the calcite is deposited under equilibrium conditions, which occurs only in deep caves where temperature and moisture fluctuations do not take place. The formation of tufa and travertine, in contrast, is a disequilibrium reaction stimulated to a large part by CO degassing resulting from the emergence of groundwater (Michaelis et al. 1985). Despite this prevalent notion, promising results have been obtained from oxygen isotope studies of tufas and travertines in calcareous terrains (Padzur et al. 1988), and it is possible that a paleotemperature curve could be obtained from similar deposits on Fort Bliss.

A final potential avenue of paleoenvironmental investigation concerns examination of biotic material incorporated into tufas and travertines. In addition to providing material for dating, biotic remains trapped in the sediments as they accrete can provide a picture of the surrounding vegetative community.

Historical Records

Historical records can provide evidence of environmental conditions and changes during the period of recorded history. These records can include, but are not limited to, formal weather records, vegetation records, photographs, engineering records, diaries, and newspaper accounts of weather events and their effects. One form of this information that has proven very informative in southern New Mexico and western Texas are historic surveyor's records containing descriptions of extant vegetation at the time of survey (cf. Buffington and Herbel 1965; York and Dick-Peddie 1969).

SUMMARY AND CRITIQUE OF EXTANT PALEOENVIRONMENTAL EVIDENCE IN THE FORT BLISS REGION

This brief summary provides a more critical overview of the state of paleoclimatic knowledge in the Fort Bliss region than was provided in Chapter 2. It includes a review of simulated climate dynamics and an overview of data available from various proxy sources. The best extant global circulation models applicable to the Late Quaternary are probably those produced by the COHMAP research group (COHMAP Members 1988; Kutzbach et al. 1993), which are the principal basis for the discussion of atmospheric dynamics in the following discussion. The treatment of empirical evidence highlights aspects of the record that are ambiguous or conflicting, and is followed by discussions of the limitations of two specific types of data that have been used most extensively for paleoenvironmental reconstruction in the Fort Bliss area.

Summary of Late Quaternary Paleoenvironmental Reconstructions

According to both models and empirical data, the late full glacial period, which peaked approximately 18,000 B.P., was a time of moist, cool pluvial climatic conditions in the Southwest. Simulation models suggest that both winter and summer temperatures were slightly cooler than present, with summer temperatures exhibiting slightly more deviation from modern conditions. The presence of the Laurentide ice sheet resulted in much more extreme temperature gradients through the middle continent, but temperatures during both seasons were relatively moderate in the southwest, and the annual surface temperature anomaly was only -1.8°C .

Precipitation was slightly higher on an annual basis due to considerably higher winter precipitation (+1.2 mm/day), even though summer precipitation was lower (-0.64 mm/day). This increase in winter precipitation is due in large part to a strong southward diversion of the jet stream and of attendant storm tracks, to roughly 30°N latitude (a 20° diversion from its typical modern winter location), by strong anticyclonic flow over the Laurentide ice sheet. Although the amount of annual precipitation predicted by the model is only moderate (roughly 10 cm/yr), Thompson and others (1993) point out that the COHMAP models use a very simplified topographic model that probably underestimates orographically-induced precipitation.

Empirical evidence from the full glacial period is largely in agreement with the simulation model. Vegetation records are suggestive of cool, moist conditions. Piñon juniper-oak woodland appears to have been ubiquitous, with cooler species like Douglas fir common at intermediate altitudes (Van Devender 1990). Faunal records are also indicative of cool, moist conditions (Harris 1989; Elias and Van Devender 1992), and lake levels were high (Markgraf et al. 1984). Although this was the period of maximum alpine glaciation, no evidence of mountain glacier accumulation or periglacial processes exists in the vicinity of Fort Bliss, and it is unlikely that sustained winter freezes were common, although occasional hard freezes almost certainly occurred.

By latest glacial time (approximately 12,000 B.P.), the ice sheet was waning rapidly and the jet stream was positioned at approximately 38°N latitude in winter. The models suggest that winters were still slightly cooler than present, while summer insolation was higher and temperatures may have been slightly warmer. Winter precipitation was considerably higher than at present (by approximately 2.3 mm/day), but summer precipitation may have been slightly lower than at present. Overall precipitation on an annual basis appears to have been as much as 40 cm/yr greater than present in the general Southwest region.

Vegetation evidence from latest glacial time indicates that the character of regional vegetation had changed little since the full glacial, although an increased incidence of cold-intolerant plants suggests that the frequency and severity of hard freezes was lessening (Van Devender 1990). However, despite the persistence of piñon-oak-juniper woodland, lake levels in the region were

apparently falling from 18,000 B.P. to 12,000 B.P. (Markgraf et al. 1984), which is inconsistent with increasing precipitation predicted by the model. However, the model does predict that temperatures should have been increasing across the Southwest from 18,000 B.P. to 12,000 B.P., particularly in summer, which may be responsible for the falling lake levels through enhanced evapotranspiration. In contrast to the gradual temperature rise indicated by these data, insect fossils suggest that warmer and drier conditions developed relatively quickly around 12,000 B.P., although vegetative response to this trend continued until about 10 ka. At present, it is unclear whether climate changed dramatically at 12,000 B.P., or the insect and vegetative changes represent threshold responses to more gradual climatic amelioration during the latest Pleistocene. However, the development of the calcic soil on the Isaack's Ranch fill (Gile et al. 1981; Monger 1993a) suggests that the climate was dominantly semiarid throughout the latest Pleistocene.

By early Holocene time (approximately 9000 B.P.), the ice sheets had largely retreated, and global models suggest that circulation patterns were rapidly approaching modern conditions. The winter jet stream was at about 45° N latitude, and upper level winds in the Southwest were much diminished from the glacial period. As a result, the models suggest that winter storm tracks were shifted to the north of the Fort Bliss region, and amounts of winter precipitation received had fallen to approximately modern conditions or below, while midsummer precipitation was considerably more plentiful (approximately +1.3 mm/day) due to strong onshore flow of moist Pacific air. Daily insolation in summer was as much as 8 percent greater and in winter as much as 8 percent less than modern conditions due to orbital forcing; as a result, winter temperatures were cooler and summer temperatures were warmer than at present.

Empirical evidence suggests that while the principal warm-intolerant species (e.g., Douglas fir, Rocky Mountain juniper) had departed by 9000 B.P., piñon-oak-juniper woodland persisted in the mountains and the modern desert scrub species were not yet present (Van Devender 1990). Isotopic evidence from the bolson floor and marginal fans (Monger 1993d; Monger et al. 1993) suggests that grasslands probably predominated. Insect faunas represent a continuation of the admixture of mesic and arid-adapted species that developed rapidly around 12,000 B.P. Thus, the empirical evidence indicates transition from late glacial to postglacial conditions, with climate still relatively more moist and cool than present but considerably changed from three millennia earlier.

At approximately 8000 B.P., continued warming and drying appears to have resulted in a sudden environmental shift in much of the area. No major shift in circulation patterns is indicated by climate models; suggesting that this change was probably a result of various systemic thresholds exceeded as the climate dried. Although many lines of evidence indicate a fundamental environmental shift sometime around 8000 B.P. to 7000 B.P., interpretation of the character of that shift varies considerably. Monger and his colleagues (Monger et al. 1993) identified sudden, -4 percent to -6 percent shifts in isotopic carbon from soil carbonates on the fan piedmont at approximately 8000 B.P. They interpret this negative shift in carbon isotopes as indicating a change from grassland to desert scrub. Unfortunately, this shift is not mirrored in sequences obtained from the bolson floor by Rightmire (1967) and Monger (1993d).

Other supporting evidence also exists, including a pollen sequence from the Gardner Springs locality on the western side of the Organ Mountains indicating that typical Chihuahuan desert scrub was established during the middle Holocene (Freeman 1972). Van Devender (1990) also identifies a shift in vegetation at approximately 8,000 B.P. on the basis of macrobotanicals from packrat middens; however, he states that this shift is indicative of a change from oak juniper woodland to a desert grassland with some of the more resilient scrub species interdigitating with grasses across the landscape rather than the rise of Chihuahuan desert scrub. Van Devender (1990) interprets the shift as indicating slightly higher summer rainfall and more frequent winter freezes than at present. Other lines of evidence do not reflect the 8,000 B.P. shift; insect faunas

continue to exhibit a mix of mesic and xeric species (Elias and Van Devender 1992), open woodland continues to exist in west-central New Mexico, and lake levels continue to fall steadily (Markgraf et al. 1984).

Slightly later (around 7000 B.P.), alluvial and eolian activity increased in the bolson, eroding the Isaack's Ranch unit and initiating deposition of the first phase of the Organ units. Gile and others (1981) and Monger (1993a) interpret the onset of this activity to increasing aridity in the region, but there is little corroborating evidence for such a shift at this time. However, it is possible that the onset of renewed geomorphic activity at around 7000 B.P. was a lag response to the vegetative changes apparent a millennium earlier that was delayed until vegetation density decreased enough to cross a critical threshold.

By 6000 B.P., the models suggest that the jet stream had essentially returned to its interglacial station at 50° N latitude. However, greater summer insolation than currently present resulted in stronger onshore monsoonal flow from the Pacific, enhancing annual precipitation compared to modern conditions; temperature during both summer and winter was slightly higher than at present. Since 6000 B.P., insolation and precipitation have decreased, and they are approaching modern levels as the climate shifted toward increasingly arid conditions.

The enhanced monsoonal flow predicted for the late middle Holocene may have been sufficient to maintain desert grassland until around 4,000 B.P., which Van Devender (1990) identifies as the time of the shift to essentially modern, Chihuahuan Desert vegetation. However, Freeman (1972) describes a more complex model, with scrub vegetation established in the early middle Holocene and changing back to mixed scrub and grassland, which it remained until it was disturbed during Euro American settlement. In west-central New Mexico, the last remnants of the pluvial lakes disappeared by 5000 B.P. (Markgraf et al. 1984), while in the Tularosa Basin, pluvial Lake Otero had shrunken to a small, hypersaline remnant of its former self (Lake Lucero) by the late middle Holocene, and the White Sands dunefield was well-established from erosion of evaporites on the lake pan (Weber and Kottowski 1959).

Notably, with the exception of the shift from scrub to grassland at Gardner Spring (Freeman 1972), none of the local data sets strongly support the notion of an anomalously warm, dry interval during the middle Holocene. This interval, termed the Altithermal period by Antevs (1948, 1955), has become an entrenched feature in the archaeological literature and is invoked regularly in explanatory frameworks of Archaic cultural patterns. Indeed, the interval is arguably present in records from many localities in the Southwest and on the southern Plains, while sediments of the proper age are lacking — presumably itself a consequence of warm, arid conditions — from many more areas (Bull 1991; Hall 1985). However, many others question whether the Altithermal period is a valid model (Mehring 1977; Thompson et al. 1993), arguing that climatic changes are driven by shifting circulation patterns, and thus are apt to be time transgressive and more complex than a simple contrast between "moist, cool" conditions and "warm, dry" conditions. Although the issue is far from settled, the data is presently too equivocal to allow uncritical application of the Altithermal model to the Fort Bliss region.

Vegetation evidence suggests that essentially all modern plant taxa (except the few imports that arrived from Europe, such as Russian thistle) were established in the region by approximately 3,000 years ago (albeit probably in different distributions and frequencies), and the mixed insect assemblage gave way to exclusively xeric species by approximately 2500 B.P. Stratigraphic evidence suggests that two depositional hiatuses/incisional events of unknown duration occurred around 2100 and 1100 B.P. It is unclear at present what the magnitude and driving mechanisms of these interludes were, but it is safe to assume that they represent some type of environmental shift. Also, although the vegetation record suggests the dominance of desert scrub throughout the late Holocene, the almost total lack of stratification in the bolson sand sheets suggests that they

may have accreted under grassy cover. Historical information also suggests that grass cover was widespread in the central basin in the late nineteenth century (e.g., Buffington and Herbel 1965); it also suggests that limited pollen information from the Rotura soil (which is the soil buried by the coppice dunes, and thus represents the pre-European settlement surface) is strongly suggestive of a well-developed grassy cover (Gile 1966a; Hall 1990b).

Mauldin (1995) presented a fairly detailed model of climate change over the last two millennia based on tree ring variations from several localities in the Sacramento and Organ mountains: longer, more distant sequences from west-central New Mexico; an alluvial sequence from Black Mesa, northeastern Arizona; and several regional pollen and macrobotanical sequences. Although Mauldin's model is interesting, the use of data as diverse as alluvial records from northern Arizona and tree ring records from western New Mexico suggest that the reconstruction should be viewed with caution; in fact, Hall (1990c) argues that the alluvial records of Black Mesa and Chaco Canyon (which are much closer to each other than they are to the Fort Bliss region) are not comparable, implying that the correspondence between Black Mesa and the Fort Bliss region should be even less so.

The dendroclimatological reconstruction of Grissino-Mayer and others (1997) provides a more accurate record of temperature and precipitation during the past 1,373 years. The sequence offers both high and low frequency resolution and demonstrates the presence of small-scale climatic fluctuations that were undoubtedly present throughout the entire Holocene. Several alternating periods of high precipitation and drought have been identified (see Chapter 2 and Figure 2.15). Grissino-Mayer and his colleagues (1997) note that several of the intervals of drought and increased rainfall, including the "Great Drought" between A.D. 1210 and 1305, are correlated with sequences across the entire Southwest.

Cautionary Critique of Extant Data

As is apparent in the preceding summary, much of the available information on the character of Late Quaternary paleoclimates in the Fort Bliss region is based on faunal and floral material recovered from packrat middens and on isotopic evidence from soil carbonates. The following discussion focuses on the character of this and other information to highlight the strengths and limitations of that data.

First, without a firm, well-established, unequivocal chronology for any paleoecological study, regardless of the method applied, the results of the study are of limited value. A chronology for paleoenvironmental records is vital for correlation with other environmental records as well as the geology and archaeology. Archaeologists working in the bolsons have obtained numerous radiocarbon dates from archaeological sites; the reasons for doing so are obvious. The same reasons apply to paleoenvironmental records. If a high-resolution sequence of vegetation, fauna, landforms, and paleoclimate is desired, then each paleoenvironmental study, regardless of scale, must be accompanied by a suite of dates.

The big picture relationship of prehistory and past environments can only be accomplished in some regions, such as the bolsons, by pulling together many fine-scale, individual case studies. Accordingly, the unequivocal age of each of these case studies must be rigorously determined. In this business, age is everything.

To look at the issue more closely, the boundaries of the paleoenvironmental record are examined. The paleoenvironmental record from southern New Mexico, as well as any region of the world, is delimited by the age and nature of local sedimentary deposits. In turn, these introduce another issue: how to link together and blend the paleoenvironmental information derived from different sources. Each methodology has its own limitations and nuances of interpretation, and each sedimentary deposit has a distinct origin that in turn places additional limits on the record.

Although a number of paleoenvironmental studies have been conducted in the Tularosa Basin and Hueco Bolson, their results have not produced more than a rudimentary level of information on local paleoenvironmental and paleoclimatic history. A very large part of this problem is a general absence of suitable localities where paleoenvironmental studies could be successfully pursued. At this point in time, paleoenvironmental data of varying levels of usefulness have originated from the following situations in the study area and surrounding region:

- Pollen analysis—archaeological sites, woodrat middens, geological deposits
- Plant macro-remains—archaeological sites, woodrat middens
- Vertebrate remains—geological deposits
- Stable isotopes—soil carbonates

Pollen Analysis: Pollen analysis, a branch of palynology, is the most mature method in paleoecology and has been applied worldwide since the 1920s. The method has been described above (see also Davis 1969; Faegri et al. 1989). Unfortunately, arid lands such as those in southern New Mexico and west Texas possess few environments of deposition suitable for pollen studies. The single reason for the failure of many pollen studies in arid lands is poor preservation of pollen grains. Over the landscape pollen is deposited by air and grains fall everywhere, although it is only preserved in a few places (Hall 1995).

Not only is pollen only preserved in a few places, when sediments weather, the pollen assemblage contained within them also weathers, generally with a significant loss of pollen grains. However, not all pollen taxa are destroyed at the same rate. Some grains such as grasses may be destroyed first; other grains such as pine are the last to deteriorate. Consequently, weathered pollen assemblages may have lost some pollen taxa but not others, a process called differential preservation. When this occurs, the percentages of the various pollen taxa are altered and are no longer valid for interpreting vegetation (Hall 1981, 1995).

In order to assess the reliability of a pollen assemblage, four aspects related to pollen grain preservation must be determined: (1) pollen concentration (i.e., the number of grains per gram or cubic centimeter of sediment); (2) percentage of corroded pollen (i.e., the grains that show clear evidence of corrosion, breakage, pollen-wall thinning); (3) percentage of indeterminable pollen (i.e., the grains that cannot be identified due to poor preservation); and (4) number of pollen taxa. It was observed by Bryant and Hall (1993), working independently, that assemblages with fewer than 1,000 grains per gram (or about 3,000 grains per cubic centimeter) may have been affected by differential preservation. While sedimentation rates influence pollen concentration values, experience has shown that most cases of low concentration are found in assemblages that have been partly destroyed by secondary weathering processes.

A note on pollen concentration is merited here. Some analysts believe that when pollen concentration is low and little pollen is recovered during conventional laboratory techniques, processing greater amounts of sediment would produce a sufficiently large number of pollen grains for counting, thereby overcoming the problem of low concentration (Horowitz 1992; Horowitz et al. 1981). Unfortunately, this is not true. No matter how many grams or cubic centimeters of sediment are processed, pollen concentration and the reliability of the percentages, whether high or low, remains the same (see similar discussion in Chapter 8 related to macro-botanical remains).

There is a tendency among archaeologists to believe a 200-grain count is sufficient. Some samples with poorly preserved grains may yield even smaller counts. Regardless, a pollen sum of 200 is simply not adequate for either ethnobotanical or paleo-vegetation analysis. To reconstruct paleo-vegetation, a 500 grain-count is a minimum. In some European studies, counts of 2,000 are

necessary to determine cultural impact on vegetation (Berglund and Ralska-Jasiewiczowa 1986). In the case of archaeological sites where large grains of cultivated plants are being sought, increased volumes of sediment may be processed and the organic detritus sieved, removing small pollen and detritus and concentrating large economic pollen (Dean 1998a). A 200-grain count is inadequate on all levels: it may miss rare grains of economic pollen and at the same time be too small to document low-frequency trends of pollen percentages in paleo-vegetation interpretations.

One of the methodological improvements in pollen studies would be to have pollen analysts select the sites to study. Palynologists generally know from experience where good pollen information can be obtained. In the Jornada, pollen studies have generally been secondary appendages to soil or archaeological projects resulting in study sites being chosen by non-palynologists for non-palynological applications. While pollen analysis can contribute significantly to other investigations, stand-alone pollen studies that produce regionally significant paleo-vegetation records have standards and requirements that are generally not met by geomorphic-, soils-, or archaeological-driven projects. At present, a well-dated, long time-span, high resolution pollen-vegetation record does not exist in the region simply because the personnel and funding have not been available to conduct the investigation.

Recent work on Otero Mesa may have identified the best potential source for a long pollen record. In 1997, Donald Johnson guided an evaluation of the pollen content of various playas in the Tularosa Basin and Hueco Bolson, including Bassett Lake on Otero Mesa. One of the small basins, Lake Tank Playa, contains a relatively large quantity of well-preserved pollen, and the sediments have a high organic content suitable for high resolution AMS radiocarbon dating (D. Johnson 1997). The samples were obtained from a soil pit that had been dug to a depth of 2 m; the lowest playa sediments in the pit dated to 5280 ± 60 yrs B.P. (Beta No. 95522). It should be noted that sampling from a soil pit is preferable to coring because a wall profile illustrates the stratigraphy, and more sediment can be collected for pollen, geochemistry, texture, and radiocarbon dating.

The late Quaternary vegetation history of the Southwest, including New Mexico, has been reviewed by Martin (1963) and Hall (1985, 1997, 2005). Only a few pollen studies have been conducted in south-central New Mexico, but they all fall short of producing a long well-dated record that would provide a clear picture of vegetation history spanning the past 20,000 years. A study in the Tularosa Basin and Hueco Bolson by Gish (1993) has been cited to show a change from grassland to chenopod shrub land during the early Holocene, supporting evidence for a shift from C_4 to C_3 vegetation about 8,000 years ago (Monger 1993a; Monger et al. 1998). However, upon closer inspection of Gish's pollen data from Booker Hill Gully (Gish 1993, Table 4), the pivotal pollen record according to Monger (1993a) and Monger and others (1998), consists of only six samples, the lower three having very low pollen concentrations that are likely a consequence of poor preservation (Figure 7.1). Thus, the Booker Hill Gully pollen record cannot be considered definitive and is less than a weak case for a major change in vegetation.

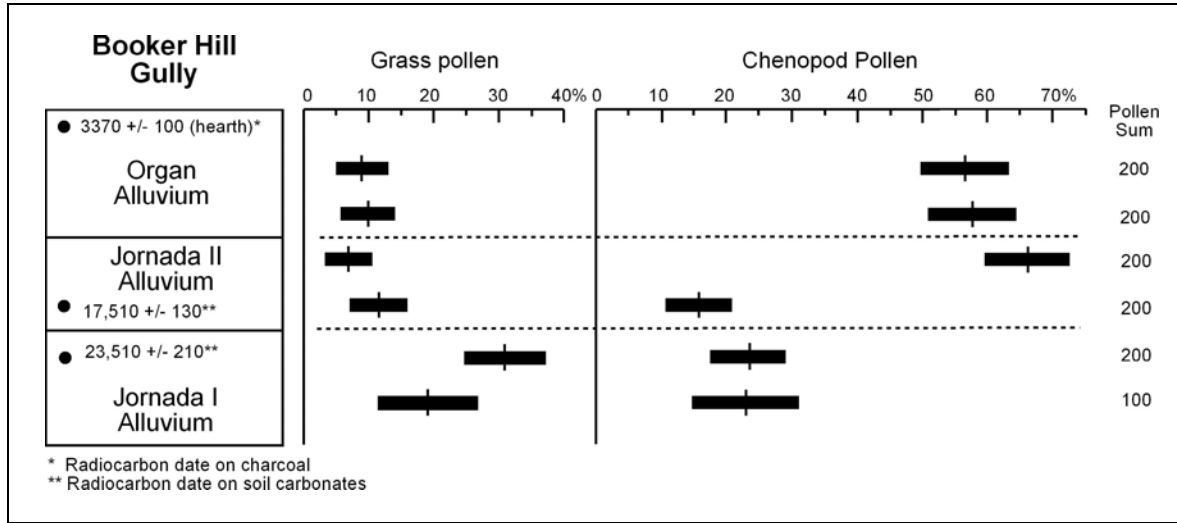


Figure 7.1. Grass and chenopod pollen percentages from Booker Hill Gully. (Gish 1993: Table 4)

Another pollen locality studied by Gish (1993, Table 3) at Old Coe Lake Gully, is a longer pollen record. Interestingly, that record does not exhibit the grass/chenopod shift seen at Booker Hill (Figure 7.2). In either event, the undated pollen records from these sites are not definitive.

The bars are 0.95 percent confidence limits (Mosimann 1965; Maher 1972) and the stratigraphic section is approximately 210 cm excluding coppice dune sand at the top. The boundary between Jornada II and Organ alluvium is thought to be ca. 7000 years B.P. by Monger (1993a). These are the key pollen data cited in support of the carbon isotope record of a shift from C4 to C3 vegetation ca. 8000 years ago in the bolson (according to Monger 1993a: 192). Two upper pollen spectra from the hearth fill and the overlying coppice dune sand are excluded from the diagram; the lower three samples have very low pollen concentrations (Gish 1993: 208, Table 1). Despite the too-young soil carbonate dates, Jornada I alluvium is thought to be 400-250 ka, Jornada II alluvium is thought to be 125-25 ka, and Organ alluvium is thought to be <4 ka (Monger 1993a; Monger et al. 1998)

Plant Macro-Fossils (Woodrat Middens): Fossilized plant remains in woodrat middens are sources of valuable information on plant biogeography that has been summarized by Betancourt and others (1990). Initially, plant species identified from the woodrat middens were interpreted as direct literal evidence of past vegetation. A midden containing juniper twigs, for example, would be interpreted as representing juniper woodland. However, it is known that woodrats do not sample vegetation randomly; rather, they select specific plants for food, nesting, and lodge construction. They are even known to select lodge sites near a juniper tree that in turn serves as a food source year-round. Therefore, middens only give an indication of presence of particular taxa within a small area around their location. Preserved woodrat middens always occur in protected places along escarpments where local plant communities differ from upland or lowland vegetation.

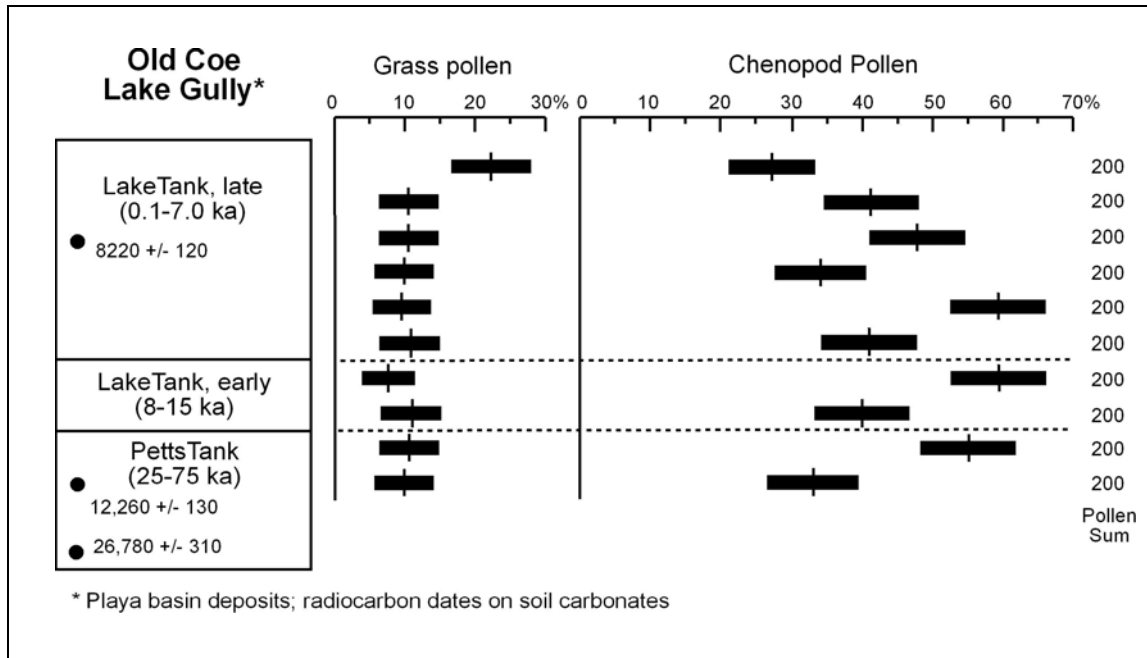


Figure 7.2. Grass and chenopod pollen percentages from Old Coe Lake Gully.

(Gish 1993: Table 3)

(The bars are 0.95 percent confidence limits [Mosimann 1965; Maher 1972] and the stratigraphic section is approximately 200 cm excluding coppice dune sand at the top. The highly variable chenopod percentages compared with the fairly constant grass percentages suggest that changes in abundance of pollen from the Asteraceae family may be affecting chenopod counts [see Gish's pollen diagram in Monger et al. 1998: Fig. 7]. If this is even partly true, then the supposed co-varying grass and chenopod pollen at Booker Hill Gully may be superficial. Regardless, a pollen sum of 200 is too small to confidently document trends in pollen percentages).

Regardless, the plant remains from woodrat middens represent only a list of species present at that locality. Plant remains in the middens do not provide any information on the abundance of those species in the vegetation (see discussions in Hall 1986, 1997). Even though midden analysts report relative abundance of macrofossils in an attempt to demonstrate species abundance (generally on a scale of 1 to 5), the effort is misleading; a midden with a thousand juniper twigs, for example, does not mean that there are any more juniper trees in the local environment than does a midden with one twig. The bottom line is that the plant remains in the middens are presence-only records. The only way to reconstruct vegetation from woodrat middens is by pollen analysis.

Van Devender (1990) presents summary descriptions from packrat and porcupine middens from caves and rock shelters near Fort Bliss; specifically the Hueco Mountains (42 middens from 1,270 to 1,495 m amsl), Bishop's Cap (12 middens from 1,400 to 1,465 m amsl), and the Sacramento Mountains (13 middens from 1,555 to 1,690 m amsl). All of these localities are situated on mountain slopes on the flanks of the bolson, suggesting that the flat bolson floor is probably poorly represented, if at all. The impact of the similar location of most packrat middens is compounded by observation of packrat behavior, which suggests that the rodents move laterally away from their dens to scavenge, and generally do not range significantly up or downslope (Elias and Van Devender 1992).

In one respect, this is a valuable aspect of the data because it implies that most packrat middens will not represent plants gathered from different ecozones, and thus allows for better resolution of diachronic trends. On the other hand, because all midden sites are situated on the mountain slopes, it implies that they only provide direct evidence of a subset of ecozones within the area of interest, and it is likely that different relief and edaphic factors resulted in strongly different vegetation assemblages elsewhere in the vicinity of Fort Bliss. Further, packrats are likely to seek out the lushest areas, particularly during arid intervals, and thus may leave a record that underestimates the impact of increased aridity on the broader landscape. As a result, packrat midden reconstructions do not always agree with other reconstructions from the same region based on other data such as pollen or geomorphic criteria (cf. Betancourt et al. 1983; Hall 1983).

Because of the above considerations, some previous interpretations of plant remains from woodrat middens should be viewed as suspect. To cite a classic example, the presence of juniper macrofossils in Holocene middens has led to the interpretation that glacial-age woodlands, and to a certain degree glacial-age cool climate, persisted in the deserts until ca. 8000 years ago (Van Devender 1977; Van Devender and Spaulding 1979). This is a case of isolated junipers growing in protected places along escarpments where woodrats selected nesting sites. In contrast to the presence/absence of juniper macrofossils, regional pollen studies clearly show a shift from glacial-age to postglacial-age vegetation ca. 14,000 years B.P. (Hall 1985). The reader should also keep in mind the caution noted by Donald Grayson (1993: 215) that studies of woodrat middens may be biased because some analysts have specifically collected only the middens that show plants that are no longer present in the area. In order to get around this bias, a sampling strategy needs to be in place when there are many middens. If the number of middens is small, then any investigation should include all of them, a 100-percent sample.

One of the reasons for the confusion is that independent tests of plant macrofossil and pollen analyses are seldom made. In one thorough test at Chaco Canyon, New Mexico, pollen from woodrat middens and from nearby well-dated alluvium was compared with plant macrofossils (Betancourt and Van Devender 1981; Hall 1988). Presence of piñon pine (*Pinus edulis*) needles and juniper (*Juniperus monosperma*) twigs in the middens had previously led to the conclusion that the Holocene vegetation in the canyon was pine-juniper woodland. Pollen analysis, however, indicated that the vegetation has been shrub grassland throughout the Holocene with isolated junipers and piñons along the sandstone escarpments (where the woodrat middens are preserved). Isolated junipers and piñons still occur along the canyon escarpments in the present-day shrub grassland vegetation of Chaco Canyon and the surrounding San Juan Basin.

Some portions of the Jornada region have potential for woodrat middens. The Hueco Mountains on the east side of the bolson, as well as Bishop's Cap on the west side all contain numerous fossilized woodrat middens (Thompson et al. 1980; Van Devender 1986; Van Devender and Everitt 1977; Van Devender and Riskind 1979). Plant macrofossil studies were also associated with the research at Pendejo Cave (Betancourt et al. 2001; McVickar 2003). Other woodrat middens, presently unstudied, are known from the Otero Mesa escarpment at Fort Bliss. Studies of these, including plant macrofossils and especially pollen, offer good potential for new paleoenvironmental information from the area. Beyond the Jornada region, new investigations of fossil woodrat middens from the Playas Valley and Peloncillo Mountains south of Lordsburg, New Mexico, have been reported (Holmgren et al. 2003, 2006, 2007). According to their work, the Wisconsinan glacial-age flora was dominated by C₄ grasslands with local trees and, after about 5000-4000 yrs B.P., C₃ desert shrubs abruptly became more prominent in the local flora. However, caution is advised in the use of these data. The paleo-floral record of plant-species presence is incomplete, and only one dated midden was reported from the critical time period between 10,350 and 4990 ¹⁴C yrs B.P. (Holmgren et al. 2006). The early Holocene and early mid-Holocene are missing from the midden record.

Vertebrate Paleontology: Vertebrate fossils provide valuable insights into past environments and climate. The Quaternary paleoecology of vertebrate fossil assemblages has been investigated for more than a century (Bell et al. 2004). In the Tularosa Basin and Hueco Bolson there have been few discoveries of vertebrate fossils; the most extensive record comes from Pendejo Cave. More than 41,000 identifiable bones were recovered from the cave, 93 percent of them mammals and the remainder reptiles, birds, and amphibians (Harris 2003). The vertebrate fauna shows that the Wisconsinan (Late Pleistocene) climate was significantly cooler than the Holocene.

Harris (2003) also lists the other vertebrate faunal localities in the region, many of them identified by him. A list of all taxa recovered from Quaternary vertebrate localities in New Mexico can be found in Harris (1993). The Lake Otero Fauna is a series of fossil vertebrate records from the Lake Otero lake beds (Morgan and Lucas 2002), recently named the Otero Formation (Lucas and Hawley 2002). These fauna indicate a cooler and wetter climate during the late Pleistocene.

Also preserved in the lake beds are mammoth (*Mammuthus* sp.) and camelid (*Camelops* sp.) tracks (Lucas et al. 2002). Fossil bones of *Mammuthus columbi* and *Camelops* sp. occur in the Lake Otero Fauna (Morgan and Lucas 2002). Holocene fossil vertebrates are rare in the Jornada. Vertebrate remains are seldom recovered from archaeological sites in the Jornada; bone preservation in thin eolian sand deposits is generally poor.

Stable Carbon and Oxygen Isotopes: Stable isotopes are not radioactive, by definition, and, in this discussion, include ^{12}C , ^{13}C , and ^{18}O . Their abundance in nature is related to complex environmental relationships that continue to be explored by laboratory experiments and field studies. The discussion below provides evidence from new isotopic studies completed since the 1996 *Significance Standards* document was published. Even in the 1996 document, it was noted that although several of the data sets from Monger (1993a, 1993d) and Rightmire (1967) exhibited interesting trends, the differences between the data sets were significant and troubling.

As noted in Chapter 5, plant species with different photosynthetic pathways will fractionate carbon, resulting in $\delta^{13}\text{C}$ values (or $^{13}\text{C}/^{12}\text{C}$ ratios), that are significantly different. C_3 plants have mean $\delta^{13}\text{C}$ values of -26 ppt and C_4 plants have mean $\delta^{13}\text{C}$ values of -13 ppt. Plant communities with both C_3 and C_4 species will have $\delta^{13}\text{C}$ values intermediate between -26 and -13 ‰.

Organic carbon content of soils can be analyzed for $\delta^{13}\text{C}$ values that will provide information on the relative numbers of C_3 and C_4 species that makeup the vegetation. Soil carbonates are problematic, however (see discussion in Chapter 6). It has been shown in one study that soil organic matter and soil carbonates consistently differ on the average of approx. 14 to 16‰ (Cerling et al. 1989). Thus, given a vegetation-soil organic matter with $\delta^{13}\text{C}$ values of -26 (entirely C_3 species), the associated soil carbonates will have $\delta^{13}\text{C}$ values of approximately -11‰; and a soil with $\delta^{13}\text{C}$ values of -13 (entirely C_4 species), the associated soil carbonates will have $\delta^{13}\text{C}$ values of approximately +2 ‰. Thus, soil carbonates formed with a plant biomass of $\frac{1}{2}$ C_3 and $\frac{1}{2}$ C_4 plants will have $\delta^{13}\text{C}$ values approximately -5 ‰.

Two studies of soil carbonates in southern New Mexico, the Tularosa Basin and Hueco Bolson, and the Rio Grande Valley, have resulted in large data sets with $\delta^{13}\text{C}$ values that, based on the above information, represent C_4 -dominated plant communities (Cole and Monger 1994; Deutz et al. 2001, 2002; Monger 1993d; Monger et al. 1998; Rightmire 1967). The Tularosa Basin and Hueco Bolson record, however, has been interpreted as showing a shift from C_4 -dominated grass to C_3 -dominated shrub vegetation about 8000 years B.P. (Cole and Monger 1994; Figure 7.3).

The Rio Grande Valley study (Deutz et al. 2001) does not support the Cole and Monger (1994) interpretation. Indeed, the data show a trend towards higher $\delta^{13}\text{C}$ values (Figure 7.4), not lower as reported by Cole and Monger. A plot of the mean values for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ (discussed below) for the pre-8000 and post-8000 yr B.P. periods of time from the two studies illustrates the

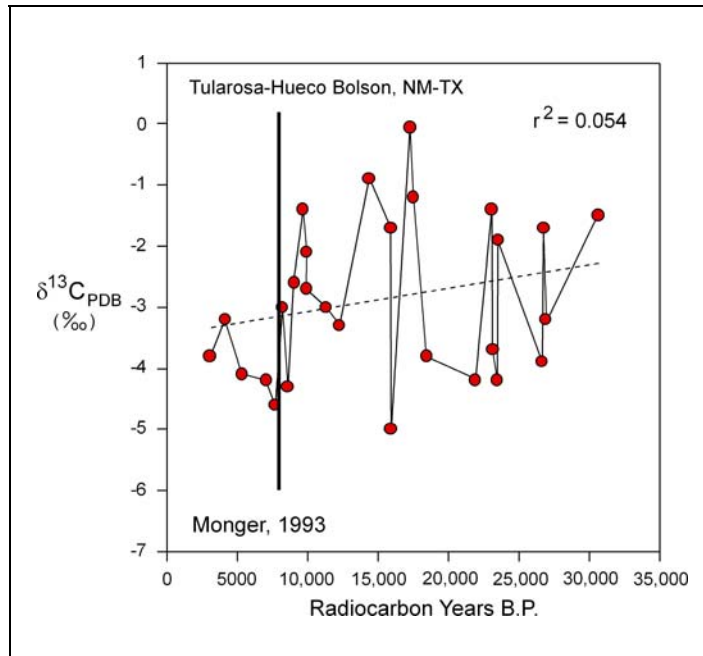


Figure 7.3. Radiocarbon dates and $\delta^{13}C$ values from soil carbonates in the Tularosa Basin and Hueco Bolson.

(data from Monger 1993d: 201-202, Table 8.1)

Note: the dark vertical line at 8000 yrs B.P. is, according to Cole and Monger (1994), a decrease in $\delta^{13}C$ values that marks a shift from C4 to C3 plant communities

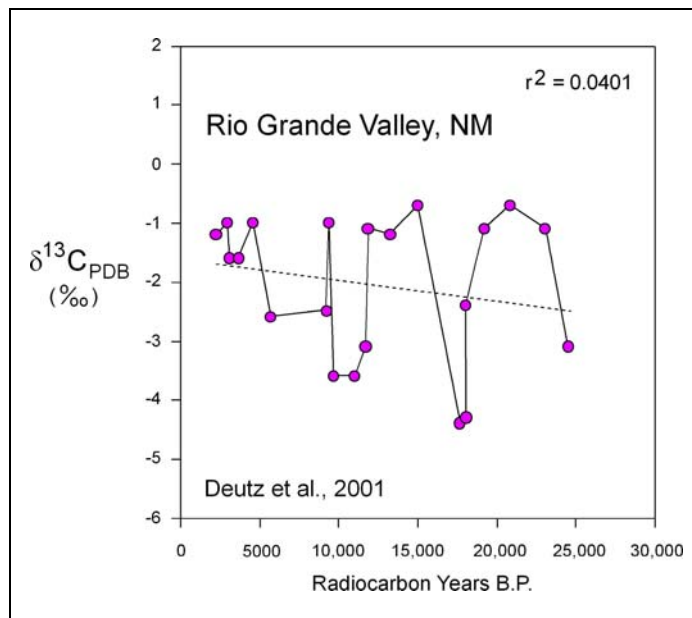


Figure 7.4. Radiocarbon dates and $\delta^{13}C$ values from soil carbonates in the Rio Grande Valley of southern New Mexico.

(data from Deutz et al. 2001, Table 1)

Note the slope of the regression line is toward higher $\delta^{13}C$ values from Pleistocene to Holocene, in contrast to the Tularosa Basin and Hueco Bolson data shown in Figure 7.3.

differences in the results (Figure 7.5). Using the criteria of Cole and Monger (1994), the Rio Grande Valley results indicate an increase in C₄ plants from the Pleistocene into the Holocene. At the same time, however, all of the soil carbonate data indicate the presence of C₄-dominated plant communities throughout the late Quaternary (see Figures 7.3 and 7.4). The data also show that, if the numbers are meaningful, the Rio Grande Valley experienced a shift towards more C₄ plants during the Holocene while the Tularosa Basin and Hueco Bolson saw a shift towards fewer C₄ plants; at the same time, however, the vegetation in both areas was dominated by C₄ species.

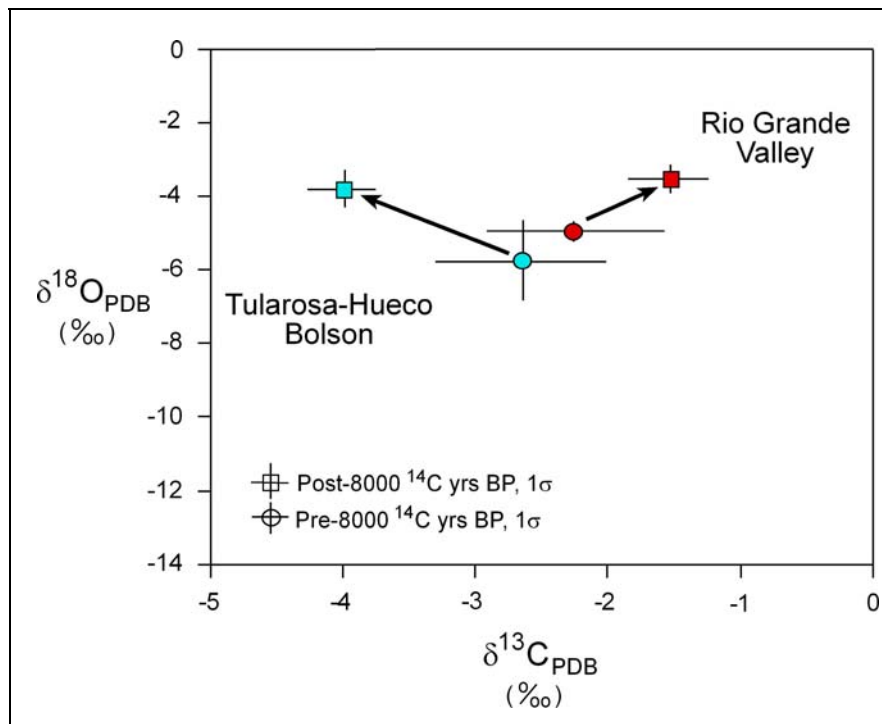


Figure 7.5. Stable isotope trends for pre-8000 and post-8000 yrs B.P. periods of time when Cole and Monger (1994) identify 8000 years B.P. as the time of a shift from C₄ to C₃ plant communities.

Note the Tularosa Basin and-Hueco Bolson data show a shift towards lower δ¹³C values and more C₃ plants; the Rio Grande Valley data show a shift towards higher δ¹³C values and fewer C₃ plants relative to C₄ plants. In both cases, the δ¹⁸O values shift from lower to higher, consistent with global trends

Macrofossils from woodrat middens in southeastern New Mexico have been interpreted to indicate that C₃ desert shrubs became established after ca. 5,000-4,000 years ago (Holmgren et al. 2007), in contrast to the stable isotope data discussed above. However, as discussed below, the midden record has a 5,000-year gap during the critical early-mid-Holocene period of time.

Planetary warming and subsequent melting of glaciers has resulted in a trend to greater or “heavier” δ¹⁸O values. The changing δ¹⁸O values show up in virtually all carbonate-precipitate environments. The trend in δ¹⁸O is also documented in radiocarbon-dated Pleistocene-Holocene secondary soil carbonates in the Tularosa Basin and Hueco Bolson and the Rio Grande Valley (Figures 7.6 and 7.7). As noted in the 1996 *Significance Standards*, the results of oxygen isotope studies from the bolson floor showed little similarity and caution was recommended. Recent studies provide greater perspective on the issue of secondary soil carbonates.

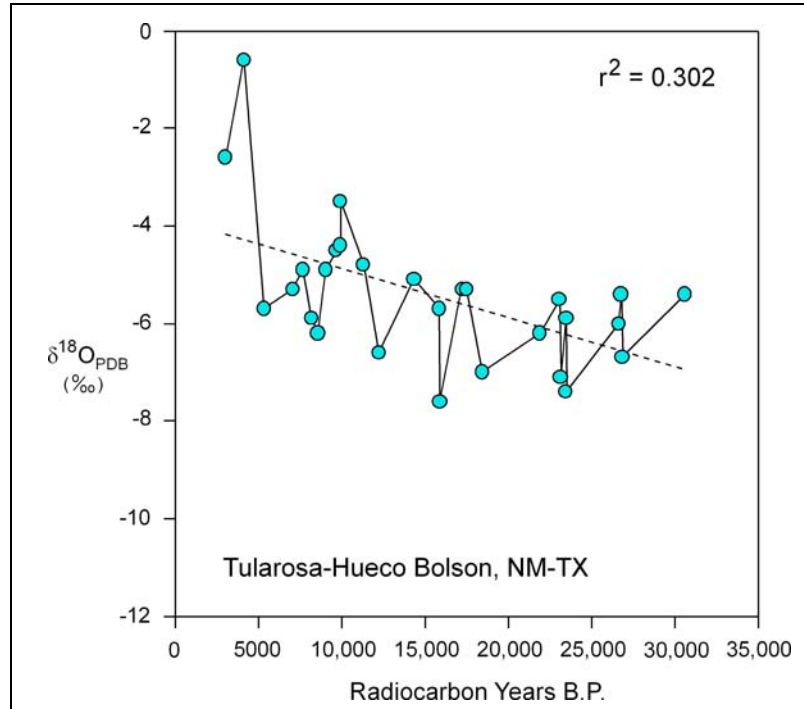


Figure 7.6. Radiocarbon dates and oxygen isotope values from soil carbonates in the Tularosa Basin and Hueco Bolson, New Mexico and Texas. (from Monger 1993d: 201-202, Table 8.1)

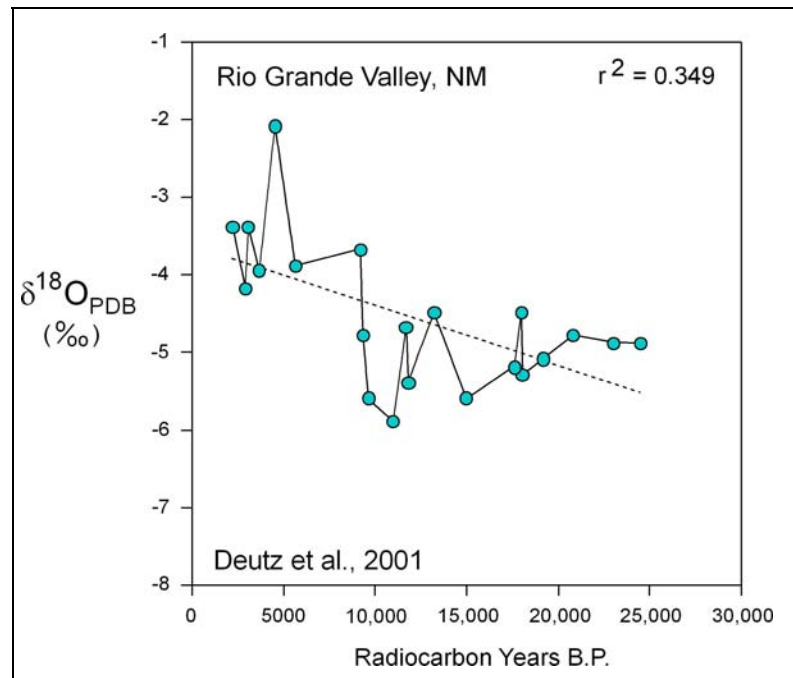


Figure 7.7. Radiocarbon dates and oxygen isotope values from soil carbonates in the Rio Grande Valley, southern New Mexico. (from Deutz et al. 2001, Table 1)

One last issue complicates the soil and carbonate isotopic data. All of the above data and their correlation are dependent upon one assumption: that the radiocarbon ages of soil carbonates accurately represent true radiocarbon years. The evidence indicates that this is not the case (see discussion in Chapter 6). Accordingly, assertions concerning the environmental significance and timing of these isotopic trends and their correlation with more firmly dated paleoecological records are likely spurious. The radiocarbon ages of soil carbonates, while a puzzle, can only be regarded as inaccurate.

Stable Carbon Isotopes in Wood Charcoal Samples: Utilizing a database of 602 $\delta^{13}\text{C}$ values measured in mesquite wood charcoal radiocarbon samples, Miller (1996) developed a long-term proxy measure of temperature. Although originally intended to evaluate effective hydration temperatures that created cyclical patterns among obsidian hydration dates, the reconstruction may also be useful for broader paleoclimatic applications. Figure 7.8 compares the tree-ring reconstruction of precipitation and related temperature against the trend of $\delta^{13}\text{C}$ values in the 1996 version of the Jornada radiocarbon database.

There are several general correlations between lower than average $\delta^{13}\text{C}$ values (indicating periods of water stress on plants) and the episodes of drought isolated in regional tree-ring sequences. Peak precipitation periods in the tree-ring sequence are not as evident in the trend of $\delta^{13}\text{C}$ values, although this may be due to the fact that water abundance is not manifested as acutely as water stress among plants. In addition, $\delta^{13}\text{C}$ values fluctuate dramatically during periods prior to A.D. 1090. This is likely a sampling problem since fewer radiocarbon dates and $\delta^{13}\text{C}$ measures are available during this period.

The $\delta^{13}\text{C}$ sequence should not be used to replace or supplant the reliable and high-resolution tree-ring sequence. The implication, though, is that the $\delta^{13}\text{C}$ may be extended back an additional 2,100 years or more with the continual addition of radiocarbon dates from archaeological sites at Fort Bliss. Thus, use of $\delta^{13}\text{C}$ trends to obtain higher-resolution paleoclimatic data beyond the 1,373-year limit of the dendroclimatic study may be possible.

ARCHAEOLOGICAL SITES AND THEIR BOUNDARY CONDITIONS

Another part of the cautionary critique of extant data are the archaeological sites themselves as they are special cases that present challenges to the paleoecologist. Open sites, excluding caves and rock shelters, may not contain sediments that were deposited during the period of habitation. The closest one might come to contemporaneity is the sediment fill in pit features. Although the sediments in a large pit are clearly post-occupation, the sediments probably date from a period of only a few years after the site was abandoned.

Deposits contemporaneous with occupation are also found in cultural middens at El Paso phase pueblo sites. Small pockets or lenses of contemporaneous sediment may also be associated with a living surface. Thus, the goal of obtaining a picture of paleoenvironmental conditions during the time that the site formed is severely limited by the fact that sediments representing the site are generally lacking.

Perhaps a more immediate question is: Are sediments from archaeological sites reliable sources of paleoenvironmental information? The answer to the question is a lightly qualified “no.” By their very nature, sites are places that have been changed by their inhabitants in a number of ways. Selected plant materials are brought to sites for fuel, food, tools, and shelter. During prolonged habitation, the local plant community at and around the site may be altered by the harvesting of specific plant species.

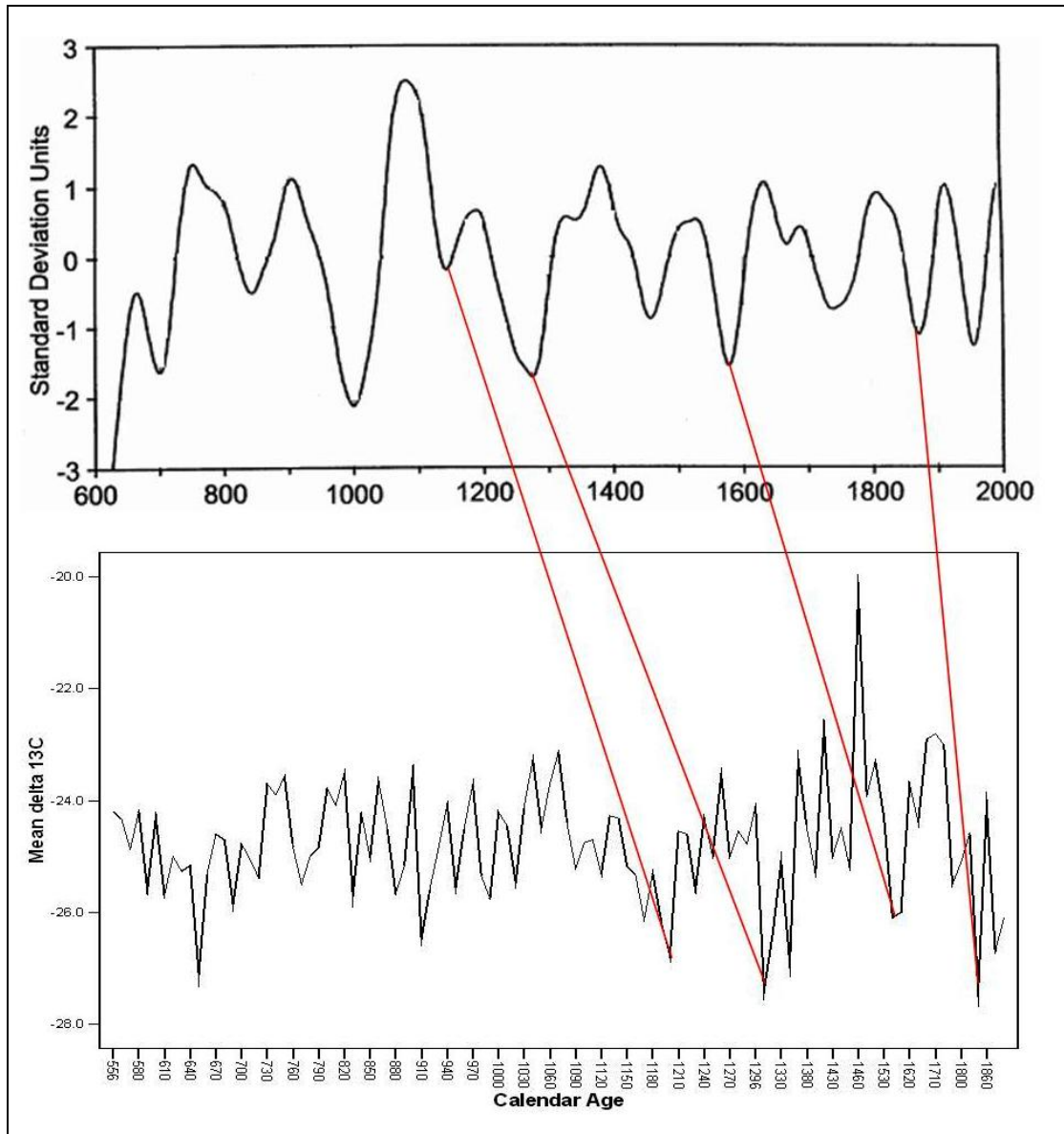


Figure 7.8. Comparison of precipitation and temperature reconstructions for the period of A.D. 600 to 1950 based on tree ring sequences and trend of $\delta^{13}\text{C}$ values. (upper figure after Grissino-Mayer and others 1997, lower figure after Miller 1996)

Local disturbance of the soil at the site may also result in the appearance of disturbance or secondary succession species such as weeds of the aster and chenopod families. The combination of plants being brought to a site and the disturbance accompanying site occupation also results in plant macro-fossil and pollen assemblages that differ significantly from non-site areas. Accordingly, plant remains from archaeological sites must be used sparingly, if at all, for paleoecological applications.

On the other side of the coin, plant and animal remains from archaeological sites may provide a valuable biogeographic record that in turn contains environmental information. For example, the presence of wood charcoal of mesquite (*Prosopis* sp.) from a dated feature at a site confirms that

during that time period, the genus was present locally. Although its presence cannot reveal whether mesquite was as abundant in the local vegetation such as it is today, it does confirm that the general environmental conditions needed to support mesquite growth existed in the bolson. Another limit is that wood charcoal can seldom be identified to the level of species or subspecies. Thus, even though it is established that mesquite was present within the site area, it cannot be determined which of the four species and subspecies that are present in the bolson today were present in the past. Furthermore, it should be pointed out that the absence of charred wood or seeds of mesquite at a site does not indicate that mesquite was not present in the local flora. Plant macro-remains are another “presence-only” type of data. The same applies to vertebrate and invertebrate faunal remains from archaeological sites.

Pollen analyses are conducted at sites to provide information on the presence of economic plants used by inhabitants of the site (Gish 1995). Site paleoecology is generally not a goal, although sometimes an unexpected discovery has paleoenvironmental implications, such as an observation of the recovery of cattail pollen (*Typha* sp.), indicating the local presence of a wet habitat. Pollen analysis, if the pollen sum is large (see above discussion), may also show cultural disturbance of local plant communities. To do this, however, pollen data from non-site localities that are the same age as the site must be in hand for comparison.

In summary, the paleoecological record is only partially understood in the vicinity of Fort Bliss. While some interesting trends are apparent, there is contradictory information about the character of paleoenvironmental history in the region although recent studies have provided some new data. The early and middle Holocene records, in particular, are poorly understood. While broad regional climatic reconstructions are conceptually valuable and probably do have some validity, the mechanism's driving climate change are complex and should be expected to result in changes that are typically time-transgressive and occasionally unique to specific areas. It follows that the key to understanding the Fort Bliss region is continued, directed research designed to answer questions pertaining specifically to the area.

SUMMARY AND RECOMMENDATIONS FOR PALEOENVIRONMENTAL RESEARCH

As has been shown, there are four lines of evidence (historical data, circulation models, proxy evidence, and direct evidence) that can be employed to examine the paleoenvironmental history of Fort Bliss. This history is important in the study of prehistoric social systems, as it allows for inferences to be made about how groups in the past managed risk, coped with their environment, or organized their dietary patterns. Therefore, improved understanding of that paleoclimatic history can refine our ability to make reasonable inferences about past groups. Based on the foregoing, several suggestions are offered for additional research that would improve our knowledge of the regional environmental history.

Paleoenvironmental Data Potential as a Criterion for NRHP Eligibility: The issue of the Paleoenvironment research as a component of NRHP eligibility evaluation programs is reviewed in Chapter 14. The basic issue is that “Paleoenvironment” is very rarely an intrinsic attribute or quality of a prehistoric site, but rather is a characteristic of the natural environment in and around the location in which a site is situated. In other words, paleoenvironmental data and study contexts may be fortuitously associated with the spatial boundaries of an archaeological site but not intrinsically with the prehistoric occupation or cultural materials of that site. In summary, for purposes of evaluating NRHP eligibility, the Paleoenvironment research domain is usually either inapplicable or is redundant with other research domains. Accordingly, it should be eliminated as a standard contributing research domain for NRHP evaluation programs. However, under certain conditions where clearly outstanding paleoenvironmental data is present within a site it may be considered, along with the Chronometric and Geomorphology domains, as an intrinsic site

characteristic. Under such circumstances it may be used as an optional criterion for eligibility, as well as for subsequent treatment and management decisions.

Research Issue 7-1

What are the paleoclimatic implications of the eolian sequence? The fan sequence? The slope deposits? Soil development? Can refined chronologies for these sequences be linked to broader paleoenvironmental processes?

As reviewed in Chapter 5, recent OSL dating studies suggest alternate chronologies for the Quaternary eolian depositional sequence in the central basins. These may have broader linkage to climatic and glacial sequence. Thus, there is considerable room for refinement of the basic sequences and for improvement of interpretive linkages. The best opportunity for understanding these problems lies in continual refinement of the questions asked as evidence from a variety of sources mounts. Slope systems, in particular, are poorly understood in the vicinity of Fort Bliss and can provide a record that differs both in the character of the information and the level of detail from that accessible through eolian and alluvial records. As projects involving archaeological mitigation on Fort Bliss expand into the alluvial fans and slopes in the Doña Ana firing ranges and across McGregor Range, opportunities to examine paleoenvironmental and depositional sequences in the fans should be pursued.

Data needs: Continued programs of OSL dating of eolian strata in the Hueco Bolson and Tularosa Basin and an expanded program of OSL dating of alluvial and slope deposits, combined with trial pollen studies to examine preservation potential in alluvial sediments.

Research Issue 7-2

What is the nature of sediments preserved in playas? Are any organisms of paleoenvironmental significance (e.g., pollen, diatoms, ostracodes) preserved in playa sediments? What rates of sedimentation are indicated? Can stratified dessication strata indicative of punctuated playa activity be isolated and dated? What are the paleoclimatic implications of the sedimentary and biotic record in playas on Fort Bliss?

Preservation of biotic and sedimentological evidence in playa pans on Fort Bliss is unproven but poses one of the best unexplored opportunities to make significant advances in knowledge about paleoclimatic and paleohydrologic conditions in the Fort Bliss region. Investigations should focus on a variety of playas, because the degree of preservation of suitable sediments is likely to be highly varied. Evaluation of size fluctuations through time is also no easy task given the relatively small scale of the playas, but should be possible given the provision for extensive chronometric sampling. Recent radiocarbon dates indicate the upper one to two meters of deposits in fan-margin playas are relatively recent in age, dating to the Late Holocene.

Data needs: Detailed, chronologically constrained studies are needed of a variety of playa lakes within the post. These studies should include provisions for exposure, sampling, and laboratory analysis of playa sediments, coupled with sampling for chronological control.

Research Issue 7-3

What is the history of lake levels in Lake Lucero, in adjacent White Sands Missile Range? What implications does this have for effective moisture through the Late Quaternary? What is the nature of the biotic and sedimentary record in the lakebed? What is implied about water chemistry, and particularly salinity, at various periods? Can significant, synchronous changes in playa size be documented on Fort Bliss? What are the implications for the paleoenvironment? For evolution of the feeder drainage net on the fans?

Although Lake Lucero is situated outside of the boundary of Fort Bliss, it represents the only extant, quasi-permanent water body in the bolson, and its potential to address paleoenvironmental questions is unprecedented. It is likely that Lake Lucero and its pluvial ancestor, Lake Otero, were never good sources of water due to high concentrations of soluble salts. However, if diatom or ostracod records can reveal trends in salinity since the full glacial, they may also indicate times when fresh-water input was enhanced or restricted.

Data needs: Sampling and analyses are needed of bottom sediments and former strandlines in Lake Lucero.

Research Issue 7-4

How can the stable isotope signatures associated with pedogenic carbonates be refined, and what are the climatic implications?

As illustrated previously, carbon isotope analysis of pedogenic carbonates has strong potential to reveal trends in the relative frequency of C₃ and C₄ vegetation, and has already yielded some interesting results on the post (Monger 1993d; Monger et al. 1993). However, the movement of carbon in the soil system is very complex, and repeated dissolution and reprecipitation of pedogenic carbonates can result in the admixture of contemporary and fossil carbon that may seriously complicate interpretation. Therefore concentration on early-stage soil carbonates (e.g., filaments and small nodules) is advocated where the problems introduced by repeated dissolution and reprecipitation are less pronounced.

Data needs: Radiocarbon dates and $\delta^{13}\text{C}$ values are needed from carefully selected samples of pedogenic carbonate, particularly samples representing earlier stages of carbonate development.

Research Issue 7-5

How can archaeology refine the faunal record of the region? What are the implications for the paleoenvironment? What do the carbon, nitrogen, and oxygen isotope signatures of faunal remains imply about the paleoenvironment?

Many aspects of environmental faunal analysis are not viable in archaeological contexts due to the intense series of taphonomic filters imposed by human selection, procurement, and processing strategies. Nevertheless, at minimum, faunal remains in an archaeological site can establish the presence of specific taxa in the broader environment at that time. Examination of the environmental preferences typical of each identified taxa can then be used to interpret broad constraints on the character of the environment at the time of site formation, as well as providing information on the types of ecozones that were exploited. Isotopic studies on bone from archaeological sites also have implications for diet, and by implication, regional character of the biotic system, particularly in regards to C₃/C₄ and leguminous/nonleguminous plant ratios.

Data needs: Faunal remains are needed from archaeological contexts.

Research Issue 7-6

What is the character of oxygen and carbon isotopes preserved in tree rings and groups of tree rings in prehistoric wood and charcoal samples?

Oxygen and carbon isotopes are indicative of paleotemperatures and past precipitation rates, albeit in a complex manner that requires careful interpretation. Tree rings are relatively unique records in that successive rings represent fixation by a single organism over a relatively long span of time, and can therefore minimize the impact metabolic biases have, particularly if the data is used to derive trends rather than absolute temperature estimates. Further, comparison of oxygen isotope values between low-growth and high-growth-season wood can potentially isolate

seasonal influences, which in turn could provide a clear interpretation of oxygen isotope records from other sources, particularly regarding whether those trends are attributable to absolute changes in temperature, rainfall seasonality, or moisture source areas. Stable carbon isotopes measured in radiocarbon-dated charcoal fragments can be used to reconstruct temperature and precipitation patterns, although the resolution and accuracy is not equal to that provided by dendroclimatic studies. A comparison of the chronometric trends among $\delta^{13}\text{C}$ values (Miller 1996) with reconstructed precipitation patterns in tree-ring sequences (Grissino-Mayer et al. 1997) shows general similarities for the period between A.D. 600 and 1950. Although not as accurate or precise, a greater time depth can be obtained with the radiocarbon-dated $\delta^{13}\text{C}$ trends.

Data needs: Wood samples containing rings are needed, either from archaeological or natural contexts.

Research Issue 7-7

What kinds of species are represented in the preserved wood charcoal in features?

This question is interesting not only from a purely paleoecological perspective (what species were available for use as fuel?) but also from a behavioral perspective, as it may provide an indication of the extent that firewood was transported in to campsites, particularly in the central bolson. Dering (2001) has used relative proportions of mesquite heartwood, sapwood, and branches to estimate resource stress due to increasing population densities.

Data needs: Wood and charcoal fragments are needed from archaeological contexts.

Research Issue 7-8

Can pollen of sufficient counts and preservation be extracted from stratified deposits in alluvial fans or playa sediments?

Pollen studies have proven to be of mixed utility. Pollen recovered from central basin eolian deposits is poorly preserved. Pollen from alluvial fans is less degraded, but few studies have been conducted to determine if suitable contexts exist in these rapidly aggrading alluvial fan deposits. Playa lakebeds offer the most productive contexts for pollen studies, such as that identified at Lake Tank Playa (D. Johnson 1997).

Data needs: Pollen sequences of sufficient preservation and counts (e.g., +500) from stratified and dated contexts.

Research Issue 7-9

Can woodrat middens offer further insights into Holocene and Late Pleistocene paleoenvironments?

Niches and caves along the Otero Mesa escarpment should be examined for the presence of woodrat middens.

Data needs: Woodrat middens of sufficient age depth and preservation.

The following is a list of recommended tasks and methodology for investigating the geology and paleoenvironments of the Tularosa Basin and Hueco Bolson. Some of these topics are discussed in the text, others are not.

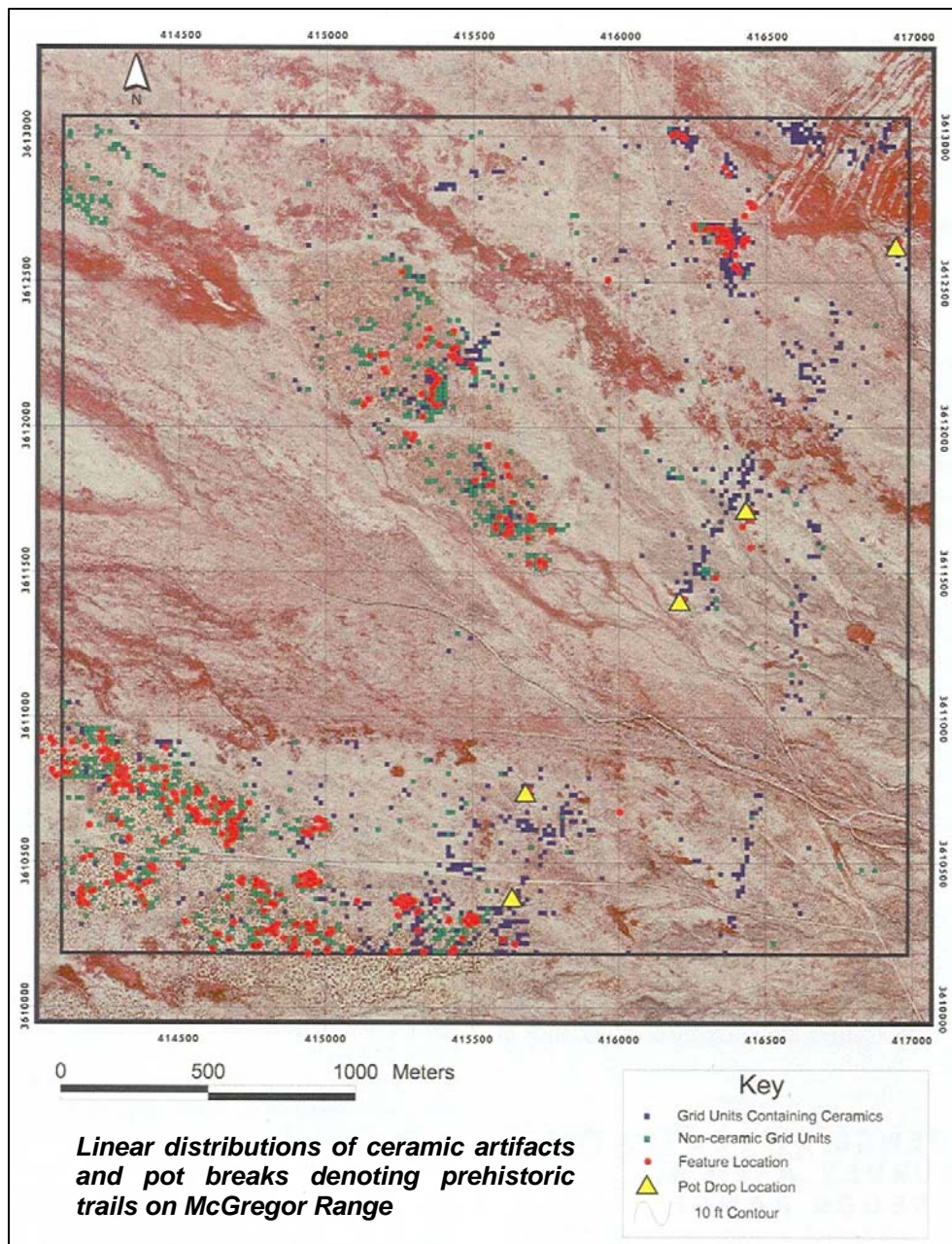
- There are two applications of pollen studies: (a) *paleo-vegetation* that can (in some circumstances) lead to paleoclimatic reconstruction and (b) *ethnobotany* that can be used to determine what plants prehistoric people were growing, harvesting, and eating. The

two applications can seldom be done using the same pollen assemblages. Indeed, paleo-vegetation work must be conducted away from archaeological sites and from any prehistoric cultural influence. The pollen samples must be collected from well-dated sediments without the presence of paleosols, and represent the longest possible period of time.

- If pollen is used for paleo-vegetation analysis, it is very important to determine: (a) pollen concentration (grains per gram is better than per cubic centimeter); and, (b) percentages of corroded pollen grains. It is also important to count a minimum of 500 pollen grains, excluding the introduced spike. Counts of 200 are considered as reconnaissance-only to assess a sediment potential for further study.
- Pollen analysis is needed at Lake Tank Playa. A previous pilot investigation showed that the sediments at Lake Tank contain an abundance of pollen and that the high organic content of the playa deposits can be easily radiocarbon dated. If a pollen study is funded, the analyst must be a thoroughly trained scientist experienced in pollen-based paleo-vegetation and paleoecology, preferably a practitioner at a major university laboratory.
- An analysis of woodrat middens needs to be conducted along the Otero Mesa escarpment. The new study should include pollen analysis of midden material. It is further recommended that the midden study include a midden-selection sampling strategy, thus avoiding the selection of middens based on the presence of extra-local plants. The plant macrofossils and the pollen should also be studied by different individuals in different institutions to increase objectivity in the analyses and conclusions.
- Additional stable carbon and oxygen isotope studies should be pursued, including samples extracted from carbonates and wood or wood charcoal samples. With sufficient radiocarbon dates, it should be possible to extend the $\delta^{13}\text{C}$ record back to circa 3500 B.P., thus encompassing much of the Late Holocene and the Late and Middle Archaic periods of the prehistoric sequence.
- The sciences of geomorphology, stratigraphy, and paleoecology can and do provide valuable information in the bolsons. These results are directly applicable to the prehistoric record. However, it should be recognized that archaeology-driven geology and archaeology-driven paleoecology may not result in a comprehensive understanding of the geologic and paleoecologic processes and history of the Jornada. The investigation by Blair and others (1990a, 1990b) illustrates the value of a geology-directed study to determine geologic history. Classic geomorphic and soils approach in the bolson, such as the valuable works by Monger (1993a) and D. Johnson (1997), have not provided the kind of stratigraphic information needed by the archaeological community actively working in the area. While soils and classic geomorphology play a role in our understanding of the geologic history of the bolson, the contributions of soil and geomorphic studies can best be done after the stratigraphy and geochronology of the bolsons deposits have been established. Continued investigations of stratigraphic-sedimentologic-OSL dating of the sand sheet, such as the test case of El Arenal Site, need to be extended across the bolson. It is anticipated that once an OSL-dated stratigraphic framework is established the soil and geomorphic information can be applied and a comprehensive geologic history of the bolson can be developed that is directly applicable to the extensive archaeological record.

PART III.

ARCHAEOLOGICAL DOMAINS FOR EVALUATING NRHP ELIGIBILITY AND THE DESIGN OF RESEARCH PROGRAMS



CHAPTER 8. SUBSISTENCE AND SUBSISTENCE ECONOMY

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and Mike Quigg

This chapter presents background on subsistence issues within the study area. It begins with a context for understanding subsistence in the northern Chihuahuan Desert. Then, after a review of biological and artifact data sets that may be applicable to investigations of subsistence, a series of general research questions are outlined that are applicable to regional, intraregional, site, and intrasite levels. Data needs that are required to effectively investigate these questions are identified at a general level. This is not an overview of subsistence in the Jornada, nor is it a detailed review of all previous investigations in the region. Rather, our goal is to provide sufficient background information on data groups, identify gaps in current subsistence research, and outline research that will begin to close those gaps.

The chapter has been modified from the 1996 *Significance Standards*. Recent data has been incorporated into some sections, and, in some cases, critical review of the utility of some studies is provided. For example, a discussion of the value of flotation analysis of features that are eroded and/or represent low-intensity use in the central basins has been added. Also, in keeping with the broader theoretical approaches presented in this revised *Significance and Research Standards*, (see Chapter 4), subsistence studies, where appropriate, are assessed for their potential to provide information on issues such as ritual or communal feasting. The discussion begins with a context for considering subsistence in the Jornada Mogollon.

A CONTEXT FOR PREHISTORIC SUBSISTENCE IN THE NORTHERN CHIHUAHUAN DESERT

The subsistence research domain in the original *Significance Standards* focused on archaeological methods used to explore subsistence issues, rather than the issues themselves. As an understanding of the prehistoric subsistence economies that evolved locally is essential to making sense of the archaeology, this updated section addresses the local issues of subsistence. To set the stage, some general context should be established. This context, while drawn from anthropological and ethnographic literature, also has to be tested as it is applied to local prehistoric conditions.

The discussion begins with population estimates. Using Birdsell's (1953) formula and based on a modern average annual precipitation level of about 22 cm, a population density of approximately 12 persons per square kilometer for the Tularosa Basin area could be expected. Using the historical low and high mean annual precipitation levels of 5.6 cm and 46 cm, respectively, the population density could have varied between .029 and .24 persons per square kilometer, respectively. This in turn translates into a mean of about 40 square kilometers per person, or, given an area of about 16,000 square kilometers, a population of nearly 400 people for the Tularosa Basin. Following Hassan and Gross's (1987) assumptions of band composition of 15 persons (three families), the number of bands operating within the region would have been around 26. Their use of 15 persons per band is lower than Wobst's (1976) "magic number" of 25, which appears to be remarkably consistent among hunter-gatherers. Using a 25-person band, 16 bands within the region would be expected.

In his examination of population and reproductive attributes of arid land populations, Hard (1986) proposes the values presented in Table 8.1.

Table 8.1.
Population and Reproductive Values Proposed by Hard (1986) for Southwestern
Prehistoric Populations

Event	Value
Adult Life Expectancy	35-41.8 years
Birth Spacing (total mean birth interval)	1.5-3.8 years
Reproductive Span	20 years
Mortality Rate	50%
Net Reproductive Rate	1.03

Under these conditions, population could be expected to double every 470 years. Hard (1986: 100) concludes:

Hunter-gatherer populations have a sufficiently high fertility that they would tend to increase under most conditions. Cultural practices, such as abortion and infanticide, reduce the rate of growth but are unlikely to reduce it to zero. The combined effects of lactation, amenorrhea, and nutritional stress are likely to increase the birth span substantially above what farming populations would experience. Thus, it is suggested that the rate of growth among Southwestern hunters and gatherers would tend to be slow over the long run.

However, Hard's low-end birth space estimate of 1.5 years seems unlikely for a fully mobile hunter-gatherer population. Studies in Africa seem to indicate that four-year birth spacing would be ideal (Kelly 1995). The main reason is that a four-year cycle avoids maternal exhaustion without severely limiting foraging range.

Kelly (1995: Table 3-1) summarizes the relationship between effective temperature (ET) and primary productivity (PP) for hunter-gatherers worldwide. Comparing an ET of 14.85 (Burgett n.d.) and a PP of 200 (grams/square meters/yr) generated for the Tularosa Basin in comparison to Kelly's data indicates that prehistoric groups within the Jornada region could be expected to have high residential mobility, with up to 30 or more moves per year and that these moves be on the order of 30-40 km in distance (Burgett n.d.). Further, subsistence efforts should be comprised of 30-40 percent hunting and 60-70 percent gathering. From this, Burgett speculates that mean annual distances traveled during these moves would approach 700 km. From every archaeological indication, this appears to be the case for the study region.

Division of labor needs to also be factored into the context. The northern Chihuahuan Desert with an ET of 14.85 is similar to that of several California populations where male food procurement contributes between 60 and 75 percent. However, as with storage, an ET of 14.85 is close to a threshold with male contributions falling below 50 percent in populations living in areas with a slightly higher ET of 15 (Kelly 1995: 264).

Based on other arid land foragers, it is expected that during periods of arid conditions prehistoric populations of the northern Chihuahuan desert were likely organized into 16-25 bands containing 15-25 persons each, with a total population of roughly 400 persons. Each of these bands would have been composed of roughly five persons each, an adult male, an adult female, children, and a relative or two. However, that band composition probably varied greatly, with individual band members moving to other bands as conditions and social needs changed. Each of these bands would have dispersed into task groups on an as needed basis.

It is expected that these bands practiced a mixed subsistence strategy weighted toward gathering, and probably more so than the ET/PP ratio would indicate, given the limited populations of large ungulates present in the region. Binford (1990: Table 8) characterizes hunter-gatherer groups in

areas with an ET of 14 as being semi-nomadic. In pursuing their subsistence rounds, each band had an annual range of up to 700 km. This range is likely to have included the entire spectrum of environmental zones present, including riverine (the Rio Grande), alluvial fans, and upland areas as no single zone, perhaps with the exception of riverine areas, could reliably meet caloric, nutritional, and raw material needs. Given the above figures, approximately 90-100 days would be spent in travel, resulting in 270 days in residence, or an average duration of nine days at each location.

Based on the discussion of resource fluctuations presented earlier, it would be expected that logistical systems dominated during arid conditions (e.g., the Formative period). However, it is entirely possible that a pure logistic strategy (sensu Binford 1980) was stretched toward the foraging end of the spectrum as environmental trends changed, perhaps even within a single seasonal round (e.g. Upham 1984). This model is explored further using data from the central basin playa zone.

Food Resources in the Central Basin Playa Zone

The subsistence systems in place in the northern Chihuahuan Desert were semi-stable over long periods, but their tactical subsystems likely varied considerably in response to local conditions. The following seasonal model is proposed, based on the temporal and spatial availability of important food resources, and to a lesser extent non-food resources. The reader should note that the model only deals with the central basin playa zone. To be viable, similar efforts are needed related to the alluvial fans and other environmental zones on the installation. Construction of this seasonal model rests primarily on the deduced expectation that, on a strategic level, populations would move to ecozones as these important resources became available.

Coupled with this basic assumption is recognition of nutritional, social, and technological needs. Again, the tactical subsystems, or as Sutton (2000: 219) defines tactics “the active methods used to execute or accomplish the goals of a strategy”, undoubtedly varied considerably. It is this variability in tactical subsystems that is ultimately of great interest in understanding how prehistoric populations coped with the dynamic environment of the northern Chihuahuan Desert.

Playa Productivity

Mauldin (1996) defined this zone as the aggregate of one-mile buffers that surround each playa. Productivity and seasonal variation of playas are essential to understanding their potential use by prehistoric populations. Leaving aside the questions of the age of the central Basin playas and their potential as water sources, simulation models of their biotic productivity can offer a stage for exploring their use. Most cultural ecological studies rely on ethnographic accounts to identify economically important resources. Indeed, ethnographic accounts need to be consulted and should form the basis for such studies. However, ethnographies, like the archaeological record, are limited and fragmentary.

As Henrikson and others (1998: 76) point out: “The strict reliance on ethnographic data for the majority of our models of prehistoric subsistence may, indeed, prevent us from exploring other potential resources that may have been of greater importance at different periods of time during the distant past.” The majority of biotic resources discussed in the following sections was identified from ethnographic records of the Southwest, but include other, potentially exploited resources. The resources discussed are not exhaustive. Included are those associated with playas but only those believed to have been significant contributors to prehistoric diets.

Playas are a focus of biotic growth because they periodically accumulate and retain moisture, whether it is standing water or increased soil moisture. A study of the geomorphic/vegetation relationships of the Chihuahuan Desert found that:

The playa is the ultimate sink for nutrients and organic matter within the catchment. The heavy clay soils in playas have the highest nitrogen content and support the highest perennial cover of any landform in the catchment (Wondzell et al. 1996: 358).

This is echoed by a study of litter decomposition in playas:

Playas that are surrounded by native vegetation receive large quantities of organic debris transported by overland flow from the watershed into the basin. Organic debris may include large pieces of wood, twigs, leaves, rabbit feces, and particles of plant and animal material in various stages of decomposition, depending on the intensity of rainfall and velocity of overland flow. This material represents a considerable input of carbon and nutrients into the decomposer subsystem of the playa and may serve as an energy source for the playa food web (MacKay et al. 1992: 89).

Table 8.2 provides productivity information for the biotic resources previously discussed. The data presented in Table 8.2 (see Table 8.2) are from a variety of sources. An effort was made to include data from areas that would be the closest, environmentally, to the central basin. None of the data presented is from studies in the central basin itself. Some data originates from the Jornada LTER project, near Las Cruces, New Mexico, some from other areas of the Southwest, or the Great Basin. In some cases no data specific to species present in the central Basin were discovered, in those cases, data from similar species are included. For example, there are no data for the specific varieties of *Sporobolus* (dropseed) grass that grows in the central basin, but data are available for other varieties of *Sporobolus* from the Great Basin. Obviously, data generated by studies in the central basin would be ideal, but such studies have yet to be undertaken.

Available Resources

Rabbits (jackrabbits and cottontails) are present in grasslands that are around the playas, although generally at lower densities than those discussed previously in playa/dune areas. Despite this, the rabbit population may have provided an exploitable resource during prehistoric times as well. Jackrabbit densities in the present day grassland region range between 30-60 per square km. Cottontail densities are much lower, ranging between 6-10 per square km (Nelson et al. 1997). Of the animals inhabiting this environment, jackrabbits are one of the larger, most common mammals available as prey in the region. Densities of jackrabbit from mixed grass/scrub communities in the area are reported at 43-80 per square km, with cottontail rabbit densities 3-18 per square km (Nelson et al. 1997). Daniel and others (1993) report no seasonal abundance variation of jackrabbit populations in the area. This is contrary to earlier studies that indicated that rabbit populations did fluctuate seasonally, with populations reaching a high point during the wet season (Davis et al. 1975). However, jackrabbits were more abundant in mixed grass/shrub communities than in either grassland or shrubland communities (Daniel et al. 1993; Smith et al. 1996).

Small mammals of the family *Neotoma* (woodrats) and *Dipodomys* (kangaroo rats) are common throughout the arid Southwest. Both species are present in mesquite/yucca vegetation communities associated with playas of the northern Chihuahuan Desert. Population densities of the kangaroo rat (*Dipodomys ordii*) range from 1 per hectare to 5 per hectare, with the lower figure reflecting drought conditions and the higher figure a period of increased rainfall. The kangaroo rat *D. merriami* exhibited densities of 10-15 per hectare. In contrast, woodrat population densities for the same area and time period remained nearly constant, with a density of about 1 per hectare around playas (Whitford 1976). The maintenance of constant populations is because this species is limited by habitat, rather than by food supply (Hallett 1982; Jorgensen and Demaris 1999; Whitford 1976; Wu et al. 1996).

Table 8.2.
Productivity Figures for Playa Subsistence Resource

Resource	Density (per hectare)	Reproductive Rate	Available Biomass (g/organism)	Effective* Biomass (kg/organism)	Energy Content (kcal/grams)	Energy Yield (kcal/organism)	Nutritional Content
<i>Yucca elata</i>	452 ¹ ; 152 ⁴ ; 221 ⁵	36-67% flowered, 34 to 57% bore fruit with 24 fruit per plant (Laslei and Ludwig 1985; Wallen and Ludwig 1978).	Fruit: 760.8 (31.7*24) (Laslei and Ludwig 1985) but 60% is seed (Smith and Ludwig 1978). Flowers: (70-200 flowers; Campbell and Keller 1932), roughly 400 g per stalk (personal field observation). Crowns: average of 6,000 (Botkin, Shires, and Smith 1943).	60-70% of fruit infested with insects (Laslei and Ludwig 1985; Wallen and Ludwig 1978). Approximately 20- 30% of the flowers are in bloom at any one time (personal field observation)			
<i>Mesquite</i> (<i>Prosopis</i> <i>glandulosa</i>)	102 ¹ ; 207 ³	0-95% fruit		Estimated 30% (Doelle 1976).	348-427 (Doelle 1976)		9-18% protein and 6-41% sugar (Lee and Felker 1992).
<i>Prickly Pear</i> (<i>Opuntia</i> <i>Engelmannii</i>)	25 ⁶ ; 254 ³	50-92% plant produce fruit and 29-32 fruits are produced per plant.		7% of fruits infested with insect larvae (Bowers 1997).			
<i>Saltbush</i> (<i>Atriplex</i> <i>canescens</i>)	31 ¹		Up to 3732 of seeds (Hennessy 1982)		2.79 (Simms 1984)		39% protein 67.9% carbohydrates ⁸ (Simms 1984)
<i>Jackrabbit</i>	.43 - .80 ⁷			Edible portion is 1000 (Simms 1984)	1.01 (Simms 1984)	1,078 kcals	
<i>Cottontail</i>	.03 - .19 ⁷			Edible portion is 600 (Simms 1984)	1.01 (Simms 1984)	647 kcals	
<i>Woodrat</i>	1 ¹⁰				Simms (1984) ground squirrel figures	309 kcals	

Table 8.2.
Productivity Figures for Playa Subsistence Resource

Resource	Density (per hectare)	Reproductive Rate	Available Biomass (g/organism)	Effective* Biomass (kg/organism)	Energy Content (kcal/grams)	Energy Yield (kcal/organism m)	Nutritional Content
<i>Phyollops</i>						2.7 per m ² (Henrikson, et al. 1998)	
<i>Waterfowl</i> <i>Deadwood</i>			mesquite 6900 (above ground dead biomass [agdb]) saltbush 3900 kg (agdb) (Gile, Gibbens, and Lenz 1997)				10.9% protein 50% carbohydrates ⁹ (Simms 1984)

Effective biomass is the amount available for human consumption.
¹ Density figures are from playa habitats in the southern Maneuver Areas of Fort Bliss (O'Laughlin and Crawford 1977).
² Density figures from a study on the Jornada LTER (Hennessy et al. 1983).
³ Density figures from a study near Laredo, Texas (Windberg 1997).
⁴ Density figures from a study near a playa on the Jornada LTER (Smith and Ludwig 1978).
⁵ Density figures from Organ II soils on the Jornada LTER (Stein and Ludwig 1979).
⁶ Density figures from Mimbres soils in the southern Maneuver Areas of Fort Bliss (O'Laughlin and Crawford 1977).
⁷ Density figures derived a study on the Jornada LTER (Nelson et al. 1997).
⁸ Figures are for *Atriplex confertiflora* (shadescale).
⁹ Figures are for *Sporobolus asperifolios*.
¹⁰ Density figure from a study at a playa on the Jornada LTER (Whitford 1976)

The breeding season for kangaroo rats in the northern Chihuahuan Desert spans from late February to early July, although in exceptional conditions a fall-winter breeding period may also occur. Within the earlier season, two litters are common, with litter sizes between two and three (Johnston 1956). Similar breeding seasons, number of seasonal litters, and litter sizes are reported from the Mojave Desert (Bradley and Mauer 1971).

The playas may have attracted waterfowl in the past, unlike present day conditions that have basin playas filling too late for the spring waterfowl migrations and too early for the fall migrations. In contrast, the present day playas of the southern high plains provide an important stopping point and breeding habitat for migratory waterfowl where waterfowl numbers can reach several hundred thousand. Species present include mallards, Canadian geese, pintails, and widgeons (Simpson and Stormer 1981). To be attractive to waterfowl, playas would need to contain aquatic food resources (plant or invertebrate), and for nesting purposes the playa would need to provide sufficient cover and have a duration of at least several months. The playas of the Tularosa Basin and Hueco Bolson of today do not attract waterfowl in any substantial numbers, probably due to the unpredictability of standing water. Whether prehistoric conditions would have been more suitable for waterfowl is unknown.

Several species of phylloids, specifically fairy shrimp, brine shrimp, and tadpole shrimp, occur in ephemeral ponds in the American West, with Arizona having the most fairy shrimp species (Belk 1977). These shrimp hatch and reproduce in the short time that the playas are filled with standing water. Their eggs can lay dormant for over a decade and shrimp densities can reach several thousand per cubic meter. Individual shrimp range in size from 7-100 mm in length. Caloric value has been calculated at 2,700 calories per square meter for one species (Henrikson et al. 1998). Abundance varies considerably from season to season. One pond may experience high densities for several seasons, followed by a complete absence even with sufficient rain. In southern New Mexico and West Texas, playa crustaceans displayed variable population densities and durations, some peaking within days after flooding and dying out within two weeks, while others reached peak densities several weeks after flooding (MacKay et al. 1990; Sublette and Sublette 1967). A second hatching is possible in playas with longer durations. Mackay and others (1990: 400) suggest, "That a flood which occurs after a period of dry years results in relatively low numbers of playa organisms compared to what occurs after a second flooding in the same year". At least one fairy shrimp and one tadpole shrimp species has been collected in a Tularosa Basin playa near Three Buttes and Hueco Tanks.

Another common invertebrate of the playas is the spadefoot toad (*Scaphiopus couchi*). Brook (1979a) reports observing thousands of unidentified tadpoles in a Hueco Bolson playa and suggests them as a prehistoric food source. Newman documented populations of spadefoot toad tadpoles in Big Bend desert ponds ranging from as little as 4 to as high as 5,000 (Newman 1987). In southern New Mexico, tadpole populations in playas have peaked within 10 days of flooding, in one case reaching densities of 1,800 individuals per cubic meter (MacKay et al. 1990). Others studies found that tadpole densities were not correlated with pond duration, but tadpoles in ponds with longer durations grew larger (Newman 1987).

The relatively abundant biotic resources found on playas and the surrounding dunefields of the central basins encompasses a variety of food and fuel resources. Among the more probable significant resources for prehistoric populations were yucca (*Yucca elata*, in particular), mesquite, jackrabbits, various species of *Chenopodium*, and grasses. Not all of these resources occur in greater densities around playas, but all do occur in the dunes of the interior Tularosa Basin.

On average, yucca comprises an eighth of the vegetative community in the Chihuahuan Desert and fruit of the yucca would have been available in the dunefields of the Tularosa Basin floor (Szarek 1979). Studies on the LTER station near Las Cruces, New Mexico, indicate that *Yucca*

elata fruit production per plant is highest along playa fringes. In this habitat, 67 percent of the plants flowered and each of these plants produced an average of 25 fruits with an average fresh weight of 31.7 grams (Laslei and Ludwig 1985). Reproductive growth is annually regular; however, one year of reproductive growth may be followed by several years of non-reproductive growth. Generally, the highest fruit production is in early summer following wet winter and spring periods (Laslei and Ludwig 1985). The density of *Y. elata* along playas in the northern Chihuahuan Desert is reported as 152 plants per hectare (Smith and Ludwig 1978). In terms of fiber, measurements of *Y. elata* near Deming, New Mexico, indicate that, on average, each plant contains 2 km of green leaf weight (Botkin et al. 1943). Given a fiber content of 43 percent an average plant could produce a maximum of .86 kg of fiber.

Evidence from packrat middens indicates that mesquite has been present in the Fort Bliss region for at least the last 21,000 years, but did not become an important community member until about 10,000 years ago (Van Devender 1995). This could reflect a lowering water table, as is indicated by paleoclimatic studies. This is further supported by Meinzer's (1927: 76) work in the Tularosa Basin, which indicates that mesquite is present only where the depth to the water table is greater than 10 feet. Others argue that mesquite, particularly *Prosopis glandulosa* (honey mesquite), established itself in abundance in southern New Mexico only recently (York and Dick-Peddie 1969). There is evidence that mesquite was originally confined to valley floors and watercourses (Harris 1966). The spread of mesquite into grassland areas is greatly enhanced when seeds and pods are ingested by wildlife and livestock and deposited in their dung (Kramp et al. 1998). Therefore, the spread of mesquite from its original habitat to other areas probably accelerated with the arrival of livestock in the sixteenth century. The spread dramatically increased with the advent of ranching in the area (Harris 1966; Wright 1982; York and Dick-Peddie 1969).

Although honey mesquite occurs along playa margins and in coppice dunes, it is primarily environmentally limited by elevation, as it relates to the number of frost-free days. Translated, that means that mesquite generally occurs below 5,000 feet where the frost-free growing season exceeds 200 days a year (Harris 1966). Honey mesquite occurs along playa margins and in coppice dunes. Vegetation communities in dunefields are generally less diverse than non-dune areas (Bowers 1982). Present day density of honey mesquite on the Jornada LTER ranges between 116-346 plants per hectare, with a gradual increase over a 10-year study period (Warren et al. 1996). Fruit production occurs in spring, usually around May (Kemp 1983) and is relatively constant from year to year (Windberg 1997). However, only about 3 percent of plants initiate fruit development annually and of those, less than 1 percent develops fruit (Windberg 1997). Further, it was observed that "heavy rainfall before and during flowering depressed fruit production" (Windberg 1997: 71). However, longer-term trends indicate that mesquite fruit production may lag several years behind years of high rainfall and will actually increase in drought years (Windberg 1997). Each pod yields about 18-20 hard seeds that are 4-8 cm long (Harden and Zolfghari 1988). Protein content is at its highest within 10 days after flowering and carbohydrate content is at its highest about two months after flowering (Harden and Zolfghari 1988).

In terms of wood production, the green biomass of mesquite in central Texas was measured from 15.8-57 kg per tree, depending upon the soil (Whisenant and Burzlaff 1978). The higher figures represent larger mesquite trees, which are generally absent from the study area. Ludwig estimates the above ground biomass for mesquite shrubs on the Jornada LTER as averaging 10 kg, with the largest harvested during the study at 60 kg. This is considerably less than the figure reported by Kaul and Jain (1967) of 480 kg. However, the above ground biomass represented the amount potentially harvested by cutting. Gathering activities would include exploitation of both above ground and exposed below ground dead biomass. In a study of mesquite root systems and soils, Gile and others (1997) provides the following figures for a single mesquite from the Jornada

LTER project: above ground live mesquite biomass 11.3 kg; above ground dead biomass 5.9 kg; and, below ground dead branch biomass 1 kg.

In comparison another potential fuel wood source, saltbush, ranges in total biomass from 12-38.7 kg in the Great Basin (Van Epps et al. 1982). Saltbush has an above ground biomass of 7.6 kg and a dead biomass of 3.9 kg in southern New Mexico (Gile et al. 1997). Various species of *Chenopodium* (Goosefoot) are major invaders of drying playa margins (Rowell 1981). Pickleweed, saltbush, and shadscale are three species of *Chenopodium* that are salt tolerant (or halophyte) and are commonly found along the margins of saline playas (Henrickson 1978). They produce numerous small seeds between May and October (see Figure 8.2). Saltbush is present in low levels in packrat middens from 42,000-11,000 years B.P., but its abundance has apparently increased substantially within the last 8,000 years (Van Devender 1995).

Spatio-temporal Fluctuations

Most archaeological investigations, when considering resource fluctuations, are limited to yearly variation and often rely on precipitation records as a proxy. The assumption is that economically important resources are linked in a simplistic and immediate manner, such as “if it rains resource availability is higher.” Ludwig tracked variation in primary production of Northern Chihuahuan Desert ecosystems over five years (see Table 8.2). Primary production around playa lakes varied considerable from year to year. However, it should be understood that primary production figures result from all plant growth. While they are likely a good general indicator of resource productivity, it does not necessarily follow that they reflect the productivity of resources exploited by humans. It is entirely possible that an area has high primary productivity, but is essentially barren of suitable resources for humans.

For the Tularosa Basin, Meinzer and Hare (1915: 89) state:

The precipitation is irregularly distributed in space as well as in time. It is on an average much greater on the high mountains than on the low plain, and for a given season, it may be much greater in one locality than in another similarly situated. The fall and winter rains and snows are likely to be more or less general, but many of the sudden summer showers are very localized.

This discussion will provide information that clearly shows that such simple linkages are superficial, and provide a misleading basis for understanding prehistoric subsistence patterns and land use:

Marginal environments are characterized by low faunal diversity, resource fluctuations, and an unstable, unpredictable resource base. Rowley-Conwy and Zvelebil (1989: 40) delineate three scales of resource fluctuation: (1) seasonal-variations that occur within one year, (2) interannual-between-year variations, and (3) long-term-variations extending over a generation or more. Many anthropologists believe the key to understanding hunter-gatherer adaptations to marginal environments lies in determining the mechanisms used for dealing with the risk and uncertainty caused by fluctuations on these scales in both resources and the physical environment” (Mandrak 1993: 52).

Resource availability around the central basin playas is the result of a complex web of climatic and biota inter-relationships producing both temporal and spatial fluctuations. Ludwig and Whitford (1979: 285) point out that “years with identical total rainfall and total primary productivity may result in very different productivities of animal species”. Belovsky and others (1989) warns that these conditions present unique challenges in understanding forager behavior.

Seasonally, the localized nature of summer rains produces a mosaic of productivity. Playas in one area may receive normal rainfall, while others less than a kilometer away would receive no

rainfall. Alternatively, one area may receive an early rainfall while others would receive late season rain. The seasonal variability in rainfall, coupled with its spatial variation in the region substantially influences many of the resources present at playas. As support, a recent study of the spatial heterogeneity of aboveground net primary productivity (ANPP) in the northern Chihuahuan Desert noted that:

Summing across an entire year (1991 [chosen as a normal year]), mean annual ANPP ranged from 48 grams/m² yr⁻¹ in one playa site to around 250 g m⁻² yr⁻¹ in two of the grasslands and nearly 325 g m⁻² yr⁻¹ in another playa. Our results confirm that ANPP can be quite variable between years in these semi-arid ecosystems, subject as they are to considerable inter-annual differences in precipitation (Huenneke and others 2001: 268).

The resulting spatial availability of resources during a season could be likened to a series of lights brightening and darkening in apparent randomness. Winterhalder and others (1988: 289) sum up this problem as it relates to archaeology by stating: “Analysis of the interaction of human population, diet selection, and resource depletion requires micro ecological models in part because the relevant processes occur on time scales largely invisible to both ethnography and archaeology”. There are some studies that indicate that even small rainfall events, producing less than 5 mm of precipitation, have relatively large effects because they trigger nutrient recycling (Sala and Lauenroth 1982).

Each of the resources present operates on these different temporal scales (seasonal, interannual, and long-term), that may, or may not be linked to precipitation. For instance, mesquite pod production is high in drought years while yucca reproduction is a three-year cycle. Likewise, rabbits will respond quickly to increased forb growth stimulated by rains, while woodrat populations will remain steady throughout periods of high and low rainfall. The result of this interlocking web of variation is that at no time will resources from all the different biotic components be available for harvest. In some drought years, playas may produce abundant and much needed resources, while in some rainy seasons playas might produce only minimal amounts of a few resources.

The playas present in the Tularosa Basin are spatially stable resource “islands”. With regard to the resources present, however, playas may be unstable over time. That is, even if the playa is flooded the resources may remain out of temporal phase, minimizing the actual attractiveness to prehistoric populations. Obviously, many of the resources associated with playas are dependent on water and/or soil moisture (e.g., game are dependent on water and yucca on soil moisture), and rainfall sufficient to substantially wet a specific playa is unpredictable. Patterns of precipitation would affect resource densities and availability. Playas might collect too much water, damaging the submerged plant resources or, during an extended drought may stay dry too long to allow survival of species dependent on periodic rainfall to propagate. In addition, playas with water would attract game either for the water or for plants that grew along the margins.

Using the above context, similar reviews of the alluvial fans, Otero Mesa, the uplands, and the riverine zone are needed. Although data sets of this nature are complicated, they reflect the reality that prehistoric groups encountered on a daily and annual basis. The models we develop to understand group dynamics will need to be similarly complex and dynamic. For example, despite the uncertainty of reliable stands of water in the playas as noted above, many of the El Paso phase pueblos were built near these playas. Yet despite that proximity, the subsistence section in the original *Significance Standards* had little discussion of agriculture. Prehistoric agriculture in the Jornada area is taken as a given, but the evidence is skimpy. What remains elusive is evidence of agricultural fields and water control features. That corn and other domesticates were grown in the Jornada is not in dispute. However, the nature, scope, and heritage of agriculture have yet to be explored to any substantial degree. In recent years, the

literature on the transition from hunting-gathering based subsistence economies to agricultural based economies has blossomed, and the following discussions will seek to incorporate some of these new data.

APPROACHES TO SUBSISTENCE ISSUES

Investigating and explaining subsistence organization within the research area logically involves:

1. the identification of resources used at various times and places within the region;
2. developing a description of the mobility and technological strategies used to acquire those resources;
3. documenting changes in those mobility and technological strategies; and
4. developing explanations for those changes.

It is necessary to address the first of these four steps before we can proceed to the higher levels. Note also that progress in subsistence research is closely linked to progress in a variety of other research realms, including paleoclimatic reconstruction, chronology, and technology.

Documenting subsistence, both through investigations into technologies used in processing resources and in the recovery of more direct evidence derived from biological data, are a critical component of the revised *Significance and Research Standards*. It is in this realm, where cultural adaptation interacts with the paleoenvironment, that adaptive strategies are created. In addition, changes in those strategies are a result, to a large degree, of interactions at this cultural and natural interface.

Changes in subsistence are brought about by the interaction of factors such as the introduction or development of new technologies, changes in the availability of prey items, seasonal shifts in the dietary quality of those items, long-term shifts in availability of resources, and social responses to the changes. Subsistence decisions, then, comprise a critical element in human societies, impacting technology, settlement strategies, mobility levels, and seasonality, as well as social, ritual, political, and economic organization.

The initial factor in structuring subsistence involves the available resources, their relative density, and changes in those resources both seasonally and at longer time scales. The resource structure, then, defines what is referred to as an economic landscape. Most aspects of the economic landscape in the current study area are, at a macro scale, associated with the Chihuahuan Desert. Recent research by Monger (1993a) supports Van Devender's (1990; Van Devender and Spaulding 1979) arguments that most elements of the Chihuahuan Desert community that currently dominate the region were essentially established during the period between 9000 and 6000 B.P., and that by 4000 B.P. the modern Chihuahuan Desert was present in its current configuration (see Chapters 2 and 7).

Within the current research area, six broad ecological zones have been previously identified that, as a function primarily of effective moisture, provide broad contexts within which to consider subsistence patterns at both site and intrasite levels. A defining characteristic for each of these economic landscapes is the presence of water, both in terms of direct rainfall and indirect moisture (i.e., runoff and rivers). Water availability, in conjunction with temperatures, soil characteristics, and extant vegetation, determine soil moisture. Soil moisture influences plant and animal production. Soil moisture in deserts, as a function of extremely high variation in rainfall and runoff, both through time and across space, result in highly variable and unpredictable production.

As a function of this environmental variation, most vegetation in the lowland portion of the study area is composed of either stress-tolerant (e.g., succulents) or annual plants. The highlands are dominated by competitive plants (see Grime 1977: 1169-1170). These plant communities have developed different strategies over long periods of time in relationship with their biotic and abiotic environments. Hard (1986: 17-32) has argued that these diverse strategies differentially invest energy in the production of reproductive elements (i.e., seeds) and green leaves that are available to humans. That is, production in areas characterized by stress-tolerant and annual plants respond rapidly to moisture, and these "pulses" are primarily comprised of production that is directly of use to humans and herbivores (see Grime 1977; Noy-Meir 1973, 1974, 1981). Conversely, areas characterized by competitive strategies differentially invest in the growth of nonreproductive elements, such as supporting tree trunks and branches (see Grime 1977). This production is generally not available for human or herbivore consumption, but does comprise the economic landscape.

While individual species of plants and animals will respond to periods of water stress or abundance in different ways, production of fruits and seeds during periods of stress will be reduced in most species. This affects the availability of jackrabbits and cottontails (Daniels et al. 1993; Davis et al. 1975), as well as large mammals (see Eicher 1978; Howard et al. 1990: 30-38; Leopold and Krausman 1991; Mello 1977: 21-48).

As noted above, the economic landscape identifies potential resources. However, not all resources within the economic landscape are necessarily used in subsistence. Thus, it is critical that research is conducted both to identify what resources are available and what resources are actually used. Many previous investigations of subsistence in the region rely heavily on ethnographic analogs, usually using plant and animal species used by groups such as the Mescalero Apache, or other groups located in arid settings, for a significant component of interpretation. While these data are important and can provide models for how the region may have been used, they are not our primary focus as they are unrelated to archaeological data collection and analysis. They are an additional source of data regarding how an economic landscape may have been used, but they do not identify which resources were used. For example, mesquite is often described as an "important" resource in most summaries of subsistence in the region. However, mesquite pods or seeds are infrequently recovered in flotation samples, and processing tools such as pestles, while present, are not a significant component of ground stone assemblages. In such situations, the archaeological data are essentially ignored. Clearly, a variety of processes can be envisioned that would not result in the recovery of significant amounts of mesquite in an archaeological situation, even when mesquite is a major resource. These contradictions provide a challenge to our methodologies.

Below, a discussion of the strengths and weaknesses of a variety of biological and artifact data that can be applied to subsistence studies in the region, as well as some of the results of their application is provided. This is followed by a discussion of the current understanding of several subsistence issues, including agricultural dependence across space and through time, and dependence on large game, small game, large seeds and nuts, small seeds, and succulents. This discussion identifies specific research questions that are applicable to developing baseline data for subsistence research.

BIOLOGICAL DATA

This section provides a discussion of various biological data groups that have been, or are, relevant to subsistence studies in the study area. The strengths and weaknesses of each data group are discussed and a brief summary of major applications of these techniques in the study area is provided.

A variety of biological data groups are relevant to subsistence studies, for they minimally provide data on resources exploited in an archaeological context. While in terms of human subsistence most biological data are best treated as presence/absence measures, some quantitative measures of diet are available for certain data groups. All biological data groups have the additional possibility of being radiocarbon dated. They can provide information on what items were exploited, when these items were exploited, and in several cases, measures of the relative contribution of various items to overall subsistence.

COPROLITES

The analysis of macrobotanical material recovered from desiccated human feces provides the most direct line of evidence for reconstructing human diets since the recovered material had been directly ingested. In addition, studies by Watson (1974) suggest that a given coprolite represents two to four meals that were consumed over the last 20-26 hours. That is, this data group records diet at an extremely short-time scale that can be estimated. Coprolites provide specific information on subsistence.

The interpretation of coprolite data, however, is impacted by the differential effect of digestion. That is, coprolite data consist of undigested material, and therefore, these samples underestimate the true diet. This is especially the case with the nonseed component of the diet. Seeds are common in such samples, as a function of their hard outer covering. However, soft plant tissues, being more easily digested, are seldom recovered from coprolite samples (Minnis 1989). Note also that coprolites are rare in any given region. They are generally recovered in dry cave or shelter settings, settings that may reflect a seasonal component of the diet.

Coupled with the short time span represented by such samples, coprolite data probably reflect only a small portion of the overall subsistence base. Finally, problems with quantification or results and standardization of extraction procedures should be considered in any interpretation of coprolite data. With sufficient sample size, coprolite data can be successfully used as ordinal data (see Minnis 1989), but presence/absence analysis may be more appropriate for most applications.

A literature search failed to recover any reference to coprolite analysis even though shelter and caves have been the focus of several excavations at Fort Bliss. In fact, no reference to coprolites could be found in the study area. If appropriate material can be collected, coprolite analysis should be a high-priority area of research. However, the very low probability of recovering this type of item should be kept in mind.

FLOTATION

Flotation analysis, introduced in archaeology in the late 1960s (Struever 1968), provides an additional source of data on the use of plant and small animal resources in archaeological deposits. Like all biological data classes, flotation has the advantage of providing both information on the types of resources used, and, through radiocarbon dating, a direct chronometric date on the timing of that use. The use of flotation in archaeology has revolutionized subsistence research.

The flotation process itself is the means by which organic remains, primarily botanical materials, are recovered from archaeological sediments using water as the separating agent. This procedure has two distinct advantages over screening because it can: 1) quickly separate organic remains from large volumes of sediment and larger inorganic clasts, and 2) can recover all size classes of organic remains allowing quantitative analysis (Pearsall 1989).

The flotation procedure is relatively simple. A known volume of archaeological sediment is placed into a water-filled container that is then agitated either manually or with a machine. Alternatively, the sample is placed in a stationary water-filled container and the water is agitated using a pump or other device. Moving water separates the sediment and organic material, and the lighter organic material, which usually includes most of the botanical remains and some lighter animal bones, floats to the surface and is collected on a 0.350-0.450 mm mesh fabric.

The heavy material, which includes large clasts, ceramic fragments, chipped stone debris, larger animal bones, and occasionally heavier plant materials, sinks to the bottom of the container. The fine clasts, including clays and silts, are suspended in the water and pass through a 1.0-1.5 mm mesh screen, in the bottom of the container. The two separated classes of material, referred to as the 'light fraction' and the 'heavy fraction', are dried and stored for future analysis (Bryant 2000; Pearsall 1989).

In practice, flotation is most often utilized to recover plant remains from archaeological sites, but to a lesser extent small animal bones are also recovered. Several factors condition the quality and quantity of data gained from flotation analysis. Bones are fairly resistant to deterioration, but plant materials are relatively delicate. Perhaps more than any other commonly recovered artifact or ecofact, the botanical assemblage is shaped by the history of cultural and natural processes affecting the archaeological deposits. These processes drastically reduce the size and quantity of the plant assemblage recovered from most archaeological sites.

As nonarchaeological elements can be introduced into a sample by disturbance and bioturbation, it is necessary to assume that only charred plant remains are of archaeological significance. Surprisingly, however, little is known regarding the factors that result in the deposition of charred materials within an archaeological deposit. Pearsall (1983) argues that the density of charred plant remains in an archaeological deposit is related to the intensity of activities involving fire. If fire is common, the potential for the accidental inclusion of subsistence items into fires is increased. Sites that have activities not involving fire, then, should have low recovery rates. Some items, such as those requiring extensive heat for processing (e.g., starchy seeds, corn) may be over represented while others, which do not require extensive heat (e.g., prickly pear fruit), may be underrepresented.

Understanding factors affecting preservation and recovery of botanical remains allows the project director to maximize the return for any flotation effort. Decisions must be made regarding the number of flotation samples, the context from which they are collected, the size of each flotation sample, and the manner in which the data are reported. The context and number of samples collected appear to be the most important of these decisions.

The history of flotation analysis in the Jornada region spans two decades, and a variety of cultivated and wild plant remains have been recovered. The cultivated remains include corn, common beans, tepary beans, and squash; though it appears that only corn and beans is reported for pre-A.D. 1000 contexts (see Ford 1977; Goldborer 1985; O'Laughlin 1986; Wetterstrom 1978). Noncultivated remains frequently include chenopodium, amaranth, and portulaca (see Dean 1994; Holloway 1994a, 1994b; Leach et al. 1996).

While there are several interesting exceptions, most flotation analyses have frequently resulted in low recovery of plant taxa. Thus, it is profitable to consider the results from previous flotation efforts. Two recent attempts to synthesize flotation data underscore problems with the recovery of plant remains in the Jornada region. The first study viewed the results of 600 flotation samples from Formative period contexts and found that only 303 (50.5 percent) contained at least one seed or other edible plant part, which is the standard definition of a productive sample. So many samples were unproductive that it was difficult to follow trends in wild plant foods and plant production. In an attempt to make sense of the data, the authors eliminated the unproductive

samples and calculated ubiquity or presence values for plant resources based only on the productive samples (Miller 2005d; Miller and Kenmotsu 2004: 249).

A subsequent synthesis of 1,120 flotation samples from 38 Formative period sites is summarized in Table 8.3 that shows the percentage of productive flotation samples along with the number and total volume of samples collected from each site. It noted that 46.4 percent of the samples contained carbonized seeds or other edible parts (Miller 2005d). The greatest flotation effort concentrated on Mesilla phase sites, but these sites produced the lowest return. Recovery rates rise for the Doña Ana phase samples. El Paso phase sites yielded fewer productive samples, but the drop may be due to the small number of sites that have been studied. This is probably also due to the fact that the seven Doña Ana phase sites in the study are remarkably well preserved habitation loci on alluvial fans. The 12 El Paso phase contexts in the study represent a broader spectrum of locations and site types. Still, the recovery rates remain much higher than those in the Mesilla phase do.

Table 8.3.
Percentage of Productive Flotation Samples Recovered from Formative Period Habitation Sites
in the Study Region, All Landforms

Time Period	Number of Sites	Number of Samples	Number of Productive Samples	Percent of Productive Samples	Sample Volume (Liters)
Mesilla phase	18	697	205	29.4%	2,611
Early Doña Ana phase	4	84	68	81.0%	466
Late Doña Ana phase	3	55	54	98.2%	428
El Paso phase	12	284	193	68.0%	393
All time periods		1,120	520	46.4%	3,898

Flotation studies from Archaic period sites, sites without a temporal assignment, or Formative period campsites without structures provide even more meager returns. A study of small sites comprised of charcoal stains and fire-cracked rock/caliche features reported that 12.2 percent of 49 features contained charred seeds (Holloway 1998). A second analysis of 30 samples collected from small features in the same study noted only one identifiable seed, for a recovery rate of 3.3 percent (Dean 1998b; Mauldin et al. 1998).

Earlier researchers argued that the low recovery rates were, in part, a function of small flotation sample size, which is generally two liters, coupled with poor preservation of botanical material in the semiarid study area (e.g., Dean 1994; Holloway 1994a; Minnis and Toll 1991: 387). Recently however, by looking at results from a variety of projects, Dering (2001) and Miller (2005d) argue that the lack of recovered organic remains may be affected by sample volume, but more important is the intensity of use of the site. Thus, in one study, 79 2-liter samples were submitted for flotation analysis, but only three had any charred seeds present and all charred material was at a very low frequency (Dean 1994; Holloway 1994a). Even with substantially larger samples, recovery rates do not seem to improve dramatically. The results from the GBFEL-TIE testing and excavation project on White Sands Missile Range, where samples in excess of 20 liters were commonly collected, produced recovery of charred seeds in only 8 of 67 samples (see Minnis and Toll 1991). Similarly, of 345 2-liter flotation samples reported by Whalen (1994a) for the Turquoise Ridge site, only 23 percent contained charred seeds, most of which were noncultivated.

These included purslane, dropseed, mesquite, yucca, and a variety of cacti. There are, however, a variety of samples from sites that have produced extensive remains. Most of these are both later in time and located along the alluvial fans. These sites also have evidence of residential settlements. Scott-Cummings (1989; see also Miller [1989]) reports extremely high recovery rates of charred remains from post-A.D. 1000 sites on the east-facing slopes of the Franklin Mountain fans. O'Laughlin (1986, 2005a) notes high rates at the Meyer Pit house Village Site near the eastern edge of the basin, Hot Well Pueblo near the Hueco Mountains, and Sgt. Doyle Pueblo near the western portion of the basin. Brook (1966b), citing an unpublished report by Vermillion (1939), reports the recovery of approximately 200 bushels of charred corn from the excavation of a single pueblo room. Leach and others (1996), in one of the few cases of high recovery from the central basin, reports the recovery of 50 charred *Chenopodium* seeds from a single 2-liter sample from the floor of a structure. These studies suggest that, though uncommon, flotation results can yield critical data for subsistence studies in the study area.

Poor recovery from flotation samples often forces changes in sampling strategy during the execution of a project. Originally, the flotation effort for the El Paso Loop 375 Project in the Hueco Bolson called for analysis of 100 flotation samples. However, 100 samples did not yield enough seeds and other annual plant parts for AMS dates. It was decided to expand the effort to 139 samples, and focus on 10 sites, seven with structures. Even though the sites included several pit houses and a surface pueblo, the final study noted that 27 percent of the samples lacked charred plant material of any kind, and only 18 percent contained seeds, fruits, or other edible plant fragments (Dering 2001).

The worst results in the Loop 375 study were obtained from campsites without structures that were located in a basin setting. Table 8.4 illustrates flotation recovery from larger campsites, which included 33 flotation samples from three multicomponent Archaic/Formative period campsites. These three sites were defined by fairly large concentrations of hearths, stains, and fire-cracked rock/burned caliche lined pits. The percentage of productive samples from each site varied from 37.5-0 percent, a very broad range of results. It is likely that results from ephemeral sites, that include both isolated features and large campsites, are dictated by the degree to which the small heating features are rapidly covered by sediments. Therefore, samples from small, ephemeral sites and larger campsites yield the fewest productive samples. These usually are either Archaic period or unassigned sites consisting of a few, often deflated, charcoal stains or burned caliche scatters/concentrations. Larger, usually multicomponent Archaic/Formative period campsites composed of similar feature types but lacking structures, may average about 15 percent productive samples, but there is extreme variation in results from these sites.

Table 8.4.
Percentage of Productive Flotation Samples Recovered from Archaic/Formative Period
Campsites in the Hueco Bolson

Site	Type	Number of Samples	Number of Productive Samples	Percent Productive Samples	Sample Volume (Liters)
41EP1143	Large campsite, multicomponent Archaic and Formative periods	15	2	13.3%	50.7
41EP2757	Mesilla phase campsite	10	0	0.0%	52.8
41EP1424	Large campsite, multicomponent Archaic and Formative periods	8	3	37.5%	32.4
	Total	33	5	15.2%	135.9

Recovery rates rise noticeably at sites with structures. Mesilla phase pit house sites yield almost 30 percent productive samples. Flotation recovery is very high at the more substantial and intensively utilized Doña Ana phase habitation sites, almost 90 percent. At the El Paso phase sites, recovery rates are somewhat lower at 68 percent, but some of these sites include contexts in deflated basin settings, and some heavily looted pueblo structures.

From this brief review, it is evident that a cost-effective flotation sampling strategy at Fort Bliss or elsewhere in the Jornada Mogollon region will need to emphasize certain contexts. Both archaeobotanical analysts and archaeologists agree that flotation recovery rates are very poor in some contexts, although the possibility of recovering plant remains from them still exists.

Table 8.5 provides a matrix summary of expected recovery rates from a range of site types and landform settings. The table is based on the review of flotation sample recovery rates and on statements made by analysts. Campsites in basins provide the lowest return on flotation sample efforts. This observation has been supported by other studies (Mauldin et al. 1998; Minnis and Toll 1991). Habitation sites with structures located on alluvial fans provide the highest return. The table reflects the reality that sites in basins are seldom as productive as sites located on alluvial fans. Sites in basins often contain few artifacts and are usually severely deflated, a process that strips the fine-textured inorganic materials and the lighter organic remains from the deposits, leaving behind the larger clasts. Sites located on alluvial fans are often in deeper soils and may be covered by downslope movement of sediments.

Table 8.5.
Matrix Summarizing Flotation Recovery Rates from Open Sites in General Terms

Time Period	Geographic Location/Landform	Site/Feature Type	Recovery
Paleo-Indian/ Archaic	Basin and alluvial fan	Campsites/ ephemeral sites	Very low
Late Archaic	Basin and alluvial fan	Campsites/ ephemeral sites	Very low
	Basin	Task specific/ ephemeral sites	Very low
Mesilla phase	Alluvial fan	Task specific/ ephemeral sites	Very low
	Basin	Habitation/structure	Very low
	Alluvial fan	Habitation/structure	Low to moderate
	Basin	Task specific/ ephemeral sites	Low
Doña Ana phase	Alluvial fan	Task specific/ ephemeral sites	Low
	Basin	Habitation/structure	Low to moderate
	Alluvial fan	Habitation/structure	Moderate to high
	Basin	Task specific/ ephemeral sites	Low
El Paso phase	Alluvial fan	Task specific/ ephemeral sites	Low
	Basin	Habitation/structure	Low to moderate
	Alluvial fan	Habitation/structure	Moderate to high

Thus, intensity of occupation appears to be the single overriding factor operating within the temporal, geographic, and cultural contexts listed in Table 8.5. Intensity refers to the size of the group and the duration of the occupation. Longer and larger occupations spanning several seasons increase the quantity and diversity of accumulated debris and increase the chance for accidental or purposeful burning and charring of plant materials. This condition is similar to the "Clarke Effect", which states that the diversity of artifacts at a site is directly connected to the length of occupation (Schiffer 1983).

The telling importance of occupation intensity is illustrated by the difference in results between Mesilla and Doña Ana phase structures. Even though both time periods are represented by habitation sites and structures, the recovery rates at Doña Ana phase sites are double that of the earlier components. Intensity of occupation appears to make the difference, as has been noted by several analysts (O'Laughlin 2002: 684; Miksicek 1987).

Decisions regarding the size and number of flotation samples, then, should be based on a realistic expectation of return or potential productivity balanced against the data gaps the archaeologist is trying to fill. Unfortunately, what constitutes an adequate flotation sample volume is a question that remains to be adequately answered. Table 8.6 summarizes the productivity of samples with reported volumes. There does not appear to be a tight relationship between average sample volume and percentage of productive samples. For example, the Archaic/Mesilla campsites and Mesilla phase samples have the same average sample volumes, but the Mesilla phase samples are twice as productive.

Table 8.6.
Overview of Volume and Productivity for 961 Flotation Samples in the Study Region

Phase	Sample count	Total sample volume (liters)	Average sample volume (liters)	Percent productive
Archaic/ Mesilla campsites	33	135.9	3.75	15.2%
Mesilla	697	2,611	3.75	29.4%
Doña Ana	139	894	6.43	87.8%
El Paso	92	393	4.27	26.1%
Totals	961	4,033.9	4.2	37.0%

There is other evidence indicating that merely increasing sample size will not always produce desired results. For example, an analysis of 101 flotation samples from 11 sites along U.S. Highway 54 in Otero County, New Mexico was implemented with sample sizes as large as 37.5 liters (O'Laughlin 2002). Despite the increase in volume, the results do not suggest a strong relationship between sample size and sample productivity. Figure 8.1 shows the relationship between sample size and productivity at three of the U.S. Highway 54 sites with more than 10 flotation samples. Average sample volume varied from 9.3-18.8 liters, considerably larger than the average of 961 samples presented in Table 8.4 (see Table 8.4). LA 115262, the site with the largest average volume (18.8 liters), has the lowest percentage of productive samples (8.3 percent; O'Laughlin 2002). In fact, the flotation samples from LA 115262 were far less productive than any other of the time periods listed in Table 8.6 (see Table 8.6), despite the fact that these were much smaller samples. It is obvious that one cannot simply increase sample volumes and expect better results. Large samples of sediment recovered from contexts devoid of plant remains will yield the same disappointing results as small samples.

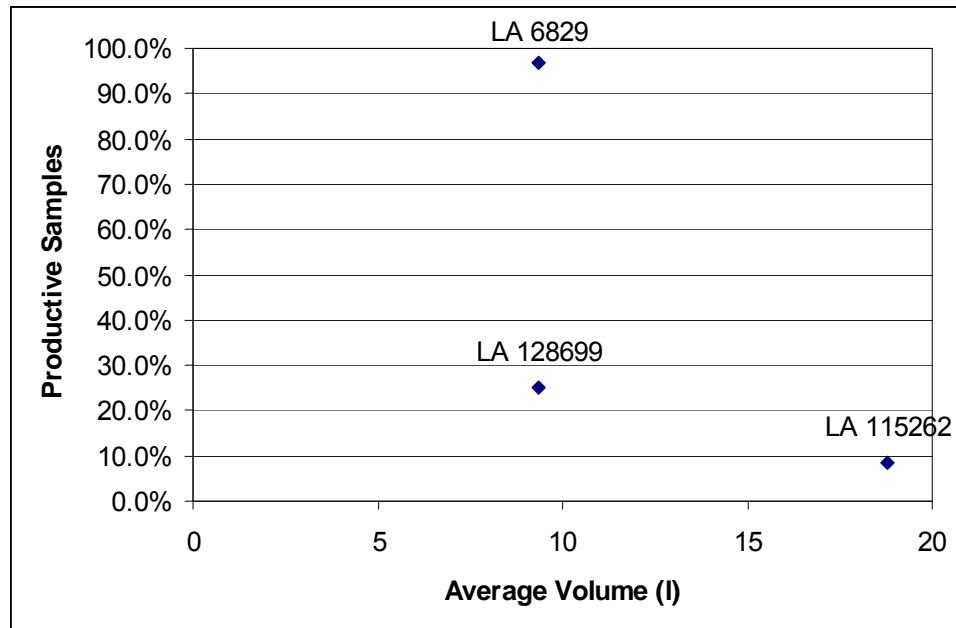


Figure 8.1. Average flotation sample volume plotted against percentage of productive samples for three sites from the U.S. Highway 54 Project, Otero County, New Mexico. (based on data from O'Laughlin 2002).

There probably is no ideal sample volume. Instead, the size of individual samples should be adjusted according to site conditions, size of the features being sampled, and time and budget constraints. As a general rule, however, collecting samples smaller than 4 liters should be avoided. Miksicek (1987) processed 8 liter samples where possible, and Dering (1996) found that samples collected from thermal features that measured between 6-14 liters contained more taxa than smaller ones.

The next question to address is the number of samples to collect. Obviously, the number of samples to be collected is dependent on the size of the project, the number of features, and temporal and budget constraints. However, two studies conducted on different continents have arrived at similar conclusions. Using 61 samples of 8 liters each collected from the Classic period Hohokam site Los Fosas, Miksicek (1987) found that 5-10 samples are required to accurately estimate the frequency of occurrence for commonly occurring and resilient plant remains such as maize. Estimating the frequency of rarer types of seeds such as amaranth requires 25-35 samples. Similar results were reported from Iron Age pits in Britain (Fasham and Monk 1978).

For any given site or feature type with adequate preservation, increasing the number of samples will produce a corresponding increase in the number of taxa. Greater variation in feature types demands more samples. Thus, a more complex site with more feature types will require more samples to characterize the plant assemblage.

To summarize:

- Carbonization of plant materials is the overriding factor controlling the recovery of plant remains.
- Rapid burial of plant remains improves conditions for preservation.
- Increased occupation intensity increases the number and diversity of plant remains.

- Larger sample volumes do not necessarily improve recovery of plant remains, especially at shallowly buried, deflated sites or features.
- Sample volumes between 6-15 liters appear to be the ideal size for sites with preserved plant materials; samples smaller than 4 liters are not as productive.
- The number of samples collected and analyzed is contingent on the number and types of features in the site, the size of the site, and time and budget constraints.

Once the samples are collected and analyzed, the results are applied to answer questions regarding land use, diet, and other subjects falling into the general category or domain of subsistence. Flotation data are also applied to broader issues such as chronology, and even to questions regarding the ritual use of structures. Increasingly, archaeologists are relying on flotation recovery to provide them with seeds or other short-lived plant parts for AMS dating.

Counts and weights of plant materials must be reported, for this is the raw material most useful for quantification. The basic data need to be presented, or converted into a format applicable for broad comparisons, and archaeobotanists have long opted to use presence value or ubiquity as the common standard for reporting results. Presence value or ubiquity is defined as the percentage of all analyzed samples, both productive (with charred seeds or wood) and unproductive (no identifiable carbonized plant remains), in which a particular taxon is present. Thus, if maize is present in 5 of 20 samples, it has a presence value of 25 percent. Presence value provides a means of determining how widespread a taxon is throughout the samples recovered from a site, and is less affected by widely varying recovery methods and preservation biases (Pearsall 1989).

However, presence value does not evaluate the abundance of a taxon. Abundance is best described using counts, weights, or a density figure. The most straightforward density ratio is calculated with counts or weight of each taxon in the numerator, and sample volume in the denominator. For example, if 20 seeds are identified in a 5-liter flotation sample, the seed density is 4 seeds-per-liter. The same figures may be calculated for charcoal or nut fragment weights, or any other category of plant material identified in a sample. Density provides a means of comparing recovery rates of charred plant material (and by extension, preservation conditions) across a suite of samples, feature types, site types, or time periods. Although density is commonly reported today, many of the older studies lack these figures, especially in reports where the archaeologists did not record the flotation sample volumes.

Standard reporting procedures now include both presence values and seed/edible plant part/volume ratios usually expressed as densities-per-liter of floated archaeological sediments. These data provide both frequency and abundance measures for future data applications, including regional or cross-regional syntheses. Although density measurements provide one indication of preservation, other aspects of flotation samples are commonly reported. These include disturbance indicators noted in the light fraction, such as roots, insect parts, and termite or rodent fecal pellets. Modern seed counts are also reported. While these data do not contribute to an understanding of prehistoric behavior, they can alert the archaeologist or analyst to potential problems with the sample (Diehl 2003; Huckell 2002; O'Laughlin 2002).

It is also becoming obvious that archaeobotanical data are best utilized in concert with other types of data, such as carbon isotope studies of human remains, changes in architecture, stone tool analyses, and ethnographic or experimental data. At issue here is the stochastic nature of flotation results. Although presence values have proven to be very useful for comparing large bodies of data gathered under a variety of conditions, it is clear that any data transformation of the archaeobotanical assemblage should be viewed as a starting point, not an ending point, in reconstructing prehistoric economies. For example, the presence of maize, or high frequencies of maize in the archaeobotanical assemblage, should not be automatically interpreted as maize dependence, especially if it is accompanied by several edible wild plant taxa (Diehl 1997; Diehl

and Waters 2005). Flotation data are best utilized as one strand of a multi-strand argument, and it is useful to examine how it has been applied in several synthetic efforts aimed at characterizing regional land use changes.

One of the first of these noteworthy studies is that of Hard and others (1996), in which maize ubiquity is combined with carbon isotope studies of human remains and analysis of mano size to assess dependence on agriculture/horticulture in six regions of the greater Southwestern United States, including the southern Jornada. They found that the timing and degree of dependence on maize varied widely from region to region, and that maize was not a major component of the diet in the southern Jornada until A.D. 1100 (Hard et al. 1996).

Another study incorporating plant ubiquity into multiple lines of evidence was conducted by Miller and Kenmotsu (2004) and later by Miller (2005d). Instead of simply tracking maize ubiquity, Miller examined ubiquity of four categories of plant resources, maize and beans, mesquite, and cacti/succulents (including *Opuntia* and *Echinocereus* spp., fleshy-fruited yuccas, and agave). The study tracked plant ubiquity in concert with stable isotope ratios of human remains, radiocarbon dates from heating features, measurements of manos, and radiocarbon dates recorded from various landforms in the region. The results present a compelling review of changing land use, settlement, and subsistence patterns in the region. The authors were able to trace a subsistence system involving the dual intensification of plant production and cacti/succulents (e.g., cactus and agave) from A.D. 1000-1275, and the consequent decline of cacti/succulents coupled with the ascendance of plant production as the economic engine of the region between A.D. 1275-1450.

Although carried out in other regions, two other applications of flotation data deserve mention. Both of these applications involve measuring changing degrees of dependence on plant production and plant gathering. In a study of the Fremont culture, Barlow (2002) argues that the archaeological record represents a continuum of variation in the economic importance of maize-based agriculture. Temporal and spatial variation in the Fremont suggest that farming was not a cultural complex to be accepted or rejected, but part of a continuum of food production or wild plant gathering activities. In this approach, emphasis on foraging or farming was dependent on changes in the costs and benefits of each activity, and these changes occurred across time and space. Using harvest yield and field investment data collected on modern farmers across Latin America, she argues that abandonment of Fremont farming villages around A.D. 1300 was due to increased yields of higher ranked wild plant foods, not to decreased farming yields. Ultimately, however, she admits that her argument must be tested by archaeological data, including a robust plant macrofossil assemblage gathered from flotation samples.

Diehl and Waters (2005) examine the emergence of maize based agriculture during the Early Agricultural and Early Ceramic periods in southern Arizona. They examine plant assemblages from the Early Agricultural period, and point out that maize is always accompanied by several wild plant food resources. Maize increased in importance only after A.D. 150, during the Early Ceramic period, when certain wild plant foods drop out of the assemblages signaling a narrowing of diet breadth and a focus on plant production. They link the rise in maize dependence to the development of ceramic vessels capable of storing and conserving harvested food resources and seed stock. A robust botanical record based on flotation recovery is a key component in this argument.

In addition to examining entire archaeobotanical assemblages, some studies focus on in-depth analysis of specific taxa. Studies of maize morphology have contributed to an understanding of the rise of plant production in the region. To date, these studies have relied primarily on maize collections from a few rock shelter sites with excellent preservation (Upham and MacNeish 1993; Upham et al. 1987; Wills 1992, 1996). However, more recent studies have begun to tap into the

rich record available through flotation from open sites. For example, changes in maize morphology, specifically increased cupule width, were described for several sites in southern Arizona beginning in the Early Agricultural period and continuing through the Hohokam Classic period. The author uses measurements of individual maize cupules and cob segments recovered from open sites, arguing that increasing cupule width indicates increased kernel size and higher maize yields. The maize for this study, especially the material from the well-dated Early Agricultural period sites, was obtained primarily by means of flotation (Diehl 2005).

Studies of mesquite wood charcoal have also provided clues to land use in the region. A mesquite wood age-class study, focusing on the anatomy of mesquite charcoal recovered from hearths in the Hueco Bolson, divided mesquite wood charcoal into five categories, heartwood, branch, sapwood, transitional wood, and roots. The results suggested differences in the intensity of fuel wood harvesting, and by extension, in occupation intensity, among Archaic period, Mesilla phase, and El Paso phase contexts (Dering 2001).

These examples demonstrate the broad utility inherent in flotation data. When successful, flotation studies can produce botanical assemblages that can be applied to several information domains, from chronology to subsistence to technology, and can be utilized effectively with other types of data. In regions where preservation is poor, flotation studies are conducted with the risk of obtaining a greatly reduced assemblage. However, the risk can be reduced through careful planning and an understanding of the potential results available from different types of sample contexts. Flotation recovery has provided data for macro-scale syntheses because it is the only means by which we can obtain the broad geographic and temporal reach that is required by such studies.

Pollen

Pollen analysis has primarily been used in environmental reconstruction, but can also provide data on subsistence. Pollen grains are produced by vascular plants during reproduction. Each species produces morphologically dissimilar pollen that can be easily used as an identifier of the family or genus level. Unfortunately, the interpretation of pollen frequencies from a location in terms of subsistence is hampered by a variety of factors, including inconsistencies in analytical conventions, destruction of pollen characteristics that allow for the identification of grains to a family or genus level, and the development of linkages between the frequencies of a given pollen group and its relationship to human subsistence (see Bryant and Holloway 1983). The potential and problems associated with the use of pollen in subsistence studies is briefly summarized below.

Being associated with plant reproduction, pollen is extremely common in the environment. A variety of different pollen production rates and methods of dispersion occur. Wind pollinated plants produce the largest number of grains and are the most widely distributed. Conversely, plants that rely primarily on birds and insects for dispersion produce fewer grains and are generally not represented in a pollen analysis. Moore and Webb (1978) suggest that a single pine tree that is wind pollinated and has lightweight grains may produce several billion pollen grains. These can disperse over hundreds of miles. Maize is also wind pollinated but is composed of much larger pollen grains. Therefore, maize pollen recovered from sediment is less likely to reflect long-distance wind transport. The variation in pollen production rates, and the fact that pollen is frequently transported by wind, complicates any simplistic association between the amount and type of grains recovered from archaeological sediment, and the use of a plant in subsistence.

The preservation of pollen in a form allowing for relatively clear interpretation is another problem, especially in arid or eroded situations. Pollen preservation is a function of a variety of factors, the most important of which seem to be mechanical and chemical weathering. Soil

movement can cause significant and differential abrasion of pollen grains; selectively destroying recognizable characteristics (see Hall 1985). In addition, Holloway (1981; personal communication 1993) has argued that pollen grains can be destroyed by alternating cycles of moisture and drying, which may be associated with seasonal rainfall patterns. To add to these mechanical factors, chemical destruction of pollen grains seems to be accelerated in settings with high alkaline soils, especially those with pH values higher than 6.0 (Bryant and Holloway 1983). While pollen can be recovered from these settings, they are often deteriorated to a point that an assemblage has little interpretive potential.

The final problem in pollen interpretation seems to be associated with procedure for quantification. The most common approach is for an analyst to count a minimum number of pollen grains from a sample (usually less than 200), and use the percentages of grains in a given plant class to infer relative plant frequencies within that sample (Barkley 1934). Comparisons between samples then provide a mechanism for monitoring change through time or across space. However, as percentage calculations sum to 100 percent, a change in any pollen frequency causes changes in other taxa. Thus, significant directional changes can occur in a given taxa when no such change is actually present in that pollen class.

To overcome this problem, several researchers have used frequency calculations tied to concentration values generated from adding a known quantity of marker spores to a sample prior to processing (e.g., Holloway 1994a). The use of a known spore count permits the calculation of pollen concentration values and also functions as a measurer of accidental destruction of pollen grains during laboratory processing (Holloway 1994a). This procedure provides a more reliable estimate of pollen frequencies as the analysis counts a minimum number of marker grains rather than a minimum number of fossil pollen grains.

While pollen analyses as a paleoenvironmental tool are frequent in the study area (Bradley 1983; Culley and Clary 1980; Scott-Cummings 1993; Dean 1989; Freeman 1972; Hall 1990b; Horowitz et al. 1981), only a few studies have recovered pollen that can be directly related to subsistence (e.g., Holloway 1994a; 1994b). Holloway (1994a, 1994b) reports the successful isolation of a high frequency of *Chenopodium/Amaranthus* (Cheno-Am) grains from a pollen wash on a metate recovered from a structure, and the recovery of maize pollen from a sample collected in the central basin. In addition, Scott-Cummings (1989) reports the recovery of Cheno-Am pollen from a variety of features along the Franklin Mountain fans. While difficult to directly interpret in terms of subsistence, these studies suggest that pollen can provide presence/absence data for analysis.

Pollen studies for either paleoenvironmental or subsistence conducted in the study area are hampered by both low concentration values and the degraded nature of the pollen recovered. A high percentage of indeterminate pollen is characteristic of most studies. This may be a function of mechanical weathering (wet/dry cycles, sediment movement) and the generally high pH values (+7.8) of sediments in the study area (see Khresat 1993). Note that the collection of larger samples for analysis will not solve this problem (contra Horowitz et al. 1981). While the collection of larger samples will certainly produce more pollen for study, these samples will still have relatively high percentages of unidentifiable remains. Thus, the interpretation of the data is still based on a relatively small number of intact grains that are probably biased toward certain pollen types.

Because of these problems, pollen washes on ground stone artifacts and the recovery of economically important pollen from sediments have seldom been successful in the region. The results of four recent pollen studies using a variety of artifacts and contents further demonstrate the poor pollen recovery rates of sites in the Tularosa Basin and Hueco Bolson. Holloway (2002) obtained very poor recovery rates for pollen washes obtained from ground stone items on pit

house floors at 41EP4719 in the Tobin Well training area (Lukowski et al. 2006). Slightly elevated *Chenopodium* counts were observed on a mano and hammerstone, but these results need to be corroborated by flotation data and other evidence. Jones (2002) also reports poor recovery and uninterpretable results from a ground stone pollen wash at the Jaca Site near the Jarilla Mountains.

Jones (2002) recent analysis of pollen samples from the US Highway 54 mitigation project (Railey 2002) is one of the more extensive and detailed studies undertaken in the region. A collection of 59 samples from numerous contexts and sites was examined. Despite some improvements in sample processing, Jones reports essentially the same findings as previous studies: low fossil pollen concentrations, poor preservation of pollen grains, and the presence of durable and widely disseminated grains typical of most Southwestern pollen studies (*Asteraceae*, *Artemisia*, *Ephedra*, *Pinus*, Cheno-Am, *Poaceae*, and *Juniperus*). A few grains representing potentially economic species were recovered, including *Opuntia*, *Portulaca*, *Typha*, *Yucca*, *Prunus*, *Rhus*, and *Zea mays*. The recovery of maize pollen from a storage feature was interesting, but otherwise the remaining economic species could represent natural inclusions. Another recent study by Smith (2007) from well-preserved organic deposits in a deeply buried pit of Middle Archaic age (Graves and Ernst 2007) again found poor preservation and the surprising presence of modern contaminants such as *Populus* (cottonwood) pollen. Finally, analysis of six pollen samples from sealed, subfloor contexts among the well-preserved rooms at Madera Quemada Pueblo yielded similar results to those described above. Pollen preservation was poor, grain counts were low, and only the most durable, widespread species such as Cheno-Am, *Compositae*, grasses, and *Ephedra* common to all Southwest pollen studies were identified among the six samples (Vaughn Bryant, personal communication 2007).

Phytoliths

Phytoliths, microscopic silica particles formed in and between cell walls by the deposition of silica absorbed from water, often have diagnostic shapes or sizes that are specific to a plant taxon (see Bozarth 1993; Pearsall 1978; Rovner 1983). The outer silica wall is resistant to decay and phytoliths can be preserved in most sediments over a significant period of time.

At a general level, phytolith analysis is comparable to the analysis of pollen and the collection techniques are essentially the same. However, phytoliths from a given taxa can vary significantly in size and form as a function of the diverse places where individual taxa grow. Consequently, to correctly identify a phytolith to particular taxa, reference collections, specific for plants within a region, must be developed. Unlike most pollen, however, phytoliths decay in place and are redeposited into soil. That is, they are not significantly disturbed directly by wind, but soil movement may redeposit phytoliths into new contexts. In addition, phytoliths can exhibit movement down through a profile (see Buck 1993). While composed of silica, phytoliths can be dated using radiocarbon procedures as they frequently trap, within a silica shell, organic material applicable to AMS dating (Bozarth 1993; Piperno 1988; Rovner 1983).

While primarily used for paleoenvironmental reconstruction, several researchers have used phytoliths in subsistence studies. These studies include the recovery of phytoliths from dental remains and the isolation of phytoliths from the edges of lithic tools (see Rovner 1983). Within the study area, however, only three studies of phytoliths have been conducted; two were for paleoclimate research. Buck (1993) reports the successful recovery of phytoliths from both fan and basin samples in the study area and concludes that additional phytolith analysis may provide important paleoclimate data. Conversely, Scott-Cummings (1993) had low recovery of phytoliths and concluded that additional studies were not recommended in the study area for paleoclimate research.

More recently, Bozarth and Railey (2002) report the results of the analysis of 14 samples from sites excavated along the U.S. Highway 54 corridor. Culturally significant phytoliths were identified in three samples from the Jaca Site. All three samples contained maize phytoliths and one sample contained a single phytolith of a domesticated bean (*Phaseolus* sp.). These data, when considered in tandem with the results of pollen and flotation analysis, provided firm evidence of maize cultivation at the Jaca Site.

Clearly, phytolith analysis is an unexplored technique, especially in subsistence studies. Despite potential problems, including low recovery rates and the lack of a comparative reference collection, phytolith analysis should be attempted in subsistence studies. In many ways, phytoliths are complementary to both pollen and macrobotanical analysis, and while not without problems, phytoliths have the potential to complement these more traditional studies.

Faunal Remains

The recovery and interpretation of faunal material from archaeological sites provide a source of information on animal dependence in subsistence studies (see Grayson 1984; Styles 1981; White 1953). However, like all biological techniques, a linkage between the recovery of remains and reconstruction of the importance of a given species faces a number of complications. These include the elimination of remains not associated with subsistence, an assessment of the impact of environmental processes on the sample, and the development of quantitative measures for the importance of a given class of remains for subsistence.

Prior to the early 1980s, most faunal analysts used the minimum number of individuals (MNI) represented at a site, usually in combination with usable meat-weight estimates for an individual animal, to arrive at estimates of the importance of subsistence from faunal remains (see Styles 1981; White 1953). However, several critiques of MNI and meat-weight procedures (see Binford 1981; Grayson 1984), coupled with ethnographic studies of faunal transport decisions and costs (see O'Connell et al. 1990; Speth and Rautman 2004) have resulted in the frequent use of the number of identifiable specimens (NISP) or one of several meat utility indices. NISP values are the most commonly used measure, and when used in combination with MNI values, seem to provide a more easily interpretable and comparable measure of the importance of fauna in subsistence (see Grayson 1984).

Another increasingly recognized problem in faunal interpretation is associated with the recognition of remains that are unrelated to subsistence. These intrusive remains, that in open sites can include burrowing animals (e.g., horned lizards, rodent species) and in cave and shelter settings can include a variety of remains introduced by carnivores and raptors, complicate any simplistic use of faunal remains for subsistence. The presence of modification, including cut marks and burning, is important in identifying faunal material used for food. While not all animals are processed by cooking, and while faunal remains can become charred in a variety of ways not necessarily related to subsistence, the presence of burning or other modification is an accepted identifier for subsistence items.

Finally, problems associated with both preservation and sampling must be considered in any evaluation of faunal data. Preservation bias, especially as it affects specific elements or species, can alter the assemblage. Bone is susceptible to deterioration, especially under extreme environmental conditions, and can be further ravaged by carnivores. A variety of studies (see Binford and Bertram 1977; Grayson 1989; Lyman 1984, 1993) have demonstrated that nonhuman factors, such as bone density and carnivore gnawing, can significantly impact what remains of a faunal assemblage at a location. In addition, several studies have consistently demonstrated that recovery, especially of smaller remains, is significantly impacted by choices of screen size. The recovery rates, and the species and elements represented in that recovery are dramatically

different in essentially the same contexts when ¼-inch mesh is replaced with ⅛-inch mesh (see Shaffer 1992a).

A variety of faunal remains have been recovered from prehistoric sites in the study area (e.g., Bradley 1983; Dawson 1993; Duncan et al. 2002; Hanson 1990; Lear 2007; O’Laughlin 1994, 2005b; Presley and Shaffer 2001; Russell and Hard 1983; Shaffer 1999; Stratton 1994; Whalen 1994a). The faunal data from sites in the lowlands consistently suggest a focus on small and medium-sized mammals (see Hanson 1990; O’Laughlin 1979, 1994, 2005b; Presley and Shaffer 2001; Shaffer 1999). While a number of species may have been used, including rodents, birds, and fish (see Bradley 1983; O’Laughlin 1979; Presley and Shaffer 2001), much of the fauna recovered seems to suggest a focus on hares and rabbits. Large mammals (e.g., deer, antelope, and mountain sheep) account for little of the recovered remains, and small mammals other than cottontails have often been considered of minimal importance once the probable intrusive taxa are eliminated (see Stratton 1994), although as noted below these taxa deserve closer scrutiny.

Faunal remains have been recovered from all major environmental zones, including the basin, fans, mountains, and along the river. Recovery seems to be highest at nonbasin sites and at sites with structural remains; occupations in the central basin, especially those without structures, have low recovery rates. Whalen (1994a) reports a mean density of 31.5 g per cubic meter of fill (median = 24 g) at the architectural site of Turquoise Ridge, a sample of which was analyzed in detail. Eighty-eight percent of the sample was lagomorphs and no large mammals were recovered.

Remains from several structures excavated at the Huesito Site, located in the central basin, were also dominated by lagomorphs, and had a median bone density of 724 g per cubic meter (Whalen 1994a). Leporids were similarly prominent from sites within the Loop 375 project area that traverses east/west through southern Fort Bliss (Presley and Shaffer 2001). Excavations at the Conejo Site along the east-facing slopes of the Organ Mountains recovered an astonishing number of jackrabbit and cottontail remains (see Lear 2007; Russell and Hard 1983). Dawson (1993) reports on a variety of fauna from excavations at Todsén Cave in the Organ Mountains, including the recovery of mule deer and mountain sheep. Bradley (1983), excavating at the Pueblo period site of La Cabrana along the river, reports the recovery of over 5,000 fish bones and scales, most of which appear to be catfish and gar.

Several large-scale and intensive analyses of faunal remains have been reported since publication of the 1996 *Significance Standards*. Among these are the analysis of faunal material recovered from multiple sites along the Loop 375 and US Highway 54 corridors (Duncan et al. 2002; Presley and Shaffer 2001), several Mesilla and Early Doña Ana phase pit house sites (Church and Sale 2003; Lear 2007; Shaffer 1999), and the Hot Well and Sgt. Doyle pueblos (O’Laughlin 2005b). The discussions and critiques presented by O’Laughlin (2005b) and Presley and Shaffer (2001) are particularly relevant for considerations of future research directions. Additionally, the models of rabbit procurement and processing outlined in Church and Sale (2003) should be reference and serve as an example for the development of additional models of prehistoric faunal exploitation.

Several common themes emerge from a review of these studies. In addition to the well-known problems of small sample numbers, poor preservation, and high proportions of unidentifiable fragments that often deter analysis and interpretation, various analysts have commented on the variable proportions of burned or calcined remains among different sites (O’Laughlin 2005b; Presley and Shaffer 2001), the apparent rarity of non-leporid small game (Presley and Shaffer 2001; Shaffer 1999), and whether the extremely fragmentary nature of the assemblages resulted from natural taphonomic processes (Presley and Shaffer 2001) or cultural practice (Church and Sale 2003). The common thread among these discussions is that, while we have accumulated

data that provide the general notion of faunal choices made by prehistoric residents of the Jornada region, the reasons behind those decisions have not been well studied. The following discussion establishes some new research directions.

New Directions for Faunal Subsistence Research

It is acknowledged that faunal assemblages from prehistoric Jornada Mogollon settlements are beset with several taphonomic, quantitative, and qualitative problems. Again, rather than bemoaning the rarity or analytical difficulty of this particular class of data, we should be exploring the underlying reasons for some of the problems. For example, the apparent rarity of small game and rodents mentioned by Presley and Shaffer (2001) offers a potentially informative avenue of inquiry that may lead to broader insights into agricultural production, field location, and maintenance. The current analytical focus for studies of Formative period faunal collections seems stuck in issue of lagomorph ratios, and it may be useful to focus on something other than the ever-present leporid remains. Can the presence, absence, or variable proportions of reptiles and amphibian remains, birds, canids, and other species inform us about resource stress and environmental change, human modification of the landscape, and other cultural phenomena?

Preservation and Cultural Factors Underlying Faunal Recovery

Within the central basin, a large percentage of many faunal assemblages, especially from those sites that lack structural remains, are characterized by a high frequency of fragments that can only be assigned to general size classes. For example, Stratton (1994), in a study of 1,176 faunal items from small sites in the central basin that had a high probability of reflecting prehistoric use, found that 931 (79 percent) were unidentifiable beyond a general mammalian size class (e.g., small mammal).

Mauldin and others (1994) suggest that one possible reason for the low recovery of identifiable faunal remains in the central basin may be related to deterioration. Using bone, which has a high probability of being associated with subsistence, they contrasted the median pit volume for a variety of features by the presence/absence of both burned bone and artifacts, and demonstrated that features with bone have a significantly greater volume. There is, however, no patterning in artifacts and feature volume. The lack of patterning in artifacts, which should not be destroyed by exposure, suggests that the greater recovery of bone in features with greater volume is a function of differential erosion and deterioration. While the rate at which exposed bone deteriorates in this environment is not known, once faunal material is exposed on the surface, deterioration may be quite rapid.

Miller (2007a) agrees that differential preservation plays a role in recovery rates of faunal material and suggests that bone preservation is best when the material is deposited in buried refuse deposits that are rich in organic matter (an interpretation similar to that above). Such deposits are encountered much more frequently at residential sites. However, it is also suggested that preservation only partially explains the extremely low incidence of faunal remains at Late Archaic sites. In this regard, a comparison of faunal recovery rates from the El Arenal and Tres Casitas sites in the Hueco Bolson is instructive. El Arenal is an extensive Late Archaic settlement measuring over 75,000 square meters in size. An area of 1,540 square meters was exposed through hand excavations and 71 features were excavated, resulting in the collection of over 10,000 chipped-stone and ground-stone artifacts (Miller 2007a). Despite the high artifact and feature recovery rates, only a single bone fragment was recovered during the excavations (O'Laughlin 1994: Tables 2 and 6). The Tres Casitas Site is a small Mesilla phase site located a distance of less than 1 km from El Arenal. In contrast to El Arenal, a total of 1,239 specimens of faunal bone was recovered from thermal features and buried deposits of secondary refuse in two pit houses at Tres Casitas.

The main periods of occupation at the two sites are separated by approximately 800-1200 years. This time period is roughly equivalent to the interval between the prehistoric occupation of Tres Casitas and its excavation in 1994. This brings up the question as to whether the younger age and deeper organic deposits at Tres Casitas provided a more favorable environment for preservation of faunal bone. Likewise, can the almost complete absence of faunal material at the more exposed and older deposits at El Arenal be explained through preservation factors? In other words, do the combined effects of 1,000 years and shallower deposits explain the virtual absence of faunal material at an intensively occupied Late Archaic settlement in an identical topographic and geomorphic setting? In opposition to these explanations, the fact that numerous relatively well-preserved hearth pits and hut structures were present at El Arenal, many of which contained organic fills, must be considered. If substantial numbers of game animals were consumed at this site, at least some quantity of bone might have been deposited and preserved in these deposits.

Cultural factors and the spatial organization of site space may also be referenced. Differing patterns of social and settlement organization (food sharing, house spacing, communal or individual hunting practices) could result in the formation of dedicated refuse disposal areas or multiple individual refuse areas. All of these factors merit further investigation. Actualistic (experimental) and bibliographic research studies on bone preservation in arid and eolian environments would be particularly relevant and should be considered during future faunal analyses.

Large Game Hunting

The question of the importance of artiodactyl and other large game hunting during the Archaic and Formative period remains open to debate. Are artiodactyl remains recovered in low quantities in Jornada sites because of intensive hunting pressure that reduced their numbers or due to human preference (see discussion in Shaffer 1999: 292)? Speth and Scott (1989) argue that as communities become more sedentary and larger, large game near the community decline. Only two Jornada sites, Gobernadora and Hot Well pueblo, contain artiodactyl remains that outnumber those of rodents and carnivores (O'Laughlin 2005b: 241). O'Laughlin notes that these animals had been brought to the site as whole carcasses to be processed, indicating that they were "hunted for their meat, bones, and probably their hides." What evidence, if any, is there that these less frequent dietary supplements may have been the focus of communal hunting efforts or community-wide events or rituals?

The question of large game hunting during the Archaic period is difficult to address using biological data, simply because very few faunal remains are preserved at Archaic sites in the central basin landform. Understanding Archaic period hunting practices and game selection thus requires the use of second and third order, proxy artifact data. The potential of residue analysis on chipped stone tools may also provide insights. Additionally, another form of proxy data would be to develop models that incorporate data on artiodactyl frequencies in neighboring upland regions (e.g., Miller 2007a). However, several interpretive problems must be overcome before interpretations based on such models can be accepted with confidence.

The Significance of Small Fauna

Another possible food choice may relate to rodents. Presley and Shaffer (2001: 422-424) remark on the surprisingly low recovery of rodents in Jornada sites and note that such mammals are commonly reported as food sources for arid-adapted peoples and have been recovered in large numbers from sites both east and west of the Jornada region. Does this represent avoidance of an available food or another example of preservation bias? Rodents and other small fauna are also typical of cleared areas such as agricultural fields (Sanchez 1996; Shaffer 1992b; Szuter 1991b). These findings in part reflect the more recent consideration of fauna in relation to how humans

modify and interact with their environment (Szuter 1991a, 1991b; Szuter and Gillespie 1994). The cultural, environmental, and taphonomic processes that resulted in the rarity of such small fauna in Jornada collections should be a focus of further study.

Procurement and Processing Models

Presley and Shaffer (2001) and O'Laughlin (2005b) comment on the highly variable proportions of burned and calcined bone among several Jornada assemblages. The reasons for such variable proportions remain unknown, but strongly suggest different processing methods (as well as possible variations in discard behavior). For example, Vehik (1977) noted that large numbers of unburned bone fragments were present at sites where bone grease was made.

Methods of communal and individual rabbit hunting by humans in relation to the natural habitat and prey avoidance behaviors of *Sylvilagus* and *Lepus* species have been described in several studies (Church and Sale 2003; Hanson 1990; Hard 1983a; O'Laughlin 2002, 2005b). The means by which the large numbers of captured rabbits and hares were processed for consumption has not received as much consideration. Church and Sale (2003) provide a detailed review of ethnographic and ethnohistoric accounts of rabbit processing methods and develop several expectations regarding the characteristics of rabbit bone assemblages that would be created through different processing techniques. Studies such as this provide a potential means of utilizing the typical attributes of Jornada faunal assemblages (high proportions of fragments, burned and unburned items) to gain insights into prehistoric subsistence rather than to discount the analytical potential of Jornada faunal collections.

Social Aspects of Subsistence

The potential for feasting, food sharing, and other social aspects of faunal consumption should be explored. Analysis of the distribution of faunal remains at the Henderson Site in southeastern New Mexico revealed a pattern of communal eating of all but the smallest game (Speth 2004a). What evidence could be used to determine if food was communally shared at sites in the Jornada region? These and other questions should be addressed with future faunal studies (see also Chapter 12).

The Future of Jornada Mogollon Faunal Subsistence Research: More Assemblages and Broader Perspectives

Although several faunal studies have been reported for the Jornada region, the number of published studies with large samples (>200 specimens) is extremely small compared to the numbers of studies available in other regions of the Southwest. For example, for his recent overview of changing faunal exploitation patterns in the northern San Juan Anasazi region, Driver (2002) was able to incorporate data from 101 faunal collections (out of 205 published collections). Given the potential limitations and frustrations of Jornada Mogollon faunal research, there is a growing perception that we may have a sufficient sample of faunal studies and that additional studies will not provide new information or insights. In light of Driver's research, and the fact that the current sample of detailed Jornada faunal studies numbers less than 15, it is evident that many more studies may be required before distinct temporal, geographic, and functional patterns can be discerned in the Jornada region.

The theoretical basis and variety of interpretations and models for faunal research needs to be expanded, and both regional archaeologists and faunal specialists should consult the broad range of studies published in neighboring regions of the Southwest and Trans-Pecos. This would include the work of Speth and his colleagues at the Henderson Site (Speth 2004b), several habitation sites in the upland areas of Sacramento and Capitan mountains (Driver 1985) and areas to the east (Akins 2002), and recent analyses of faunal assemblages from stratified rock shelter

deposits (Akins 2004, 2005). Additional data and insights may be found among the studies of faunal material from NAN Ranch in the Mimbres Valley (Sanchez 1996; Shaffer 1991, 1992b). Studies of faunal remains from Hohokam settlements (Szuter 1991a, 1991b; Szuter and Gillespie 1994) are useful for Jornada research because of the similar lowland desert environments of the two regions. Finally, Driver's (2002) comprehensive analysis of faunal exploitation in the northern San Juan region offers several insights into the ecological, environmental, and cultural contexts of faunal subsistence.

Isotope Signatures in Bone Collagen

The use of stable carbon and nitrogen isotopes to investigate diet in archaeological research is a relatively recent technique of the past decade (DeNiro 1987; DeNiro and Epstein 1978; Vogel and van der Merwe 1977). While variation in nitrogen isotopes (N14/N15) have been used to study changing dependence on marine relative to terrestrial animals, the principal isotopic signature, or interest here is variation in carbon. Carbon isotopes analysis is based on the observation that plants incorporate carbon from the atmosphere using one of three photosynthetic pathways that result in distinct stable isotope ratios of carbon (Bender et al. 1973; Smith 1971, 1972). As discussed in Chapter 7, these isotopic signatures are then incorporated in the bone collagen of animals that eat those plants (DeNiro 1987; DeNiro and Epstein 1978).

Most plants use the C3 or Calvin-Benson pathway to assimilate CO₂, which results in an isotopic value expressed in parts per thousand, of around 26.5 $\delta^{13}\text{C}$. Although there is considerable variation in the isotopic signatures of plants that use this pathway, there is no overlap between the carbon isotopic ratios produced by C3 plants and those of the other major plant pathway, the C4 or Hatch/Slack pathway. Plants that use a C4 pathway have more ^{13}C and thus are isotopically "heavier," with $\delta^{13}\text{C}$ values averaging around -12.5 parts per thousand (ppt). That is, these C4 plants are enriched in ^{13}C relative to C3 plants. A third pathway, CAM, is characteristic of succulents and results in an isotopic signature that falls between, but can overlap with, the C3 and C4 values (Bender 1968, 1971; Farnsworth et al. 1985; van der Merwe 1982).

When animals eat plants, these isotopes are incorporated into their bone collagen, with an additional fractionation of 2-5 ppt. Bone collagen, then, is enriched in ^{13}C relative to the values for the plants in the diet (DeNiro 1987; DeNiro and Epstein 1978; van der Merwe 1982). An herbivore that subsists only on C3 plants (average of -26.5 $\delta^{13}\text{C}$ ppt) would have a bone collagen value of around -21.5 $\delta^{13}\text{C}$, whereas an animal that subsisted only on C4 plants (average of -12.5 $\delta^{13}\text{C}$) would have a bone collagen value of about -7.5 $\delta^{13}\text{C}$.

While modeling the diets of herbivores is relatively straight forward, omnivore diets are more complicated as they incorporate both plants and animals in their diet. Different factors may control the collagen synthesis in animals who eat both plants and animals (see Bumstead 1984; Krueger and Sullivan 1984; Parkington 1987; Sillen et al. 1989), and the precise factors governing the production of the $^{13}\text{C}/^{12}\text{C}$ ratios in human bone collagen are not well understood.

In spite of these potential problems, the results of stable carbon isotope studies on human bone collagen that attempt to identify dependence on corn agriculture have been impressive, especially in areas like the eastern United States. Corn uses a C4 photosynthetic pathway and when incorporated into environments dominated by C3 plants, such as the eastern United States, radical increase in delta ^{13}C values in human collagen can be directly interpreted as evidence of increased dependence on corn (see Ambrose 1987; Boutton et al. 1984).

Although the technique of stable carbon isotope analysis has considerable promise in C3 environments, the use of the technique in semi-arid environments such as the study area is problematic. Plants that use the C4 and CAM photosynthetic pathways are common in such settings (see Black 1973; Stowe and Terri 1978; Teeri 1988; Teeri and Stowe 1976). Human

dependence on these plants should result in less negative $\delta^{13}\text{C}$ values in bone collagen, even without any dependence on corn. Essentially the same $\delta^{13}\text{C}$ pattern, then, could result from either a dependence on maize or a dependence on other C4 and CAM plants and animals. Carbon isotope ratios in human bone from arid settings, then, may only yield an estimate of dependence on C4 and CAM foods.

MacNeish and Marino (1993) present the only isotopic analysis of carbon and nitrogen on human remains conducted in the region to date. While plagued by a number of interpretive problems, including the identification of piñon as a C4 plant when it uses a C3 pathway, MacNeish and Marino present results from burials that span the period between 2600 B.C. and historic period burials. Of specific concern are data from 11 burials from the prehistoric sequence. Their work demonstrates a significant change through time in the delta ^{13}C signatures, which indicate increased consumption of C4 plants through time with a significant jump associated with the pueblo period. MacNeish and Marino (1993) interpret these changes as being solely related to increasing agricultural dependence. However, a variety of C4 plants, and animals that feed on C4 plants, are present in the local environment (see Hard et al. 1995, Katzenberg and Kelly 1991). Thus, all that can be concluded from this study is that a change in dependence on C4 based plants and animals occurred during the period represented by these samples.

In a recent isotopic study of a small sample of burials and bison bones from the Henderson Pueblo in southeastern New Mexico, Schoeninger (2004) reports that both bison and human samples displayed a C4 signature. Henderson is outside of the Jornada Mogollon and relatively close to the Southern Plains. Fauna from the site show the occupants had a heavy reliance on bison in their diet (Speth and Rautman 2004) along with corn (Dunavan 2004). Interestingly, while the consumption of corn and bison that fed on grasses of the Southern Plains and are known to have a higher C4 signature should have led to human samples with a C4 signature equivalent to other pueblos in eastern New Mexico that also had heavy reliance on bison and corn, "the data from Henderson indicate that approximately 85 percent of the people's calories and/or protein came from C4 foods compared to 90-95 percent among the agriculturalists from Pecos and Hawikuh (Schoeninger 2004: 417). These findings are of interest and illustrate that the ratio of C4/CAM foods to C3 foods is an important component of subsistence remains.

When coupled with other data sets (e.g., flotation data, ground stone attributes), the isotopic signatures can provide important data directly informative of both subsistence in general and agriculture in particular. This is especially critical as the carbon isotopic signature represents diet over a long time scale, perhaps over much of an individual's lifetime; therefore, they provide a critical measure of long-term subsistence change. Current Department of Defense policies regarding Section 106 and the Native American Graves Protection and Repatriation Act of 1990 (NAGPRA) consultations with Native American tribes prohibits the use of invasive and destructive analysis of human remains. Therefore, it is unlikely that additional isotopic studies on human remains will be permitted at Fort Bliss.

Residue Analysis

In an effort to expand our understanding of subsistence, several researchers have recently explored the utility of residue analysis on artifacts and feature sediments. A variety of different techniques, including immunological-based analysis (see Cattaneo et al. 1993; Downs 1993; Lowenstine 1985; Loy 1993; Newman and Julig 1989), lipid studies (Marchbanks 1989), and research into the recovery of DNA (Pena et al. 1993), have been attempted. The most common of these involves the use of immunological-based analysis, usually designed to detect and identify blood residue on stone tools (see Cannon and Newman 1994; Newman and Julig 1989). Researchers using immunological techniques have identified a variety of animal residues on stone tools, several of which are Paleo-Indian in age (see Amick 1994a; Brush et al. 1994; Cannon and

Newman 1994). The validity of immunological results on archaeological samples is, however, questioned by several researchers (see Cattaneo et al. 1993; Child and Pollard 1992; Eisele 1994; Gurfinkel and Franklin 1988; Hyland et al. 1990; Smith and Wilson 1990).

Essentially, two different immunological techniques have been used in the study area. Downs (1993) has used a combination of microscopy and chemical test strips as a preliminary screening procedure. Suspected residue samples are then subjected to an immunological technique for species identification. Downs (1993) conducted a series of such tests on artifacts from MacNeish's excavations at Todsens Cave. No evidence of blood residue was uncovered on any of the artifacts scanned from the Todsens Cave excavation.

The immunological technique of crossover immunological electrophoresis, or CIEP (see Newman and Julig 1989), has also been attempted in the study area. The CIEP technique involves the exposure of residues isolated from artifacts or feature sediments to a series of antisera developed for particular species (see Child and Pollard 1992; Eisele 1994). Amick (1991; 1994a) was the first to employ residue analysis in the current study area. He submitted a number of Folsom points to a commercial laboratory that conducted CIEP analysis, and positive reactions were recorded to rabbit, bison, and bear. Following Amick's initial study, over 200 archaeological samples, including ground stone, fire-cracked rock, chipped stone tools, ceramics, and feature sediment, have now been submitted for residue analysis using the CIEP technique (see Leach and Newman 1994; Mauldin et al. 1995). While positive reactions occur at low overall rates (less than 20 percent), a variety of plant and animal species have been identified that are not commonly represented in other subsistence remains. These include the identification of both Felidae (e.g., bobcat and mountain lion) and Canidae (e.g., dog, coyote, and fox). These have not been documented previously as subsistence items in the region.

Subsequently, however, a series of actualistic tests of the validity of the CIEP immunological technique to correctly identify modern residues were conducted that suggested significant problems still needed to be overcome before this particular technique can be successfully applied (see Amick 1994a; Mauldin et al. 1995). In the most extensive of these, Mauldin and others (1995) note that in only 17 of 31 chipped-stone artifacts with blood of known animals submitted for CIEP identification were correctly and unambiguously identified at a family level. In four cases, the CIEP technique failed to identify any residue on the blood-coated artifact, and in three cases, the modern residues were incorrectly identified. These results suggest that any subsistence information based on immunological results should be viewed with caution (see also Leach and Mauldin 1995).

Church and Sale (2003: 42-45) identify several errors in reporting and data presentation among the studies reported by Leach and Mauldin. Their reanalysis of the original data reports submitted by Margaret Newman resulted in a more favorable rate of residue identification and reduced error rate. They suggest that additional research, especially involving more blind tests, is required before the immunological techniques are discounted in general or the CIEP-based immunological analysis in particular. This continues to be a developing field and a variety of advances will no doubt occur over the next few years.

Lipid or fatty acid studies may offer a promising alternative. Fatty acids are the major components of saturated and unsaturated fats and occur in nature as triglycerides, consisting of three fatty acids attached to a glycerol molecule by ester-linkages (Quigg et al. 2001, 2002). Unsaturated (e.g., fish and plants) and saturated (e.g., animals) fats occur throughout nature in a variety of forms, are identifiable in cooked and uncooked foods, and are relatively insoluble in water. Gas chromatography has been used exclusively in analyzing the fatty-acid composition of such archaeological residues. The reader is referred to Comdamin and others (1976), Malainey

and others (1999), and Marchbanks (1989) for a more in-depth discussion on the chromatographic technique.

The application of lipid analysis on Fort Bliss and elsewhere in North America is gaining acceptance. The reluctance to use this technique appears to stem from a lack of refinement in the data results. For example, a lipid residue signature of mesquite/corn/fish or animal/seed/nut/fruit is initially ambiguous. However, this ambiguity can be overcome by comparing isomer ratios and frequency percentages within and between samples to develop a more accurate statement on the residue.

The application of lipid residue analysis as a means of potentially identifying the remnant plant and animal residue present on burned rock has expanded from the initial focus on prehistoric cooking activities to investigating processing activities and storage strategies (Quigg et al. 2001). Since 2002, 80 samples from prehistoric sites located within the Fort Bliss Military Installation have been analyzed in an attempt to identify patterns in fatty acid frequencies present on ceramic sherds, ground stone artifacts, hammerstones, and thermally altered rock (i.e., burned-caliche cobbles and fire-cracked rock) (Condon et al. 2005; Condon, Hall, et al. 2006; Quigg et al. 2002). At best, the residue data provide a proxy measure for potentially identifying prehistoric food resources found within the archaeological record. As such, the process does not identify specific species, but based on triglyceride percentages, provides a range of species that fall within a particular fatty-acid signature. By correlating fatty-acid residues found on prehistoric artifacts with modern plant and animal lipid compositions, inferences on prehistoric adaptive strategies can be attempted. With this in mind, lipid residue analysis is best utilized as a supporting technique to be used in conjunction with other more established analyses.

Based on isomer percentages, several inferential statements on prehistoric subsistence strategies can be suggested for the Fort Bliss region (Table 8.7). The presence of low levels of both C18:0 and C18:1 isomers may reflect the decomposing fatty oils associated with plants (e.g., roots, berries, etc.). Moderate levels of C18:0 may indicate the presence of fish or foods similar in composition to corn. While fish, which has a similar signature, is somewhat unlikely, it cannot be dismissed from the prehistoric record on Fort Bliss as fish remains have been recovered from sites in the region (see Bradley 1983). Corn, on the other hand, may provide a more reasonable food source for the interior basin. Elevated percentages of C18:0 isomers are indicative of large herbivores. Elevated percentages of C18:1 with low levels of C18:0 may be indicative of beaver or animals with similar fatty acid composition, such as *Lagomorpha* (Condon et al. 2005; Quigg et al. 2001).

Of the 80 samples submitted to Brandon University or to Lipid Technologies, LLC, 72 retained a sufficient amount of organic residue for analysis. The prehistoric sites from which the sample groups were derived can be divided between sites located within the Hueco Bolson (n=25) and those found on the alluvial fans (n=47). Many of the sites within the Hueco Bolson represent a subset of residential Archaic and Formative occupational events. In contrast, many of the components identified along the alluvial fans are interpreted as Formative age task-specific occupations. The exceptions are sites LA 97943 and LA 97945, which tentatively reflect more extensive, long-term occupations. It is believed that sites within the basin may have subsisted on a variety of resources and this diversity should be reflected in the residue analysis. Sites along the alluvial fans, consisting primarily of burned rock features and roasting facilities, are typically interpreted as resource-specific and should reflect data sets that are more restrictive.

Table 8.7.
Summary of Average Fatty Acid Compositions of Modern Food Groups Generated by Hierarchical Cluster Analysis
(from Quigg et al. 2001: 292, Figure 4)

Cluster	A						B						C		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Type	Mammal fat and marrow	Large herbivore meat	Fish	Fish	Berries and nuts	Mixed	Seeds and berries	Roots	Seeds	Mixed	Greens	Berries	Roots	Greens	Roots
C16:0	19.90	19.39	16.07	14.10	3.75	12.06	7.48	19.98	7.52	10.33	18.71	3.47	22.68	24.19	18.71
C18:0	7.06	20.35	3.87	2.78	1.47	2.36	2.58	2.59	3.55	2.43	2.48	1.34	3.15	3.66	5.94
C18:1	56.77	35.79	18.28	31.96	51.14	35.29	29.12	6.55	10.02	15.62	5.03	14.95	12.12	4.05	3.34
C18:2	7.01	8.93	2.91	4.04	41.44	35.83	54.69	48.74	64.14	39.24	18.82	29.08	26.24	16.15	15.61
C18:3	0.68	2.61	4.39	3.83	1.05	3.66	1.51	7.24	5.49	19.77	35.08	39.75	9.64	17.88	3.42
VLCS ^a	0.16	0.32	0.23	0.15	0.76	4.46	2.98	8.50	5.19	3.73	6.77	9.10	15.32	18.68	43.36
VLCU ^b	0.77	4.29	39.92	24.11	0.25	2.70	1.00	2.23	0.99	2.65	1.13	0.95	2.06	0.72	1.10

^a VLCS- Very Long Chain (C20, C22 and C24) Saturated Fatty Acids.

^b VLCU - Very Long Chain (C20, C22 and C24) Unsaturated Fatty Acids.

Table 8.8 provides the complete Fort Bliss residue-analysis data set compiled between 2002 and 2006 (see also Malainey and Malisza 2002; Miller and Lowry 2006 for additional Jornada studies) Alluvial fan sites exhibit a broad range of possible exploited resources, while the basin sites exhibit a more restrictive range of lipid residue frequencies. These preliminary findings run counter to a generalized model of prehistoric hunter-gatherer adaptive strategies noted for the basin and alluvial fans environments.

Table 8.8.
Summary Data for Lipid Residue Analysis

Site	Provenance	Sample type	C18:0	C18:1	C18:2	C16:0	C14:0	
41EP3152	Feature 6	Pottery	14.28	24.41	4.45	35.61	1.53	Mesquite/Corn
41EP3152	Feature 6	Pottery	n/a	n/a	n/a	n/a	n/a	
41EP3152	Feature 8	Pottery	n/a	n/a	n/a	n/a	n/a	
41EP3152	Feature 2	Flaked tool	9.77	31.32	14.05	20.79	6.02	Texas Ebony/ beaver
41EP3375	Feature 1	BC	n/a	n/a	n/a	n/a	n/a	
41EP3375	Feature 1	BC	n/a	n/a	n/a	n/a	n/a	
41EP3375	Feature 1	BC	10.25	40.67	9.15	24.18	2.06	Seeds, nuts, rendered fat
41EP3201	Feature 1	Metate frag.	19.29	27.54	2.48	29.71	3.34	
41EP3096	Surface	Mano frag.	19.06	13.93	1.07	46.87	1.80	Mesquite/corn
41EP3096	Feature 2	Metate frag.	31.23	19.90	2.00	24.36	1.78	Fatty meat
41EP3211	Feature 1	Metate frag.	12.85	43.93	3.82	20.57	5.23	Seeds, nuts, rendered fat
41EP3211	Feature 1	Pottery	10.27	49.58	2.26	16.77	5.65	Seeds, nuts, rendered fat
41EP3211	Surface	Metate frag.	16.73	32.88	4.47	32.22	3.55	Texas Ebony/beaver
41EP3211	Feature 5	Mano frag.	9.19	44.17	3.55	28.10	1.73	Small animal
41EP3211	Feature 4	Pottery	18.40	35.40	4.31	27.96	2.38	Small animal
LA 97943	Test Unit 10	Flake	6.76	18.25	1.19	13.75	4.01	Small animal/plant
LA 97945	Feature 23	Pottery	6.07	17.14	1.70	17.74	2.14	Small animal/plant
LA 97945	Feature 26	Pottery	6.89	17.40	2.33	12.54	1.97	Small animal/plant
LA 97945	Surface	Stone ball	7.98	42.78	2.17	11.17	3.65	Small animal/plant
LA 97945	Surface	Metate	2.83	45.42	3.07	10.43	2.93	Small animal/plant
41EP1039	Feature 10a	BC	9.06	39.88	1.43	15.51	4.25	Small animal/plant
41EP1039	Feature 15c	BC	8.15	43.59	2.70	12.24	2.09	Small animal/plant
41EP1046	Feature 35	BC	7.10	18.09	3.39	20.65	6.64	Small animal/plant
41EP1046	Feature 52	BC	6.77	41.52	2.48	15.22	4.93	Small animal/plant
41EP1046	Feature 7	BC	8.39	51.26	2.67	15.64	4.50	Small animal/plant
41EP1050	Feature 1	BC	8.66	42.23	2.12	12.46	3.98	Small animal/plant
41EP3330	Surface	Pottery	12.80	34.16	3.91	19.21	11.51	Plant
41EP3330	Feature 4	BC	5.02	55.22	12.21	11.91	4.50	Small animal

Table 8.8.
Summary Data for Lipid Residue Analysis

Site	Provenance	Sample type	C18:0	C18:1	C18:2	C16:0	C14:0	
41EP3049	Surface	Hammerstone	4.54	46.88	3.07	17.95	11.90	Plant
41EP3049	Feature 1	BC	2.80	58.02	13.00	9.94	2.95	Small animal
41EP3049	Feature 2	BC	5.01	61.21	2.33	14.37	3.57	Small animal
41EP3137	Feature 1	Mano frag.	6.42	41.37	1.95	17.33	14.91	Plant
41EP3137	Feature 2	BC	5.00	52.02	7.30	14.78	4.17	Small animal
41EP3137	Feature 1	BC	n/a	n/a	n/a	n/a	n/a	Small animal
41EP3081	Feature 1	BC	n/a	n/a	n/a	n/a	n/a	Small animal
41EP3081	Feature 4	BC	n/a	n/a	n/a	n/a	n/a	Small animal
41EP3469	Surface	BC	n/a	n/a	n/a	n/a	n/a	Small animal
LA 117704	6	BC	0.97	22.77	39.19	23.86	0.35	Seed, nut, fruit
LA 117704	8	BC	0.00	38.38	15.77	22.78	0.47	Fish/bird +corn
LA 117704	n/a	Pottery	29.68	19.01	6.39	26.93	0.88	Large herbivore Large herbivore/seed, nut, fruit
LA 117704	n/a	Pottery	14.14	37.38	23.95	14.05	0.00	Large herbivore/seed, nut, fruit
LA 117704	2	Pottery	14.32	26.98	13.57	23.78	0.68	Large herbivore/seed, nut, fruit
LA 117704	6	BC	6.13	50.80	12.58	14.61	0.00	Piñon /mescal
LA 117705	7	BC	16.84	8.92	5.64	34.99	2.99	Plant Texas Ebony/ beaver
LA 117705	12	BC	8.35	42.68	9.96	26.84	1.27	Plant Texas Ebony/ beaver
LA 117712	3	BC	19.95	14.33	0.20	41.42	5.11	Plant Texas Ebony/ beaver
LA 117705	20	BC	7.76	37.48	6.20	32.10	1.67	Mesquite/corn Texas Ebony/ beaver
LA 117705	22	BC	16.91	24.53	8.16	35.74	1.47	Plant Texas Ebony/ beaver
LA 117705	22	BC	11.61	38.36	16.95	24.01	0.85	Plant Texas Ebony/ beaver
LA 117705	24	BC	17.99	10.37	3.75	41.00	4.59	Plant Texas Ebony/ beaver
LA 117710	s	BC	9.01	41.92	1.94	23.42	1.78	Plant
LA 117710	ee	BC	16.98	8.83	1.85	42.95	1.56	Plant
LA 117710	ff	BC	5.50	52.93	16.71	18.20	1.45	Piñon/mescal
LA 117710	kk	BC	18.12	7.23	0.00	51.93	3.72	Plant
LA 117712	1	BC	20.20	11.02	2.99	45.31	4.66	Plant Large herbivore + plant
LA 117712	1	BC	24.78	6.25	2.15	47.27	1.25	Plant
LA 117712	2	BC	52.19	3.14	1.87	29.31	0.92	Large herbivore Large herbivore, seed, nut, fruit
LA 117712	3	BC	20.32	46.26	15.37	14.74	0.30	Plant
LA 117713	3	Pottery	18.84	24.29	7.90	28.41	1.04	Mesquite/corn/fish Texas Ebony/beaver
LA 117704	4	BC	3.34	46.60	9.79	22.78	1.07	Piñon /Mescal Texas Ebony/beaver
LA 117704	2	BC	3.34	46.60	9.79	22.78	1.07	Plant
LA 117704	7	BC	7.50	44.50	8.61	23.80	0.51	Piñon /mescal Ebony/beaver
LA 117704	5	BC	4.45	62.00	7.82	15.28	1.44	Plant
LA 117704	8	BC	5.80	30.99	10.43	26.14	1.04	Fish/Bird +corn Texas Ebony/beaver
LA 117704	8	BC	7.61	34.94	7.48	24.68	3.03	Plant

Table 8.8.
Summary Data for Lipid Residue Analysis

Site	Provenance	Sample type	C18:0	C18:1	C18:2	C16:0	C14:0	
LA 117706	2	BC	3.51	52.16	29.77	10.24	0.34	Piñon /mescal
LA 117706	5	BC	4.84	63.78	7.27	15.18	0.52	Piñon /mescal
LA 117706	9	BC	0.00	53.20	22.47	9.52	1.02	Piñon/mescal
LA 117706	13	BC	2.71	54.37	9.18	16.60	0.68	Piñon/mescal + fish/bird
LA 117713	1	BC	5.55	31.06	21.57	23.06	2.47	Corn
LA 117713	2	BC	1.33	77.57	6.19	7.19	0.20	Animal or seed/nut, fruit oil Texas
LA 117713	3	BC	0.00	46.78	16.94	14.82	2.35	Ebony/beaver
LA 117720	b	BC	3.77	61.07	12.65	15.18	0.65	Animal or seed/nut, fruit oil Texas
LA 117721	f	BC	10.61	39.33	9.57	25.60	1.31	Ebony/beaver
LA 117721	k	BC	3.33	56.22	13.57	12.79	0.43	Piñon/mescal
LA 117713	1b	BC	1.23	20.86	2.32	25.96	0.48	Aquatic specimen/bird
LA 117713	4	BC	1.64	53.11	10.17	15.72	2.33	Piñon/mescal
LA 117704	n/a	Pottery	1.46	74.93	11.50	7.94	0.24	Animal or seed/nut, fruit oil
LA 117704	n/a	Pottery	1.53	62.78	20.25	9.40	1.37	Animal or seed/nut, fruit oil
LA 117704	n/a	Pottery	6.49	38.61	9.29	15.97	5.16	Beaver/mescal

Like many analytical techniques, lipid residue analysis should be used as a supporting technique that enhances the information potential for a given site. Moreover, analysts need to consider the following recommendations:

- Because fatty oils are susceptible to decomposition, samples recovered from good contexts should be considered first, before moving on to less-desirable specimens.
- Analysts should combine analytical techniques that will provide the maximum data about a particular feature (e.g., radiocarbon, faunal, macrobotanical, and lipid residue analysis) and thus about the site.
- Recent work has identified a number of problems that need to be overcome before the identifications from this type of analysis can be accepted as completely reliable (Buonasera 2005).

If these recommendations are followed, lipid residue analysis can provide a useful tool in attempting to interpret the past. While still developing, use of this technique holds promise in establishing a broader comparative data base, and if used correctly, can result in inferential statements on past environments, processing activities, and subsistence strategies on Fort Bliss.

Summary of Biological Subsistence Data

This section has provided an overview of strengths and weaknesses of several biological data groups that can be used in subsistence research in the study area. Each of the biological data groups outlined above is relevant to subsistence studies, for they minimally provide data on resources exploited in an archaeological context. With the exception of coprolite analysis, all have been used in subsistence research in the region with varying degrees of success. Persistent

problems of preservation, sampling, and interpretation exist with all data groups, and the above summaries suggest that these biases, especially those associated with preservation, may pattern with geomorphic zones. Moreover, it is evident that the most productive analytical approach to biological analysis of prehistoric subsistence practices is one that incorporates multiple methods and corroborative samples from the same context or item. This is especially true of experimental methods.

ARTIFACT DATA

This section provides a discussion of various artifact groups that are relevant to subsistence studies in the region. The strengths and weaknesses of each data group are discussed, and a brief summary of major applications of these techniques in the study area is provided.

Unlike the biological data discussed in the previous section, artifactual data groups cannot be directly dated. Consequently, we are forced to assume either that technological or stylistic changes are an appropriate indicator of temporal change, or that some level of spatial association between a given artifact and a chronometric date provides a date on the artifact. As noted in Chapter 9, the assumptions underlying stylistic or technological change are interwoven with cultural history notions of why that change occurs. Furthermore, given the complex patterns of erosion and deposition typical of many sites, associations between a chronometric date and an artifact should be questioned, especially when detailed geomorphic observations of the relationships are not available. Nevertheless, these artifactual data groups are relevant to subsistence studies, for they provide information on assemblages used to extract and process subsistence resources. While chronological placement is problematic, changes in these data groups provide an additional source of information.

Here, four data groups are discussed that can provide information on subsistence. These include lithics, ceramics, feature types, and perishable remains. In each of these data sets, morphological variability, as an indication of intended use, is the focus.

Lithic Artifacts

Two general categories within this data group, ground stone and chipped stone, are discussed. Within each of these categories, the focus is on tool morphology (e.g., small manos, pestles, and projectile points) and use (e.g., striation and edge damage). It is assumed that there is some relationship between the frequency of these various tools at a location during a given time frame and the frequency of subsistence items processed using these tools. While tools used in processing are not necessarily deposited at the location of use, attention to tool-breakage patterns, especially those associated with use, and overall size attributes of lithic tools, which may condition transportability, should allow for the identification of spatial and temporal patterns that implicate subsistence.

Ground Stone

While a variety of ground stone tool categories can be distinguished (e.g., mauls and axes), three general categories that are directly related to subsistence processing are of concern here. These are: 1) mortars and pestles; 2) small "one-hand" manos and basin metates; and 3) larger "two-hand" manos and slab, trough, and through-trough metates. While each of these grinding sets can be used to process a variety of subsistence remains, ethnographic descriptions (see Christenson 1987b; Hard 1986; Mikkelsen 1985; Mauldin 1993b; Wright 1994) and studies of use-wear characteristics (see Adams 1989; Lancaster 1983) suggest that these morphological distinctions correlate with processing of several general sets of resources.

Mortars and pestles appear to be designed and used for breaking hard-shelled nuts (e.g., walnuts and piñon) and for mashing moist seedpods and nuts (e.g., mesquite). A number of ethnographic descriptions are available of the use of this tool set (see Bell and Castetter 1937; Mikkelsen 1985; Kroeber 1925). Mortars can be fashioned out of rock, wood, or earth, and pestles can be fashioned out of either wood or stone; some relationship may exist between pestle form and mortar characteristics (see Kroeber 1925). The archaeological visibility of mortars made of either wood or earth, and pestles made of wood, is, of course, limited.

Within the current study area, several researchers have noted the presence of mortars and pestles. Lehmer (1948: 32) notes such tools at the site of Los Tules, and a variety of mortars and pestles have been described in the region (Carmichael 1981; Cosgrove 1947). The only detailed study of the distribution of such tools in the current study area is reported by Carmichael (1981). He provides an overview of mortars and pestle in relationship to the potential processing of mesquite. Based on his Maneuver Area 3-8 survey (Carmichael 1986a), and a review of mortars and pestles from ethnographic and archaeological sources, Carmichael suggests that many of the pestles in the local area are "...the narrow type associated with wooden mortars" (Carmichael 1981: 61), therefore, he focuses his investigation on pestles. The 3-8 survey recorded a total of 70 pestles or pestle fragments, and two stone mortars. Thirty-six single-component sites had pestles. Based on the association, Carmichael (1981: 61) suggests that pestles are most frequent on Mesilla phase sites (n=9) relative to other sites. He concludes that mesquite processing is, therefore, most common in the Mesilla phase, but is also well represented throughout the prehistoric sequence. With regard to spatial distribution, Carmichael (1981) also notes that many of the pestles are located in the central basin and may be associated with playas.

While Carmichael's review is extremely useful, the conclusions that mesquite is an important resource may not be justified, as the overall occurrence of pestles is extremely low. Less than one pestle was discovered for every 14 square km of survey area, and less than 1 percent of the sites recorded in Maneuver Area 3-8 have any pestles present. While mesquite may have also been processed with manos and metates, especially late in the season when the pods tend to be dry, the low overall frequency suggests that the question of mesquite dependence as indicated by pestle frequency remains unresolved.

A variety of researchers, especially within the last few decades, have argued that variation in attributes of manos and metates can be used as a gross measure of agricultural and nonagricultural processing rates and, by implication, overall dependence on these resource groups (see Adams 1988, 1989, 1993; Hard 1986, 1990; Hard et al. 1996; Lancaster 1983; Martin and Plog 1973: 216-217; Martin and Rinaldo 1947: 316; Mauldin 1993b; Mauldin and Leach 1994; Plog 1974). Much of this research focuses on differences in mano/metate size attributes, either grinding surface area, or length and width used as a proxy for grinding surface area. As manos are frequently more common in both collections and in the archaeological record, much of this research has focused on these ground-stone tools.

The relationship between mano grinding area and processing of both agricultural and nonagricultural grain is supported both by ethnographic, archaeological, and experimental data (see Bartlett 1933: 27-29; Hard 1990; Horsfall 1987: 340-347; Lancaster 1983: 75-86; 139-141; Mauldin and Tomka 1988, 1989; Mauldin 1993b, 1995; Plog 1974). Larger, "two-hand" manos and slab, trough, or through-trough metates seem to be associated with situations of high agricultural dependence (see Morris 1990; Schlanger 1991). Smaller "one-hand" manos, conversely, are involved in many tasks. While these tasks may include the processing of both wild foods and agricultural grains, situations in which agricultural grains are a significant portion of the diet are consistently dominated by larger mano/metate sets (e.g., Mikkelsen 1985; O'Connell et al. 1983: 88-93; Wright 1994). While other factors, such as limits on raw material size (see Stone 1994), mobility levels (e.g., Calamia 1983; 1991), and alternative processing

trajectories for agricultural grains (see Christenson 1987b; Hard 1986; Weatherwax 1954) complicate this relationship, the occurrence of different ground stone sets can provide data on processing of both agricultural and nonagricultural items. Consequently, the other two ground stone data sets considered here are small (one-hand) manos/basin metates and large (two-hand) manos and slab/trough/through-trough metates.

Within the current study area, several researchers have considered mano and metate attributes, with most focusing on mano size attributes. Calamia (1983, 1991) provides temporal and spatial data on mano and metate size attributes, though he is primarily concerned with mobility levels rather than subsistence. Hard (1986) provides background to the use of manos and metate size attributes, as well as an overview of these data with regard to subsistence. Recently, however, two studies have synthesized spatial and temporal aspects of ground stone in the region. The first of these is provided by Mauldin (1995) in his examination of mano size attributes using collections from a series of spatial zones. While data provided by Mauldin is primarily limited to spatial variation, Hard and others (1996), in a more general overview of ground stone, provides temporal data on mano size changes in the study area.

Mauldin (1995) uses area measurements on over 771 manos from a series of environmental zones to consider patterning in size attribute. His spatial zones combine several of the Fort Bliss ecological-geomorphic zones. Mauldin's central basin zone encompasses both the central basin and central basin playa area. He combines the alluvial fan/runoff zone and the Rio Grande area into a second spatial unit. Finally, his third zone, the Mountain area, focuses primarily on the Sacramento portions of the uplands. In addition, Mauldin (1995) uses both site and isolated data in his mano study.

Using mano area, Mauldin demonstrates that the mean grinding area of 410 manos collected from the central basin is only 86.6 square centimeters, and just over 11 percent of the manos would be classified as two hand manos. Using area estimates of 225 manos from the better-watered alluvial fan/Rio Grande zone, he demonstrates that mano area is, on average, significantly larger (mean = 119 square centimeters), and almost a third of all manos (31.7 percent) are in the two-hand class. Finally, the 136 manos from the Sacramento Mountains have an average area of 151.3 square centimeters and over 50 percent fall into the two-hand size range. These size differences are statistically significant, and in combination with the differences in the percentage of two-hand manos, may suggest that agricultural activities were concentrated outside of the central basin zone, primarily along the fans and river areas, and in the mountain settings. That is, the lack of larger manos in the central basin reflected limited corn processing in this area and a focus on wild resources. Agriculture seems to have occurred along the fan/river area and in the mountains. The effect of distance on ground stone material selection has not been demonstrated. A half-day to a day walk from the central basin to the fans probably excludes logistical procurement, but not as an embedded strategy. More research is warranted into this issue.

These differences may not only reflect spatial differences in the importance of agriculture, but also temporal differences. Hard (1986, 1990), using mano lengths as a proxy for area, has argued that agriculture becomes increasingly important late in the archaeological sequence. Hard and others (1996), using data on mano area collected from both excavation and survey data, demonstrate that mano area increases dramatically from Archaic sites to late ceramic (post-A.D. 1000) sites. These patterns suggest that although agriculture is introduced into the region quite early (see Tagg 1993; Upham et al. 1987), it is only after A.D. 1000 that it contributes a significant component to the overall subsistence in the lowlands. Interestingly, it is after A.D. 1000 that settlement patterns are concentrated along the alluvial fans and river setting, which are areas of more consistent water availability.

Chipped Stone

While a variety of chipped-stone tool categories can be distinguished based on morphological attributes, a clear link between most commonly distinguished forms and specific subsistence attributes has not been established. Consequently, a single morphological category, projectile points, which have been linked to hunting, will be the focus; other tool forms (e.g., retouched flakes, utilized flakes) will only be discussed at a general level. In addition, raw material characteristics that have been linked to relative dependence on plants or animals are also reviewed.

Throughout this discussion, it is assumed that a given task, or set of tasks, places constraints on tool morphology. A set of morphological attributes is assumed to provide an optimal solution to a task with changes in that morphology resulting in reduced efficiency. Yet, the gains in efficiency that result from an optimal solution are properly seen against other costs. These include the cost of tool production, quarrying activities, and tasks associated with the total activity (see Jobson 1986). Variations in tool morphology, then, should provide some insights into the specific subsistence activities.

While ethnographic data on the range of chipped-stone tools are limited, experimental research (see Jobson 1986; Jones 1980) shows that tool size and edge attributes are important elements in tool performance. Larger tools are more easily manipulated, especially without hafting. In addition, edge angles affect performance in that certain angles, by virtue of their sharpness and durability, are well suited for some activities and inappropriate for others.

Raw materials are a major component of overall tool size, edge-angle characteristics, and the durability and sharpness of a tool. Nelson (1981; see also Goodman 1944; Kelly 1985), after a review of ethnographic sources, suggests that coarse-grained raw materials are, as a function of the material, resistant to damage during use. That is, coarse-grained raw materials produce durable edges. However, coarse-grained edges tend to be relatively dull. In contrast, cryptocrystalline materials can produce extremely sharp edges, but such edges tend to be quite brittle. Nelson (1981) suggests that, given these material characteristics, activities that are focused on plant processing, or the production of wood tools commonly used in plant processing should involve an extensive use of coarse-grained materials. In contrast, activities involving hunting, including butchering, should focus on cryptocrystalline materials.

Projectile points, frequently associated with various hunting activities (see Churchill 1993) or warfare, are one of the most intensively studied tool classes. While most investigations are concerned with the use of point forms as indicators of cultural interaction or diachronic change, there has been little investigation with regard to subsistence. Christenson (1986, 1987a) provides an extensive review of projectile point attributes that may be relevant to functional, and by extension, subsistence considerations. Relying on experimental, ethnographic, and modern archery studies, Christenson outlines a number of variables (e.g., shoulder width, thickness, and weight) that affect the wound size and penetration depth. These changes suggest different weaponry delivery systems and killing power (Christenson 1986) and may reflect changes in prey.

Other tools, such as simple utilized flakes and retouched tools have been described for use in a variety of diverse activities. However, both macro-level and micro-level use-wear studies have suggested that characteristic use-wear patterns may be indicative of processing materials of different hardness. While use-wear patterns are difficult to quantify and are dependent, to a substantial degree, on specific raw materials characteristics, use-wear studies may provide an additional indicator of macro-level changes in subsistence (see Keeley 1980; Shea 1992; Tringham et al. 1974).

Within the study area, projectile points have commonly been used in cultural chronology/culture history studies, but have not been extensively investigated with regard to subsistence. No detailed study of point attributes as they relate to weaponry or delivery systems could be located and the practice of summarizing metric attributes at a type-level hindered detailed functional studies. However, two general temporal trends may be present in the projectile point database. First, as in most regions in the Southwest, projectile points decrease in size through time. While specific studies of this are not available, it appears that later Ceramic period sites are dominated by small points, usually in the size range of less than 2.5 cm, which tend to have thin cross sections. In contrast, many of the earlier forms are larger than 3 cm in maximum length and tend to have thicker cross-sections.

Second, there may be changes in raw materials used, especially between the Archaic and Late Ceramic period. Archaic points, especially those from the Early and Middle Archaic periods, tend to be made of coarse-grained materials such as basalt and rhyolite. Conversely, Late Ceramic points are dominated by high-quality materials, including a dependence on obsidian. These diachronic changes, when considered in a functional framework, are usually seen as relating to a reduction in mobility resulting in more use of locally available, small obsidian nodules. Basic research, however, has not been conducted to address these suggestions.

In general, the number of projectile points from controlled archaeological contexts is not great, especially prior to the Late Ceramic period. Points have been recovered in large numbers from the extensive surveys conducted during the late 1970s and 1980s, but in low overall densities given the size of the region. For example, Carmichael (1986a) reports approximately 900 points from the MA 3-8 survey, which is an overall frequency of less than 1 point per square km. Collectors have been taking points from Fort Bliss sites for over 50 years, and this may have served to skew the numbers recorded archaeologically in recent years. Nonetheless, recent excavation on Fort Bliss suggests this is not the case. Fewer than 45 projectile points were recovered from over 11,000 square meters of excavation (Mauldin et al. 1998). While there are notable exceptions at the regional level, especially in cave and shelter locations (see MacNeish 1993: 155-156), projectile points in the desert portions of the Hueco Bolson do not appear to be common. One exception may be Twelve-Room Pueblo where over 200 arrow points have been recovered (see Seymour 2002: 168, Figure 6.93). Yet even this site's collection pales in comparison to the Robinson Site in the Sacramento Mountains where Kelley (1991) reports the recovery of over 3,000 projectile points. Interestingly, the faunal material recovered from mountain sites, as well as the range of fauna potentially available, is dominated by large game. In contrast, the lowland fauna are dominated by small and medium-sized mammals. Summaries of faunal remains from the lowland suggest that large game, though infrequent, appears to be more common on Late Ceramic sites.

The remaining morphological forms, consisting of other formal tools and utilized flakes, have not been extensively studied in the current study area (see Dockall 1999; Miller 1990, 2007a; Shafer et al. 2001b for exceptions). While raw material changes through time have been noted, these are usually tied to mobility changes rather than subsistence. No detailed use-wear studies have been conducted, though several macro-level investigations have produced results that suggest that additional investigation may be warranted.

Clearly, chipped-stone tools in the study area are an underutilized class of material that may be related to subsistence. Any clear interpretation of chipped-stone tools are complicated by changes in mobility, the ambiguity associated with changes in projectile point forms, and a lack of detailed study of use-wear characteristics produced by local materials. Researchers generally believe that changes in both raw materials and projectile points recovered from a site or landform during a given time, as well as changes through time, should be associated with changing dependence on plants and hunting practices.

A focus on tool morphology and raw material variation in bifacial tool forms other than projectile points can offer additional insights into prehistoric technological organization in response to changing subsistence practices. In a recent analysis of chipped-stone assemblages from the El Arenal and Tres Casitas sites, Miller (2007a) presents several observations that have implications for understanding subsistence and settlement organization during the Late Archaic and Early Formative periods. Based on the technological patterns observed at El Arenal, it was proposed that logistically organized hunting forays to obtain artiodactyl species and other medium and medium-large sized game were a distinct organizational strategy of the Late Archaic period. Changes in hunting strategies and the increasing dependence on plant foods during the subsequent Formative period Mesilla phase led to the changes in raw material texture commonly observed among regional chipped-stone assemblages.

During the transitional centuries between the Late Archaic and Early Formative periods, the decreasing emphasis on hunting and distant logistical forays resulted in a corresponding reduction in the need for preferred materials such as fine-grained cherts and chalcedonies for production of bifaces and formal extractive tools. The reduction or elimination of the logistical hunting component of Late Archaic settlement resulted in a corresponding decrease in the need for fine-grained materials to manufacture maintainable bifacial tools. Moreover, the reduced logistical mobility and termination of long-range hunting forays also reduced access to distant and varied raw material sources. The combined effect was a noticeable reduction in bifacial technologies and attendant decline in the use of fine-grained raw materials and raw material diversity among Formative period lithic assemblages. Thus, a reduced emphasis on extractive tasks associated with hunting is seen as closely related to a reduced emphasis on formal, maintainable bifacial tools. Meanwhile, the growing dependence on plant foods and bulk processing of such foods created new requirements for tool design, resulting in the selective acquisition and use of more durable, coarse-grained materials for processing cacti and other plant materials. Increasing sedentism and agricultural production led to a new range of production and maintenance roles for stone tools. The construction of substantial residential structures and their roofing elements required more intensive preparation of wood, fiber, and other material. Stone digging tools or wooden tools shaped by stone tools may have been needed to dig adobe borrow pits and storage pits.

These two opposing but complimentary patterns ultimately lead to the long-held observation of decreasing raw material “quality” during the Formative period. The reduced emphasis on hunting, increasingly limited logistical procurement, and decreased need for bifacial extractive tools resulted in an appreciable reduction in the use of geographically diverse assortments of fine-grained lithic material. Bulk plant processing tasks and other domestic tool needs resulted in the increasing use of durable, coarse materials. This process also relates to arguments linking increasing sedentism and core technology. In the case of the Jornada, the argument is best phrased not in terms of a shift to an expedient core technology, but rather a shift away from a minor bifacial component. Core technologies and the use of expedient flake tools occurred throughout most of the prehistoric sequence; what differs during later periods is that the formal tool production and particularly bifacial reduction decreases markedly while expedient tools shift from fine to coarse materials to meet the new set of processing and maintenance requirements. These factors explain the apparent chronological changes in raw material “quality” historically observed among studies of Jornada lithic technology.

Other recent studies, however, hint that the patterns may be complicated by recycling (Camilli 1988; Shafer et al. 2001b). In their analysis of the lithics recovered from the testing of 32 sites and the mitigation of six of the same sites within the foot print of Loop 375 through Fort Bliss, Shafer and others (2001b) examined raw materials, reduction strategies, and recycling of lithics at sites ranging from the Late Archaic through the El Paso phase of the Formative period that are

situated on alluvial fans, the central basin floor, and toe slopes. They anticipated finding different patterns through time as the processing of corn intensified. Instead, “the findings were not what we expected. The land-use practice that came into focus [from our findings] was one of scavenging raw materials from discarded artifacts” through all time periods (Shafer et al. 2001b: 405). Future studies at Fort Bliss should seek better understanding of the role of lithics in food processing and whether that role did, in fact, change through time.

Ceramics

Ceramics, frequently used in cooking and storage activities, reflect subsistence change (see Braun 1983; Nelson 1985). It is assumed that a given task, or set of tasks, places constraints on vessel morphology. Consequently, changes in ceramic vessel form, as well as engineering characteristics (e.g., vessel thickness and temper), may be related to subsistence change (see Braun 1983). Here, the focus is on changes in vessel morphology, though changes in temper characteristics and vessel thickness may also be relevant to subsistence change.

Ethnographic studies (see Linton 1944; Longacre 1991) suggest that bowls are generally used as serving implements while jar vessel forms are more likely to be used for cooking or for storage. Jar forms, because they are used in food preparation, are directly relevant to subsistence change. Vessel opening determines vessel access, while storage vessels, especially those designed for liquids, may be characterized by small openings. Cooking vessels, in contrast, should have both larger openings and be designed to reduced spillage.

Major changes in subsistence, such as the shift to agriculture, should be reflected in changes in vessel morphology. For example, several authors have argued that corn is frequently processed by steeping and soaking, activities that can be effectively accomplished with necked jars. Thus, locations that depend on grain agriculture should be dominated by necked jars. In contrast, necked jars would be less effective for boiling or liquid storage as their inverted rims would increase spillage and they generally lack large openings for easy access to vessel contents. While they can certainly be used in cooking, it is less likely that they would be involved in preparations that involve extensive boiling.

Within the current study area, a variety of studies have focused on ceramic vessel form (see Brewington and Shafer (1999); Lukowski et al. 2006; Michalik and Batcho 1988; Miller 1989; Miller and Burt 2007; Scarborough 1986, 1992; Seaman and Mills 1988; Shafer et al. 2001a; Whalen 1981). Frequently hampered by small sherd size, a low frequency of rim sherds, and highly eroded body sherds, many researchers have focused on primary distinctions between bowls and jars rather than focusing on jar forms. Several researchers have identified somewhat greater proportions of bowls, which may be associated with serving activities, on large sites located along the margins of the central bolson. Scarborough (1986, 1992) reports that on 52 rim sherds from Meyer Pit house Village, bowls comprise 48 percent of the assemblage. Brewington and Shafer (1999: 170) and Miller (1989) report that on Gobernadora, a large site that was excavated in two separate phases with several substantial pit houses, bowls make up 39 percent and 22 percent, respectively, of the rim sherds. Recent study of vessel rims from the Conejo Site located along the Organ Fans, indicated that bowls constituted 34.4 percent of the collection, a percentage that is somewhat greater than at most Mesilla phase sites (Miller and Burt 2007: 5-1). Conversely, several studies of the central basin suggest lower bowl frequencies. Michalik and Batcho (1988) report that bowls generally comprise less than 10 percent of the ceramic assemblage on several small sites in the central basin. Mauldin and others (1998) report a similar percentage for jar sherds in the central basin. While details of jar vessel forms are lacking, these patterns may suggest that different processing requirements may be implicated at a landform level.

Changing frequencies of jar forms are of primary interest with regard to subsistence. Hard (1983a, 1986, 1987) undertook an analysis of Mesilla phase settlement and subsistence through a comparative analysis of El Paso brownware vessel forms and sizes. He hypothesized that the Conejo Site, posited as an example of a winter base camp positioned on the alluvial fan landform, would have more jars, more necked jars, and larger vessels than the Huesito Site, which is thought to represent a shorter-term summer habitation in the central basin landform.

Contrary to the model's expectations, Hard's (1987, 1994) comparative analysis of the assemblages from the Conejo and the Huesito sites found no statistically significant variation between the two in terms of vessel form or orifice diameter. Recently, Miller and Burt (2007) conducted additional work at Conejo and expanded the rim sherd analysis to the more comprehensive database compiled during the Fort Bliss CRCP report (Miller 1996). The sample consisted of 1147 El Paso Brown rim sherds from nine Mesilla phase sites located in a range of settings: Tres Casitas (Miller 2007a), Hill 100 (Fort Bliss site files), Huesito (Whalen 1980), Los Tules (Lehmer 1948; Magers 1973), Roth (O'Laughlin 1981), Tortugas (Stuart 1991), FB 9686 (New Mexico State University), Turquoise Ridge (Whalen 1994a), and Conejo.

Using the one-way analysis of variance (ANOVA) test to determine if statistically significant differences exist for orifice diameter, vessel wall tangent angles, and vessel wall thickness among the samples of jar rim sherds from each site, the test confirmed the earlier findings of Hard (1987, 1994) in that there is surprisingly little variation among all nine sites in terms of orifice diameter and vessel wall tangent angle (Miller and Burt 2007: 5-3, 5-4). Wall thickness did differ among the sites but, as shown in Figure 8.2, that difference was not related to patterned variation among different landforms as suggested by Hard's model. For example, the thickest rim wall sherds were recovered from the Tortugas Site, a catastrophically or intentionally burned pit house on the first Rio Grande Valley terrace. However, the Los Tules and Roth sites, located in the same landform within ten miles of the Tortugas Site, each have much thinner mean rim wall values.

Changing ceramic vessel forms, especially within the jar category, provide clues to subsistence as they may imply different levels of boiling/steeping that suggests general subsistence change. While a variety of other factors (e.g., changes in mobility) complicate this pattern, both the presence of ceramics, and changes in vessel form, should reflect major changes in subsistence.

Miller (2007a) and Miller and Burt (2007) have recently proposed that one aspect of Mesilla phase subsistence involved a greater emphasis on bulk seed processing, similar to that suggested for later prehistoric periods in the Great Basin (Eerkens 2003, 2004). The incorporation of ceramic containers as part of the mobile toolkit of Mesilla hunter-gatherer groups may reflect this increased emphasis on seed collection, storage, and processing via boiling. Temper and compositional attributes of Mesilla phase brownware assemblages suggest the ceramic vessels were designed to function as portable and durable container and cooking tools (Miller and Burt 2007).

Production decisions and temper selection by Mesilla phase potters were designed to satisfy both the requirements for strong vessels that could be moved from site to site in addition to having moderate resistance to thermal fatigue from cooking and boiling. Domestic vessel inventories appear to have been limited to a small range of functional, transportable pots. The evidence from NAA suggests trans-basin transport of vessels, a finding corroborated by the results of temper attribute analysis that indicate technological production of early El Paso brownware vessels were designed as a compromise between strength and thermal shock resistance, and that this functional compromise may best characterize Mesilla phase ceramic production.

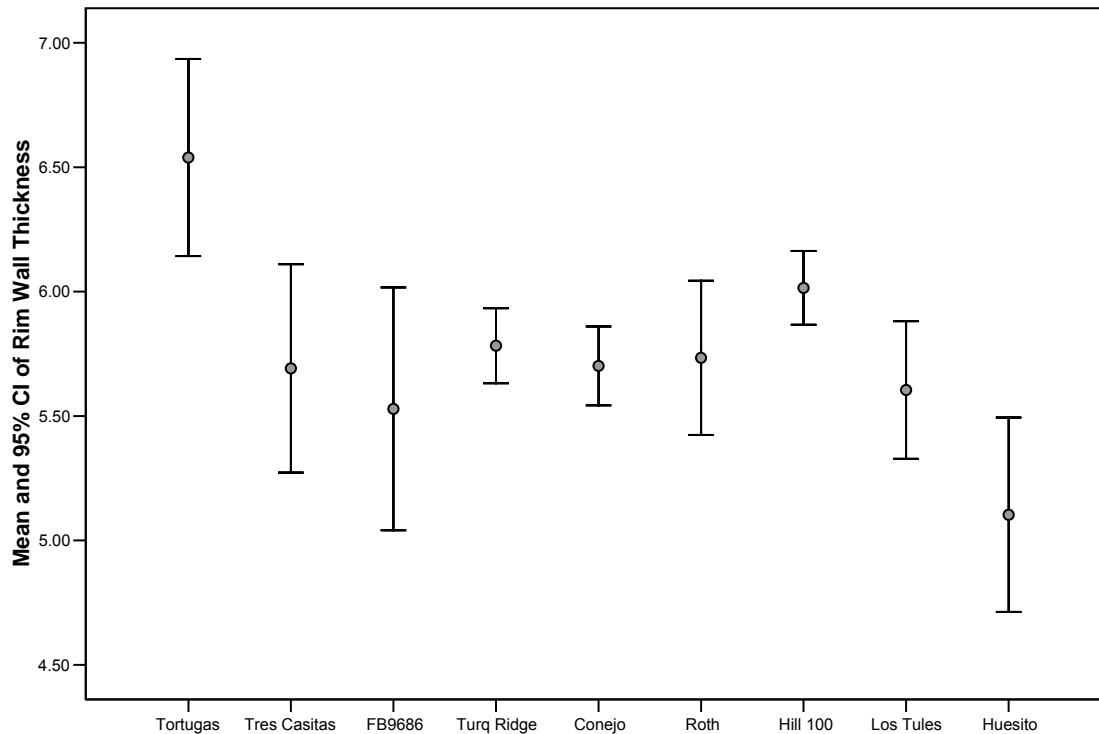


Figure 8.2. Mean and error bar plot illustrating variation among mean rim wall thickness values for nine Mesilla phase El Paso Brown jar assemblages.

Recent studies of ceramic production and functional uses in the Southwest and elsewhere have explored the use of ceramics in rituals and feasting (see Crown 1994; Mills 1999; Shafer 2003). Shafer (2003: 191) has argued that several large ceramic vessels, including one El Paso brownware olla, recovered from a Mimbres storage room at the Nan Ranch were used for feasting and possibly for fermenting corn beer. Noting the similarity of the vessels used by the Tohono O’odham to make saguaro wine and the vessels used by the Raramuri to make *tesgüino* (corn beer) with large El Paso Polychrome ollas, and noting the worldwide commonality of feasting that includes some type of fermented drink with such events, Jackson and others (2004) were able to successfully brew corn beer in replicated El Paso brownware ollas. While acknowledging that their experiment does not prove this was the use for the large ollas, they recommend that residue analysis be undertaken for these large vessels. Drawing from Kenagy’s (1985) study of crenellated vessels elsewhere in the Southwest, Jackson and Thompson (2006) also note that crenellated vessels are first seen in the Jornada Mogollon region during the Formative period. Still used in some pueblos today, these vessels are called prayer bowls or prayer meal bowls. While their function may have differed among the Jornada Mogollon, it is intriguing that three crenellated vessels (an El Paso Brown, an El Paso Bichrome, and an El Paso Polychrome) were found together in a room at Twelve Room Pueblo along with several other vessels, a metate with yellow ochre, and:

...additional loose yellow ochre, two stone balls, a few turquoise beads, and a large number and variety of shell beads (Moore 1947: 99). These artifacts were all buried beneath a thick layer of burned roofing material, consisting of grasses, wooden sticks and poles and adobe. The description of this context suggests a ceremonial cache, complete with a ritual “closing” of the compartment (Jackson and Thompson 2006: 17).

In sum, ceramics—that were certainly used for everyday subsistence—may also provide insights into ritual and communal feasting that add a social dimension to subsistence economies.

Features

As with previous data groups, the primary concern here is with morphological variation that may be related to subsistence. While a variety of nonstructural features can be distinguished based on cross-sectional feature shape, size, and depth, three primary types are the focus here: thermal features that have rock (e.g., caliche, rhyolite) present, nonthermal (storage) features, and trash middens or trash-filled pits. Thermal features that lack rock could be conceived as a separate category. However, the variability described within the study area in plan view, shape, cross-sectional shape, size, and depth, along with descriptions from ethnographic sources, suggest that a variety of functions are probably represented in these nonrock thermal features, many of which are not related to subsistence.

In contrast to general heating functions attributed to nonrock thermal features, the addition of rock may be related to processing requirements associated with certain plant types. Ethnographic accounts of succulent processing (see Basehart 1974; Bell and Castetter 1941; Castetter and Opler 1936; Castetter et al. 1938) involve the use of "pit-baking." While details vary, this involves the use of rock in relatively large, deep, earth-covered ovens. The presence of such features then may be one indicator of their use for subsistence activities.

The second feature type, consisting of pits with straight or under-cut walls, is probably related to storage. Ethnographic descriptions of the use of such pits are common (see DeBoer 1988). While a variety of storage options, including aboveground storage in baskets or ceramic vessels as well as in storage rooms is available, a common storage solution, especially where soil moisture is not a problem, involves belowground storage (DeBoer 1988; Gilman 1983). While additional data groups are necessary to clarify what specific items are stored, the presence of such features implicates subsistence strategies.

The final type of feature that yields subsistence-related information is the trash midden or trash-filled pit. Unlike rock-lined or straight-sided subsurface pits that are used to process or store food, trash-filled pits contain the discard of food processing or consumption activities. Ethnoarchaeological study of discard is relatively robust (see Binford 1980; O'Connell 1987). For sites occupied for only a short time or a few days by a small group of people, such features are hard to detect (O'Connell 1987: 91) and, even if detected, it may be difficult to determine if any plant remains within them are the result of natural or cultural processes since discard areas at such sites tend to be left open to the environment. At sites occupied for longer periods and by larger populations, areas or intentionally dug pits are set aside that are designated for the disposal of food or other trash (O'Connell 1987).

Within the current study area, features, especially those that have either burned caliche or other rock (e.g., limestone, rhyolite) are extremely common. Leach (1994) reports the presence of 1,273 features observed during surface collection of 14 square km near the Hueco Mountains, a density of over 90 features per km. The majority of these (n=894) contained fire-cracked rock, burned caliche, or a combination of both. Mauldin and others (1998), working in the central basin, report a density of well over 200 features per square km. Using these density estimates, there are between 400,000 and 1 million features within the 4,500 square km area encompassed by Fort Bliss.

A variety of researchers in the local area, relying primarily on ethnographic descriptions from the Southwest, and to a lesser extent, archaeological patterns in the local area, have argued that features with rock are designed to process succulents. Several authors have distinguished between large rock features (generally greater than 1 m), and small rock features (less than 1 m in

maximum size; see Carmichael 1985a; Greer 1968; Hard 1983b; O'Laughlin 1980; Whalen 1977, 1978). The implication of this distinction is that these two feature sizes may reflect different functions. However, O'Laughlin (1980), again relying on ethnographic sources, suggests that both are primarily used for succulent baking, with the primary distinction reflecting quantity of material processed rather than any difference in the items processed.

Mauldin and others (1998; see also Bearden and Gallagher 1980; Duncan and Doleman 1991) have conducted a variety of experimental studies with heat retention in rock that further elucidates the use of rock. Using temperature probes in experimental features with and without rock, they demonstrate a consistently higher temperature in rock features. In addition, the features with rock seem to retain the heat of the fire for a longer period of time. After nine hours, the features with caliche have an average temperature of over 300°C, which is twice that of features that lacked stone. This research suggests that the function of rock seems to be heat retention over long period of time. If these features are used for cooking, then long-term temperature advantages probably relate to processing resources that have high starch content, such as agave and sotol.

Analysis of the dimensions and burned rock weights of thermal features throughout the Jornada area, and their temporal distributions among topographic zones has been reported. Using over 80 features with data on rock weight and associated radiocarbon dates, Leach (1993) demonstrates that while the vast majority of features with rock are less than 1 m in maximum pit diameter and have total rock weights of less than 10 kg, a small number of cases have rock weight well in excess of 50 kg and are well in excess of 1 m in size. In several cases, weights in excess of 100 kg of rock have been recorded. Miller and Kenmotsu (2004) observe broad correlations between the use of various thermal and storage features and their locations across the landscape with trends of increasing architectural formality, agricultural production, and settlement intensity (see Chapter 11).

The second feature type, subterranean pits that likely were involved in food storage, has just recently been investigated in the region. Whalen (1994a) reports multiple storage pits at Turquoise Ridge, and in a subsequent article (Whalen 1994b) uses the presence of such features to argue for increased sedentism and seasonal scheduling. In contrast, storage pits have rarely been observed at other Mesilla phase and Early Doña Ana phase sites (see Church and Sale 2003; Miller 1989, 1990; Miller and Burt 2007; Miller and Stuart 1991; O'Laughlin 1981; Shafer et al. 1999), and so it is likely that seasonal and functional aspects of settlement are related to the use of storage pits.

Pits are a common feature at residential settlements of the Late Doña Ana and El Paso phases (Church et al. 2007; Kegley 1980; O'Laughlin 2001; Railey et al. 2002; Scarborough 1986) and are likely related to agricultural production and storage. Church and others (2007) report several isolated pits in association with grinding tools that are interpreted as special off-site processing areas. Railey and others (2002) provide the most detailed analysis of such features, and tentatively conclude that such features were used to store agricultural surplus but also suggest that larger pits may have served as water catchments. Extensive numbers of pits have been identified as early agricultural villages in southern Arizona (Gregory 2001; Mabry 1998) and morphological and functional analyses of these features (Gregory 2001; Hackbarth 1993; Wocherl 1998) should be consulted by archaeologists working at Fort Bliss.

Recently, an unusual type of pit feature has been documented in association with Middle Archaic period settlements (Railey 2002; Graves and Ernst 2007). This feature is a slightly conical pit that extends nearly a meter in depth below the surface. The lower levels of these features are typically filled with very dense deposits of charcoal and organic fill, although no economic or subsistence plant remains have yet been identified in pollen and flotation samples. The function

of such features remains speculative at present, but the possibility of their use for storage cannot be ruled out.

The third feature type, trash middens and trash-filled pits, have rarely been encountered on the desert floor, where the majority of the sites have been occupied for short periods. Exceptions are residential sites situated near large playas or along ridges that are present in the central basin. At site 41EP2724, an El Paso phase settlement located near the western edge of Fort Bliss on the basin floor, three trash-filled pits were excavated that varied in size from 355 cm by 630 cm to 160 cm by 380 cm (Burden and Dering 2001: 212-221, Table 6: 9). Because the materials were not analyzed for some years after the excavations, gaps exist in the information. Nonetheless, Burden and Dering (2001: 240) were able to determine that the three pits were intensively used with little to no cessation until the site was abandoned after A.D. 1400. All three contained the highest density of both animal bone and plant remains found at any of the sites in the Loop 375 project (Dering 2001: 453). Macrobotanical analysis revealed maize kernels, cupules, and pollen, bean seeds, cholla pollen and seeds, and Poaceae were present in the features. Maize ubiquity was particularly high at the site (81.8 percent). When Dering (2001: 459) compared these samples to the Gobernadora and North Hills sites, both dating to the earlier Doña Ana phase, he found those sites had a lower percentage of maize but a much higher proportion of seeds and wild plant remains, supporting the notion of more intense use of corn during the period after A.D. 1200. Future studies at Fort Bliss need to build on Dering's work to verify his findings.

Thermal feature comprised of both fire-cracked rock/burned caliche and those with possible storage or trash functions provide important data on subsistence processing and storage strategies. Unlike most of the artifact classes discussed above, these types of features are not mobile, and thus their occurrence at a site can be directly interpreted. Fire-cracked rock/burned caliche may be involved with processing of plants, such as sotol and agave, and possibly yucca. While additional research is clearly required to explore this question, fire-cracked rock/burned caliche features may be some indication of dependence on these plant sources. Storage features, especially if through phytolith and pollen analysis the material stored can be identified, are an additional source of dietary information and may provide important data on subsistence organization. To ensure that the data from features are useable, however, the nomenclature in which features are defined, interpreted, and ultimately disseminated to the archaeological community gives cause for concern. A standardized classification system, such as provided by Miller (1989) and Quigg and others (2001), should be developed to provide consistent documentation.

Perishable Remains

Information on the perishable component of subsistence technology is extremely limited as a function of preservation (see discussion in Chapter 9). Only in a few cases and in a single environmental zone (mountains or uplands) are data available. Thus, it is highly likely that any picture provided by such data is skewed. Nevertheless, ethnographic studies of both hunter-gathers and agriculturalists (see Pennington 1962; Steward 1938) suggest that wood and fiber components of subsistence technology is a critical element in both subsistence acquisition and processing.

Within the study area, a variety of excavations and collections of cultural material from cave sites in the Hueco and Sacramento mountains provide the most detailed information on perishable remains (see Cosgrove 1947; Human Systems Research 1973; Lentz 2006; Oakes 2004; O'Laughlin 1977b). These investigations recovered a variety of items, including reed arrows and arrow foreshafts, a complete atlatl, a variety of basketry fragments, fiber and cotton cordage and netting, and throwing sticks (see Chapter 9). While of limited utility for the investigation of non-cave/shelter sites, these data provide a glimpse into the complex acquisition and processing

technology represented by wood and fiber component of the subsistence technology. Clearly, additional work in these settings is needed, including detailed excavation, dating of these deposits, and a systematic inventory of these technologies.

Proxy Indicators of Subsistence

This section focuses on correlations, or proxy evidence, between archaeological and land use patterns and specific subsistence activities that have been suggested in previous literature. “Proxy evidence” is used when something cannot be measured directly, but can be inferred from other evidence. For example, an internet search will turn up lots of references to proxy evidence in relation to climate change. The temperature several thousand years ago cannot be measured, so scientists rely on proxy indicators such as tree ring growth. The same internet search makes it obvious that multiple lines of proxy evidence are the preferred basis for scientific interpretation when direct evidence is lacking. For example, the current controversy over climate change is largely a reflection of the use of proxy evidence because of its inherent uncertainty, which leaves conclusions based on proxy evidence more open to argument than direct evidence.

Many inferences regarding prehistoric subsistence practices may have to rely on second- and third-order proxy data, as is typically done for many paleoenvironmental studies (*sensu* Caran 1998). Unlike botanical and faunal remains that offer first order evidence, second and third order evidence is important since the first order evidence is not always recovered from archaeological contexts. The use of second and third order evidence usually carries with it a level of assumption that is open to argument and care must be taken to understand the limitations of second order evidence and not cross the line into “belief.” In fact, several of the biological data analyses reviewed in the preceding section, such as isotope signatures in bone collagen and the various artifact and features technologies, are actually more representative of secondary proxy data.

Over the years, a number of investigators have suggested correlates between archaeological remains and behavior. For instance, fire-cracked rock thermal features have often been attributed to succulent baking. This and many other proxy forms of subsistence data are derived from ethnographic analogy or experimental archaeology. In the following discussion, these and other lines of evidence will be reviewed. First to be examined are tool types that have been associated with specific subsistence activities. This will be followed by a discussion of features, land use, and bioarchaeological evidence that have been used as proxy indicators of subsistence.

Pestles and Mortars

Mesquite was one of the most important wild plants gathered by late prehistoric and protohistoric populations in the Southwest (Bell and Castetter 1937: 15-19). Despite this fact, evidence of mesquite use in the Hueco Mountain Caves is minimal (Cosgrove 1947). For processing mesquite, flat grinding rocks are unsuitable for freeing the seeds from their mesocarp (Doelle 1978), and Castetter and Opler (1936) report the Mescalero Apache use metates for processing the pods once they are separated from the seeds. Ethnographic accounts often mention the use of bedrock or stump mortars and wooden or stone pestles. On the other hand, Fowler reports that the Timbisha of the Mojave never used stone metates for grinding mesquite (Fowler 1995: 114). Locally, Carmichael (1981) observes that many of the pestles found within the Tularosa Basin are “the narrow type associated with wooden mortars. Carmichael (1986: 220) noted that the occurrence of pestles could indicate initial processing of mesquite:

The pattern of use shows some general similarities to the dispersed distribution of Mesilla components. Of particular interest is the evidence for mesquite use in the northern portion of the survey area, to the east of Davis Lake. This area shows considerable occupation by Mesilla groups. While pestles were found in all assemblages besides Paleo-Indian, 36 percent of the ones from temporally identifiable contexts were of the Mesilla phase. This is a larger proportion than is shown by any other period and suggests that mesquite was relatively important for Mesilla phase peoples.

As noted earlier in this section, the relationship between pestles and mesquite processing remains questionable. The possibility that these items were also used for processing piñon nuts or other plant foods must also be considered, although the presence of pestles in the central basin would clearly not conform to the distribution of piñon pine trees. The correlation between mortars and pestles and mesquite processing could be examined through a modest study of such tools employing organic residue analysis.

Two-hand Manos and Trough Metates.

Diehl (1996), Hard and others (1996), and Mauldin (1993b, 1995) have argued that the presence of larger two-hand manos and slab or trough metates indicate an intensification in processing, which they link to the requirements of maize processing and increased agricultural dependence. This correlation rests mainly on an assumption that to process significant amounts of maize into flour, technologies would have developed to optimize the energy input versus production output. To date this is an inference that has yet to be confirmed. The correlation seems logical and the main ambiguity lies in the exclusiveness of the correlation. Were two-hand manos and trough metates only used for maize processing, or were they used to process other resources as well? Again, this correlation can be tested by a study of an organic residue study of these tools. Finally, while the presence of two-hand manos and trough metates may be indicative of maize processing, the absence of these tools should not be taken as indicating an absence of maize processing. Grinding reflects the production of flour, but maize could also be eaten green, roasted, boiled, or steamed.

Unifacial Scrapers

Often attributed to the preparation of hides on the northern plains, the rarity of unifacial scraper outside of Paleo-Indian and Archaic assemblages locally would seem to indicate a lack of hide preparation in the Formative period, with a concurrent suggestion that hunting itself diminished in intensity. This apparent lack of hide preparation tools in the Formative may reflect an abandonment of formal scrapers and the use of expedient, multi-use tools for the same purpose. This question could be examined by a study using microwear and residue studies as has been advocated by Rots and Williamson (2004) and is discussed in greater detail in Chapter 9.

Tabular Knives

Fish and others (1992: 83) state that:

Broad, flat stone tools made on raw materials with naturally tabular fracture are prominent in field assemblages. The common term in the ethnographic and archaeological literature for this tool type is agave or mescal knife. Varying in outline from rectangular to rounded, such specialized implements were used historically by Southwestern groups to sever agave leaves from the hearts. Supporting this analogy, calcium oxalate crystals like those present in agave tissue have been observed in microscopic examinations of Hohokam knife surfaces.

While not a particularly common artifact, classic agave knives have been found on Fort Bliss and surrounding lands. Again, this seems like a logical correlation based on ethnographic data. However, the correlation has yet to be verified locally, and the strength of the correlation remains to be established. These issues can be resolved by formalizing a definition of this tool type, documenting the location and context of finds of the tool type, and conducting an organic residue/use-wear study. Many agave knives either may have been collected by relic hunters and military personnel or may have been overlooked by archaeologists unfamiliar with this form of tool. Recent investigations of burned rock features have recovered several examples of such tools such as the collection from LA 91264 shown in Figure 8.3 and TRU surveys have identified several such tools in association with large burned rock roasting facilities on remote areas of McGregor Range (Mike Stowe, personal communication 2007).



Figure 8.3. Whole and partial examples of large tabular tools (agave knives) collected from a large burned rock feature at LA 91264 in Maneuver Area 5B.

Scraper Planes

Scraper planes (or pulping planes) are another distinctive tool form common among Southwestern and Western agave fields or collection areas. This tool form is basically a core tool with steep, rounded edges that generally exhibits heavy use-wear patterns. Both ethnographic accounts and experimental studies have demonstrated the utility of this tool form for removing fibers and spines from agave leaves (Bernard-Shaw 1990; Hester and Heizer 1972; Kowta 1969; Osborne 1965; Rogers 1939; Salls 1985). Without close inspection or use-wear analysis, such tools may often be misclassified as cores, utilized cores, or hammerstones and the specific functional aspect may thus be overlooked. A closer inspection of lithic tool forms and wear patterns should be undertaken.

Ceramic Temper

Experimental studies have shown that changes in ceramic temper attributes (abundance, shape, and texture or size) affect the strength, porosity, and thermal resistance of ceramic vessels (see Braun 1983, Reid 1989, and Rice 1987 for useful summaries). Experimental studies have sometimes yielded conflicting results, particularly among the group of studies examining the relationship between temper texture and thermal shock resistance. The relationships between the desired performance characteristics of ceramic vessels and temper attributes are summarized in Table 8.9.

Table 8.9.
Summary of Temper Attributes and Ceramic Impact and Thermal Shock Resistance
(from Miller and Burt 2007: 5-2)

Temper Attribute	Performance Characteristic	
	Increasing Thermal Shock Resistance	Increasing Impact Resistance
Abundance	Higher temper proportions	Lower temper proportions
Texture	Inconclusive – coarser textures?	Finer textures, small size grades
Shape	Angular temper grains	Rounded temper grains

The analysis of temper attributes is time-consuming and requires dedicated training by experienced ceramicist. Analyst measurement variability is also a problem that needs to be addressed: temper studies must be designed to reduce such bias as much as possible. Nevertheless, the potential benefits of a large body of consistently recorded El Paso brownware temper data from a variety of site types and temporal periods would considerably enhance our understanding of the role of ceramics in prehistoric subsistence. Several recent studies have provided a start in this direction (Burgett 2006; Miller 1990; Miller and Burt 2007; Brewington and Shafer 1999; Whalen 1994a) but these studies have examined ceramics from a limited range of sites and time periods.

Large Ceramic Vessels

The potential use of large El Paso brownware vessels for fermentation and communal feasting rituals deserves further study (Jackson et al. 2004; Shafer et al. 1999). Unfortunately, whole vessels are seldom recovered from Jornada sites; large El Paso brownware ollas are known almost exclusively from museum collections. It may be useful to examine large collections of El Paso Polychrome rim sherds for bimodal size ranges and orifice diameters that may indicate the presence of two size classes of vessels.

Rabbit Sticks, Hunting Crooks, Nets, and Traps.

The use of these perishable technologies is discussed in Chapter 9 and will not be repeated here. That these artifacts can be linked to small game hunting seems secure. Significant ethnographic and ethnohistoric literature exists to make a strong argument for the correlation. Unfortunately, as practical proxy indicators of subsistence these artifacts are almost irrelevant as they are rarely found, even in rock shelter deposits.

Storage Facilities

As suggested in a preceding discussion, the presence of storage facilities appears to have a strong correlation with agriculturally- based and horticulturally-based settlements, although the recent descriptions of unusual pits associated with Middle Archaic period occupations suggests that pits could have been used to store other foodstuffs. A more intensive and focused program on the function of such pits utilizing multiple types of analyses (pollen, phytolith, residue; see Railey 2002) should be undertaken when such features are encountered.

Small Fire-cracked Rock Thermal Features.

The correlation between small fire-cracked rock thermal features and succulent processing is rife in the archaeological literature of the Jornada region and is often used as a rote explanation. Despite its prevalence in the literature, this correlation is probably one of the weakest simply because it is so broad. Logically, given the sheer numbers of such features, succulent processing would appear to be the main subsistence activity for much of prehistory. Perhaps this is true, but other evidence strongly indicates that prehistoric populations exploited a number of wild resources throughout prehistory.

The function of small fire-cracked rock thermal features, particularly isolated features, has perplexed several investigators. Several efforts have been made to retrieve botanical remains from small site thermal features to shed light on their function (see discussion on flotation above). Mauldin, in his small sites study, submitted 79 samples for botanical analysis, with only three of the samples actually producing charred economic seeds. Church and Stowe (2006), in a somewhat similar study, submitted samples from 39 features for botanical analysis. Although 20 of the features had charred economic seeds identified in the sample, only two produced charred seeds in sufficient abundance to rule out unintentional charring. Residue analysis has also been attempted, but at the present time, the results are too vague and ambiguous to be useful.

It is likely that the paucity of subsistence remains indicates that many, or even the majority, of such features were used for purposes other succulent processing. Interestingly, the most common plant species possibly used for food that has been recovered from such features are small seed-bearing plants such as Cheno-Ams, *Portulaca*, and several grass species. Although many of these seed remains represent incidental inclusion and burning in thermal features (i.e., background seed rain, after Minnis 1981), it is also possible that they were being used as food (Miller 2007a; Miller and Burt 2007). Rock heating elements may have been used to increase heat retention or for stone boiling of seeds in ceramic vessels. It is also likely that such features served multiple functions, including non-subsistence roles for providing warmth and light, heat-treating wood and stone material, and other activities. The social roles and domestic focus of hearth features should also be considered.

Burned Caliche Thermal Features

There has been a long simmering suspicion by some that the use of caliche in thermal features indicates a functional difference of these features from those that contain just fire-cracked rock. O’Laughlin made the suggestion that caliche hearths reflect “general purpose domestic hearths” (Carmichael and Gerald 1986: 200) while limestone hearths were constructed for baking agave. In an examination of thermal features on Doña Ana Range, Church (2005) found that caliche features were relatively uncommon and were clustered only in one area in the central basin. If O’Laughlin’s suggestion were true it would be expected that caliche hearths, reflecting general-purpose use, would be spatially widespread and numerous. However, exactly the opposite is the case, as limestone hearths are much more numerous and widespread.

In contrast to O’Laughlin’s interpretation, it is suggested that a correlation exists between caliche and agave or sotol baking. This is based on experiments by Mauldin and others (1998) that documented higher temperatures and longer heat retention by caliche. This suggestion assumes that both attributes were beneficial in the processing of agave and sotol, in that long-term exposure to heat was advantageous for the processing of such plant foods with high starch contents. These assumptions have yet to be proven valid, and Kludt’s (2006) experimental work would seem to suggest that the use of limestone, a much more common rock type, is perfectly suitable for agave ovens.

Burned Rock Roasting Features and Fire-cracked Rock Discard Middens

More specific than the correlation discussed above, rock-lined pits, rock rings, and associated burned rock middens have long been interpreted as evidence of agave processing, mainly based on ethnographic and ethnohistoric data (the literature on agave ovens is too extensive to list here, but the work of Black and others 1997 and Dering 1999b are good places to start). While the correlation between these feature types and agave baking appears strong, was it exclusive? In other words, was agave also baked in small fire-cracked rock thermal features? Recent work by Kludt (2006) indicates that from an economic standpoint, three types of agave ovens were likely employed; with each of the three types being strictly standardized in configuration to reduce risk. Kludt’s three types are family, small communal, and large communal. It is the later that is typically recognized by archaeologists and attributed to agave processing. It should be possible to calculate the rock needed for each type of agave oven to better recognize the smaller ovens in the archaeological record and verify Kludt’s model.

Compilations of macrobotanical data from rock-lined pits and fire-cracked rock middens provide evidence that such features were also used to process other foods beyond cacti and succulents. Miller and Lowry (2006; see also Miller 2005d) present a quantitative summary of these macrobotanical data. A total of 3,149 economic and subsistence plant parts and seeds have been recovered from rock-lined pit features (Table 8.10; this total does not include 10,000+ amaranth seeds recovered from a rock-lined pit at the Ojasen Site). In addition to seven species of cacti and succulents, at least 21 other plant species are represented among these remains, including mesquite, corn, Cheno-Am, and grasses, and several miscellaneous plants of possible economic, medicinal, or ritual use.

As illustrated in Figure 8.4., prickly pear (*Opuntia* sp.), datil (*Yucca baccata*), and various small cacti (*Echinocactus* sp., *Echinocereus* sp., *Mammillaria* sp.) represent 88 percent of the recovered seeds and plant remains. Mesquite seeds and pod or endocarp fragments represent approximately 8 percent of the total and Cheno-Ams represent around 1.5 percent. The remaining 2.5 percent of the samples include very small quantities of grass and *Portulaca* sp. seeds, a few corn cupules and kernels, various medicinal and economic plants, as well as several unidentified seeds.

TABLE 8.10.
 CHARRED MACROFLORAL REMAINS RECOVERED FROM ROCK-LINED PIT THERMAL FEATURES
 IN THE JORNADA MOGOLLON
 (FROM MILLER 2005d; MILLER AND LOWRY 2006)

SCIENTIFIC NAME OF TAXON	COMMON NAME
<u>CACTI AND LEAF SUCCULENTS</u>	
<i>MAMMILLARIA</i> SP.	FISHHOOK CACTUS
<i>OPUNTIA</i> SP.	PRICKLY PEAR, CHOLLA
<i>ECHINOCACTUS</i> SP.	HEDGEHOG CACTUS
<i>ECHINOCEREUS</i> SP.	STRAWBERRY CACTUS, TURK'S CAP CACTUS
<i>YUCCA BACCATA</i>	DATIL OR BANANA YUCCA
<i>YUCCA ELATA</i>	SOAP-TREE YUCCA
<i>YUCCA</i> SP.	UNIDENTIFIED <i>YUCCA</i> SP. FIBERS
AGAVACEAE	AGAVE FAMILY (MOST LIKELY AGAVE <i>LECHUGUILLA</i>)
LILIACEAE	DASYLIRION OR YUCCA GENUS
<u>MESQUITE</u>	
<i>PROSOPIS PUBESCENS</i>	SCREWBAN MESQUITE
<i>PROSOPIS GLANDULOSA</i> OR <i>JULIFLORA</i>	HONEY MESQUITE, MESQUITE
<u>CHENO-AMS, PURSLANE, GRASSES</u>	
<i>CHENOPODIUM/AMARANTHUS</i> SP.	GOOSEFOOT, PIGWEED, CHENO-AM
<i>PORTULACA</i> SP.	PURSLANE
GRAMINEAE	UNIDENTIFIED GRASS FAMILY
<i>SPOROBOLUS</i> SP.	DROPSEED
CF. <i>BOUTELOUA</i> SP.	GRAMA GRASS
<u>CULTIGENS</u>	
<i>ZEA MAYS</i>	CORN
<u>MISCELLANEOUS ECONOMIC AND MEDICINAL PLANTS</u>	
<i>DESCURAINIA PINNATA</i>	TANSY MUSTARD
<i>KALLSTROEMIA</i> SP.	MEXICAN POPPY
<i>IPOMOEA</i> SP.	MORNING GLORY
UNID. LEGUMINOSAE	UNIDENTIFIED MEMBER OF LEGUME FAMILY
<i>ATRIPLEX CANESCENS</i>	FOUR-WING SALTBUCH
<i>POLANISIA</i> SP.	CLAMMY WEED
UNID NYCTAGINACEAE	FOUR O'CLOCK FAMILY
CF. <i>PHYSALIS</i> SP.	GROUND CHERRY
UNID. EUPHORBIACEAE	SPURGE FAMILY
<i>ASTRAGULUS</i> SP.	MILKVETCH, LOCOWEED
<i>CROTON</i> SP.	CROTON
MALVACEAE	MALLOW FAMILY
TRIANTHEMA	TRIANTHEMA

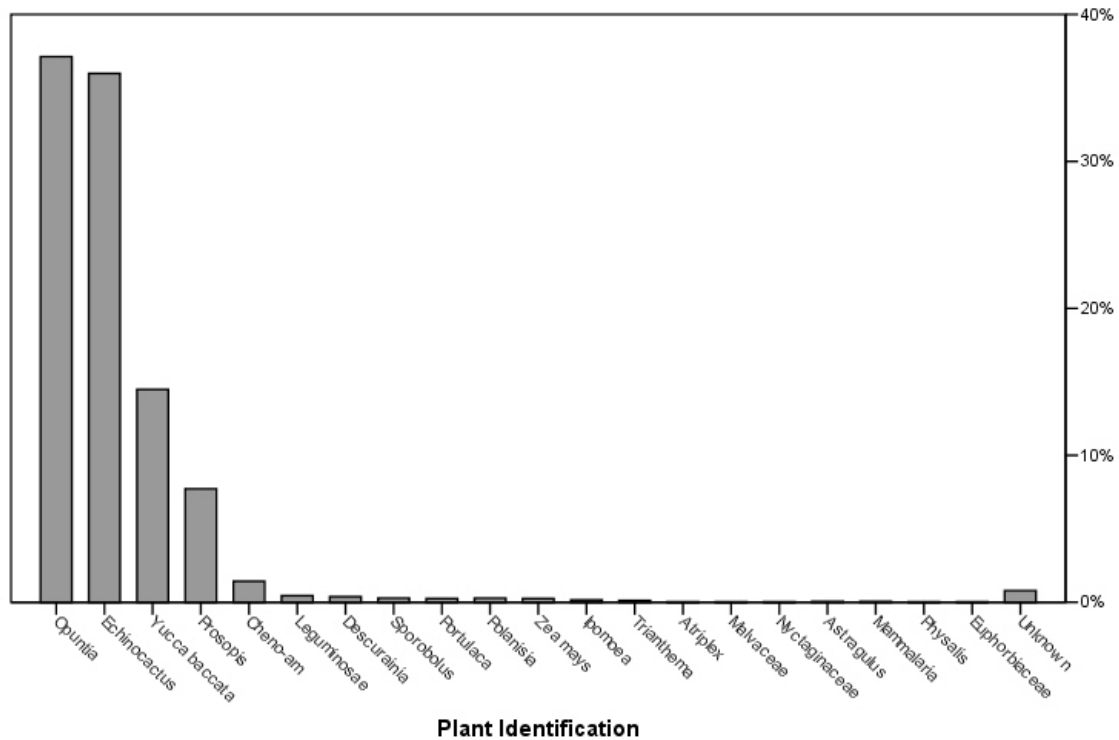


Figure 8.4. Bar chart summarizing the plant taxa represented among 3,149 charred economic and subsistence plant remains recovered from rock-lined pit features in the Jornada region.
(from Miller 2005d)

Many of the miscellaneous seeds may have been introduced as background seed rain and through the introduction of fuel sources into the pit (e.g., *Atriplex* sp. and *Sporobolus* sp. seeds introduced when saltbush plants or grasses were used as tinder and fuel). However, it is also likely that some seeds were introduced during parching (e.g., Cheno-Ams) or other processing events. Feature 1 at the Ojasen Site, a large and well-preserved rock-lined pit, had over 10,000 amaranth seeds clustered within a small area of the western edge of the pit (Miller 1989). This concentration of seeds represented a spill event that occurred while the seeds were being parched.

Despite the body of ethnographic data, direct evidence of succulent processing has seldom been recovered. It has often been argued that the preparation practices and processing requirements of these plant foods resulted in the introduction of little or no organic material into the features, and thus the minimal archaeological evidence is recovered through excavation or examination of macrofloral samples.

In a small number of archaeological cases charred leaves, spines, fibers, or vascular bundles of Agavaceae or Liliaceae family plants have been recovered from flotation or macrobotanical samples in the region (Dering 1999a, 2002, 2007; Holloway 1983), supporting the inference that burned rock features were indeed used to prepare such plant foods. However, the sample of such plant remains is miniscule compared to the thousands of seeds from cacti and datil pods recovered from burned rock features. Moreover, the paucity of succulent plant remains is rather surprising given the large quantities of organic debris and waste products produced by processing and baking leaf succulents that have been observed during actualistic experiments of burned rock oven baking (Dering 1999b).

Counts of 1,169 prickly pear, 1,133 *Echinocactus/Echinocereus* sp., and 456 datil seeds have been recovered from numerous rock-lined pit features throughout the Jornada region. It is possible that many of the prickly pear seeds were introduced through the use of prickly pear pads to line pits during baking (Dering 1999b), although equally likely is that such seeds represent debris left over from the baking the flowering fruits, as well as those of various *Echinocactus*, *Echinocereus*, and *Mammillaria* sp. cacti. The presence of datil (banana yucca) seeds suggests the use of rock-lined pits for baking, roasting, or drying the pods of this plant as described for several historic Native American groups across the Southwest (Bell and Castetter 1941). The common presence of Cheno-Am and *Portulaca* sp. seeds and evidence of large spill events indicates an ancillary use of the features for parching seeds. The substantial counts of various cacti and datil seeds are rather indisputable evidence that plant species beside leaf succulents were processed in rock-lined pit features.

In addition to pit baking the hearts of lechuguilla and sotol, rock-lined pit facilities were used to bake pods, the fruits of prickly pear and small cacti, and to parch or roast various Cheno-Am seeds and perhaps other subsistence or medicinal plants. This larger and more expansive multi-functional role of burned thermal features is seldom acknowledged, and thus the broader economic and subsistence role of rock-lined pit features and burned rock middens in prehistoric technological adaptations and subsistence economies has been underestimated.

Land Use Patterns

Mauldin (1986), following Beckes (1977a), Whalen (1977, 1978), and others, proposed that the lower alluvial fans were used for agriculture. In that paper he proposed a model of El Paso phase land use that postulated that primary habitation sites were located along the lower alluvial fans to take advantage of that landform for run-off agriculture. This correlation is based on vaguely defined proxy data. The explanation is essentially that the lower fans would be a good place for agriculture because that is where other Southwestern populations did it.

The fact is that the archaeological evidence for agricultural use of the lower fans is lacking, and what exists is mainly proxy in nature itself. No one as yet has conclusively identified an agricultural field in the southern Jornada. Water control features are also absent or rare. The nature and extent of agriculture locally is one of the last big questions to be examined. There have been a few efforts, the earliest probably being Hubbard's (1987) identification of field related patterns and features from aerial photographs. This study has proven troublesome because the majority of the vast agricultural fields identified via aerial photographs have been found to be natural features or historic and modern constructions such as roads, fencelines, and terraces constructed by the Soil Conservation Service during the 1930s and 1940s.

With the widespread availability of GIS today some studies have been undertaken, or are underway relating to this topic. Church and others (2002) used basic precipitation and run-off models to identify potential areas suitable for run-off agriculture on slopes of the Jarilla Mountains. That study concluded that long-term, large-scale run-off agriculture was unlikely. Using techniques and datasets that are more sophisticated, Kludt (2007) has begun construction of a series of catchment models for the western slopes of the Hueco Mountains. These promise to be suitable platforms for isolating areas for archaeological examination of this issue.

Perhaps the strongest of the land-use proxy indicators is based on environmental, ethnohistoric, archaeological, and biological data that suggest the alluvial fans were used for agave procurement and processing. There is strong evidence that agave processing was done at, or near, the place of procurement, and coupled with similarly strong evidence that large rock middens were employed in agave baking this one seems secure. That is not to say we should attribute every prehistoric site situated on upper alluvial fans as relating to agave processing. Other wild resources on the

upper fans were also likely exploited and identification and verification of these should be a focus of any project on the upper alluvial fans.

It has long been suggested that upland areas such as the Sacramento Mountains were used for hunting, at least during the Archaic period. This widely held correlation is mainly based on the historic ranges of larger game animals. Species such as elk, mountain goat, bighorn sheep, etc., are today found in uplands and therefore, should have attracted prehistoric hunters as they do modern hunters. Locally, Spoerl (1985) notes that a number of prehistoric sites are located in good elk and deer habitat in the Sacramento Mountains. The prehistoric use of uplands has been the topic of growing research (e.g. Bender and Wright 1988; Osborn 1993; and more recently Madsen and Metcalf 2000). Our picture of the historic range of elk has also been questioned, suggesting any models based on the modern distribution of elk may well be in error (Truett 1996).

Bioarchaeological Indicators

To date the number of human remains recovered from the Jornada region remains low, and those that have been recovered have not been extensively studied due to access limitations. Larsen (1997: 162) states: “The study of pathological and non-pathological changes of articular joints and behaviorally related modifications of non-articular regions offers a wealth of information on activity and workload in past populations.” Bridges (1989, 1995) first tackled the issue of bioarchaeological indicators of the transition from hunter-gatherer to agricultural subsistence strategies in the Southeast. Similar studies by Olgilvie (2000) where the same topic is explored for the Southwest are most relevant to the Jornada. Her sample populations surround the Jornada area, being drawn from west Texas, northern New Mexico (Pottery Mound), and southeastern Arizona (Tucson Basin). Adopting a functionalist approach, Olgilvie (2004: 192) used biomechanical modeling of femora: “Biomechanical models predict that the changes in physical activities associated with subsistence shifts will be reflected in behaviorally-conditioned skeletal morphology.” Olgilvie’s conclusions indicate that hunter-gatherer populations exhibit similar femoral dimensions between males and females, while agriculturalist populations exhibit a sexual dichotomy apparently reflecting a decreased level of mobility for agriculturalist males from their hunter counterparts but still higher than that for agriculturalist females. The transitional population showed the most dichotomies, with males retaining indicators of high mobility, while females begin to show a noticeably decrease in mobility indicators:

It was during this economic transition that the sexual division of labor was noticeably impacted. During the incorporation of early maize into the economy, male femoral structure reflected high levels of mobility equivalent to those of the mobile male Texas foragers. The maintenance of behaviors necessitating high mobility by males is compatible with a strategy of logistical resource targeting. Interestingly, the Tucson Basin females showed a marked decline in mobility at this time. The femoral data demonstrate that their locomotor behavior was not significantly different from sedentary female agriculturalists (Olgilvie 2004: 195).

Unlike the analysis of bone collagen stable isotopes that require sampling procedures that are invasive and destructive to bone, the analysis of physical traits does not involve damage to human remains.

In summary, the use of proxy indicators of subsistence may be necessary at this point in time, but should not be generally accepted as “stand alone” evidence. Instead, work should continue on testing the suggested proxy indicators, with the goal of replacing them with direct evidence. Proxy indicators are best examined in the context of corroborative evidence and multiple analytical techniques. Proxy indicators of subsistence organization and functional links between

features and the processing of specific resources are fraught with problems at this point. It is not that such goals are unachievable; they are just not as solid as some would have us believe. At this point, we recommend that faster progress can be made linking specific tool types with specific subsistence activities by further development and analyses of tools for organic residues.

SUBSISTENCE RESEARCH QUESTIONS

A coordinated investigation into subsistence involves answering a variety of questions including identifying what resources were used, what the level of dependence on a given resource was, where resources were acquired, how and where those resources were processed, what temporal changes occurred, and why those changes occurred. As noted in the introduction to this chapter, the primary concern in this investigation of subsistence involves documenting actual resource use at a location and, in combination with chronometric dates, considering changes in that use through time. This question must be answered before we can proceed to the higher-level questions of culture change and evolution. However, it is critical that as research on the nature of subsistence is conducted, these higher-level questions are kept in mind. The first part of this section looked at the array of data for just one environmental zone of the Tularosa Bolson and its complexity to provide a context for subsistence studies. The following three subheadings provide an overview of biological and artifactual data groups, including proxy indicators that may be useful for identifying resources used for subsistence in the region. Each of these data groups have strengths and weaknesses, therefore, the most effective way to proceed involves the consideration of a variety of different data groups in combination.

In addition to the interpretive issues, the discussions of analytical methods – the first-order proxy biological data and second- or third-order proxy artifact and settlement indicators – demonstrates that the analysis of prehistoric subsistence practices requires a coordinated and integrated multidisciplinary approach. Given the poor preservation of organic remains throughout most of the major environmental zones and among the most common site types at Fort Bliss, a greater emphasis on integrated studies incorporating phytoliths, residue analysis, and detailed analysis of lithic and ceramic tools is required. In addition, experimental research on residue and use-wear patterns on ground stone, chipped stone, and ceramic artifacts is indicated.

Diachronic Research Issues

Research Issues 8-1 through 8-5 are concerned with investigating changes in the overall subsistence base through time. The question of spatial scale – pan-regional (southern Southwest), regional (Jornada), subregional (lowlands), zonal (e.g., alluvial fans, central basin), site, and intrasite levels - are applicable to all questions, provided that the necessary data can be acquired. The structure of the research questions are guided by the expanded theoretical perspectives reviewed in Chapter 4 and the ecological perspective briefly outlined at the beginning of this chapter. Consequently, we focus on changes in the natural environment, potentially brought about by climatic change and human use of the region, to structure the investigation. However, the principal concern here is with a description of changes through time rather than with explanations for that change. While the two realms are certainly related, a variety of explanations, both from a cultural/ecological perspective as well as from other perspectives, can be applied to the same description.

Research Issue 8-1

Diachronic Trends in Subsistence Intensification

This is a broadly phrased research issue intended to explore patterns of subsistence change and intensification across multiple time intervals. Given the focus of this research design and the

observation that changes in the economic landscape should result in changes in subsistence economies and associated technologies, it is appropriate to structure investigation into diachronic change based on major changes in the economic landscape. A variety of temporal scales of change can be investigated (see Mauldin 1995).

One of the major changes in the economic landscape within the region is associated with the transformation to the Chihuahuan Desert (see Monger 1993a; Van Devender 1990; see also Chapter 7). Thus, an appropriate starting point would be to investigate the pre-Chihuahuan Desert subsistence regimes separate from the post-Chihuahuan Desert subsistence regimes. Little is known regarding the resource structure prior to that development, but it appears that at the close of the Pleistocene, woodland and grassland communities dominated the region. Conversely, the Chihuahuan Desert Scrub community is characterized by xeric species such as mesquite, sotol, agave, yucca, and a variety of cacti.

The development of the Chihuahuan Desert, then, introduced an entirely different suit of resources, many of which (e.g., agave) have specific processing requirements. The exploitation of this new economic landscape should be considerably different from that reflected in the pre-Chihuahuan ecological setting.

For subsequent time periods, the major research emphasis is concerned with two related issues: changing patterns of resource exploitation and patterns of intensified resource procurement and processing. Causal factors underlying the reduction in artiodactyl hunting and intensification of rabbit procurement and, of course, agricultural intensification may be explored under this topic. The possibility of more intensive use of seeds during the terminal Late Archaic and early part of the Mesilla phase merits additional research.

Several of these processes are best explored through reference to optimal foraging theory and human behavioral ecology, although demographic pressures and reduction in territorial mobility ranges should also be considered. Another development of interest is with the intensification of cacti and succulent procurement. Based on direct biological evidence from flotation analyses combined with proxy evidence in changing numbers of roasting features and landscape settlement, Miller and Kenmotsu (2004) propose that intensification of both wild and domesticated plant foods occurred in tandem during the Late Doña Ana phase (A.D. 1150-1275/1300).

Data Needs. Data requirements can be identified for the general subsistence classes. For floral resources, these include the presence and characteristics of rock features, lithic use wear patterns, lithic raw material patterns, pestles, small manos and basin metates, macrobotanical samples, pollen and phytolith samples, and ceramic vessel forms. For animal resources, data requirements include faunal, projectile morphology, raw materials, lithic use wear, nets, snares, clubs, and possibly residue analysis. As noted in the introduction to this heading, an integrated analysis of biological and proxy data will be required.

Research Issue 8-2

Diachronic Patterns in Hunting Practices for Medium and Large Game

With the unlikely possibility of excavating a rock shelter or perhaps the discovery of a buried kill site, it must be acknowledged that analysis of hunting practices based on direct biological evidence in the form of faunal assemblages will continue to be almost entirely restricted to Formative period habitation sites. As discussed in the faunal review of this section, faunal remains are exceptionally rare at Archaic period sites due to a combination of preservation and possible cultural factors. Given the absence of faunal bone at Late Archaic settlements in the central basin - and the odds against encountering such sites - archaeologists may have to rely on

the faunal data from upland sites, including rock shelters and architectural sites in the Sacramento and Capitan mountain area. In doing so, however, it must be acknowledged that the potential biases resulted from the fact that upland faunal assemblages reflect population densities that differ markedly from population densities in the lower elevations of the desert basins and mountain foothills.

Data Needs. With the abovementioned problems in, archaeologists will have to focus on an integrated analysis of proxy evidence to make inferences regarding prehistoric hunting and procurement strategies during the Paleo-Indian, Early Archaic, Middle Archaic, and Late Archaic periods. Given the rarity of subsistence contexts, such proxy studies should involve models of chipped stone technological organization and more detailed focus on proxy artifact indicators discussed in this section. These analyses will require data sets from multiple landforms and should also incorporate analyses of faunal assemblages from neighboring regions.

Research Issue 8-3

Exploring Alternative Interpretations of Subsistence Economies and Associated Extractive and Processing Technologies

Studies of prehistoric subsistence seem to be locked in to the study of food resources that have long been the subject archaeological, ethnographic, and ethnohistoric investigation in the Southwest and other regions of North America. This includes gathering and processing cacti, succulents, and mesquite, hunting of rabbit and artiodactyl species, and horticultural or agricultural production based on corns, beans, and squash. A wider range of plant and animal foods, subsistence economies, and even the social dimensions of subsistence (see below) should be considered. The possibility of intensified seed gathering and processing, as well as the accompanying technological adaptations among ceramic containers, grinding implements, and thermal features, should be examined in greater depth. The possible exploitation of small game (particularly rodents), or the reasons for the apparent rarity of such species at prehistoric sites in the Jornada, might be another productive avenue of inquiry, particularly when the relationship between the presence of such species and agricultural production is considered.

Conventional studies should be expanded and investigated using more sophisticated analyses and models. Church's (Church and Sale 2003) model of rabbit procurement and processing is based on sound ethnographic and ethnohistoric research and establishes several testable material correlates for different processing and consumption practices. The development of additional models that explore variation in subsistence practices and associated technologies is highly encouraged.

Data Needs. Integrated analyses of biological and proxy data. The development of models exploring technological and organizational aspects of extractive and processing technologies, including chipped stone, ground stone, and ceramics, should be undertaken. In addition, models that explore the nature and formation of faunal assemblages in relation to both cultural and taphonomic processes require greater consideration.

Research Issue 8-4

Changing Agricultural Dependence through Time

As noted previously, agriculture develops in the region at around 1000 B.C. based on direct dates on corn from the Organ (Upham et al. 1987) and Sacramento (Tagg 1993) mountains. However, the level of dependence remains unknown. Ceramics, which are commonly associated with high levels of agricultural dependence, do not appear until around A.D. 200-400. As summarized above, currently available flotation data suggest that agricultural remains are not commonly in flotation samples until after A.D. 1150. Changes in ground stone suggest a similar pattern with

larger ground-stone artifacts comprising a significant portion of ground stone in the region after A.D. 1000. Finally, carbon isotope data also suggest a jump in dependence on C4 plants, which would include maize, late in the prehistoric sequence. The present evidence suggests that the pre-A.D. 1000 pattern is one of limited dependence on agriculture.

The period between 1000 B.C., when agriculture was first introduced to the area, and A.D. 1150, when agriculture appeared to be a larger component of subsistence, is of considerable interest. The degree to which agriculture was actually practiced in the lowlands prior to A.D. 1000-1150, what level of dependence agriculture represents during this period, and what brought about the increased dependence suggested after A.D. 1150 remains unclear. The apparent dual intensification of both agricultural production and cacti/succulent processing during the Early and Late Doña Ana phases is of considerable interest in this regard. Because agricultural strategies are closely related to so many other components of a cultural system (including mobility, occupational intensity, overall land use, and technology), which are not directly covered in this chapter, documenting agricultural levels is a primary concern.

Data Needs: To effectively considering these questions involves the collection of ethnobotanical samples, ground stone information, phytolith and pollen samples, data on ceramic presence and vessel form, data on possible storage features, physical analysis of human remains, lithic use-wear and raw materials used, and coprolite information.

Research Issue 8-5

The Social Dimension of Subsistence Economies

Subsistence is not only restricted to the foods gathered, produced, and processed by a specific kin or social group for basic sustenance. The possibility of exchange – including both import and export – of foods should be explored. As noted in Chapter 12, feasting and other communal rituals involving fermented cacti or the results of successful hunts may have left evidence in the form of unique archaeological deposits and ceramic vessels. The role of unusual plants in subsistence should also be explored. Table 8.10 (see Table 8.10) lists over a dozen plant species recovered from roasting facilities. While many of these species may have served medicinal or ritual purposes and thus were not involved in subsistence per se, the possibility of their use as supplemental foods, condiments, and so forth during feasting or communal events should be considered.

Data Needs: Ethnographic and ethnohistoric accounts of the use of atypical plants; residue analysis of ceramic vessels and storage containers; greater attention toward documenting archaeological refuse deposits and detecting evidence of feasting events.

Synchronic Research

In addition to the investigation of diachronic issues, a variety of synchronic subsistence issues should be investigated. Synchronic research questions are focused on developing descriptions of the actual resources used as represented on sites in various landscape zones. Currently, potentially available resources include a variety of succulent (e.g., agave, sotol, yucca, cacti), large seeds (e.g., mesquite), small seeds and shrubs (e.g., drop seed, amaranth, *Chenopodium*), large mammals (e.g., deer, antelope), small- and medium-sized mammals (e.g., cottontails, jackrabbits, rodents), and a variety of other resources (e.g., birds, fish). In addition to these natural resources, agricultural resources appeared in the region around 1000 B.C. These natural resources, as well as the viability of agriculture, change in distribution and density in part as a function of soil characteristics and moisture that varies with landforms (see Bradley 1983; Mauldin 1995; Satterwhite and Ehlen 1980, 1982).

A number of general summaries regarding the distribution and periods of availability for specific noncultivated plants and animals are available (see Bradley 1983; Hard 1986; Mauldin 1995; O'Laughlin 1980), though they tend to be based exclusively on modern distributions. Progress in documenting subsistence in the synchronic realm is, in part, dependent on progress in paleoenvironmental reconstruction as well as the successful use of proxy indicators discussed in this section. Mapping those resources potentially available within a zone (the economic landscape) and documenting changes in that economic landscape provides the background data for comparing resources at a site with what resources are available within that zone.

Once a detailed understanding of resources is available, it is then possible, using methodological tools outlined above, to investigate synchronic subsistence patterns. For example, if charred fish remains were identified in archaeological features in the central basin we could suggest that they have a high probability of being related to subsistence and also that they are not derived from that zone.

While comparisons of subsistence remains to naturally available resources can be especially important for elucidating higher-level strategies (e.g., mobility, interaction), they complicate any interpretation of resources at the synchronic level. That is, the presence of resources or artifacts associated with processing those resources on a site within a given zone does not necessarily mean that those resources were acquired from that zone. The relationship between the recovery of resources at a location and the location of acquisition, production, processing, and consumption is closely linked to higher-level questions of strategy of resource acquisition, land use, and mobility strategies. For synchronic description, then, the more indicators of the use of a given resource type (e.g., corn kernels, maize phytoliths, maize pollen, two-hand manos/trough metates, necked jars, storage features) on a site or series of sites within a zone, the better the potential that the resource was produced and processed in that zone. Efforts should be made, then, to collect as many different data types from archaeological settings as possible for any given resource.

Basin Floor

This landform unit consists of the remaining portion of the central Hueco Bolson not encompassed in the playa zone. The central basin is currently dominated by mesquite-stabilized sand dunes, interdunal blowouts, sheet sands, and sparse vegetation. Much of the erosion appears to have occurred over the last 200 years. No permanent water resources are available in this zone and all plant production is a function of rainfall, which is highly variable across space and in time. Resources in this zone occur, therefore, at both a low density and with a low degree of predictability. The principal resources available in this zone appear to be small- and medium-sized mammals and mesquite.

Alluvial Fans

This landform zone consists of the alluvial fans associated with the mountain uplands. This zone corresponds to the "runoff" zone defined by Whalen (1977, 1978) as the distal ends of the fans receive runoff from the mountain uplands; however, it should be kept separate from the playa zone discussed below. The combination of runoff, rainfall, and soil characteristics of the alluvial fan zone results in the production of a variety of plant and animal resources. More importantly, these resources appear to occur at a relatively high density and are available on a more consistent basis. The principal resources in this zone include a high density of agave and sotol, as well as yucca and a variety of mammals, including deer at low densities during certain seasons.

Otero Mesa

This landform consists of the upland mesa along the northwestern edge of Fort Bliss on McGregor Range. In contrast to other landforms, relatively little is known about the archaeological patterns within the Otero Mesa zone. A sample survey and some limited testing were conducted in the 1970s (Beckes et al. 1977); additional survey and mitigation has been recently conducted (Quigg et al. 2002). The resource structure remains relatively unknown. Currently, this unit is dominated by relatively stable grasslands with a variety of cacti and other succulents present. A variety of faunal resources has been observed in this region, including several small herds of antelope and the occasional deer.

Uplands

This landform unit consists of the bedrock uplands, including the nonalluvial portions of the Organ, Franklin, Hueco, and Sacramento mountains. Resources vary, primarily as a function of temperature and precipitation associated with higher elevations, and there is data to suggest that the uplands, in some sense, have a complementary structure of resources relative to the lowlands (see Hard 1986; Mauldin 1995). Major resources in this zone have included large mammals (e.g., deer, elk, and bison) and nut resources (e.g., piñon).

Riverine Zone

This landform unit consists of the Rio Grande and associated floodplains and terraces. While not represented on Fort Bliss, the zone provides a variety of resources that are not available in any other zone. These include a variety of riparian plants and animals, including fish. As this landform is not present on the post, we must rely on the results of investigations outside of Fort Bliss to provide data relevant to this landform.

General data needs for synchronic research among each of these zones are similar. For a given archaeological feature or structure, site-level deposits are required. At the scale of a landform, efforts should be made to collect the biological and artifactual data discussed in this section. In addition, background research on paleoenvironmental patterns, chronometric dates, and technological aspects related to processing of subsistence resources should be conducted.

Research Issue 8-6

Specific Synchronic Research Questions for Each Landform Include:

- What are the natural plant resources used in subsistence at prehistoric sites in this zone?
- What are the animal resources used in subsistence at sites in this zone?
- Are these noncultivated plant and animal resources represented in the subsistence base available in this zone?
- Is agriculture a subsistence strategy used in this zone?
- What is the level of dependence on the various subsistence resources at any given point in this zone?

Below, partial answers are provided for some of the issues in the central basin playa zone. Similar efforts are needed for the other zones.

Central Basin Playa Zone

This landform unit consists of playas that dot the central basin and a radius, arbitrarily set at one mile, of area surrounding those playas. A one-mile radius is an arbitrary and conservative approximation of the peripheral resource exploitation zone commonly used by mobile societies around a tethered resource such as a playa (see discussion in Chapter 9). The one-mile radius

represents a 20-minute foraging pattern and will include most of any special purpose sites that may be functionally linked to the playa. The Central Basin Playa zone roughly corresponds to the Basin-Playa zone (see Hard and Mauldin 1986). The playas in this zone, several of which have been observed to occasionally hold water on a short time scale after intensive summer rains (see discussions in Chapters 2 and 7), potentially have a higher density of plant and animal resources relative to the remaining portion of the central basin. This zone may have provided opportunities for the collection of a variety of plants and animals. The principal resources available in this zone appear to have been small- and medium-sized mammals, yucca, *Chenopodium*, some grasses, and mesquite.

Many sites in this zone are eroded or represent low intensity use facilities. In the past two decades, flotation has been used extensively and macrobotanical samples from many fire-cracked rock/burned caliche features and charcoal-stained features from these types of sites have been collected and floated. As pointed out above, the results of such analyses have been disappointing. Two recent studies of small sites in the basin had recovery rates of only 12.2 percent and 3.3 percent (Dean 1998b; Holloway 1998). Samples from campsites without structures and located in basin settings, across all time periods, had the worst results in the Loop 375 study (Dering 2001).

Even when they are present, the preservation of the botanical remains is inadequate to examine diversity of plant taxa among or within sites. Together, these data beg the question of the efficacy of flotation analysis at such sites and whether this is a wise use of project dollars. Based on the data in Tables 8.3 and 8.4 (see Tables 8.3 and 8.4), it appears that sites that had low intensity use provide little if any information. Even when the features at such sites contain charred plant material, few contain seeds, fruits, or other edible plant fragments (Dering 2001). The only exceptions appear to be campsites that were rapidly buried (Dering 2001). Thus, unless there is evidence that a small, low intensity site in the basin was rapidly buried and has potential for recovery of plant remains, such sites cannot address what resources were utilized at that location. In contrast, sites with evidence of more intense use, with intact charcoal-stained features and associated artifact assemblages in non-eroded contexts may have the potential to address subsistence strategies and economies in the region. The following general resource questions should be investigated.

What are the natural plant resources actually used in subsistence at sites in this zone? Church (2002) has addressed this issue in the following way:

The primary productivity of various ecosystems in the northern Chihuahuan Desert can be extremely variable. Primary production around playa lakes varies considerably from year to year (Ludwig 1986). It should be understood that primary production figures result from all plant growth. While they are likely a good general indicator of resource productivity, it does not necessarily follow [that] they reflect the productivity of resources exploited by humans. It is entirely possible that an area [had] high primary productivity, but be essentially barren of suitable resources for humans.

Among the more probable significant wild plant resources in the playa zone for prehistoric populations were yucca (*Yucca elata* in particular), mesquite, various species of *Chenopodium*, and grasses. Various parts of the yucca were used for food. The heart was harvested much like agave just prior to stalk formation. The stalk itself was also harvested, and the pods produced from the stalk were harvested. The density of *Yucca elata* near playas in the northern Chihuahuan Desert is relatively high and the presence of yucca fibers in archaeological deposits confirms they were used prehistorically. In addition to its use as food resource, yucca also provided fiber for cordage and basketry.

While mesquite may have only recently established itself in abundance in southern New Mexico and west Texas, honey mesquite occurs along playa margins and in coppice dunes. Other than its

Pods that could have been used for subsistence, mesquite appears to have been the preferred prehistoric fuel wood, based on its identification in numerous thermal features throughout the area (Dering 2001). Various species of *Chenopodium* (goosefoot) are major invaders of drying playa margins (Rowell 1981). Three species of *Chenopodium* are salt tolerant and commonly found along the margins of saline playas (Henrickson 1978).

What are the animal resources actually used in subsistence at sites in this zone? Of the animals inhabiting this environment, jackrabbits are one of the larger and most common mammals available as prey. Moreover, rabbit (jackrabbits and cottontails) densities are generally higher in playa/dune areas. Small mammals of the family *Neotoma* (woodrats) and *Dipodomys* (kangaroo rats) are also common throughout the arid Southwest. The playas may have also attracted waterfowl in the past, unlike the present day conditions, in which basin playas fill too late for the spring waterfowl migrations. However, whether prehistoric conditions would have been more suitable for waterfowl is unknown at this time.

Several species of phylloids, specifically fairy shrimp, brine shrimp, and tadpole shrimp, occur in ephemeral ponds in the American West, with Arizona having the most fairy shrimp species (Belk 1977). These shrimp hatch and reproduce in the short time that the playas are filled with standing water. These may have been an important resource for prehistoric populations, as they certainly would have had a high caloric value. Another common invertebrate of the playas that may have been a food resource is the spadefoot toad (*Scaphiopus couchi*).

Are these noncultivated plant and animal resources represented in the subsistence base available in this zone? The playas present in the Tularosa Basin are spatially stable resource “islands”. With regard to the resources present, however, playas may be unstable over time. That is, even if the playa is flooded, the resources may remain out of temporal phase minimizing the actual attractiveness to prehistoric populations. Obviously, many of the resources associated with playas are dependent on water and/or soil moisture (e.g., game are dependent on water and yucca on soil moisture), and rainfall sufficient to substantially wet a specific playa is unpredictable. Patterns of precipitation would affect resource densities and availability. Playas might collect too much water, damaging the submerged plant resources or, during an extended drought may stay dry too long to allow for survival of species dependent on periodic rainfall to propagate. In addition, playas with water would attract game either for the water or for plants that grew along the margins.

Is agriculture a subsistence strategy used in this zone? The relationship between playas and agriculture has been almost universally referenced in the regional literature, but the hydrological and agricultural potential of playas has recently been questioned (Church 2002; Church et al. 2002; Kludt 2007; Miller 2004b). A large body of proxy settlement pattern and architectural data clearly shows that Late Formative period horticultural villages are clustered around major playas. However, there may have been a substantial component of risk and uncertainty in farming playa margins.

SUMMARY

Subsistence decisions comprise a critical element in human adaptations, impacting technology, settlement strategies, mobility levels, seasonality, and the overall cultural organization. Investigating and explaining subsistence organization involves: (1) the identification of resources used at various times and places within the region; (2) developing a description of the mobility and technological strategies used to acquire those resources; (3) documenting changes through time and across space in those mobility and technological strategies; and (4) developing explanations for those changes. We have focused on methods that may be relevant to answering the first of these questions, documenting what resources were involved in subsistence at various

times and places. In addition, specific research questions, involving both differences in space and through time, have been presented. Clearly, this represents an initial step, and the higher-level questions of changes in mobility and subsistence organization must be investigated once the initial patterns have been defined. Of course, progress in this research area involves progress in the chronometric, paleoenvironmental, and technological research realms.

CHAPTER 9. TECHNOLOGY

Christopher R. Lintz, Tim Church, and Russell Greaves

This chapter has been moderately revised from the 1996 *Significance Standards* document. The chapter investigates the role of technology as a research domain with specific reference to the Fort Bliss region. The term *technology* is defined as the knowledge, skills, methods, and procedures for fabricating and using tools to convert elements of the natural environment into culturally useful materials. Technology covers a tremendously broad array of specific studies that can range from the examination of specific artifacts, to fundamental studies of the full assemblage and feature range upon which inferences about prehistoric adaptations are based.

The current chapter examines as background discussions the range of concepts used to examine technology/technologies, summarizes the theoretical models, surveys the literature of the Fort Bliss region to identify gaps in a number of technological issues, and postulates a series of viable research questions related to technology. The chapter in its present form provides a more detailed review of individual artifact classes and studies from the Jornada and adjacent regions, incorporates a new discussion of perishable technologies, and presents a revised set of research questions.

BACKGROUND DISCUSSIONS

Although technology is seemingly a straightforward research domain principally dealing with material culture remains, archaeologists have used the term technology in a multitude of ways. It includes the support assemblages, organization, and culturally patterned behaviors underlying (1) the methods of raw materials acquisition, (2) the sequence or stages in manufacturing implements and features, (3) the use, damage, and repair of implements and features, and, (4) the patterns of discard, or storage and recycling of implements, and features. Since all materials, organizations, and behaviors potentially change through time, technology forms the basis for describing cultural variations upon which inferences about past adaptations are derived.

In a few instances, technology has also been erroneously used as a term synonymous with assemblage, as in discussions about the array of tools stashed on site as "a curated technology." Technology generally involves studying material culture items (artifacts and features) to derive information about prehistoric procedures, ideas, strategies, and the organizations of groups underlying specific task and activities; whereas assemblages generally refer to the specific collections of implements and features used by a group. Due to the breadth in the scope of technology (ranging from culturally transmitted ideas to specific objects), some aspects of technology overlap other research domains of settlement patterns, subsistence practices, cultural interactions and, of course, chronology.

Ellis and others (1994: 81-99) developed the concept of technology as a means of investigating prehistoric cultural adaptations. Assuming that cultural systems of shared behaviors and traits are transmitted by socialization from one individual to another, then the adaptation of cultural systems involves both a "reproduction mode" to replicate behaviors perceived to be effective in meeting the group goals and an "adaptive mode" that attempts to adjust behaviors to perceived changing environmental conditions.

Ellis and others (1994: 83) advocate that:

An adaptation is a knowledge base and a decision making structure socially transmitted within, and historically implemented by a community of people in order to meet their subsistence and other goals in an environment that contain a finite array of materials that can serve as the resources people use to meet their goals.

Drawing on the notions developed by Winner (1977), Ellis and others (1994) note the basic structure of technology consists of three parts: (1) organization involving the social arrangement of people, (2) apparatus referring to the raw materials, tools, and features, and (3) techniques involving the culturally transmitted procedural knowledge about how an individual/group accomplishes a goal, and background knowledge involving perceptions about the natural and cultural environmental setting within which people operate.

Since people are rarely devoid of an existing material assemblage, Ellis and others (1994) point out that a group's ultimate survival goals (primarily subsistence and shelter needs) are accomplished by several tiers or levels in the structure of basic technology. A distinction is made between "use technology" (the apparatus, organization, and techniques employed to achieve an ultimate procurement, or processing resource goal – usually related to subsistence), and "support technologies" (the apparatus, organization, and techniques employed to create the tools and features contributing to or comprising the apparatus of the use technologies). Several layers of support technologies underlie a specific kind of use technology. In addition, several kinds of use technologies are linked together to acquire and convert natural resources into a consumable product.

For example, first order support technologies for projectile delivery systems (organization, techniques, and apparatus) exist for the procurement of raw materials (i.e., knappable resources). Secondary order support technologies (organization, techniques, and apparatus) convert raw materials into projectile points, just as other second order support technologies make the dart shafts and atlatls. Third order support technologies combine these various components into a projectile delivery system. This projectile delivery system constitutes the apparatus portion, (along with hunting group organization, stalking/killing techniques, and the knowledge of animal behavior) of a "hunting use technology" for the slaying of game.

Other use technologies (each with several subordinate levels of support technologies) exist for a butchering use-technology, a processing/cooking use technology, perhaps an animal product storage use-technology, and an animal product consumption use-technology. Complementary systems exist for a range of plant resources, as well as for the goals of providing clothing and shelter.

The technological notions advanced by Ellis and others (1994) are important since they explicitly outline a way of looking at how materials are assembled to achieve a specific end, and understanding the relationship between support technologies and use technologies within a functional context. It forces archaeologists to contemplate the problems and procedures that must be addressed to meet a group's survival goal and to consider the interrelationship between tools made of different kinds of raw materials as a functional part of the assemblage.

This perspective is quite contrary to the procedures implemented in most archaeological reports, which organize the materials descriptions around the raw materials types (chipped stone, ground stone, ceramic, organic, etc.), but make little effort to discuss the interrelationships through the delineation of activity areas and relationships of implements of different material types. Progress in understanding how specific prehistoric groups are organized and behave is apt to be slow until archaeologists deal with issues beyond mere descriptions organized by raw material types.

A second aspect of the technological approach proposed by Ellis and others (1994) involves comparing the recovered archaeological assemblage at a site against the expected assemblage derived from the various tiers of support and use technologies to make inferences about the site's function and role in a settlement system. Rarely were the entire range of support or even use activities performed at a single site, and the absence of expected materials in an assemblage may be almost as informative as what components are present. This approach has the potential to define complementary sites and the spatial and behavioral range of activities across the landscape along the procurement-processing-consumption continuum.

Site assemblage data in conjunction with knowledge about paleoenvironmental conditions, models of resource distributions, seasonal resource availability and chronometric data all allow archaeologists to formulate inferences about how people organized themselves at various times in the past. Testable hypotheses can then be developed for examination at other sites. Clearly, preservation, sampling limitations, and contextual associations must be critically evaluated in defining the position of a site in the settlement system.

The final aspect of the approach defined by Ellis and others (1994) establishes a set of interrelated testable hypotheses that, when answered in a stepwise manner, provides information about a group's organization and adaptive strategies. The interrelated hypotheses are hierarchically arranged to examine (1) site functions, (2) the spatial organization of individual technologies, (3) stability and change in technology and subsistence, (4) delineation of the arrays of technologies and subsistence resource bases for a temporally specific interval, and (5) delineation of adaptive strategies for a specific time interval by delineating the array of site functions, seasonality (scheduling), and degree of subsistence orientations along the forager-collector continuum.

The strength of this approach involves an explicit way of using the basic structure of support and use technologies to infer adaptations from the artifact assemblages present at a series of relatively contemporaneous sites across different landforms and throughout a region. It provides a theoretical mechanism for archaeologists to use in comparing and interpreting patterns in relative contemporaneous site assemblages, and for searching for contrasting patterns in assemblages dating to other periods.

The approach is holistic and elegant, but not without practical problems in its implementation. As a heuristic device, it assumes that intact sites will be located on all landforms to permit the identification and reconstruction of complementary activities. In practice, this may be a major problem at Fort Bliss, particularly in the desert basin. Some parts of the technological approach may be easily implemented, especially where contextual relationships are relatively intact. Application of other parts of the technological approach (where landforms are not conducive to the preservation of segregated occupational contexts) may require diligent study and a modicum of luck to understand the nature of prehistoric activities. Many regions have dynamic landforms experiencing differential periods of stability or kinds and rates of deposition and erosion. Landform settings will differentially affect the preservation of complementary behavioral activities.

In practice, sites with neither temporally diagnostic artifacts nor datable samples are especially difficult to analyze with respect to technology issues, regardless of landform. Many sites consisting of little more than sparse fire-cracked rock or lithic debris scatters may have to be regarded as ubiquitous low level cultural "background noise" in the suite of activities. In other situations, the consistent correlation of specific tool or feature types to specific landforms suggests fundamentally different, but temporally vague, activity patterns. Initially the distribution may only be useful in delineating gross activity differences. However, if the tool or feature type is sufficiently morphologically distinct to permit confident and replicable identification, it may

eventually be found in datable contexts, which will permit classification of such behaviors to a specific time period. Thus, the program involves long-term studies but not quick or easy solutions.

While Ellis and others (1994) use technology to investigate prehistoric cultural adaptations, other archaeologists and ethnoarchaeologists employ technology to study choices (Stark 1998: xvii). For example, because pottery in the Tonto Basin of Arizona remained largely undecorated and utilitarian throughout most of the ceramic sequence, conventional methods of stylistic study of design styles were inadequate tools to understand the symbolic aspects of goods that were circulated in tightly restricted social networks (Stark 1998: xviii). In contrast, when looking at the technological choices made by the potters in the manufacture of the vessels, archaeologists could begin to detect different scales of social boundaries within the basin. Similar studies of technology on the El Paso brownware from the long-lived Mesilla phase in the Jornada Mogollon region, particularly when combined with NAA studies, may also begin to help understand social networks and social boundaries of these groups.

A drawback in implementing any technological approach involves the procedures to recognize, and ascribe significance to cultural variability as a means of measuring adaptation. In lieu of recovering potentially highly perishable materials, and/or understanding the contextual relationships of artifacts, the criteria for distinguishing genuine behavioral differences are vague, difficult to quantify, and somewhat capricious. How does an individual interpret assemblage variability and ascribe behavioral differences? Clearly, the tactic involves the investigation and analysis of numerous components to understand differences in the site functions, seasonal variations, and organizational differences.

THEORETICAL MODELS AND EXPLANATORY APPROACHES

A somewhat more pragmatic approach of dealing with technology recognizes the inherent complexity of the subject, and structures this complexity in a manner that highlights the relationships of the technological components. By explicitly identifying these relationships, new questions can be formulated that yield additional information about the underlying human behavior. The complexity of technology involves integration of the following:

- (1) raw materials (to fabricate artifacts and features);
- (2) cultural materials (general artifacts, features, rock art, etc.);
- (3) a spatial scale (ranging from a single item through feature clusters, activity areas, sites, environmental or landforms, to regional investigations);
- (4) a temporal/atemporal component (preferably attributable to a stage or phase level); and
- (5) analytical modes including morphology, material production, function/use/damage, and recycle/curation/disposal).

The relationships of these components can be conceived as a five dimensional matrix table with a primary goal of providing an analytical framework for structuring technological questions. Ideally, the intersecting matrices delineate a succinct and isolatable research question. However, the structure of the matrix also characterizes the relationships between variables.

Due to the conceptual unwieldiness of a five dimensional matrix table, some technological components can be conceptually linked together to produce a three dimensional matrix table, more amenable for consideration and discussion. The three primary axes consist of a raw material-cultural material-spatial scale axis, a temporal/atemporal framework axis, and an analytical orientation axis (Figure 9.1). The recombination of the material-spatial and analytical orientation axes creates some problems; these are discussed below.

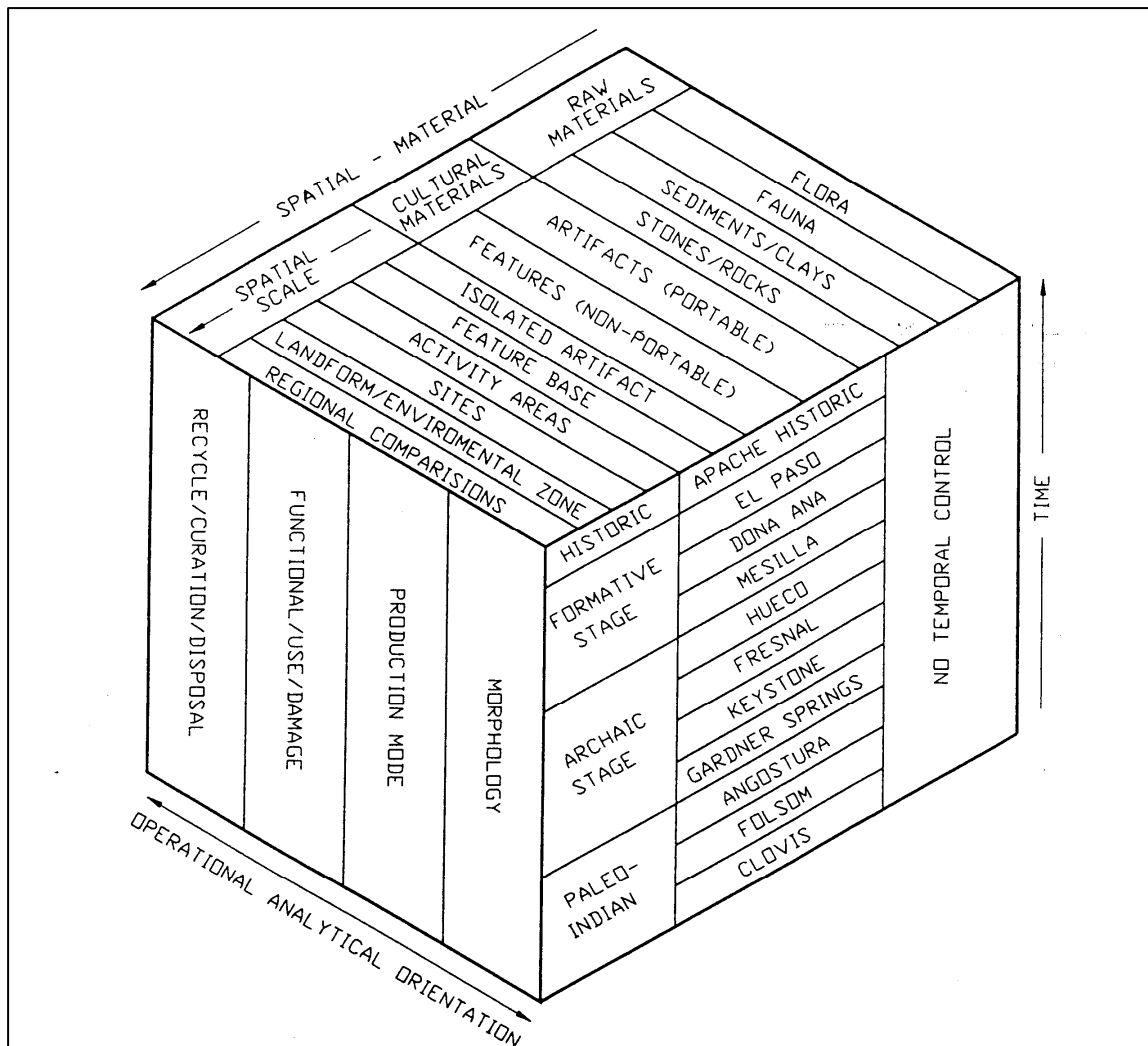


Figure 9.1. Three-dimensional matrix of technological components

The Material Types and Spatial Dimension

The material-spatial axis of the matrix actually involves the melding of three relatively distinct technological components. Material types consist of both raw material resources and cultural materials. Both of these categories correspond to the Ellis and others (1994) apparatus component in technological studies. The spatial scale component acknowledges that valid technological studies can occur on various micro to macro levels and yield important technological data relevant to understanding technological behaviors.

In general, as the analytical scale of space increases (feature based associations, buried activity areas, sites, landscape and environmental zones and regional studies), the level of confidence in establishing associations with a single group are apt to become lower. Nevertheless, macro scale studies yield important insights into prehistoric utilization of landscape diversities.

The listing of raw material resources should be regarded as illustrative, but includes raw materials for producing both tool components and features. Floral resources include plant foodstuff (pollen, fruits, nuts, seeds, leaves, stalks, and roots, etc.), and materials for manufacturing

implements or feature products (fibers, wood, leaves, etc.). Faunal resources similarly include the raw foodstuff (organs, meat, marrow, digestive track contents, etc.), and products needed for implements (hides, sinew, organs, feathers, bones, horns/antlers, shell, etc.). Sediments/clay resources include raw materials potentially useful in manufacturing ceramics (clays and tempers), adobe/mortars, pigments, and other materials where earthen materials are acquired, modified, and transported to a state where they can be detected archaeologically as being manipulated by people. The lithic resources include the broad suite of materials that include quarry blanks, cobbles, and pebbles suitable for modification by knapping, pecking/grinding, and heating.

The realm of cultural material types is distinct from raw materials, since it applies to the manufactured tangible aspect of culture—the object (artifact or feature)—and not the process or knowledge of production. Note that materials in these categories are generic types, which do not necessarily stipulate any specific form, method of manufacture, stage of completion, or specific function. These items may represent artifacts made from a single kind of raw material (e.g., baskets), or they may represent composite materials (e.g., a house). The intent of recognizing this realm as a discrete entity along this axis is to permit the kinds of analytically oriented studies that can focus on specific kinds of artifacts or features. The intent is not to identify the full range of artifact types or feature types, for that is one of the analytical orientation topics. Rather, the inclusion of artifacts and features recognizes the importance of technological studies of single classes of cultural materials from a temporal, spatial or analytical perspective.

The spatial scale segment acknowledges that legitimate technological studies can focus on differential levels of space ranging from the location of an isolated artifact or feature, up through distributional studies the size of a region or culture area. Although the provenience of an isolate may be recorded with relative precision, its association with other artifacts and features may be contextually unknown. Feature based associations (materials within structures, pits, hearths, ovens etc.) are apt to have relatively good associational contexts. The association of materials within activity areas surrounding features become more tenuous and may require geomorphic interpretation of the locality dynamics before the association of artifacts can be properly defined.

Even though the three dimensional spatial proximity between artifacts is no assurance of contextual relationship due to potential intervening depositional events, it is equally true that with increasing physical distance, the scale of interpretative resolution must become coarser (Chang 1958). On many parts of Fort Bliss, landscape dynamics are sufficiently active to preclude the confident construction of artifact assemblages ascribable to a specific component even in small site areas. Despite these limitations, important technological studies can be accomplished on the environmental or landscape and regional level by altering the tactic of investigations to macro scale distributional patterns of specific kinds of artifacts and features. Without abundant absolute dates, it may be difficult to temporally relate many of these macro scale distributional study findings. However, significant patterns in the occurrence and frequencies of select features and distinctive artifacts provide valuable behavioral information about prehistoric land use practices, and general landscape activities.

The Temporal Dimension

The temporal framework is a major matrix axis, since it provides the ability to control time depth and, where feasible, permits delineation of the succession of technological issues. Three temporal states are recognized: synchronic time control, diachronic time control, and atemporal control or the absence of time control.

For illustrative purposes, the regional stages (following Willey and Phillips 1958) and the cultural sequence of phases as defined by MacNeish (1993) have been added. However, since many of the Archaic phases are based on results from stratified rock shelters where numerous natural and cultural factors translocate artifacts into different contexts, considerable investigations are still

needed to verify and refine the technological context and chronological controls for the Fort Bliss sequence of phases, as well as understand the composition of the artifact assemblages in other environmental settings. The present intent was merely to provide labels for discussing synchronic and diachronic technological changes.

Synchronic studies involve the compilation of data from near contemporaneous time periods. These kinds of studies examine material culture as a "slice of time" and characterize activities and behaviors occurring in diverse settings and resource zones. Chronological control is most reliably assessed through absolute dating, especially in dynamic landscapes prone to episodes of deflation and mixing. Some kinds of artifacts and features (perhaps projectiles, ceramics, and contiguous structures) may be assignable to a specific period based on morphology alone. Furthermore, as brief occupation sites with good contextual relationships are identified and studied, other aspects of a material assemblage can be related to specific synchronic studies.

Diachronic studies examine the changes in material culture through time. Such studies can range from the examination of one class of material (projectile points, ceramics or fire-cracked rock hearth features [Mauldin 1995; Mauldin et al. 1998; Miller and Kenmotsu 2004; Whalen 1994b]), to comparisons of material assemblages from a series of components, and synchronous phase assemblages (MacNeish 1993). Diachronic studies provide the basis for identifying the dynamics of culture, changes in behavior and, when temporally correlated to variations in other natural and cultural environmental factors, provide the primary data for postulating adaptive/maladaptive cultural patterns.

The Analytical Orientation Dimension

The analytical orientation axis of the technological matrix is concerned with identifying manufacture, use, and discard behavioral patterns, which can be examined by material class, spatially or temporally. Analytical orientation is concerned with studies about an artifact/feature's form and its stages of formation, use, and disposal.

One analytical approach to technology is morphology. The first analytical orientation on the matrix is concerned with the study of artifact form and classification. Such studies can range from the mere creation of "pigeonhole" typological classifications of specific artifact forms (as with projectile types), to the characterization of the range of tool forms within an assemblage. In the most rigorous approaches, factor analyses can be used to delineate pertinent attributes, whereas cluster analysis defines group memberships. Other aspects of the assemblage can be used to ascribe significance to the groupings.

Another approach to technological studies is that of production. The second analytical orientation on the matrix is concerned with the manufacturing trajectories of tool production including delineation of the strategies of raw material acquisition, and stages of tool production for all components of an assemblage. Although most often conceived as applying to a single kind of raw material, such as the stages of manufacture of a particular chipped stone tool form, in a larger sense, technological production also pertains to the related implements and features needed to make the target artifacts. The technological approach varies according to the kinds of medium used, and whether the manufacturing process involves subtractive or additive characteristics (e.g., chert knapping reduction versus clay modeling in ceramic production).

The next category on the analytical orientation face of the matrix is that of function/use/damage. This approach is concerned with how an implement was used, and its relationship to other components of the artifact assemblage. Typical approaches involve studies of gross morphological forms (inferences about use edge angles on tools, wear patterns on ceramics, etc.), detailed microscopic use wear evidence such as abrasions and polish on the edge of chipped stone tools, or analyses of residues on the implements.

The last category is recycle/curation/disposal. This technological study element pertains to the strategies or processes and evidences of use by recycling, curating, and/or discarding the array of implements used by a group of people at a select point in time, or through time, to modify and manipulate their environment. The use of the term recycle here is taken to mean secondary use of items whose original function changes (Camilli and Ebert 1992: 120). The reworking of ground stone as hearth rock or as chipped stone cores are two examples of recycling. Another element of technology is curation. In the technological sense items which are important within a group's technology (food processing equipment), or an important personal implement are likely to be curated or maintained in anticipation of future use.

Often these kinds of items are not discarded on sites unless they are broken or worn out (Hitchcock 1982: 370). Some of these items may be left on sites in anticipation of future need and/or use (e.g., metates). Binford refers to these sorts of items as site furniture (Binford 1978: 339). Disposal or discard is a category that reflects the ultimate trajectory of implements or byproducts of implements into the archaeological record. Implements or byproducts of implements are disposed of as they have been deemed unusable as they are worn out, broken beyond repair or simply not worth the effort of curation (Hitchcock 1982: 371). Many analyses conducted on chipped and ground stone assemblages for instance are directly applicable to questions of activities and functions. They can also infer occupational stability and perhaps to some extent seasons of use.

EXISTING KNOWLEDGE OF TECHNOLOGIES

Lithics and Landscapes

As a component of the archaeological record, lithics form one of the most important residues of past technological behavior. Recent trends in research on technology emphasize the integrative nature of lithic assemblages with features, site structure, and geoarchaeological information that implicate activities carried out at archaeological sites, settlement dynamics, and site formation events. It also has been recognized that lithics, along with other technical remains, can provide crucial information not only about manufacture, but also about maintenance and subsistence. Spatial patterning of debitage and stone tools and their associations with other classes of archaeological materials implicate the organization of technological production within the particular labor, social, and occupational events that formed archaeological sites. In the following discussion, a landscape approach to lithic technology is emphasized. However, it is acknowledged that other approaches exist. The emphasis on landscape approaches in the archaeology of Fort Bliss offers opportunities to analyze lithics as an integrated component of a diverse and complex archaeological record.

Landscape Approaches to Lithics

In order to build inferences about the activities performed at individual sites and their relation to larger organizational systems, site level analyses will focus on a variety of standard methods to describe artifact assemblages, spatial and feature associations, assess the site context through geoarchaeology, and provide potential paleoenvironmental data. These investigations will address several characteristics of each site that can allow determination of their research significance.

Many sites in the central basin at Fort Bliss area are lithic scatters that are or may be Archaic period occupations. Many lithic sites represent palimpsests of mixed Archaic and later Formative (Ceramic) period sites. While the definition of Archaic sites is often problematic due to the lack of diagnostic artifacts, the presence of charcoal that can provide secure chronometric dates has demonstrated the presence of Archaic components at many of these sites. While a significant

portion of lithic sites are from the Archaic period, some lithic scatters may refer to post-pueblo hunter-gatherer adaptations or to activities by ceramic using populations. Even if the specific subsistence, settlement, and technological organization of such groups differ, all lithic sites can be addressed with comparable methods employing archaeological research problems associated with our current understanding of the Archaic. The issues of using analyses of lithic technologies to understand past behavior is best articulated in relation to questions about Archaic lifeways. Archaeology of later systems tend to focus on derived technologies (i.e., ceramics), differences in settlement (i.e., greater sedentism, selection of different areas), and the particular demands of subsistence patterns that are distinct from Archaic adaptations. At Fort Bliss, the presence of lithic and ceramic sites cannot a priori be identified as either palimpsests from disparate time periods, temporally related distinct multiple occupations that could include aceramic occupations and ceramic generating visitations by related systems, or single or multiple occupations responsible for simultaneous lithic and ceramic debris. Approaches to understanding lithic sites are described here in relation to improved knowledge of Archaic lifeways and later post-pueblo aceramic foraging events responsible for part of the archaeological record at Fort Bliss.

Identification of the extent of Archaic systems is difficult because of the problems associated with using hunter-gatherer sites within a region to postulate different scales of mobility and seasonal strategies (Vierra 1990). The size variations of Archaic foraging ranges are important. They would be useful to help determine the portion of subsistence systems that may be represented in an archaeological investigation (survey, testing, or data recovery) in a particular landscape. This is important in the management of large areas such as Fort Bliss and any landscape approach to archaeology. Variable estimates of Archaic foraging ranges have been suggested (i.e., contrast Vierra 1994 with Huckell 1996). While these usually offer predictions of annual mobility, the archaeological record presents both small- and large-scale evidence of land use at a temporal scale that more appropriately references generations of occupation effects rather than occupation of a single generation. Vierra (2003) has tried to link technological complementarity of lithic reduction in a sample of sites from the central portion of the Pajarito Plateau with raw material sources to demonstrate contemporaneous area use. In doing so, he (Vierra 1994) argues that it is possible to link lithic resource use to large scale mobility systems in the San Juan Basin. Vierra and Foxx (2002; Vierra 2003) note that a broad variety of foraging options could be supported based on their identification of plant resource dynamics in the Pajarito Plateau sample.

A crucial aspect of regional knowledge about Archaic period components is to determine the range of behaviors that can be documented for these sites. Such knowledge will help us understand what types of Archaic adaptations were performed within a project area. Our assumption is that the Fort Bliss record does not necessarily contain the range of behaviors the Archaic systems represented. This is a reasonable working hypothesis that emphasizes the research value of both larger sites and the more analytically problematic small sites that are likely to represent short-term use events. As a corollary of this inference, an important methodological challenge for Fort Bliss is designing recovery and analyses to evaluate past exploitation of this environment for an individually limited suite of activities at any particular site, but potentially a quite broad set of adaptations when such sites are compared with each other. This can be tested through examination of artifacts assemblages, contrasting presence of features, indicators of seasonality, and site placement within the landscape. It is not expected that there is a single, redundant set of activities represented in all Archaic components or activities that can be inferred through lithic analyses. It is equally important to determine whether it is possible to identify activities not represented in the Fort Bliss project area (i.e., residential locations, particular seasonal absences, evidence of lithic provisioning or plant or animal remains with distributions outside of the project area). Such negative evidence would provide strong indications of the articulation of these sites with other regions.

Other questions that implicate regional patterns of landscape use include determination of periodic occupation dynamics through dating, seasonal indicators, and spatial analyses that may segregate site use events. Lithic analyses can help identify variable states of tool systems passing through sites that allow researchers to identify contrasting technological production, use, and discard. For example, lithic debitage, if sufficiently robust, can indicate what kinds of cores (i.e., large blocks, raw material with much cortex, bifaces) were used, the kinds of knapping activities undertaken at the site (core preparation, bifacial shaping, edge modification), and the kinds of end products of knapping even when the end products are not present in the assemblage (i.e., if biface production flakes are present but bifaces are absent). It is not expected that reduction strategies will be redundant across all Archaic sites, lithic scatters from other time periods, or mixed lithic and ceramic sites. Thus, different lithic assemblages can provide important information about contrasting strategies or use of sites by study of the stages the technological system (i.e., core reduction, biface production, maintenance of existing tools) represented in the assemblages. Such an analysis also links sites to previous events through whatever state of lithic provisioning is responsible for the materials worked at any individual site. It also can connect sites to activities performed after leaving a particular site by identifying the lithic assemblage that may have been removed following site abandonment.

Lithics cannot be looked at in isolation. Analyses of debitage and tools must be compared broadly with other classes of artifacts and features in order to infer information about site function and occupational events. For example, the presence of ground stone has implications for food processing and re-occupation. Some sites with ground stone may represent locations revisited for processing because they were equipped with ground stone as site furniture (Binford 1979). Paleobotanical recovery combined with spatial analyses may identify redundant or contrasting processing events at sites with metates versus those sites with features.

Sites within the Fort Bliss project area provide significant challenges in tying lithic remains at multiple sites as related assemblages and defining temporal trends in past behaviors. Often considered especially problematic are small sites or those with low densities of artifacts. Such sites may represent short-term use from single occupations or a number of short visits with minimal technological entropy from lithics. Larger sites may represent qualitatively different occupations, but they also could be the result of events and organization similar to those seen at smaller sites that simply had more frequent visits to a particular magnet location. The potentially complex nature of these short-term use locations means that the scale of resolution for archaeological dating may not be able to separate significantly useful components of these accretional sites (Vierra 1980; Wills 1988: 65). While it is expected that there are likely to be some organizational differences in lithic technologies associated with temporal changes in population dynamics, landscape use, subsistence, and site functions between Archaic and later Formative (Ceramic) period occupations, clear differences are not yet well understood.

Part of the problem may be a culture historic bias that expects such differences, but evaluates lithic technologies only from a limited set of expectations about their structure of production and use. Consistency in analyses is necessary to identify what distinctions are apparent at individual sites and develop an understanding of chronological changes associated with other differences in social and labor organization. If, for example, analyses that address formal Archaic period bifacial technology are applied to later ceramic period assemblages and do not appreciate the importance of expedient core or tool production, then the initial descriptions obscure how those adaptations differ. The lack of equivalent bifacial reduction does not explain what a contrasting technology is designed to perform. Part of this may be the common overemphasis on bifacial implements, more formal tools, and bifacial reduction. The production and use of more situational core and tool technologies can be as informative. Because the use of bifacial implements can be curated across multiple contexts while many expedient technologies are

locally made and used, less formal implements may be more directly related to events performed at the site where they are found.

The difficulty of understanding small sites is common to management of large landmasses. This is simply a characteristic of the archaeological record within the Fort Bliss landscape and is not a handicap to productive research and cultural resource management. Large and stratified sites may provide large artifacts samples and excellent temporal control for a specific location, but their implications for chronology, local settlement, and activities are not necessarily superior to single occupation sites or those with multiple, small and limited use components. Short-term use locations have the advantage of having potentially more precise separation of temporal deposits and behaviors. Separating components within large multiple occupation sites can be difficult. Smaller sites with fewer potential visitation events or single occupations make interpretation of associations of lithics and their relationships with other classes of artifacts, spatial data, and subsistence implications less complicated.

The large-scale surface survey and excavation approach, such as that employed by Fort Bliss, can provide a significant sample size of such small sites that often receive minimal excavation attention because of assumptions that larger sites are more important and provide greater temporal control. Realistically, a large sample of small, limited component sites can provide better control that may less ambiguously identify the nature of behavioral variability for particular time periods than more complex, multiple time period palimpsests. While large sites may offer crucial insight into how a particular location's use may change through time, such inferences depend on information derived from single component or stratified sites. The large landscape area represented by the site sample at Fort Bliss is an ideal laboratory for addressing the unique advantages that both small and large sites offer toward archaeological understanding. The application of comparable methods of recovery and analyses for such a sample allows multiple scales of archaeological interpretation. Such an ability to alter comparative scales takes advantage of the structure of archaeological landscapes and is not confined to expectations about what information should be present at any specific archaeological site.

Temporal divisions of sites are useful for a variety of investigations about how adaptations change through time. However, it is not apparent how the short-term use sites may be expected to vary in relation to knowledge about other sites from the same time periods. As in any archaeological record, activities at one location may not necessarily be comparable to those performed at other places assignable to the same time period. Ethnographically, it is well known that highly variable activities are performed among members of a single community in the course of even a short-term sample of behavior[s] (O'Connell 1987). Seasonal differences in subsistence, settlement, and demography are often quite dramatic, resulting in settlement and material records that can appear to represent completely unrelated social and economic practices (Greaves 2006). Archaeologically, a number of behavioral tactics, taphonomic events, and our own analytic interests and practices can result in a record that demonstrably over-represents some components of past adaptations. Ethnographic documentation of behavioral variability is often much greater than the models used by archaeologists. The archaeological record represents a much broader geographic and temporal sample of potential adaptations than the ethnographic literature contains for limited areas where hunting and gathering peoples live. This results in a dramatic under appreciation of the significant potential differences in adaptations at archaeological sites. The result is both an overly simplistic set of expectations about past human behavior, myopia about how archaeological recovery and those limited models obscure appreciation of strategic variability, and may lead to untested and perhaps erroneous assumptions about normative practices.

A significant advantage of the landscape approach employed at Fort Bliss is that multiple prehistoric sites with temporal assignments can be compared to create a mosaic of the behavioral

variability represented within any single time period. The relatively large sample of sites, investigations using comparable recovery and analytic methods, information from contrasting environments, attention to taphonomic processes, and auxiliary information from isolated occurrences, all offer opportunities for archaeological perspectives that appreciate and use variability to advance understanding of past adaptive systems. This provides a fine-grained landscape view of sites in relation to their contextual integrity, not expectations about the kinds of sites (i.e., large, residential) usually selected as productive excavation projects. In such a perspective, characteristics common to many archaeological records that often are considered problematic can be used to better understand critical reasons for variability in sites. The presence of small sites with low-density artifact distributions, taphonomic evidence of complex, site formation histories, and multiple occupation sites lacking simple stratigraphic separation of events are all part of the nature of the local archaeological record. Lithic analyses can contribute to unraveling subsistence practices, settlement, mobility, site formation, and technological strategies.

General Discussion of Lithic Technology

It is necessary to design laboratory research on lithic materials that can investigate technological manufacture and use, as well as link them to larger scale questions about mobility, subsistence, seasonality, and labor organization. The following discussion presents the archaeological perspectives that direct the projected artifact analyses and outlines the goals of lithic research.

It is often assumed that discarded artifacts can provide information about past subsistence or technological activities at archaeological sites. Several ethnoarchaeological studies (see Fisher 1989: 188-191, 196-200; Yellen 1977: 103) have investigated this premise and concluded that relying on the discarded material (which includes many organic components lost in most archaeological sites) for identification of the activities practiced would be extremely difficult to impossible. Alternative strategies of artifact analyses have productively focused on smaller scale issues that have implications for understanding other aspects of site use. Reduction studies have taken advantage of the overwhelming presence of lithic debitage on many archaeological sites that can help identify production sequences.

Other ethnoarchaeological (Binford 1978, 1979, 1982; Gould 1969; Greaves 1997; Hayden 1987; Saffirio and Scaglione 1982) and archaeological (Nelson 1991; Torrence 1983, 1989) research has provided frameworks for evaluating potential behavioral implications of individually identifiable technological systems. An important assumption in all these investigations is that direct inferences about technological activity from debris are complex. For example, identifiable tool production may be embedded in locations where those tools are never used. Their manufacture can often be scheduled during periods when tool use is not required. The studies also recognize that the condition of a lithic assemblage can be highly variable and that manufacturing events do not necessarily represent the full suite of production performed within any technological system. Tool use at any particular site also is likely to represent only a portion of the total activities carried out at a site or the technology of the site occupants in general. Many implements, even if used, may be archaeologically invisible at certain sites if they are not made, modified, or discarded at the site. These effects are often considered to be averaged at long-term occupation sites so that the archaeological record does represent a broad range of production and use events. However, temporary camps, such as many of the sites in the Fort Bliss area, are each expected to contain evidence for only a limited set of technological activities. It is currently unknown how redundant or variable those events were. The majority of sites in Fort Bliss may contain technological debris with ambiguous relationships to the activities that occurred at those sites.

There is much debate about how inferences from analyses of lithic debris or tools can be used to better understand past subsistence, technological organization, mobility, or seasonality. The

behavioral implications from other classes of remains also are problematic, but most artifacts at sites on Fort Bliss are lithics or ceramics. Creative analyses are necessary to link quantifiable characteristics of lithic assemblages to issues beyond their manufacture and direct use. Additionally, many suggestions about past activities at sites provide little pertinent information about how those events were organized or have structured the archaeological deposits. For example, to suggest that hunting occurred at a site does not address the vast alternative practices of animal procurement that have significantly different potential consequences for site content and patterning. There is no simple expectation regarding how identifiable hunting technology is expected to be related to zooarchaeological evidence for particular animal exploitation.

Archaeology often suffers from minimal use of ethnographic information about behavioral variability and over-reliance on just a few models derived from ethnoarchaeological research. For example, several of Binford's (1978, 1979, and 1982) observations about technology have been adopted as typological schemes, and are assumed to be qualities of particular assemblages. Their "identification" is often stipulated without methods for distinguishing whether those inferences are warranted (Bamforth 1986; Bleed 1986; Shott 1996). The initial explanations for Binford's organizational groupings were entirely behavioral and included highly disparate gear items. There are no simple intuitive ways to infer such behavioral roles as curation, expedient use, logistical mobility, or situational use purely from the physical characteristics of those implements. It is their use, not their physical characteristics that define their roles. While these relationships can be obscure, they are not beyond the abilities of our current analytic techniques to identify. In sum, organizational qualities such as curation or expedient use cannot be assumed to exist in particular assemblages and many potential past organizing parameters are likely to be unique and unrelated to measurable qualities of the remains of technical systems (i.e., labor force and consumer make up of a group, previous activities and anticipated future events, seasonality or social structure).

It is critical to develop linkages between common lithic technological residues and other classes of remains that offer independent means of evaluating inferences from and about technology. An additional and significant obstacle to more inclusive analyses of artifacts is the assumption that what is preserved in the archaeological record (primarily lithics and ceramics) represents important components of that past system. While it is possible to create a range of suggestions about raw material provisioning and production trajectories from lithic analyses, there is no reason those inferences represent activities that are causally linked to the structure of working spaces, mobility, or subsistence. Aside from non-technological behaviors that condition the patterning of archaeological remains, lithics are represented disproportionately to their probable influence on spatial and associational relationships. Evidence from ethnoarchaeology and rare preservation contexts demonstrate that in many settings (including the American Southwest) organic technologies such as baskets, string, and wood are significantly more critical gear behaviorally (Adovasio et al. 1996; Thomson 1964: 406). The manufacture of string and wooden items can command much greater time, energetic efforts, and spatial commitments than the relatively rapid production of lithic implements (Albright 1984: 57-58; Gallagher 1977: 410; Gould et al. 1971: 157, Hayden 1987; Thomson 1964: 404, 411-417, 420; Tindale 1972). The manufacture and use of these organic technologies can be linked to significant camp spatial organization, seasonal material collection, mobility, and labor structure.

As noted above, while debris studies do potentially allow very sophisticated understanding of production sequences (i.e., raw material choices, reduction, and refitting), use (i.e., use-wear, tool rejuvenation, refitting), and discard (i.e., raw material, reduction methods, refitting, use-wear), the relationship of those behaviors to subsistence activities is complex. The most appropriate use of lithic analyses is to link them to other classes of material residues that may have more direct implications for activities. For example, at the Bugas-Holding Site in northwestern Wyoming

(Rapson 1990; Rapson and Todd 1992), the lithics recovered consist almost entirely of flakes that are 3-5 mm in maximum dimensions. Fetal bison bone at the site provides very good seasonality for the site (late winter-early spring) and abundant bone remains yield detailed information about subsistence hunting during that occupation and in the fall before the site was used. The lithics do not suggest what specific implements were being made, used, or discarded at the site. However, the dominance of small retouching flakes and the seasonality data strongly indicate that lithic raw materials were being very minimally re-worked to conserve them, probably because of the difficulty in restocking lithic supplies during winter. The results of this analysis were independent of expectations about the kinds of tools that would be useful in the context of fall-spring bison procurement and extensive bison processing. The lithic remains themselves offered few clues about technological organization without the secure seasonality data supplied by fetal bison remains.

As an example of larger landscape scale problems of technological analysis, expansive surface lithic scatters along the Río Grande in Texas are associated with immense nearby deposits of gravels rich in a broad variety of cherts and a large numbers of minimally reduced bifacial pieces (Greaves 2001: 16-17, 302-303; Vierra 1998: 120-121, 126). Several such areas of the Río Grande Plains have been interpreted as lithic procurement sites (Epstein 1969: 6; Uecker 1994: 12; Vierra 1998: 222-223), and the bifaces from these sites are considered preforms of bifacial tools (Epstein 1969: 43-46; Vierra 1998: 134). The assumption that these implements represent the knapping trajectory of the production of a particular biface is not always supported by analyses (Greaves 2001: 274-275; Vierra 1998: 127-128, Table 9-10).

Debitage at some of the sites is dominated by small flake sizes, minimal cortex presence, and dorsal flake scars; all suggesting mid- to late-stage bifacial reduction. Vierra (1998: 222-223) argues that material procurement costs at site 41MV120 were moderately high, based on the recovery of lithic tools that had been heavily resharpened and only discarded after extreme tool exhaustion. These arguments seem contradictory given the ubiquitous availability of a wide variety of good raw materials. However, the occurrence of the gravels along the Río Grande is spotty and the closest outcrops to site 41MV120 are found 800 m southwest of the site. Moreover, the presence of prepared cores and large flake blanks brought to 41MV120 from the procurement locality represents an increased investment in the production beyond that needed to simply replace exhausted tools (Vierra 1998: 222). Lithic economy was important prehistorically under many circumstances (see above discussion of the Bugas-Holding Site). For the occupants at site 41MV120, the distance to suitable gravels was ameliorated by bringing prepared cores to the site. Hence, while the abundant presence of many cherts in some portions of the Río Grande Valley suggests that all sites in a broad region have ready access to lithic raw materials, decisions about traveling the distance needed to acquire the goods can and did vary. Under circumstances where lithic resources are abundant, there is little premium on conservative reduction behavior, and discarding bifacial cores (or even “potential” preforms) with minor flaws, or using expedient flake production are economical activities because of the ease in locating other suitable cobbles. Bifaces are the products of a technique of reduction (Kelly 1988) and not solely a tool form or single production strategy.

Inferring subsistence activities from lithic artifacts assemblages is not simple (Andrefsky 2005: 201; Greaves 1997: 287-290). It is problematic to identify specific subsistence behaviors unambiguously. However, there are characteristics of site re-occupation dynamics and artifact diversity that can provide baseline information useful in suggesting the kinds of organizational parameters behind foraging (Andrefsky 2005: 201-244). Lithic analyses must be combined with the broadest possible range of recovery and analytic approaches to rigorously provide contextual information that can be used to address past subsistence. Faunal and plant remains offer information about potential foods that may have been exploited. The relationships of activities to

acquire those resources (even hunting) rarely provides direct information that is useful for understanding most lithics. The majority of stone artifacts are debitage, and they cannot be readily associated with the production of particular tools. There are qualities of those assemblages that provide information about mobility to access raw materials, target kinds of reduction activities, relative duration of occupations, potential resource availability, and specific technological events that all can be linked to larger questions of settlement and subsistence. Faunal and plant remains do offer information about the kinds of exploitation activities and where they might have occurred that can provide a framework useful in modeling the production and use of stone tools. They provide seasonality data and other crucial information about past environments that affected how technology was integrated into the other behaviors necessary for living in the Fort Bliss area. The lithic analyses advocated here stress an integrated use of debitage and other remains to exploit their implications for a range of understanding of past adaptations and are not focused solely on functional explanations or only to describe past technological systems of production.

The analyses goals and methods proposed for the artifacts from Fort Bliss address conventional issues of raw material procurement, manufacture, use, and discard. Through collection of other classes of archaeological remains, relational data and context determination, links can be created that allow the use of lithics and other artifacts to investigate a range of past behaviors that are not directly identifiable solely from the artifacts' technological attributes. Comparisons between different classes of materials will include assemblage diversity, density, associations with any features, temporal variability, evidence of re-occupation or single use events, seasonality data, environmental location, and proximity to other sites or isolated occurrences.

Research and Analysis Methods

Lithics are the most common artifact class recorded for sites on Fort Bliss. Lithic analyses should focus on several standard approaches to raw material representation and use, lithic reduction, and functional interpretation, and combine these with spatial analyses and comparisons with other artifact assemblages. Recommended typological and attribute analysis methods are outlined in Appendix B.

Perishable Technologies

Perishable artifacts have been recovered from a number of local and regional rock shelters and caves. Early excavations at Ceremonial Cave and Hueco Mountain Caves on Fort Bliss, and Fresnal Shelter, Chavez Shelter Tularosa Cave, Cordova Cave, and Bat Cave in southern New Mexico produced over 2,500 perishable items. Excavations by New Mexico State University field schools at a number of Organ Mountain rock shelters (Located just outside of Fort Bliss) in the 1980s recovered perishable items as well, with Roller Skate Rock Shelter producing the most (see MacNeish 1993).

The full range of perishable artifacts is probably unrecognized in the archaeological record at present. Archaeologists tend to focus on what they can see. Because examples of actual organic technologies are rare, archaeologists tend to overlook their role in day-to-day prehistoric life. Yet perishables were very important in prehistoric day-to-day life. Clothes, containers, shoes, shelter, and the majority of hunting technologies used were likely perishable items. Recognition and understanding of the role of perishable technologies is only beginning to be addressed in the Jornada Mogollon region and perishable technologies were not addressed in the original *Significance Standards*. The following discussion seeks to correct that oversight. However, this is not an exhaustive review, but focuses on the major perishable technologies known, or suspected, to have been used in the desert Southwest. These mainly include; wood, fiber, gourds, and animal (hides, bones, etc.) materials. Oswalt (1973), in his study of technologies and

habitats, highlights the essential role of simple perishable tools in the survival of desert dwellers. He (Oswalt 1973: 66-67) states:

I am led to conclude that early historic gatherers could not have survived in extremely dry areas without the following forms:

- two simple instruments, one being a digging stick
- two simple weapons, one being a spear
- one complex weapon: either the bow and arrow, or spear and throwing-board.

With these five items in addition to production tools and at least one carrying container, basic survival could have been achieved.

Clearly perishable tools, or perishable components of tools, dominate his list.

Wood Technologies and Artifacts

The most numerous wooden artifacts recovered have been projectile, spear shafts, bows, throwing sticks, hunting crooks, and snares. The evidence for these artifacts from sites in or close to the Jornada Mogollon region is reviewed below.

Cosgrove (1947: 48-50) reported the discovery of two unbroken atlatls as well as several fragments of atlatls from the Hueco Mountain Caves. The atlatl themselves were made of oak, mesquite and “thorn-growth tornillo”, while the shafts were made of “sotol bloom stalks”. Hibben (1938) reported on the contents of a cave in the Mogollon Mountains to the south of the Gila Cliff dwellings. The contents included 92 wooden bows. Most of the bows were apparently formed from oak, although piñon, pine, willow, mountain mahogany, and sycamore were also used. Most of the arrow shafts were made of sacaton reed.

Interestingly, only a few of the shafts were notched for stone points; the vast majority was wooden-tipped. The bows described by Hibben (1938) are in direct contrast to the bows and arrow shafts recovered by Cosgrove (1947) during his exploration of Hueco Mountain Caves. From the various caves, he reports reed arrow shafts with hard wood foreshafts, often notched for stone points or with stone points attached (Cosgrove 1947: 36). Some of the arrow shafts were described as “sotol bloom stalks”.

While spears and bows were used to stalk rabbits, it appears the preferred tool in the Southwest and Great Basin was the throwing stick. A number of them were recovered from Ceremonial Cave. The classic throwing stick is similar to a boomerang with its curved appearance. However, unlike the boomerang, the throwing stick is a non-return weapon. These sticks are known from ethnographic records and from prehistoric caches throughout the Great Basin and Southwest. The sticks may be decorated and there is some evidence that the lethality of some were enhanced by embedded sharp lithic flakes in the leading edges. Thus, they were formal, rather expedient tools, taking some skill and effort to manufacture.

The sticks were made out of hardwood, with mesquite, oak, dogwood and others mentioned in the literature. Examples recovered from a cache in California are about 70 cm (27 inches) in length with a weight of 250g (Koerper 1999). Rabbit sticks are ethnographically documented throughout the arid west, including among Apaches (Koerper 1999). Although predominantly identified as a small mammal, and specifically rabbit weapon, there are ethnographic accounts of use of the throwing stick for hunting larger game and birds as well. Generally, they were crafted from hard woods, including mesquite.

Koerper (1999: 258) describes them as “...roughly lenticular [in cross-section], but the weapon may have a slight airfoil shape that would cause lift, thereby counteracting gravitational forces”. In use, the weapon was:

hurled edgewise with sidearm motion, and with the anterior wind directed inward. Thrown so that it sailed just off the ground the rabbit stick had a greater range than a thrown rock, and cut a lethal swath of about 1 meter wide, increasing the likelihood of hitting the target (Koerper 1999: 258).

The advantage of a throwing stick over a projectile weapon such as a spear or bow and arrow lies in the performance characteristics of the throwing stick. In flight, the stick rotates, effectively widening the path of possible contact up to 1 m wide. Sticks also have a greater range than spears because of their inherent lift characteristics in flights. Based on modern experiments, throwing sticks are best used in open or semi-desert terrain.

Examples of throwing sticks found locally were made from oak, mesquite, and ocotillo, were either round or flattened, and were from 19-24 inches in length (Cosgrove 1947: 60). This length is shorter than those described above from California, but it is unknown if this was a cultural preference or if a specific length had a technological advantage.

In contrast to throwing tools, hunting crooks can be considered a type of active snare. Hunting crooks are long, cane-like tools that were primarily used on woodrats, but were also employed in rabbit hunting. Their use involved thrusting the crooked end down a burrow until it either flushed the animal out of the burrow to waiting hunters, or was twisted into the fur of the animal to extract it from its den or burrow. The hunting crook was a widespread tool common in the Great Basin and Southwest (Mohr 1951).

Snares are one of the simplest hunting tools and require very little in terms of preparation and use. Snares were generally simple loops of fiber tied at the entrance of the burrow or along rabbit paths. The loop of these noose snares were slightly larger than the head of the rabbit; once placed over the head and pulled tight it prevented the rabbits' forward motion. Pitfalls were also employed and consisted of one or more deep holes (4-5 ft deep) dug along rabbit trails (Fowler 1989). Shaffer and others (1996: 145), in a study of snare hunting depiction on Mimbres pottery conclude: "These motifs portray the deployment of multiple snare traps to procure multiple game by male trappers." Additionally, trapping activities were probably conducted in conjunction with other hunting activities. A number of snares have been recovered from local caves. These include "hinged-stick snares", and "cord snares" consisting of either simple sticks and yucca cords or just cords themselves (Cosgrove 1947).

Another hunting tool made of wood is the wooden bunt. The bunt consists of the ends of wood logs at least 5 cm in diameter. The distal ends are shaped to a rounded form while the proximal ends are reduced by carving them to a narrow handle, several centimeters smaller than the distal end. The proximal end would have been hafted to a pole, much like dart points were hafted to spears. Once hafted, they would be used to stun small mammals and birds. Several wooden bunts were recovered from Ceremonial Cave in the Hueco Mountains. The workmanship on these specimens demonstrates that the carver(s) was highly skilled.

Tool Wood Procurement

There has been very little published on the techniques and economics of wood procurement for tool manufacture (as contrasted by an immense body of literature on lithic procurement). Wilke (1988) reviews the ethnographic and archaeological evidence of the harvesting of juniper for bow staves in California and this remains one of the more informative studies. However, other than Wilke's (1988) study, the procurement of tool wood is *terra incognita* at this time.

Given the evidence that the dried stalks of yucca would serve as serviceable atlatl and arrow shafts, and given that yucca stalks are numerous in the central basins and foothills, at least under the current climatic regime, experimental and archaeological inquiry into the use of dried stalks

of yucca for tool manufacture by the prehistoric residents of the Hueco Bolson and Tularosa Basin could be informative. At the same time, land use studies should consider how wood procurement needs might have affected settlement strategies.

Fiber Technologies: The vast majority of prehistoric fibers in the Southwest seem to have come from *Yucca* sp. and *Agave* sp. The processing of both is similar and, because the literature on yucca fiber processing is larger, the following discussion will focus on yucca fiber. As stated earlier, both *Yucca elata* and *Yucca baccata* were valued sources of fiber for a variety of woven items such as sandals, baskets, pouches or containers, and mats. *Yucca elata* leaves grow more quickly than the stem and remain green throughout the year (Campbell and Keller 1932: 367). During their study of *Yucca elata*, Wallen and Ludwig (1978) found that leaf growth was low during periods of low rainfall, but that two periods of growth, corresponding to spring and winter rainfall, were possible annually.

There is conflicting information concerning what time of year yucca leaves are harvested. Ethnographic accounts describe both year-round collection and a preference for new leaves (Bell and Castetter 1941: 6; Stevenson 1915). Experimental archaeological work suggests that weathered, dried leaves are easier to process: “It seems probable that the Indians cut leaves in the fall and subjected them to winter weather” (Osborne 1965: 47). In contrast, agricultural studies state: “In practically all cases the green leaves were more easily decorticated than the dry [leaves]” (Botkin and Shires 1944: 25). Elsewhere, agricultural studies of yucca find that: “The fiber of the younger leaves from the center of the crown of *Yucca glauca* was found to be stronger than that of the older bottom leaves” (Botkin et al. 1943: 34). New leaf growth is not seasonally constant, and would affect scheduling if harvesting focused on new leaves. Ludwig and Whitford note, “When production of fruits [in *Yucca elata*] is high, production of new leaves remains very low” (Ludwig and Whitford 1979: 274).

Saunders (1992), in his analysis of lithic assemblages from the Lower Pecos region of Texas, provides evidence that bifaces, unifaces, and utilized flakes were used to cut the leaves of yucca (as well as lechuguilla and sotol). He bases this on previous experimental work and use wear analysis of the stone tools that exhibit both polishing and organic residue (Saunders 1992). Elsewhere, Downum (1986) attributes the cultivation of several wild species, including yucca, to the location of linear terraces and specialized toolkits at a Classic period site in the Tucson Basin.

Osborne (1965), in experimental work involving the entire preparation process, found that a bone tool made from a humerus and held against a cobble stone was not an effective method of preparation. Further, she did not find that pounding the leaves was an effective method to breakdown the leaf. Soaking and boiling were effective, but roasting was unsuccessful (Osborne 1965). Another often-mentioned technique was the chewing of yucca leaves to separate the fibers, leaving behind quantities of chewed yucca quids. Such quids and quantities of chewed yucca fiber have been reported from caves in the Hueco Mountains (Cosgrove 1947). However, Osborne, based on her experimental work, doubts that chewing would have been an effective technique. Most recently, Haas (2001) proposes a model of yucca fiber processing based on the analysis of fibers from Utah and processing experiments.

The tools needed to harvest and process yucca leaves for fiber are largely undocumented, but they may have been much like the sharply pointed wooden digging sticks and stone hoes (or knives) used by the Mescalero Apache when harvesting agave. The stone hoes are large, palm-sized, flattish bifaces. A cutting tool for detaching the leaves from the plant and probably a basket, carrying net, or cord for bundling the leaves would be all that would be necessary to harvest the leaves. Questions about the processing of plants for fiber and the tools necessary have resulted in three experimental studies examining the function of a type of lithic tool termed the scraper plane or pulping plane. Scraper planes are common tools in some arid areas and time periods. In

California, they are used as one of the diagnostic characteristics of the Millingstone Culture (Kowta 1969). In Arizona, scraper planes have been associated with Hohokam agave cultivation (Fish et al. 1992). Some studies support an interpretation of scraper planes as soft plant (yucca and agave) processing tools used in fiber processing. However, one study has concluded that these artifacts are not tools, but are actually only cores (Salls 1985). On the other hand, ethnographic information, albeit scanty, indicates that scraper planes were used as tools and also indicates the manner of using them:

[A] Southern Diegueno informant has described them [scraper plane tools] as being used in the preparation of fiber for cordage. The green leaves of various species of agave were placed on flat rocks or the backs of metates and the pulp pushed out with these heavy planes, which were manipulated exactly as a carpenter's plane (Rogers 1939: 50).

Hester and Heizer (1972) tested an unused but archaeological scraper plane to remove the pulp from agave leaves and concluded:

our experiment showed that tools such as those from Mitla and Yagul [archaeological sites in Oaxaca, Mexico] could be effectively used in a push-plane motion to decorticate and express the pulp from Agave leaves. The close correspondence of the use-wear on the tool used in the experiment and those with ancient wear patterns provides the best indications of the function of the tools at Mitla and Yagul.

At odds with these results is another set of experimental work on yucca that found the tool performed poorly if used like a carpenter's plane when worked, but functioned well if held at an angle (Salls 1985). Scraper planes have not been identified in the local literature to date, but it is possible that they are present but have been misidentified as cores. Agave knives have been recovered from sites in the Tularosa Basin and Hueco Bolson (see examples in Chapter 8), but have not been subjected to detailed analysis.

Fiber Containers

The striking thing in reviewing current perishable technological literature, particularly those of woven fiber, is the myopic focus on the objects themselves. This view stems from a general assumption that perishable artifacts "offer singularly high levels of cultural sensitivity and analytical resolution" (Hyland 1997: 1). This has resulted in seemingly over-detailed examination and classification of these items. For example, McGregor (1992), in her study of Pecos (Texas) basketry classifies them with nomenclature like Type XV and defines the type as having "90 degree self-selvage and double 90 degree self-selvage: Twill Plaiting, 2/2 Interval" (McGregor 1992: 58). She does go on to present a brief ethnographic summary of basketry use and then relates her types to function, but it seems almost an afterthought.

Basketry fragments have been recovered from rock shelters in the Jornada region. One fragment from Ceremonial Cave was coiled using yucca fibers around small twigs. Photographs of Mescalero Apache women taken in the early twentieth century by Edward Curtis show them traveling with large carrying baskets on their backs secured by a tumpline across their foreheads.

Pitched baskets for liquids are found in numerous Southwestern and Great Basin cultural groups. These baskets require a substantial labor investment and considerable skill to make. Willow seems to have been a preferred material, although any material that would swell and tighten the coils upon soaking would work. After completion, the interior is coated with plant resin (e.g., Van Stone 1997; Zigmund 1978). Often two or three lug handles of twigs or horsehair were woven around the upper circumference of the basket. Bundles of grass were used as stoppers (Reagan 1930). At least one author reports these baskets were not used for long-term water

storage as the water would take on the flavor of the pitching substance (Haley 1981: 106). Opler (1983: 433) reports that “In a [Mescalero Apache] household would be found pitch-covered woven water jars (for camp use, since on the march the Mescalero carried water containers made from the stomachs or intestines of animals). . .”

Long nets were used as barriers in communal hunts. “Two or three men put their nets together....Then they spread out and drove the rabbits towards the nets. The drivers shot the rabbits with their bows and arrows whenever the rabbits were close to them” (Fowler 1989: 27-28). A number of these nets have been found cached in caves, the longest being over 50 meters long (Kaemlein 1971).

Sandals have been found in some abundance locally (Ceremonial Cave had in excess of 900), almost all of them are constructed of yucca fiber and cords. No sandals made of leather have been found. Several construction varieties of yucca sandals were noted by Cosgrove (1947) in his examination of sandals from local and regional caves and rock shelters. A number of these different types occur locally, with two, Types 7 and 8 Full Length, limited to the Hueco Mountains and the Big Bend area (Cosgrove 1947: 94).

Gourd containers were perhaps some of the earliest known containers in the New World (Doran et al. 1990; Wilson 1950). Wilson (1950: 84) states: “The gourd has held an important place among the Indians of the Southwest. From numerous archaeological sites have come bits of gourd-rind, gourd-seeds, and gourd-shaped ceramics; and ethnologists and historians have included the gourd in their descriptions of Indian economic life, myth, and religious beliefs and practices”. Gourds were often used as ladles and cups, with the larger ones used for water canteens (Wilke and Fain 1974). Their use as rattles has also been described as important ceremonial items.

Animal Materials

While antelope and deer hide were undoubtedly used, rabbit fur provided cold weather clothing. Steward reports that a Paiute rabbit blanket required the skins of 50-75 jackrabbits (Steward 1933). To procure that many skins, communal rabbit hunts were probably the preferred method. As Shaffer and Gardner (1995: 14) point out: “While meat was always consumed and was a significant dietary component, another very important impetus for the rabbit drive was the procurement of skins”. A rabbit-skin blanket was recovered from Ceremonial Cave where it had been used to cover an adult woman and a child who had been buried together. At least one burial at Granado Cave in the eastern Trans-Pecos was covered with deer hides (Hamilton 1998).

Status of Local Research

The only study of local perishable technologies since 1996 has been Hyland’s dissertation on Pendejo Cave (FB 9366) (Hyland 1997). Over 800 perishable items from nine cultural layers were recovered during MacNeish’s excavation of the cave. Excavations at Tornillo and Todsens rock shelters recovered another 400 items. The Pendejo Cave excavations produced cordage, basketry, sandals, netting, fiber wrapped twigs and other items, quids and pads, cane cigarettes, bundles of grass, and feathers.

Hyland’s study focused on the perishables in relation to site function and technological development. Acknowledging the controversial aspects of MacNeish’s proposed chronology for the site (see Chapter 3 for a summary), Hyland (1997: 319) states: “...the refutation of the context and associated dates of these deeply placed materials [pre-Clovis and Clovis] does not fundamentally alter the basic interpretation about site-use parameters”.

Hyland proposes a six stage developmental sequence. In Stage 1 (found in the deepest deposits), the perishable technology is summarized with the following: “The principal cordage byproduct is

knotted netting with sheet bend or weaver's knots. Miscellaneous *ad hoc* utilitarian constructions are also present in the form of modified stick and twigs, bark rings, etc. The preferred raw material for most types of perishable production is *Yucca* sp." (Hyland 1997: 321).

Stage 2 (recovered from the next deepest deposits, and thought to correlate with late Paleo-Indian period) is unusual in that it is almost devoid of perishable items. Hyland notes that this is striking because Colorado Plateau and Great Basin populations at this time used extensive perishable technologies. He offers two explanations: (a) a local abandonment during this time; or, (b) a shift away from perishable technologies locally. He does not endorse either of the explanations.

In Stage 3, cordage technology is similar to Stage 1, with additional cordage types becoming more numerous during the later parts of this stage. Coiled basketry appears during Stage 3, and is similar in construction to Colorado Plateau baskets.

Hyland suggests a fundamental change took place in perishable technologies in Stage 4 and he attributes the change to technologies found in Mexico blended with local traditions. He (Hyland 1997: 324) notes: "As none of these innovations [in perishable technologies] has a previous record north of the Jornada Basin and given their extensive antiquity to the south, a southerly point of origin for these changes is virtually certain". He adds: "By the middle of this stage, the distinctive Mogollon ethnic signature is apparent in the perishable industry of the Jornada Basin a full 1,000 years before the appearance of ceramics" (Hyland 1997: 324).

In Stage 5 the hybrid technologies from northern sources (Colorado Plateau) and southern sources (northern Mexico) continue, but undergo significant change. Fabrics and distinctive Anasazi-type baskets appear. "The miscellaneous inventory is highly varied and includes non-utilitarian or ritual items like cane cigarettes, pahos, and related paraphernalia, all of distinctly Basketmaker/Anasazi flavor" (Hyland 1997: 325). The final stage, Stage 6, corresponds to the post-pueblo period. In this stage, the perishable industry is sharply reduced until about the time of European contact when a number of 'alien' technologies (Apache, Navajo, and Numic) appear in the local record.

One of the last frontiers in the analyses of prehistoric technologies is the interplay between the various technological systems, perishables being the most problematic. How did organic (perishable technologies) influence and interact with other technologies? Did ceramic technologies supplant or supplement basketry? Too often, each technological subsystem (lithic, ceramic, etc.) is treated as a stand-alone entity, when in reality it is not. The challenge in understanding the role and interaction of perishable technologies with other and with non-perishable technologies is how to measure and study the impact of perishable technologies when the perishable artifacts are no longer present. How can the interaction of basketry and ceramics be interpreted on a site when the basketry has long since disintegrated? What are the factors relating to the choice between lithic technology and organic technology for hunting tools? Without considering the role of perishable technologies, interpretations of the archaeological record are biased.

There has been some recent work that may provide an avenue to examine some of these questions. These works stem from *Human Behavioral Ecology* using the perspective of 'investment' by factoring energy requirements into tool selection in an optimal foraging framework (Ugan et al. 2003). Bettinger and others (2006) takes issue with the application of this model by arguing that it does not accurately reflect the interplay between available and which of those available technologies will be adopted under various 'use times' inherent in the technology. Use time is defined as "...the amount of time the tool is used for procuring resources" (Bettinger et al. 2006: 539). Kirk, in a long forgotten article, provides some ethnographically based estimates of the time to make various types of baskets, making it clear that baskets are 'costly' in terms of time investment (Kirk 1952). Thus, this approach may allow for the examination of

why, and under what conditions, ceramic container technologies were chosen over woven container technologies. Other than the obvious suitability differences between the two technologies, is 'use time' a significant factor? How does 'technician time' relate?

Deficiencies and Needs of the Existing Knowledge Base

Recent work in the El Paso area has highlighted some deficiencies and needs in the regional database. Whalen (1994a) set out to investigate the role of residential mobility in late prehistoric (or Formative period) adaptations to the Jornada Mogollon area. In pursuing his investigations at Turquoise Ridge, Whalen noted that few large-scale excavations at Formative period sites were represented in the Jornada region as compared to the rest of the Southwest. This may be a fair statement for all periods in the Jornada area. Most of the sites where excavations have been conducted situated in only three environmental zones: the central basin, the alluvial fans, and the Rio Grande Valley.

Since publication of the 1996 *Significance Standards*, over 30 data recovery projects have been undertaken at Fort Bliss. These include several Mesilla, Doña Ana, and El Paso phase residential settlements (Church and Sale 2003; Church et al. 2007; Lukowski et al. 2006; Miller 2007a) and numerous small sites in the Hueco Bolson (Condon et al 2005; Condon, Hermann et al. 2006; Condon, Hall et al. 2006; Condon et al. 2007; Graves and Ernst 2007; Mauldin et al. 1998; Sitton et al. 2005) and Otero Mesa (Quigg et al. 2002). Details of investigations at the Conejo Site (FB 46) on Fort Bliss that has figured prominently in various research studies over the past 20 years (Goldborer 1985; Hard 1983a; Hard et al. 1996) but was never fully described or reported, have been published and provide a first view of site layout and several aspects of material culture for this site (Miller and Burt 2007).

Investigations at several sites outside of Fort Bliss have also been reported, including the U.S. Highway 54 project (Railey 2002), the Loop 375 project (Dering et al. 2001), and the EPAS excavations at Hot Well Pueblo (Lowry 2005). These mitigation programs have provided a near exponential increase in the amount of information on settlement adaptations ranging from mobile, low-intensity occupations to sedentary pueblo settlements. As a result, excavations have been completed in a wider array of environmental zones and in more temporal periods. Early and Middle Archaic and Paleo-Indian components, nonetheless, continue to be underrepresented. Unfortunately, these components are the most difficult to identify and, when identified, often are small, eroded sites located in the central basin where considerable deflation has occurred.

Because of the Fort Bliss CRCP report (Miller 1996), the chronological picture for the Formative period has improved substantially since Whalen's (1994a: 23-26) call for more precise dating of ceramics and architecture in the Jornada region. Nonetheless, there continues to be a need for extensive excavation, dating, and intensive analyses at extramural features in pueblo sites. Only at Firecracker Pueblo and the Jaca Site have trash and storage pits, hearths, and other extramural features been extensively sampled (O'Laughlin 2001, 2002; Railey et al. 2002). A broader range of pueblo period sites, selected for their ability to yield data on activity patterns, subsistence practices, group compositions, stability of residence and seasons of occupations, need to be investigated.

Miller (1990) focuses on ceramic developments during the Doña Ana phase (Transitional period: A.D. 1100-1200). Miller notes that despite 40 years of archaeological work in the Jornada Mogollon, a reliable and consistent ceramic chronology is still lacking. Questionable ceramic associations have been further exacerbated by the fact that much of the work in the region has consisted of surface surveys (see also Hard et al. 1994: 267-283). Another continuing problem is a lack of chronometrically dated assemblages that would allow for such developments to be independently tested, as well as a lack of excavation data to examine ceramic associations and their relationships to architectural or midden features (Miller 1993). Some specific vessel form

differences may be temporally significant. Studies of vessel form through time, coupled with analyses of decorative styles, should produce more precise understanding of Jornada ceramic trends relative to regional cultural developments.

In contrast to the advances in ceramic studies, stone artifacts are common on the region's sites but continue to be less intensively studied than ceramics. Whalen (1994a: 92) points out that tool function analyses are uncommon in the region's literature and ground stone tool studies are rarer than chipped stone analyses, although the number of studies have increased in recent years. With the increase in excavations over the last decade, archaeological understanding of intraperiod variability in lithic usage has improved (see Miller 2007a).

Church and others (1996), working on Fort Bliss, located, documented, and sampled 228 lithic sources during a three year fieldwork effort. They point out that prior to their study, lithic source studies in the region generally consisted of poorly defined material types based on visual criteria and an incomplete understanding of the nature, distribution, and variation of the lithic resources available. These deficiencies have inhibited investigations on mobility, trade, lithic procurement strategies, and intraregional interaction. While their work has improved studies on those investigative fronts, as pointed out in Chapter 2 there are limitations and much work remains to be done. Church and others (1996) also note the paucity of recognized lithic procurement sites, although Lukowski and others (2006) and Knight and Miller (2003) have recently identified lithic procurement areas in the Hueco and Sacramento mountains, respectively.

RESEARCH ISSUES

Humans have often been defined in terms of their special ability to make tools, and archaeologists in the past have seen human progress largely in technological terms. For instance, in the nineteenth century the human past was divided into "ages" of stone, bronze, and iron. The analytical focus on a variety of aspects of technology allows a gain of information regarding what raw materials were used, the source of the raw materials, the possible place and mode of production, and a possible date or period of manufacture and/or periods of use. Technology touches on every aspect of prehistoric existence, subsistence, settlement, etc. Clearly, inquiries into technology often overlap into other research domains.

That said, the set of technological research questions in the 1996 *Significance Standards*, many of which are still expressed below, reflected a basic analytical perspective of the 1980s and 1990s. That is, a focus on spatio-temporal patterning, that essentially asks is there a pattern and if so, what is it? There were no expectations derived from anthropological models and thus research was directed in a way that was unfocused, expensive, and required substantial investment in dating or pan-project data compilation.

For a cultural resource program under pressure from increasing land use demands, such an approach is ultimately doomed to disappointment as it produces little or no advance in knowledge. If these questions are the only perspective used, they result in collecting data and suggesting general, often redundant, pseudo-anthropological explanations (i.e., mobility increased, mobility decreased, subsistence shifted, etc.). Instead, the development of research questions should arise from an overall research initiative and acknowledge the regulatory environment and its limitations and needs with some of the questions below used as intermediary steps in the broader research initiative. Examples of those broader research frameworks are presented in Chapter 14.

The following questions are framed within the context of the Analytical Orientations as part of the Technology Matrix illustrated in Figure 9.1 (see Figure 9.1). Often questions are not and can not be couched within a discrete category such as "Function/Use/Damage" without also touching

on, or including other categories such as scales of spatial dimension (e.g., landform, region) or temporal dimension (e.g., Doña Ana phase or Paleo-Indian period). The following questions should be viewed from the flexible perspective of being applicable at all spatial scales of analysis (i.e., regional, zonal [environment], intersite, and intrasite). As has been stated previously, the technology matrix has the possibility of a myriad of permutations for questions moving from synchronic to diachronic, from relatively low levels of abstraction to higher levels of abstraction. Questions posed here are but a few. Answers to questions asked evolve into other questions, which can be formulated using the matrix. The goal is to move toward higher levels of complexity and abstraction.

Morphology

This category of questions deals with the individual aspects of tools but larger frames of reference are sought. The following questions were in the 1996 Significance Standards but still merit investigation under broader, anthropologically framed questions to achieve the broader characterization of artifact patterning through time and/or space. Information related to recent work is provided below some of the research questions. The enumerated research issues are as follows:

Research Issue 9-1

What are the spatial and temporal parameters for projectile point types known to exist in the region?

This basic building block of material culture studies continues to be essential. The only study undertaken since 1996 has been Seymour's (2002) work on Protohistoric assemblages. She proposes that Soto, Hidalgo (Variety A), Animas (Variety C), Rancho (Variety D), Chihuahua, and Bliss style projectile points are attributable to the Protohistoric Canutillo Complex (A.D. 1300/1400-1550). However, this proposal has been debated by Kenmotsu and Miller (2008).

Research Issue 9-2

What are the temporal parameters for specific ground stone forms?

The only temporal aspect of ground stone is the two-hand mano as a general indicator of an El Paso phase assemblage. However, this is misleading, since the real linkage is between two-hand manos and the intense processing of maize. Since the intense processing of maize is thought to occur primarily in the El Paso phase, two-hand manos have been used as temporal markers for that phase.

Research Issue 9-3

Does the morphology of ground stone change between broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) on Fort Bliss?

Research Issue 9-4

Does the morphology of ground stone change through time within those broad environmental zones?

Research Issue 9-5

What is the pattern of morphological variability of architectural structures through time?

Research Issue 9-6

What is the pattern of morphological variability of architectural structures over all broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) on Fort Bliss?

Research Issue 9-7

What is the ceramic chronology for the area and the region? What are the spatial and temporal parameters for the types and varieties?

Research Issue 9-8

What ceramic types are associated with the architectural forms in the region?

Research Issue 9-9

What architectural features and ceramic types are associated with the Early and Late Doña Ana phases (Transitional period)?

Research Issue 9-10

How does ceramic vessel form relate to function through time?

Production Mode

This set of questions involves the manufacturing trajectories of tool production, which involves acquisition of raw lithic materials, stages of tool production, and the delineation of temporal and spatial parameters. The following questions should be investigated to answer questions of spatial organization of individual technologies, stability and/or change in technologies, and ultimately stability and/or change in adaptive strategies overall.

Research Issue 9-11

Are there specific broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) that should be targeted for lithic sourcing studies? If so, what bearing does this have on acquisition strategies and can these be discerned?

Generally speaking, while having an idea of the lithic resources available in secondary sources such as alluvial fans, basin gravels, etc. is good, for sourcing studies the primary outcrops on the mountain slopes and upland mesas should be targeted.

Research Issue 9-12

Can specific lithic sources help to identify changes in strategies through time?

Research Issue 9-13

Were sources targeted for discrete temporal periods?

Research Issue 9-14

Do aggregate and morphological analyses have value for the Fort Bliss area as a whole?

Research Issue 9-15

Are there patterns to be perceived within these two methods that can be perceived through time or on a geographical scale?

Research Issue 9-16

Can ground stone sources highlight mobility patterns within the Fort Bliss region? Is there a difference east to west, north to south?

Given the localized nature of the preferred ground stone materials, ground stone should be an excellent indicator of mobility patterns, although no one has addressed the issue to date.

Research Issue 9-17

Can clay or temper sourcing effectively map acquisition strategies within the Fort Bliss region? Is this achievable?

Function/Use/Damage

This category is concerned with how implements were used, (e.g., microwear and edge damage analysis on lithics or ceramics), and their relationship to other components of artifact assemblages. These can also contain dimensions of time and space to discern patterns within features, sites, etc. The following questions should be investigated in order to achieve the integration of data at a higher level and to delineate adaptive strategies through time.

Research Issue 9-18

What are the differences in lithic usage between broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) on Fort Bliss?

Specific patterns have yet to be identified, but the general pattern is that local material types will dominate the lithic assemblage and hence reflect the environmental zone being occupied.

Research Issue 9-19

Do patterns of lithic use and edge wear change through time?

Research Issue 9-20

What are the patterns of variation in function/use among ground stone tools in the different broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) on Fort Bliss?

Research Issue 9-21

What are the patterns of variation in function/use among ground stone tools through time?

Research Issue 9-22

What are the functional differences among ceramic vessel forms at broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) on Fort Bliss?

Research Issue 9-23

What are the functional differences among ceramic vessel forms through time?

Research Issue 9-24

Do changes in form/function relate to organizational aspects or social arrangements?

Recycle/Curation/Disposal

The questions posed here deal with the strategies or processes and evidence of use by recycling or reuse, curation or caching, and disposal of implements or features. There are elements of both time and space that can be invoked in this category. Ultimately, answers to these questions prompt questions of a higher order involving social organization, adaptive strategies, and changes through time.

Research Issue 9-25

What are the patterns of recycling of manos and metates within or among broad environmental zones (i.e., basin floor, distal fan, proximal fan, mountain slope, upland mesa) on Fort Bliss?

Research Issue 9-26

What are the patterns of reuse or recycling of lithic materials at differential scales of analysis (i.e., region, zone, etc.)?

Research Issue 9-27

What are the patterns of reuse or recycling of lithic materials over time?

Research Issue 9-28

What are the patterns of recycling of ceramic materials over broad environmental zones and/or time?

Research Issue 9-29

What are the patterns of size variability for metates over the broad environmental zones and through time?

Research Issue 9-30

What patterns of artifact variability can be discerned about caches in the area?

Research Issue 9-31

What are the temporal patterns for caches?

Research Issue 9-32

What are the spatial patterns concerning caches?

Research Issue 9-33

What sociological implications do caches portray?

DATA NEEDS

Much of the key information to address gaps in the regional database can only be obtained through excavation. There is a need for large-scale excavations at sites of all periods and within the different environmental zones, particularly in rock shelters, in the alluvial fans, and along playa margins, encompassed by Fort Bliss's boundaries. These large-scale excavations in different settings and temporal periods are more likely to encounter data (in this instance technological data) that will highlight the full range of variation within the area. These projects

can focus on various data needs within Fort Bliss boundaries and for the Jornada region as a whole. Site structure is a data element that needs amplification. Recording the patterning of architectural features along with their attendant features such as trash pits, middens, storage facilities, etc., and artifact assemblages are necessary so that they may yield information on the entire range of prehistoric lifeways (i.e., subsistence practices, group composition, stability of residence, and seasons of occupation). The study of the technological aspects of all of these elements aids in bringing the full picture into focus. These projects would lend themselves to acquiring data on the technological/morphological variability among features, structures, and sites, and delineate changes through time and over the landscape.

Data needs in both lithic and ceramic developments across geographic and temporal planes can be addressed through large-scale excavation projects as well. Data are needed on lithic and ceramic associations and their relationships to architectural and midden features. Additional intraperiod temporal and spatial controls are needed on lithic and ceramic tools. Accumulation of temporal and spatial data for features is needed as well.

Continuing data gathering and analyses on all categories of lithic and ceramic tool functions are needed. Continued data gathering on the morphological, functional, and use-wear patterns of tools is essential. However, spatial analyses are crucial to the analysis of tool production and tool use. Continued collection of technological data on lithic and ceramic raw materials (and sources of those raw materials), and their acquisition and use over time and space are essential to answering higher-level questions of group social organization and adaptive strategies. These aspects cannot be inferred from tools alone. These must be inferred from results drawn from spatial distributions of stages of tool production processes relative to the distribution of raw materials. Inferences regarding the social organization of tool use can be derived from spatial distributions of tools within sites, from site to site, and the distribution of tools relative to exploited resources or paleo-landscape features in the absence of direct evidence for exploited resources (Ellis et al. 1994: 91).

CHAPTER 10. SITE FORMATION AND SITE STRUCTURE

Myles R. Miller

This new addition to the *Significance and Research Standards* reviews natural and cultural site formation processes and several issues involving the identification and interpretation of site structure. A fundamental understanding of site formation processes - the geomorphic, geoarchaeological, natural, and cultural transformations of artifacts and cultural deposits - serves as a prerequisite for understanding site structure. In turn, site structure provides important insights into the occupational histories of specific locations or sites. Site structure is therefore viewed as a critical prerequisite for broader-scale analyses of settlement pattern and land use. If we cannot understand the occupational history and group composition of specific locations and thus define even basic and generic settlement “types” (e.g., logistical/residential, camp/hamlet/village, multi-occupation palimpsest) how can we propose to model and understand larger settlement and adaptive systems?

Concerns with site formation and site structure are related to larger programmatic issues of site integrity and research potential. Therefore, this domain is not only important for prehistoric research but has direct implications for the NRHP-eligibility evaluation process. For example, determining whether any form of association exists between the scattered hearths and artifact distributions commonly found across the Hueco Bolson and Tularosa Basin is a paramount issue for any subsequent archaeological inference regarding this type of “site.” This is an essential component of evaluating the research potential and NRHP eligibility of sites that are often arbitrarily comprised of one or more of such hearth-artifact distributions.

Aside from geomorphic and geoarchaeological studies that dominated research during much of the late 1980s and 1990s, elements of site formation and site structure have received surprisingly little attention among Jornada archaeologists. As an example, the term “site structure” is mentioned only twice and “site formation” only three times in the 1996 *Significance Standards* volume. This is surprising as well as disconcerting for a number of reasons. First, as noted above, a basic understanding of the formation and structure of cultural deposits, features, and artifacts provides a critical empirical foundation for any subsequent interpretation of settlement history or function. For example, Mesilla, Early Doña Ana, and Late Doña Ana phase pit house sites often contain superimposed structures, multiple pit houses filled with refuse, and other evidence of multiple occupations. Viewing such sites as having been formed during two or three occupational events by one or two family groups (residing in one or two pit house structures) provides a very different analytic framework for broader considerations of population aggregation, mobility, and social structure than if such sites are viewed as coherent, single component village settlements consisting of four to six or more family groups (Miller 1989, 2003). Additional insights can be gained through analysis of refuse disposal patterns and comparative studies of refuse densities. Overall, refuse disposal patterns can offer several important clues to occupational duration and history at both long-term residential settlements and low-density, short-term hunter-gatherer camps. In addition, the spatial clustering of hearth features and house structures at Jornada Mogollon sites has intriguing parallels with several ethnographically documented hunter-gatherer settlements in other arid environments. Site structure - or community pattern - as expressed by the layout of residences and activity areas can offer insights into social organization.

Second, many sites on Fort Bliss provide very favorable contexts for the analysis of site structure. In fact, *the contribution of Jornada Mogollon site spatial analysis to the archaeological domain of hunter-gatherer settlement organization is potentially one of the most profound yet presently unrealized contributions of Jornada archaeological research to broader questions of archaeological and anthropological importance.* The thousands of multiple hearth and artifact scatters lying exposed or slightly buried in broad interdunal deflation surfaces across Fort Bliss provide an ideal context to study hunter-gatherer site formation and settlement structure. In many situations, substantial and important aspects of settlement structure can be revealed through simple point plotting of surface artifacts and features. In cases of slight burial, the numerous hearth features can be chronometrically dated, providing both an overall temporal assignment for the site as well as allowing for a basic estimation of whether or not multiple hearth clusters represent contemporaneous occupations. This fortuitous situation is quite unlike the typical prehistoric campsites throughout most of the world where immense efforts are required to expose, plot, and recover artifacts and features from deeply buried deposits.

The focus on settlement pattern and settlement organization that has historically dominated much of the research program at Fort Bliss has often been investigated or modeled at broad landscape scales, and thus it is perhaps not surprising that a rather casual attitude has been expressed towards site structure. However, the importance of site structure research was noted in the 1996 *Significance Standards* document:

“Site structure is a data element which needs amplification. The patterning of architectural features along with their attendant features such as trash pits, middens, storage facilities, etc., and artifact assemblages are necessary so that they may yield information on the whole range of prehistoric lifeways (i.e., subsistence practices, group composition, stability of residence, and seasons of occupation) [Lintz 1996: 172].”

Given the perspective that an understanding of site formation processes and site structure is a fundamental prerequisite to the study of prehistoric settlement organization, landscape use, and social organization, it was decided to add a new section to the revised *Significance and Research Standards* that dealt with these issues in greater detail. The archaeological literature on the variety of processes and phenomena described under the concepts of site formation, site structure, and community pattern is quite extensive, and only a cursory review is provided in the following section that outlines some potentially useful and productive avenues of research for Fort Bliss.

DEFINITIONS: SITE FORMATION PROCESSES, SITE STRUCTURE, AND COMMUNITY PATTERN

Prior to expanding on the issues mentioned above, it is necessary to define and clarify conception of the terms site structure and site formation, as the phrases carry different meanings among different researchers. Generally, the classic connotation of site structure - or what may more appropriately be termed settlement structure - is derived from Binford's (1983: 144; see also Binford 1982 and 1987) definition as the combined attributes of site size and the spatial arrangement of living spaces, activity areas, and other features such as hearths, pits, and storage facilities. This definition has subsequently been expanded to include discard and refuse disposal areas and other patterns reflecting the systematic use and discard of material culture (Hayden and Cannon 1983; Jones 1993; Murray 1980; O'Connell 1987; O'Connell et al. 1991).

Much of our understanding of site structure is derived from ethnographic and ethnoarchaeological research on camps and settlements of hunter-gatherer and horticultural groups. In archaeological research, it is usually involves methods of pattern recognition used in conjunction with models of behaviorally based material distributions derived from ethnographic, ethnoarchaeological, and actualistic research. This approach helps identify and characterize the locations of past activities

from which interpretations ranging from the duration and season of occupation, settlement function, group composition, and so forth may be drawn. Thus, it is clear from this definition that a precise conception of site or settlement structure serves as an important and indispensable prerequisite for higher order anthropological interpretations.

Site structure is sometimes conflated with the concept of site formation processes. As defined by Schiffer (1976), site formation processes are the events and processes that create an archaeological site. These processes were further classified under what Schiffer (1976) codified as *n-transforms* and *c-transforms*, or simply transformations that were created by natural processes and those produced by human behavior.

With the fluorescence of geoarchaeological research over the past decade the term site structure has sometimes been used to describe natural site formation processes. That is, the manner in which episodes of soil erosion, deposition, and stability, or other geomorphic processes, affect and condition - or "structure" - the distribution of cultural materials and deposits. For our purposes, "site formation" serves as an umbrella term that subsumes the combined long-term cultural processes and natural phenomena that result in the structure of a site as revealed through archaeological investigation excavation. Site structure may be viewed as a series of short-term "time-slice" impressions of spatial arrangements, while site formation processes are viewed as both short-term and long-term phenomenon. In other words, site formation processes create both the individual synchronic impressions of site spatial layouts and also condition them through the long-term until ultimately presenting what is recovered and viewed as the *statics* of the archaeological record (after Binford 1977:6, 1981:29).

The term "community pattern analysis" is also occasionally used in place of site structure, although traditionally it has involved a more restrictive form of analysis involving architectural layouts and social inferences derived thereof (Chang 1958). Analyses of this sort begin with establishing functional classifications of architectural units and domestic features and then proceeding to examine their spatial and configurational relationships. The fundamental assumption underlying such studies is that human groups situate their residences and activity locations in order to provide and maintain access to important economic and social resources (Lipe and Hegmon 1989).

One of the more common approaches of this sort of analysis in the Southwest involves the social and organizational aspects of unit pueblos, or Prudden units, and the ratios of kivas and great kivas to counts of rooms and room blocks (Prudden 1918; Rohn 1977). As with studies of site structure, community pattern analysis is often based on models derived from the ethnographic record, although recent critiques have taken issue with the restricted definition of community when applied to mobile and fluid Southwestern societies (Adler 1989, 1994, 2002; Hegmon 2002; Varien 1999).

It is sometimes perceived that community pattern analysis involves a larger social dimension than site structure analysis, which is viewed as more concerned with functional relationships between site spatial layouts and landscape settlement organization. This may also reflect the conceit, whether conscious or not, that social communities exist among agricultural societies but are not as prominent and relevant in less complex hunter-gather societies. This distinction is not maintained throughout the present discussion and the terms site structure and community pattern analysis are used interchangeably to refer to the same domain of investigation.

SITE FORMATION PROCESSES

A multitude of natural and cultural transformations exist, most of which have been enumerated and discussed in detail in Schiffer (1976, 1983, 1987), Wood and Johnson (1978), and Nash and

Petraglia (1987) and do not need to be repeated here. Many transformations and formation processes common to other regions of the world, such as agricultural plowing, are not necessarily relevant to conditions at Fort Bliss (although plowing has had some effect on historic sites in the lower valley of El Paso). The discussions in this section deal specifically with transformations common among the natural environments and prehistoric cultural contexts in the Fort Bliss maneuver areas. The past decade has witnessed several advances or new findings regarding site formation processes that deserve wider consideration.

Modern cultural practices have altered the exposure and erosional rates affecting archaeological deposits and the content of sites on Fort Bliss. The primary modern cultural transformations include:

- Military maneuvers and training
- Artifact collecting
- Modern refuse dumping
- Previous archaeological investigation

The most important and widespread natural transformation processes that effect and condition artifact distributions and the integrity of cultural deposits at Fort Bliss include:

- Eolian processes that serve to bury, expose, and collapse natural and cultural stratigraphy and degrade cultural deposits
- Alluvial burial and fluvial erosion via channelized or sheetwash flow
- Bioturbation

Prehistoric cultural transformations, which will be discussed in greater detail later in this section, include:

- Refuse disposal and discard behavior
- Recycling and scavenging
- Reoccupation
- Abandonment

Military Maneuvers and Training

In addition to eolian erosion and bioturbation, military vehicle maneuvers and training practices have had perhaps the most profound effects on cultural resources on military installations. Unfortunately, the effects of military maneuvers at broad landscape scales are largely based on anecdotal evidence, since there has been little attempt to systematize the vast information on military maneuvers over the past 50 years or more. As part of the Fort Bliss Impact Study (Project 94-02), maps and Form-88 files were compiled and digitized for construction of GIS layers. The results of this study were not published and the status of the data is unknown. Preliminary reviews of the results showed that major areas of tracked and wheeled vehicle maneuvers, such as the “pivot maneuver” conducted in the southern part of Maneuver Area 2 (the Hueco Mountain Project area), were clearly visible. Otherwise, the precise effects that the various types of military maneuvers have on the landscape and cultural resources remains largely unknown. It is clear, though, that intensive military vehicle maneuvers are directly associated with increased erosion of eolian deposits in the central basins.

Artifact Collecting

Surface artifact assemblages across the Fort Bliss maneuver areas have been affected to various degrees by uncontrolled collecting. Avocational and amateur archaeologists collected projectile points, shell and mineral items, certain decorated sherds, and even ceramic vessels during the 1960s and 1970s (e.g., Davis 1975; Phelps 1967; Krone 1975). Military personnel undoubtedly

picked up surface artifacts over the many years of training exercises conducted across the maneuver areas. Quantifying the amount and extent of casual and dedicated uncontrolled surface collection that has taken place over the past 50 years or more would be a difficult, if not impossible, endeavor, although it is possible to evaluate the qualitative effects on assemblage content and structure,

The incidence of surface collecting decreased considerably as a result of increased security during the past two decades. In addition, military personnel receive training on environmental and cultural resources regulations and restrictions. More importantly for the longer-term preservation of cultural resources, the military presence had a dampening effect on more destructive practices of looting and pothunting. Most instances of serious damage to rock shelter deposits, pueblo rooms, or other favored targets of looting occurred prior to the military's stewardship of the area.

Recent experience at Madera Quemada Pueblo demonstrates the degree to which the content and diversity of surface artifact assemblages were modified by uncontrolled collecting. Madera Quemada Pueblo is part of the larger site LA 91220, a 1.7 km by 1.0 km, multicomponent settlement located at the eastern margin of Old Coe Lake Playa. Prior to excavation the site surface in the vicinity of the pueblo room block and several surrounding midden area was carefully searched for technologically diagnostic and temporally diagnostic artifacts.

It was discovered that the surface assemblage consisted almost entirely of small, undecorated El Paso brownware sherds and chipped-stone debitage. Anything unusual or of interest to casual and dedicated collectors, such as large decorated sherds, imported ceramics, marine shell, beads, obsidian, or ground stone items, was missing from the site surface. Despite the almost complete absence of such materials on the surface, substantial numbers of shell and mineral samples, tools, large ground stone tools, and imported ceramics were recovered during subsurface excavations inside and around the pueblo room block.

These findings suggest that many sites at Fort Bliss may have degraded surface assemblages, whereas collectors have removed the majority of decorated ceramics, formal tools, jewelry, and otherwise visually outstanding items. This is probably truer of the more obtrusive and visible Formative period sites, although projectile points and outstanding chipped stone tools and grinding implements were collected from sites of earlier periods.

This fact is even more striking in light of recent experiences during TRU surveys across McGregor Range. The restricted access and much lower intensity of training exercises on the McGregor Range training areas served to reduce the severity of illicit collecting. Although the survey information is in the process of being reported and is not yet widely disseminated, archaeological field crews are reporting numerous instances of undisturbed, high integrity surface assemblages including high counts of projectile points and other tool discards, large ground stone collections, and even occasional whole or partial vessels, stone effigies, and other outstanding items.

The systematic removal of particular classes of material culture has implications for studies involving comparative analyses of surface assemblages. Whether the study involves the analysis of settlement pattern or site function based on inter-assemblage variation in artifact content and diversity, the assignment of temporal components or analysis of regional interaction based on counts or proportions of imported decorated ceramic wares, or a comparative analysis of bifacial tools and projectile points, each will have been affected and potentially biased to some extent by the use of degraded surface assemblages. These problems are most pervasive among survey and test investigations that rely primarily on surface observations, and are less of a problem for excavations.

Refuse Dumping

Large swaths of the maneuver areas on Fort Bliss that border the urban limits of El Paso, Texas, have been affected by illicit trash dumping over the past 50 years or more. Along the southern margins of Maneuver Areas 1 and 2, it is not uncommon to encounter the prehistoric archaeological sites covered by mounds of modern construction and landscaping debris. The adverse effects to sites caused by the trash dumps are surprisingly extensive and include the destruction of features, loss of artifact visibility, and contamination of prehistoric organic deposits by hydrocarbons (motor oil, chemicals, asphalt). While enterprising disciples of Rathje and the Tucson Garbage Project may someday find interest in the types of items discarded throughout the desert by the residents and businesses of modern day El Paso, the extensive dumping along the margins of Fort Bliss have resulted in serious damage to numerous sites. The practice has largely been abated over the past decade by the construction of a boundary fence and increased security signage and patrols along the boundary of Fort Bliss. Additionally, Fort Bliss commendably sponsored a clean-up campaign in the late 1990s that removed much of the modern trash from the desert.

It should be noted that this problem is not restricted to Fort Bliss lands, but has been an issue for the city and county of El Paso for many years. In one instance that likely accounts for one of the more extreme and multigenerational forms of cultural transforms on record, an archaeological “site” was created at the edge of the city limits when the artifact collection and other household trash belonging to an unknown El Paso avocational or weekend collector was tossed in the desert (Canavan et al. 1989). The newly formed “site” contained distinctive ceramic ware and lithic materials from east-central Arizona, southern New Mexico, and the Rio Abajo of central New Mexico in association with modern magazines, lawn clippings, and flowerpots.

Archaeological Investigation

Finally, the effects of our own endeavors have served to transform the nature and content of archaeological sites. Surface collections conducted during the numerous and often overlapping surveys conducted since the 1970s resulted in the collection of large inventories of temporally and technologically diagnostic items. Approximately 1,200 projectile points were collected during surveys of the Fort Bliss maneuver areas in Texas and New Mexico (Beckes et al. 1977; Carmichael 1986a; Skelton et al. 1981; Whalen 1977, 1978). While the site-level provenience of these items is relatively secure, the intra-site provenience for many items is unknown, and thus important evidence regarding the locations of temporal components may be lacking. This is intended as a criticism, as this was common practice across the region prior to the time archaeologists gained an appreciation of site multicomponency.

The intensive excavations conducted at several sites by the EPAS in the 1960s and 1970s had a profound and lasting effect – both positive and negative - on our understanding of the El Paso phase puebloan record. Extensive excavations were conducted at Hot Well, Sgt. Doyle, and McGregor pueblos (see Lowry 2005; Lukowski et al. 2006). Given the cultural historical concerns of the period, the EPAS excavations were concerned primarily with documenting architectural form and ceramics, although Vernon Brook (1966a, 1971) deserves credit for attempting some of the first interpretations of social organization in the region based on comprehensive studies of architecture and some artifact types recovered from pueblos.

Bioturbation

The degree to which sediments and stratigraphy across Fort Bliss and elsewhere in the Jornada region have been affected by bioturbation is gaining increasing recognition since Johnson's (1997) discussion of the effects of the burrowing behavior of badgers, gophers, and other desert mammal and reptile species (see Chapter 6). Over the past decade, the specific and cumulative

effects of burrowing have been revisited by Johnson and Johnson (2004) and have been further explored by Mauldin and Leach (1997), Hall (2002), and Hall and Goble (2006).

Although most desert mammals dig burrows for shelter, escape, nesting, or in pursuit of prey, those dug by badgers (*Taxidea taxus*) and coyotes (*Canis latrans*) are by far the most destructive. Badger burrows can extend up to 9 m in depth (Schmidly 1988) and can extend into the petrocalcic (caliche) horizon. Large quantities of debris are displaced from the burrows and the sediment, rock, and caliche brought to the surface forms spoil piles on the present ground surface. Stone cobbles up to 29 cm in length and weighing up to 5.5 kg (Figure 10.1) were observed among badger spoil piles studied by Johnson (1997) and Mauldin and Leach (1997). Mauldin and Leach (1997) excavated and screened 14 badger spoil piles in Padre Canyon in the southeastern Hueco Bolson, and observed that the burrows had displaced a total of 1,023 kg of rock from below the surface. Through continued wind and water erosion, the spoil piles spread across the surface, leaving scatters and pavements of excavated rock and caliche. Of course, buried prehistoric artifacts are also brought to the surface during this process.

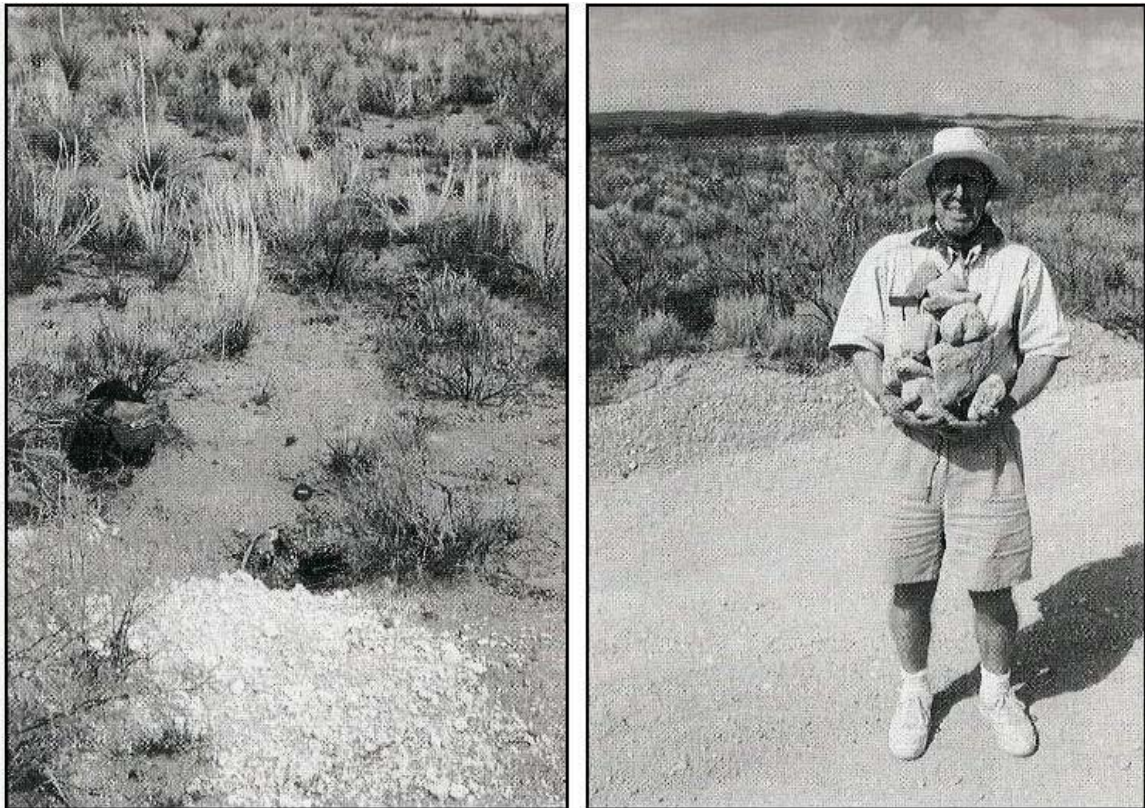


Figure 10.1. Examples of debris from badger burrows.

Left figure: example of a badger spoil pile.

Right Figure: Don Johnson holding examples of cobbles recovered from badger spoil piles.

(from D. Johnson 1997: 187, Figure 99).

At any scale of analysis, the potential displacement of soil deposits wrought by years of burrowing is immense. Mauldin and Leach (1997: 130) counted over 300 badger burrows along a 30-m wide by 1.4-km long transect in the southern Hueco Bolson, suggesting the presence of over 7,000 recent burrows per square kilometer. Johnson (1997: 181) measured 100 burrows within a small area in the Tularosa basin east of McGregor Range camp, and calculated they

covered an area of over 13,000 square meters. Smaller rodents, prairie dogs, and reptiles cause additional burrowing, but these mammals tend to dig smaller burrows and displace smaller amounts of sediment. Nevertheless, the long-term effects of these smaller burrows could be profound.

More recently, the effects of burrows created by cicada insect nymphs have been considered (Hall and Goble 2006; see Chapter 6), with the observation that, over time, the 10-20 cm wide burrows could displace and redeposit most of the sediment in a stratigraphic column. Finally, the potential effects of ant burrows have also been noted. Although ant colonies displace small sediment particles, it is again the cumulative effects that are potentially significant. Studies of burrows in southeastern New Mexico found that ants displace 84 g of sediment per square meter per year (Whiteford et al. 1986). As noted by Hall (Chapter 6), if this rate is uniform through time, ant colonies will displace and mix 37 tons of sediment per acre per century. Again, this may displace sediments and prehistoric artifacts, albeit at smaller scales than that resulting from mammal burrowing.

The cumulative effects of hundreds of years of burrowing behavior on natural stratigraphy, cultural stratigraphy, and artifact provenience could be potentially enormous (see Johnson 1997: 176-181, 187-189, 212-222). The rock and sediment (and prehistoric artifacts) displaced by burrowing forms a biomantle of exhumed materials on the modern ground surface.

Eolian and Alluvial Processes

The effects of eolian and alluvial processes on site visibility and integrity are discussed in greater detail in Chapter 6. The following discussion examines the two processes of natural stratigraphic deposition and resultant effects on site formation. The stratigraphic relationships and research potential of cultural deposits in the Jornada region has been approached primarily from the standpoint of their perceived absence or lack of integrity. It has been generally assumed that eolian erosion of natural stratigraphic units in the central basins has had the corollary effect of collapsing cultural stratigraphy. The ultimate effect of such erosional transformation processes is the so-called “lag” deposits of cultural materials intermixed within a single horizon (Doleman. 1992; Monger 1993a; Seaman et al. 1988).

This seemingly benign perception of eolian transformation processes and stratigraphic integrity has had broad and lasting implications for the management of archaeological resources. It has also had a pervasive influence on evaluations of site integrity, in that sites with apparent concentrations of materials in deflated surfaces are thought to lack “integrity” based on the absence of stratigraphy. The revised age estimates for the Holocene Q3 unit present a new set of potential interpretations regarding stratigraphy and vertical association of cultural materials.

Age and Sedimentation Rates in the Central Basin

One of the more critical issues affecting the conceptions of site formation involves the soil sedimentation or aggradation rate of the Holocene Q3 stratigraphic unit. The contrasting age profiles for the Q3/Organ surface presented in Chapter 4 provide very different sedimentation rate models. If the Q3 stratum is considered to have a terminal age of 7,000 B.P., it is estimated that it would have taken a period of 50 years for 1 cm of sand to accumulate. In contrast, if the much greater terminal age of 22,000+ B.P suggested by OSL dates is taken into account, it is estimated that it would have taken between 100-130 years for 1 cm of sands to build up, a rate that is double or triple that of the younger age model. These rates would therefore result in very different stratigraphic positions of archaeological features and deposits dating to broadly separated time intervals. Figure 10.2 provides a schematic illustration of this effect of soil sedimentation rate models on the stratigraphic positioning of cultural features and artifacts. The figure illustrates the relative positioning of two features representing widely separated temporal intervals (Middle

Archaic period at 4,000 B.P. and Late El Paso phase of the Formative period at 500 B.P.) that would occur based on different soil sedimentation rates.

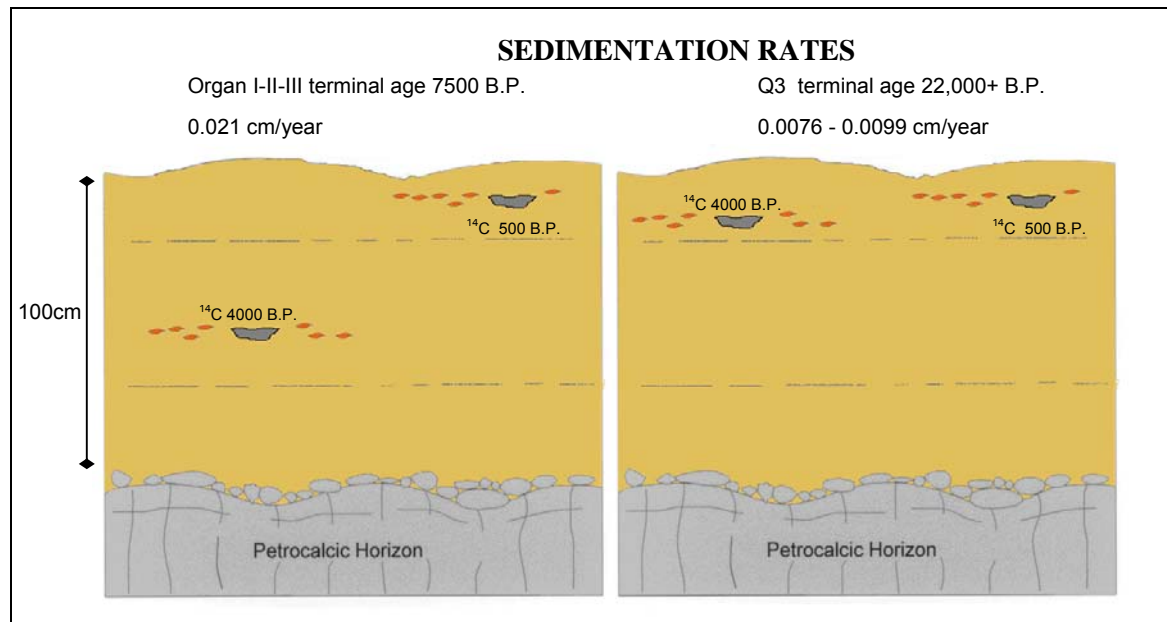


Figure 10.2. Schematic illustration of stratigraphic site formation under two models of soil sedimentation rates.

Using the faster sedimentation rate as calculated by using the younger termination date for Q3, the features would be stratigraphically separated by approximately 70 cm. The slower sedimentation rate would result in the two features being vertically separated by only 20-30 cm. Of course, if eolian deposition substantially slowed or ended at circa 5,000 B.P. as proposed for the Mescalero Sands (Hall 2002), features and cultural deposits formed during both periods would occupy equivalent stratigraphic positions across the basin floor.

The latter situation more aptly describes the context of archaeological features in the central basin. There are numerous cases of two or more features in close horizontal and vertical proximity yielding age estimates that vary by several thousand years. In the western portion of the El Arenal Site on Fort Bliss, two hearth features located within 20 m of each other and at identical vertical positions yielded radiocarbon age estimates of 4030 ± 70 and 400 ± 40 (Miller 2007a: 8.18). At site 41EP1037, El Paso brownware ceramics were recovered from the vicinity of a hearth pit that yielded a Middle Archaic date (Mauldin et al. 1998: 141-146). Several additional cases of 2000-4000 year age disparities among groups of features situated at relatively equivalent elevations have been reported (for example, Burgett and Poche, in prep; Camilli et al. 1988; Condon, Hermann, et al. 2006; Dering et al. 2001; Mauldin and Leach 1997). This aspect of archaeological distributions was a discussion topic during the first Significance Standards meeting on geomorphology. Most of the attendees agreed that this was indeed the norm and few could recall instances of deeply stratified hearth features in the central basin.

The implication of the revised sedimentation rate is that eolian depositional processes in the central basins were too slow and prolonged to result in the formation of vertically separated and stratified cultural deposits. This helps explain the rarity of isolable stratigraphic contexts in basin landforms at Fort Bliss and surrounding areas. More critically, it creates several implications for evaluating research potential and integrity of archaeological sites. If there was little or no vertical

separation among prehistoric occupations and activity locations in the first place, then the issue of stratigraphic integrity is pointless for considerations of research potential and integrity. Instead, the common observation that features of different age are generally positioned at equivalent elevations suggests that the finding of preserved features equates with some degree of geomorphic integrity. Can it be assumed that, if remnant hearth pits or structure floors are present, then the Q3 stratum and associated cultural landscape is sufficiently intact despite the apparent depth or extent of the Q3?

The ultimate implication of these differing models and perceptions of stratigraphic site formation is that archaeologists should focus more on elucidating patterns of *horizontal* integrity among distributions of prehistoric features and artifact distributions in the basin landform. This would involve a fundamental reorientation of the concept of site structure, in that evaluations of research potential would be based on whether isolable temporal and occupational components can be differentiated across the horizontal dimension of basin landscapes. While this is by no means a simple proposition, a consequential effect is that a revised emphasis on the horizontal dimension of spatial integrity may actually help simplify the often difficult conceptual relationship between geomorphic (i.e., stratigraphic) integrity and chronometric potential as set forth in Part II of this document. Both chronometric and geomorphic integrity may be demonstrated in tandem, provided that a sufficient portion of the Q3 stratum is present to retain cultural features and remnants of features.

Formation of Cultural Stratigraphy in Alluvial Fans

The issue of cultural and natural stratigraphy also has implications for prehistoric sites situated in the alluvial fan topographic zones at the margins of the basins. The absence of stratification among Holocene depositional units in basin landforms reviewed above (and Chapter 6) has sometimes led to a tacit assumption that temporally- or occupationally-stratified deposits are rare to non-existent in the Jornada region, with the exception of the small number of excavated or preserved rock shelters. The fact that most of the archaeological work at Fort Bliss and elsewhere in the Jornada region has taken place in the central basin is partly to blame for this perception.

Alluvial fans, formed through different geomorphic processes than basin sediments, offer an underappreciated context for archaeological stratigraphy. Regional surveys have consistently noted that Archaic period sites are rare on the surfaces of alluvial fans. This may be more a fact of geomorphic visibility than prehistoric settlement intensity, as much of the Archaic period landscape and evidence of human settlement of alluvial fan landforms lies buried within deposits of Organ alluvium.

Hearths and roasting facilities of Archaic age have been encountered in the walls of historic and modern arroyo channels downcut through Organ alluvium, the most prominent of which are the series of hearths encountered along Gardner Springs Arroyo that were dated to define the age boundaries of the Organ alluvial sequence (Gile and Hawley 1968; Gile et al. 1981). Additional features of Middle Archaic age were discovered in road cuts near Gardner Springs Arroyo in the late 1990s (Alvarez 1990; Miller and Stuart 1991). At the North Hills II Site (41EP356), numerous Late Archaic hearth features were found at depths of up to 2 m in an arroyo channel downcut through the Organ alluvium on the east side of the Franklin Mountains. A small Mesilla phase settlement was present on the surface of this location. Examination of arroyo cutbanks has revealed additional deeply buried features in Organ deposits of the Sacramento Mountains (Beckes et al. 1977; D. Johnson 1997).

A recent investigation of one of these sites (LA 37297; originally reported in Beckes et al. 1977) has identified houses and middens of Late Formative age buried at depths of 2 m in alluvial deposits (Figure 10.3). Thus, it may be possible to encounter Late Archaic and Early Formative

materials in stratigraphic context, although it must be acknowledge that excavation of deep alluvial deposits is much more time consuming and costly than dealing with shallow sites.

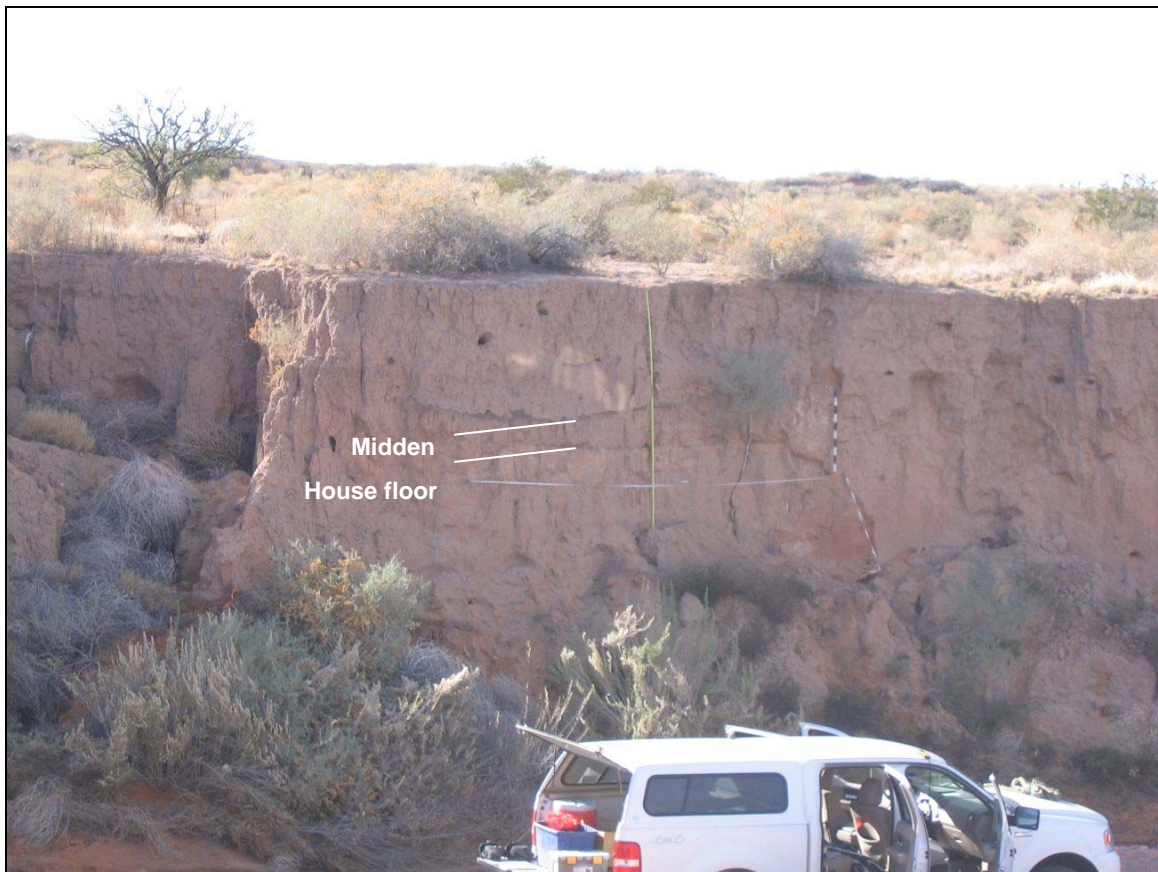


Figure 10.3. Late Formative period house floor and superimposed midden deposit exposed at a depth of 2 m in an arroyo channel through site LA 37297 on McGregor Range. (Horizontal scale rod at the right edge of the deposit is 1 m in length.)

For purposes of archaeological investigation, the Organ alluvial stratigraphic unit is most relevant. The Organ alluvial formation represents a period of general landscape instability and sedimentation occurring along the frontal axes of steep mountain slopes and major canyons. Radiocarbon dates for charcoal recovered from the Organ unit on the western flanks of the Organ Mountains range from 4,550 B.C.-A.D. 850 (6,500-1,100 B.P.; Gile and Hawley 1968; Gile et al. 1981; Ruhe 1964, 1967). Some researchers (e.g., O’Laughlin 1979; Miller 1990) date the termination of the Organ alluvial sequence (Organ/Historic Blowsand boundary) to ca. A.D. 1000 (950 B.P.) based on the consistent observation that pre- A.D. 1000 materials are buried and post-A.D. 1000 materials are often on the surface of Organ alluvial deposits of the Franklin Mountains.

However, it should be noted that recent investigations at LA 37297 (see Figure 10.3) might force a reconsideration of the timing and extent of alluvial deposition at Fort Bliss. While aggrading alluvial deposits appear to have almost ceased along the Organ and Franklin mountains in the southern Jornada region, it appears that deep alluvial deposits continued to accumulate along the flanks of the much more massive Sacramento Mountains escarpment at the northern margin of Fort Bliss.

Setting aside the geomorphic and paleoenvironmental implications of alluvial fan formation, a more significant issue for archaeological research is that the combination of relatively fast sedimentation rates on alluvial fans and the more intensive occupations characteristic of Formative period settlement often resulted in the formation of stratified cultural and natural deposits. These offer a productive context for the study of site formation at Mesilla, Early Doña Ana, and Late Doña Ana phase pit house settlements. Owing to the less frequent military training and maneuver exercises conducted near mountain ranges, excavations at settlements in alluvial fan contexts have been unfortunately rare at Fort Bliss. The most notable exceptions include the work conducted during the 1980s and early in 2000 at the Conejo Site along the Organ Mountain fan piedmont during the 1980s (Hard 1987; Miller and Burt 2007) and several sites in the vicinity of Meyer Range (Church and Sale 2003; Graves and Ernst 2007; Lowry 2005; Peterson 2001).

Outside of Fort Bliss, archaeological excavations at sites situated in alluvial fans have been more common along the eastern alluvial fans of the Franklin Mountains because of construction projects resulting from the urban expansion of northeast El Paso, Texas. Investigations at several sites in this alluvial fan piedmont, such as Gobernadora, North Hills I, and sites on Castner Range, have provided evidence of cultural stratigraphy (Hard 1983b; Miller 1989, 1990; Shafer et al. 1999).

Figure 10.4 illustrates a 100-m long cross-section of natural and stratigraphic relationships at the North Hills I Site. The surface of the alluvial fan has a slope of 1.6 m over this distance. Six pit houses, three middens, and several rock-lined pit, processing areas were identified through systematic backhoe test trenching and hand excavation. The depths of these features vary considerably across the site. Feature depths are especially pronounced at the southeastern margin of site, with the basal midden deposits, hearth features, and the floors of some structures positioned between 50-70 cm below the modern ground surface. The lower figure shows a plot of radiocarbon ages by depth at North Hills I. There is a marked separation between the ages of features and other contexts buried within alluvial deposits. Those found at shallower depths or on the surface had age estimates that post-date the estimated termination of alluvial aggradation along the Franklin Mountains.

The stratigraphic and chronological relationships between the deeply buried deposits to the east, the less deeply buried features to the west, as well as among the stratified cultural materials contained within refuse deposits of middens and pit houses, were complex and varied. An integrated analysis of ceramic seriation and radiocarbon-age estimates allowed for the development of a site-wide chronology and helped demonstrate that the complex process of site formation at North Hills I resulted from an equally complex occupational history of multiple occupations (Miller 2003).

It is anticipated that the expansion of military training at Fort Bliss will result in increased use of the alluvial fans bordering the Organ, Hueco, and Sacramento mountains. Should mitigation excavations be required in these settings, archaeologists are encouraged to consider the likelihood that stratified cultural deposits will be encountered. Research designs should include provisions for stratigraphic excavation and analysis, detailed chronometric dating, and seriation of artifact assemblages recovered from stratified contexts.

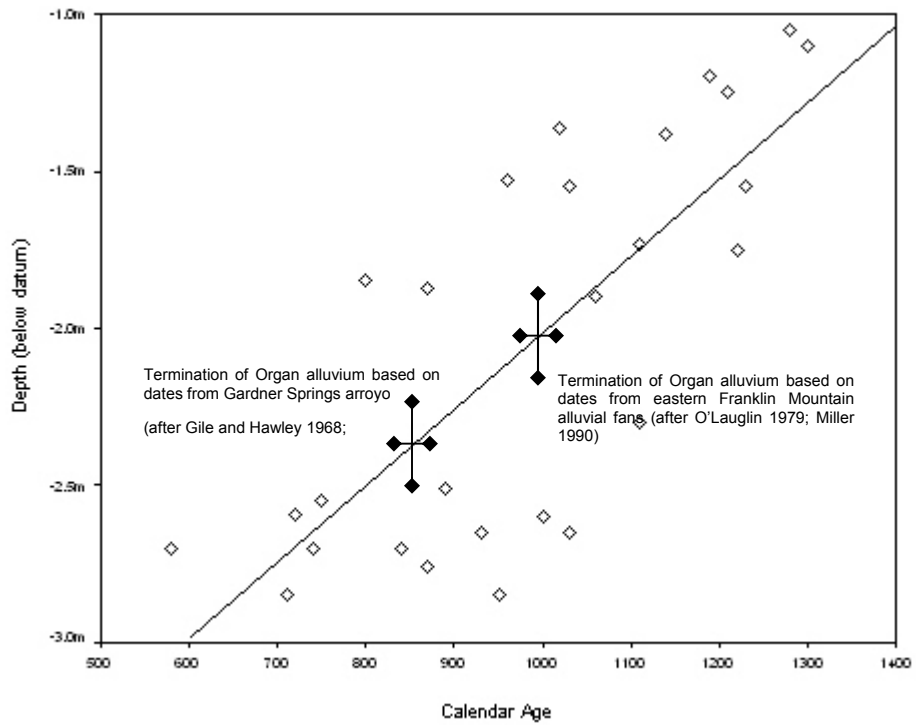
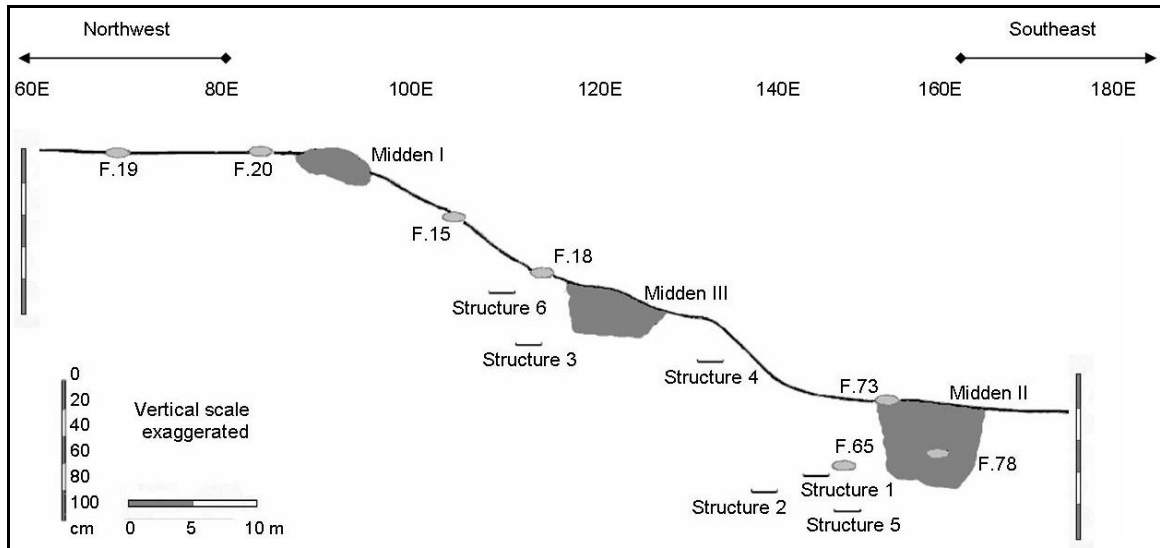


Figure 10.4. Stratigraphic and chronometric relationships at North Hills I (41EP355).
 Upper figure: stratigraphic relationships between pit houses, middens, and hearth features.
 Lower figure: plot of radiocarbon age estimates by depth.
 (from Miller 2003).

PREHISTORIC CULTURAL TRANSFORMATIONS

Prehistoric cultural transformations are among the most influential and interesting of the various natural and cultural transformation processes. Prehistoric behavioral and cultural transformations include refuse disposal and discard behavior, recycling and scavenging, and reoccupation and abandonment. Most common and pervasive are the behavioral and cultural patterns of material disposal and discard, as the majority of material culture documented or recovered during typical archaeological investigation consists of various forms of trash and discarded items. Disposal and discard behavior includes the maintenance of living or activity areas and resultant formation of trash pits, middens, and other dedicated refuse areas, the discard of various materials during extractive or production tasks that created widespread artifact distributions across the landscape, as well as the creation of localized ritual deposits. As such, it is also important to consider that such formation processes are multi-scalar, occurring at the level of individual features or ritual deposits and habitation structures, to site-wide abandonment processes, and may even be considered at regional scales of mobility, abandonment, migration, and reoccupations.

Schiffer (1972, 1985) differentiates between two primary contexts for archaeological materials: systemic context and archaeological context. Systemic context is the result of the original behaviors that produced archaeological remains; archaeological context is what is observed through archaeological investigation. Systemic contexts become archaeological contexts through various transformation processes. Given the extensive mobility and site reoccupation characteristic of prehistoric settlement organization in the Jornada region, the following behavioral and cultural processes are most relevant to understanding the formation of archaeological contexts at Fort Bliss.

Artifact Discard and Refuse Disposal

Most cultural material enters the archaeological record through processes of discard and disposal, and accordingly most of the prehistoric and historic archaeological record at Fort Bliss, as well as throughout most of the world, consists of one or another form of refuse. Behavioral patterns of refuse disposal and the composition of refuse deposits or discarded artifacts offer critical insights into site formation and site structure. Understanding such patterned processes of artifact discard and refuse disposal – whether through archaeological, ethnographic, or behavioral studies – provides a means of understanding how sites and deposits were formed. As such, it is particularly useful to apply the concepts of systemic context to the interpretation of refuse. Schiffer reviews the systemic context of refuse and defines three forms representing different behavioral processes: *de facto* refuse, primary refuse, and secondary refuse.

De Facto Refuse

De facto refuse consists of items intentionally or accidentally left in place and abandoned. *De facto* refuse often provides the most direct insights into the spatial arrangements and locations of specific activities and behaviors. However, caution is required during such interpretations because *de facto* refuse often consists of items that might have otherwise been removed and discarded elsewhere if the location had not been abandoned, or may represent a partial inventory consisting of the larger and less valuable items left behind during the process of site abandonment.

Examples of *de facto* refuse are most common at residential settlements with formal architecture and more stable, sedentary occupations. Items recovered on the floors of pit houses and pueblos often represent *de facto* refuse (Figure 10.5). Notable examples of abandoned pit house or pueblo rooms with *de facto* floor refuse deposits include Northgate House 1 (Aten 1972); the Tortugas

Pithouse (Stuart 1991), Embree Pueblo (O’Laughlin 1985), Room 17 at Hot Well Pueblo (Lowry 2005), and Madera Quemada Pueblo.

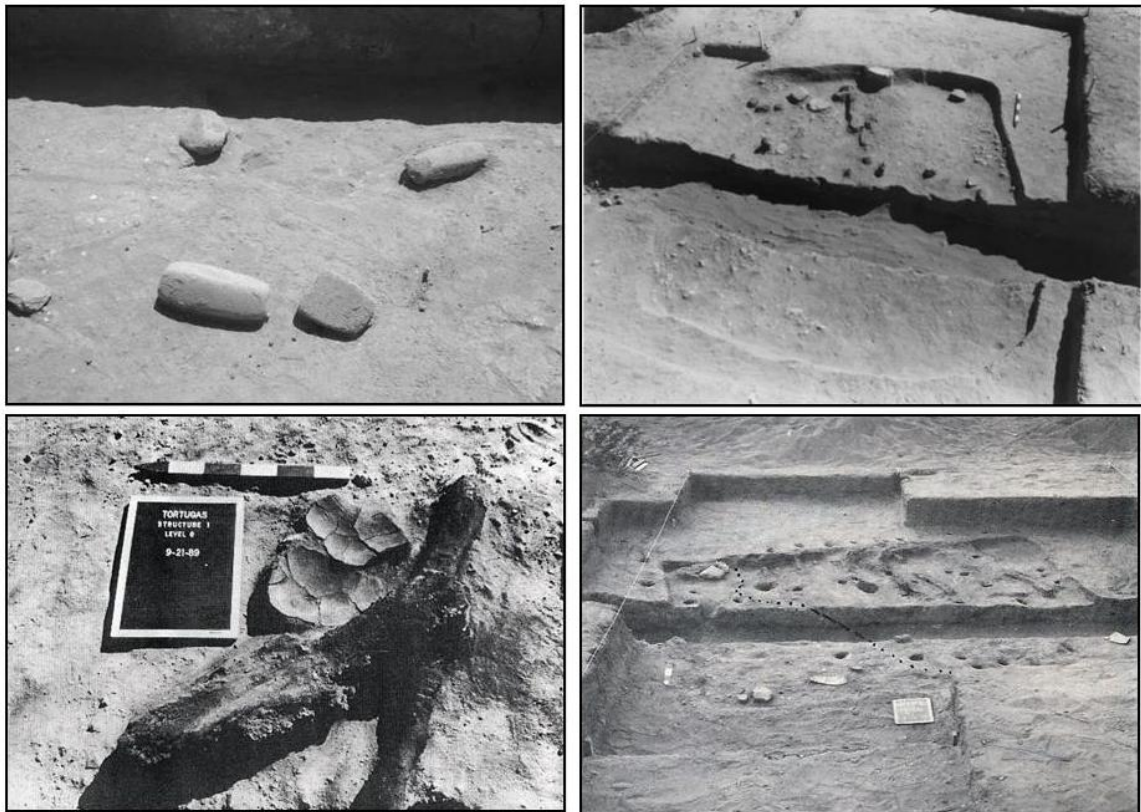


Figure 10.5. Examples of de facto refuse on house floors.

Upper left: ground stone tools on floor of Room 12 at Madera Quemada Pueblo.

Upper right: ceramic plates, grinding tools, and support beams on floor of Structure 4 at North Hills I.

Lower left: ceramic plates and support beams on pit house floor at the Tortugas Site.

Lower right: House 1 at the Northgate Site with large Mimbres sherd, ceramic plates, grinding tools, and support beams on floor.

Additional cases of de facto floor deposits are known from the regional literature but are not well described or illustrated. Examples include Twelve Room House (Moore 1947) and an unidentified pueblo in the southern Tularosa Basin from which 200 bushels of corn was recovered in a single room (Brook 1966b; citing an unpublished 1939 paper by Vermillion). Interestingly, burned structures typically are the instance where de facto refuse is commonly encountered. Otherwise, most pit house and pueblo rooms contain little in the way of abandoned materials and often appear to have been swept clean or had most tools and items removed prior to abandonment.

It should be noted that such cases represent only the most visible and easily recognized forms of de facto refuse. Disposal of the dead represents a unique depositional process that forms a type of archaeological deposit that was intentionally abandoned, although it must be emphasized that mortuary deposits are a special form of ritual deposit not considered as refuse. Trail markers, as suggested by Seymour (2002), would represent another form of de facto deposit formed at

broader scales resulting from prehistoric landscape use. Ritual caches and deposits are additional types of intentionally abandoned deposits.

Ritual deposits (Walker 1995, 1998, 2001) are a form of de facto refuse. Such deposits represent individual items or collections of items that were intentionally deposited and abandoned in the context of ritual performance (Figure 10.6). They have often been neglected or understudied due to the misperception that they are rare or, as noted by Walker (1995), due to an absence of method and theory guiding their identification and study.



Figure 10.6. Example of a de facto ritual deposit: Feature 11.2, an intrusive pit in Room 11 of Madera Quemada Pueblo (LA 91220), Fort Bliss, New Mexico.

(Contents include over 150 items including stone palettes, large ceramic sherds, numerous types of minerals, ores, and pigments, crystals, shell jewelry, fossils, and various types of residues and organic matter.)

Many such deposits are formed through ritual burning and, in fact, the entirety of a burned pit house or pueblo room and all the contents contained within may be considered a ritual deposit. As noted above, most cases of substantial de facto floor deposits in Jornada house structures involve burned structures.

A distinction must be made between the behaviors involved in caching and the creation of ritual deposits. Not all caches were ritual deposits, nor were all ritual deposits formed by caching behavior. Caching behavior involves the intentional concealment of items for future use and was often associated with economic issues and settlement organization, such as the well-known examples of chipped stone raw materials or ground stone tools being cached for use during anticipated return to an area.

A ritual cache would be one in which ritual paraphernalia was stored or protected in a concealed location for future use. In contrast, ritual deposits involving termination or initiation rites for structures, the disposal of ceremonial items or intentional destruction of such items, or ritual emplacement as offerings, do not involve caching behavior since no return to the location or reuse of the objects was planned or anticipated.

Several ritual deposits, ritual caches, or economic caches have been documented in the region. They have often been found in unique locations such as hilltops and niches in limestone hills or mountain escarpments (Achim 1984; Hedrick 1997; Moore and Wheat 1951; Wooldridge 1979), although the High Lonesome bead cache described by Kelly (1977) was found in the basin landform. Items have also been found deposited or cached within subfloor pits at residential sites (Hill 1971; Lowry 2005; Phelps 1967). These deposits include items ranging from thousands of beads to collections of miniature vessels and fossils and even the placement of single items of exotic stone or fossils (Figure 10.7).



Figure 10.7 Drilled fossil placed in the base of a posthole as an initiation or termination object in Room 1 of Madera Quemada Pueblo.

It is often difficult to untangle and differentiate the economic and ritual components of these deposits and caches. Based on ethnographic and ethnohistoric accounts (Ortiz 1969; Parsons 1939), it may be inferred that items and collections of items placed on hilltops served as ritual offerings that were not intended to be reused, and thus do not reflect caching behavior. In contrast, the large collections of beads found in the Mesilla basin and within a ceramic vessel hidden in a niche in the Sacramento Mountains escarpment (Kelly 1977; Wooldridge 1979) may reflect economic caching of valuable items. It is evident that much greater attention should be paid to the study of de facto deposits of unusual and rare items.

Primary Refuse

Primary refuse is composed of items discarded or lost at their place of use. Since primary refuse consists of materials disposed of in the context of production and maintenance, it has direct association with the activities through which it was produced. Thus, the identification and study of primary refuse often serves as one of the primary means of identifying the locations of past activities.

The most common form of primary refuse encountered in Jornada Mogollon archaeological contexts includes waste flakes and debris produced during the reduction of cores or the production and maintenance of tools. Small seeds and faunal bone lost during food preparation and consumption are often incorporated into archaeological contexts as primary refuse. Based on these descriptions, it is evident that primary refuse typically consists of items left in areas that were not maintained or cleaned, or consists of small items from frequently maintained occupation or activity areas. For example, most of all chipping debris produced during a session of tool maintenance at a short-term settlement or camp may have been left in primary context. In contrast, floors in habitation structures were often swept clean of debris and hazardous objects, leaving only the smallest debitage, seeds, and other small items in primary context.

Thus, there is often a size dimension to primary refuse that correlates with use intensity or occupational stability and duration. Schiffer (1983: 679) refers to this phenomenon as the McKellar Hypothesis: smaller items are more likely to become primary refuse in contexts that are periodically cleaned, while larger items will be removed during cleaning and redeposited in other locations as secondary refuse. Although this hypothesis has rarely been formally cited, it is a pronounced component of ethnographic and ethnoarchaeological hunter-gatherer site structure archaeology of the past two decades. Several processes of site formation involving the size-sorting effects of cleaning and refuse disposal in relation to occupation intensity and duration will be reviewed in forthcoming sections of this document. In addition to hunter-gather settlement analysis, the distinctions between primary and secondary refuse are useful for modeling site abandonment and community organization (LaMotta and Schiffer 1999). For example, Rice (1985, 1987; see also Rice and Dobbins 1981) offers an underappreciated method for evaluating site formation and community pattern among Hohokam and Salado pit house settlements based on the quantitative classification of refuse deposits.

Secondary Refuse

Secondary refuse consists of discarded material that has been removed from its primary location of production and deposited elsewhere. At more intensively occupied and residentially stable settlements, this process often involves dedicated refuse areas such as trash pits, trash middens, and trash mounds. Secondary refuse disposal areas at less intensively-occupied hunter-gatherer camps are much less formalized or standardized, and generally consist of diffuse and scattered areas of debris surrounding the main camp or individual residences.

In contrast to primary refuse that on the average consists of small items such as lithic waste flakes, seeds, and small bone fragments, secondary refuse often consists of higher proportions of larger items such as ceramic sherds, lithic cores, and large food items. Secondary refuse deposits also include unpleasant items or potentially hazardous materials such as discarded animal parts and bones or fragments of broken, sharp-edged tools. In contrast to de facto refuse deposits that often have high proportions of complete objects, secondary refuse will often consist of high proportions of broken items (refer to the artifact “completeness index” of Schiffer 1987: 282). Ceramic sherds from broken vessels comprise a significant proportion of artifact debris in secondary refuse deposits.

The processes by which secondary refuse is formed results in distinct patterns of composition, quantity, and location compared to de facto and primary refuse. First and foremost, it is critical to understand that the process of displacement and transport means that the primary context of use for the material comprising secondary refuse is no longer present. Materials produced and discarded during different tasks performed in several locations could have been combined and mixed in secondary refuse deposits. The potential for mixed deposits among different contexts should be considered. Small, individual trash pits may be more representative of short-term intervals of refuse accumulation and may even contain single episodes of meal preparation or the cleaning of floors and activity spaces. Middens, on the other hand, will consist of long-term deposition that may span the entire range of occupations at the site. Refuse disposal in abandoned house pits will often be somewhat more episodic and may even contain stratified deposits. These formation processes are also critical for designing and interpreting radiocarbon dating programs since charcoal and organic matter retrieved from even the lowest levels of pit house fills may not represent the target dating event of the occupation of the structure.

Another important observation is that the amount of secondary refuse generated is usually much greater than other forms of refuse. This holds true particularly at sedentary settlements and requires the creation of dedicated refuse disposal spaces such as abandoned house pits, subterranean storage pits, or designated locations that form mounds of refuse through continual use. As noted by Kelly and others (2005), the distance between habitation areas and refuse disposal areas increases as settlement duration increases. The quantities of refuse discarded at residential settlements often means that the majority of artifacts are actually recovered from secondary refuse deposits, and interpretations of site chronology and function must take this bias into account. The high densities of artifacts in secondary refuse deposits can also be of value for estimating the duration of site occupation and intensity through comparative analysis of artifact densities using accumulations research models (Schlanger 1990; Shott 1996; Varien and Mills 1997; Varien and Potter 1997).

Recycling and Scavenging

Behavioral practices of scavenging and recycling of various forms of material culture has long been recognized in the Jornada region. This is not surprising in light of the pervasive trends of landscape mobility and fluid settlement characteristic of most time periods. Since the earliest period of archaeological survey and excavation in the region, it has been recognized that whole and fragmentary ground stone tools were frequently recycled as heating elements or cookstones in hearth features (Beckes et al. 1977; Carmichael 1986a; Hard 1983b). Patterns of scavenging, recycling, and secondary use have also been observed among chipped stone assemblages, projectile points, ceramic sherds, and several other types of material culture.

Again referring to the concepts of archaeological and systemic context, Schiffer (1976: 34) differentiates among the processes of recycling and scavenging. The process of artifact *recycling* involves a continuity of systemic context. In other words, the item remains in continual use during its use life. In contrast, the term *scavenging* is used to denote the process by which

materials are collected from an archaeological context (e.g., an abandoned site or activity area), are reutilized, and thus again enter into a systemic context.

Schiffer (1976, 1987) also defines several subtle differences among patterns of recycling. *Lateral cycling* is the transfer of an item from one user to another with no corresponding change in the function of the item. *Recycling* is the modification of an existing item to serve a different function. Recycling involves the reworking or modification of items, and frequently involves broken items, such as the common reworking of broken projectile point fragments into other types of formal tools. In contrast, the term *secondary use* is used to denote a form of recycling that does not involve the remanufacture of broken, used, or discarded items. The functional use of the item simply changes, such as the use of a ground stone fragment as a hammerstone.

Conservation is used to describe the process by which an item remains in systemic context beyond its normal use life or function (heirloom items). It is useful to consider that the frequency of artifact recycling is related to the cost of manufacture of the original item or the effort required to procure materials used in its manufacture. Formal bifacial tools tended to be recycled at greater rates than informal flake tools, and large wood beams used as structural supports may have been frequently recycled.

The distinctions among these behaviors are rather subtle and often will be difficult to discriminate in archaeological contexts. For example, a piece of broken ground stone may have been used as a battering stone without any modification or one or more surfaces may have been slightly shaped (through pecking and battering) to provide a more suitable battering surface. Similarly, it may not be possible to determine whether or not a large ceramic sherd was slightly shaped or reduced in size before being used as a parching plate, palette, or scoop. In these and other cases, it would be very difficult to determine whether such items were the objects of recycling or secondary use as defined by Schiffer. Therefore, in many situations the terms recycling and secondary use may be used interchangeably.

The most commonly observed objects of scavenging and recycling among Jornada contexts include chipped stone cores and tools, ground stone tools, and broken ceramic vessels. Materials less commonly recognized but often of equal significance include wood construction elements, faunal bone, and fire-cracked rock. With the exception of fire-cracked rock, these materials are less commonly encountered outside of residential sites. Faunal bone was often recycled, such as the common use of artiodactyl long bones to fashion awls, gaming pieces, and jewelry. The ubiquitous presence of burned corn cobs, kernels, and cupules at El Paso phase residential sites demonstrate that corn cobs were reused as a common source of fuel for cooking and heating fires. Wood was a particularly valuable resource in the desert lowlands. Wood construction elements such as large support posts and roof beams were likely reused and may have even been transported some distances during residential moves to new village settlements (Cameron 1990, 1991; Varien 1999).

Even the lowly material class of fire-cracked rock was subject to scavenging and recycling. Fire-cracked rock and burned caliche was often recycled during multiple use episodes of hearths and burned rock roasting facilities, and studies of fracturing and discoloration can often yield insights into use intensity of features (Doleman 1997; Duncan and Doleman 1991). Additionally, large rocks used to line the bases and sides of roasting pits were often replaced if fractured, and were subsequently reused as part of the capping layer. Fire-cracked rock was also used as shims and supports for roof support posts.

The widespread secondary use in the region of whole and fragmentary ground stone tools has long been recognized (Beckes et al. 1977; Carmichael 1986a; Hard 1983b). Secondary and recycled uses of ground stone items includes metate fragments recycled as manos, mano and metate tools or fragments used as battering stones, anvils, cores, or pigment grinding surfaces,

and the use of ground stone as shims or basal supports for structural beams in houses. However, the most common and pervasive secondary use of ground stone was for heating elements or cookstones among hundreds of thermal features across the central basins.

A consensus of the third Significance Standards meeting is that the presence of ground stone in hearth features deserves a greater level of attention and documentation that is more consistent. It is clear that the secondary use of ground stone as cookstones and heating elements represents a significant manifestation of widespread change in subsistence practices and technological organization. Unfortunately, surprisingly few descriptions of chronometrically dated hearth features include information on whether or not recycled ground stone was recovered from the feature, and therefore the exact period or periods during which such recycling behavior took place or was most pronounced remains unclear. One hypothesis is that the reuse of ground stone items as cookstones reflects an increased emphasis on bulk seed processing during the transition from the Late Archaic period to the Mesilla phase of the Formative period.

Chipped-stone items were also the subject of scavenging and recycling. Several studies of chipped-stone assemblages have proposed that discarded lithic material was widely scavenged and recycled throughout the central basin landforms (Camilli 1988; Camilli et al. 1988; Camilli and Ebert 1992; Mauldin 1984; Shafer et al. 2001b). These landforms, considered to be “stone poor,” lacked locally available deposits of stone material and therefore materials left during previous occupations served as a viable and useful source. Camilli (1988: 150) terms this “planned expedience” in that mobile groups expected to encounter and use lithic materials from previous occupations. Lithic recycling would have several potential affects on the interpretation of assemblage content. First and foremost, many items would be removed from their original context and redeposited in modified form at sites occupied during later time periods. Camilli (1988) notes that fine-grained materials would be preferred, thus biasing inter-assemblage comparisons by reducing the amounts of fine-grained materials (and corresponding evidence of tool production and use of such materials) at earlier occupations and inflating the proportions at later occupations. Continual recycling is also a problem when considering the effects on core size and the ability to detach useable flakes and flake blanks (Shafer et al. 2001b).

One potential critique is that the interpretations of recycling are based on the premise that fine-grained materials were highly preferred and selected during later (i.e., Formative) time periods, a premise that often runs counter to what is known regarding the material texture and functional characteristics of Formative period chipped-stone technologies. Miller (2007a) questions the extent and effect of recycling on Formative period chipped-stone assemblages. He suggests that technological and functional requirements of chipped stone technological organization of the Formative period placed a greater emphasis on the use of coarse-grained material. Therefore, this would have lessened the need to scavenge fine-grained material from earlier occupations. Clearly much more work is needed to define the nature and extent of scavenging on chipped-stone material in the Jornada region.

Finally, ceramics were subject to widespread and extensive patterns of scavenging and recycling. Both locally produced El Paso brownware and imported ceramics were scavenged and recycled, often in roughly equivalent proportions. Sherds retrieved from broken ceramic vessels were recycled and reused as tools for a variety of tasks. Data on worked or edge-modified sherds is available from several habitation sites in the region (see discussions or examples in Aten 1972; Dering et al. 2001; Hard 1983b; Lehmer 1948; Miller 1989, 1990; O’Laughlin 1980, 1981; Reed et al. 2002; Sale 2003; Smiley 1979) but is lacking for assemblages collected from low-intensity occupations or landscapes.

Several forms of utilized sherds and edge modifications have been identified. One of the more common sherd tools has rough, uneven and heavily worn edges, suggesting the secondary use or

recycling of sherds as scoops or digging tools. Sherd scoops and digging tools are more common at plant processing sites on alluvial fans and were likely used during the construction and emptying of roasting facilities (Hard 1983b; Miller 1989; O’Laughlin 1980). Similar forms of sherd tools have been recovered from Hohokam agave processing sites (Van Buren et al. 1992). Another common form of edge modification involves relatively smoother edges with striations and displaced temper particles that indicate the use of sherds as pottery production tools during the scraping of coils and smoothing of vessel surfaces. A third common use attribute is smooth, rounded and straight edges suggesting the use of sherds as finely shaped disks and palettes. Partial vessels with roughly shaped outlines are often found on the floors of houses and sometimes near thermal features. The convex surfaces (the exterior surfaces of the original vessels) of these items are usually burned and sooted; the interior concave surfaces occasionally contain burned organic material or residues, indicating their use as grills for parching seeds or plates for serving food.

Other functional uses have been suggested for sherds worked into small, circular and rectangular shapes. Circular sherds with ground edges often have holes drilled in the center and have often been interpreted as “gaming pieces” (e.g., Gladwin et al. 1937), as spindle whorls due to their similarity with wheel-shaped clay or stone weights, or “flywheels”, used on weaving spindles in Mesoamerica and elsewhere (Herr 1993), and as ritual or hunting paraphernalia (Fulton 1941; Koerper 1998). Another possible use was to close or seal the orifices of ceramic vessels during transport. As suggested by the context and different wear or shaping patterns observed among worked sherds, the uses for such items often can be inferred on contextual and other evidence at habitation sites (e.g., Oppelt 1984). Most ethnographically documented practices of secondary use of sherds involve domestic production and subsistence tasks such as scoops, palettes, potholders, temper, lids, pottery tools, and kiln wasters (see summary in Rice 1987: 294).

The recycling and secondary use of ceramic sherds as tools and for other special uses may have contributed to the extensive ceramic distributional patterns observed across most of the landforms of Fort Bliss. An important distinction between this use of ceramics and those reviewed above is that it was sherds, rather than vessels, being transported across the landscape. The observed ceramic distributions across regional basins, or at least a component of such distributions, would have resulted from discarded and broken sherd tools rather than broken vessels, and thus should exhibit different forms of distributional patterning and specific attributes. Most notably, of course, will be the presence of ground, chipped, or abraded edges on sherds.

Case Study: Refuse disposal, artifact scavenging, site reoccupation, and processes of site formation at Gobernadora

Several of the behavioral and cultural practices reviewed in the preceding section may appear to be relatively trivial or could be thought of as having little effect on the archaeological record. Such is not the case. The combined site formation processes of scavenging, recycling, and refuse disposal can contribute significantly to the composition of cultural deposits and artifact distributions. Moreover, chronological interpretations based on the presence of one or two temporally sensitive items may be misleading unless corroborated by other evidence.

The Gobernadora pit house site in northeast El Paso, Texas, presents a noteworthy case study of site formation processes involving refuse disposal, site reoccupation, and artifact scavenging and recycling. Gobernadora (41EP321) is an Early and Late Doña phase settlement consisting of five pit houses surrounded by numerous discrete activity areas consisting of rock-lined pits and associated fire-cracked rock discard scatters (Miller 1989; Shafer et al. 1999). Studies of ceramic use have noted that high proportions of the artifact assemblages at Gobernadora and other late Mesilla and Early or Late Doña Ana phase village settlements show evidence of secondary use and recycling. Proportions of modified sherds range from around 1-2 percent (Reed et al. 2002;

Sale 1999; Shafer et al. 2001a) to upwards of 10 percent of the assemblages at the Gobernadora and North Hills sites (Miller 1989, 1990). Based on these proportions, it is clear that a substantial number of sherds were being scavenged, recycled, and redeposited in various contexts across these sites.

Seventy-two sherds of a distinctive Chihuahuan Viejo period, painted and textured vessel (Mata Red-on-brown or Mata Polychrome) were recovered from several contexts at Gobernadora. Many of the sherds were conjoinable, including all the rim sherds that together formed at least 50 percent of the rim or orifice diameter. The paste, finish, and surface color of the vessel were so distinctive that it is confidently assumed that non-conjoinable sherds were from this single vessel. The contexts from where the 72 sherds were recovered are illustrated in Figure 10.8. Sherds were recovered from trash fills of four out of five pit houses, a large trash midden at the eastern margin of the site, and three of the major activity areas on the site. The activity areas consisted of rock-lined roasting pits and associated burned rock discard scatters. The Viejo period painted and textured sherds recovered from these activity areas were shaped and edge abraded and likely served as scoops and digging tools.

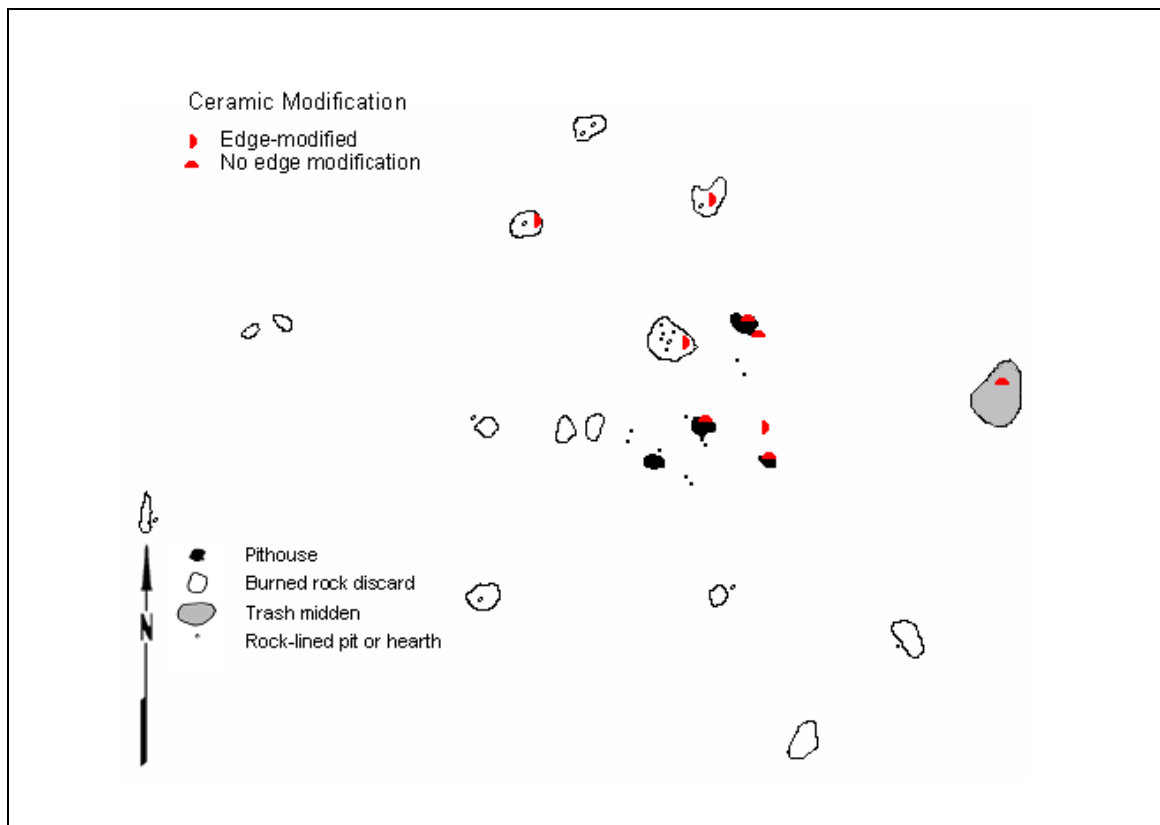


Figure 10.8. Distribution of sherds from a single Viejo painted/textured vessel at Gobernadora.

Contextual analysis of chronometric dates from Gobernadora, Ojasen, and North Hills I determined that the terminal use episodes for the majority of burned rock activity areas postdate the occupation of most pit houses and formation of most midden deposits (Miller and Kenmotsu 2004). If an extensive radiocarbon dating program had not been undertaken at Gobernadora, these contexts would have been dated based on ceramic cross dating. The result would have been an erroneous conception of site chronology and occupational history, including the

multicomponent aspects of the site that would likely have been obscured. Instead, consideration of the various behavioral formation processes of artifact scavenging, recycling, and discard and potential for site reoccupation provides a much more realistic framework for understanding how the site was formed through various occupational events.

SITE ABANDONMENT AND REOCCUPATION

The study of *de facto* refuse offers important insights in settlement organization and the process by which sites or locations were abandoned. The planned abandonment of habitations and locations often results in the deposition of items having particular attributes or qualities. Generally speaking, complete and planned abandonment results in large and easily replaced items being left behind, while smaller and more valuable items will often be taken along. This does not always hold true, as in the case of ritual deposits that may contain valuable items. In planned and gradual abandonment, most valuable items will be moved to the new settlement location. Additionally, during the terminal stages of abandonment, artifacts and materials that normally would have been collected or cleaned and deposited as secondary refuse tend to be left as primary refuse.

Decisions involving the types, sizes, and weights of objects left behind during a planned change in residence depend upon several factors, including the time the occupants have to prepare for the move, the distance to be traveled, and whether they intend to return (Lightfoot 1993; Varien 1999). When little or no *de facto* refuse is found on the floor (or cached in below the floor) of a structure, it may generally be assumed that useful items were removed during abandonment and therefore the abandonment was planned and gradual and return was not anticipated (Schlanger and Wilshusen 1993; Varien 1999).

Conversely, if large quantities of *de facto* floor items are encountered, it may be that the items were left behind either because abandonment was unplanned or because the residential move involved a large distance. In situations of catastrophic or unplanned abandonment, many items of value, including whole and unbroken items, will be left in place. The presence of large wooden construction elements, ceramic vessels, stored foods, and so forth may be indicators of unplanned or catastrophic abandonment. The situation can be complicated by ritual acts of abandonment such as the intentional burning of structures and belongings. It is possible that *de facto* refuse on room floors was left behind as ritual offerings. The potential for termination objects (Creel and Anyon 2003) to be placed prior to subsequent ritual abandonment and/or burning of structures should be considered. The widespread burning evident at Embree Pueblo, complete with substantial quantities of foodstuffs that likely would not have been left for destruction, may argue against ritual burning at this site. On the other hand, several rooms at Madera Quemada, Twelve Room, and Hot Well pueblos may have been ritually burned, with termination objects placed in floor and subfloor context.

In contrast to pueblo rooms, it is surprising how few pit houses contain substantial amounts of *de facto* floor assemblages that would indicate unplanned or forced abandonment. In fact, the floors of many excavated pit houses in the southern Jornada region are almost completely devoid of artifacts. Little in the way of site furniture or other evidence of rapid abandonment appears to exist. These contrasting patterns of structural burning, *de facto* refuse, and abandonment merit further study.

SITE STRUCTURE AND COMMUNITY PATTERN

As noted throughout the current document, the nature of prehistoric settlement and land use in the Jornada Mogollon region has been a relatively constant avenue of inquiry over the past two

decades. Numerous models and modes of analysis have been proposed, the majority of which reference the collector-forager dichotomy and attempt to identify logistical and residential site or assemblage attributes that can be related to one or another organizational strategy. The majority of these studies have been hampered by a general inability to differentiate various site types on an *a priori* basis (or even *ex post facto* basis) for modeling expectations of assemblage attributes. A firm understanding of the variability among site layouts and site formation processes representative of different settlement and organizational strategies is lacking.

To better illustrate this point, the following question may be asked: without specific reference to assemblage characteristics, what exactly constitutes a Late Archaic or Early Formative period prehistoric residential site among the low-density and low-intensity occupations typical of the central Hueco Bolson? In some cases, the presence of one or two house structures may be used to infer a residential occupation. However, this belies the fact that many sites had ephemeral hut structures that either did not leave identifiable archaeological traces or were not discovered during archaeological investigations. The presence of multiple hearth features is also occasionally referenced as an indicator of more complex residential settlements, although multicomponency must first be ruled out through chronometric analysis. Often, the expectations reflect agriculturally based and relatively sedentary systems, with the result that residential sites are expected to contain dense artifact deposits, clustered house distributions, multiple features, and so forth. In an important observation in opposition to this perspective, Mauldin (1995, 1996) suggests that many of the low-density sites in the Jornada region are indeed residential in nature and thus will often defy these expectations.

An alternative approach would be to begin to identify and characterize spatial patterns of features and artifacts representative of differing site types and settlement organization. Sites with hearths and structural features representing residential settlements should have attributes of site structure and artifact patterning that reflect artifact cleaning and refuse disposal and patterned use of space during longer-term use of a location, as has been documented through numerous ethnographic and ethnoarchaeological studies (Binford 1978, 1983; Fisher and Strickland 1989, 1991; Hitchcock 1987; Kent 1991; O'Connell 1987; Yellen 1977). In contrast, artifact scatters and hearth-artifact scatters representing logistical land use should not have such spatial qualities, but rather a more random and unsystematic spatial patterning.

The identification and interpretation of spatial patterning is not intended as an end unto itself, but rather is intended to be a precursor to several research pursuits and goals. By first identifying site structure and arriving at some general concepts of site function, occupational history, residential duration, and so forth, other aspects of prehistoric adaptation can potentially be examined further and modeled. Seldom can a concise statement be made about whether or not the scattered and clustered distributions of hearths and artifacts encountered across the Hueco Bolson and Tularosa Basin represent overlapping remains of logistically-organized land use patterns or multiple-loci residential settlements. If at some general level a means of differentiating between various forms of residential components can be discerned, then modeling of the various technological signatures for these components can occur.

Before proceeding, it is necessary to outline the principal perspectives that guide the research program set forth in the following discussion. These perspectives reflect a fundamental reconsideration of the research potential of archaeological sites and certain characteristics of those sites on Fort Bliss and the greater Jornada region. First, the spatial and temporal integrity of many sites on Fort Bliss is better than commonly acknowledged. Site multicomponency, landscape distributional patterns of artifact discard and loss, and artifact recycling are all potential problems. Yet, more detailed analyses of chronometric dates and spatial associations between features and artifacts suggest that problems of assemblage mixing and landscape palimpsests may not be as pronounced, extensive, or intractable as once thought. When smaller scales are

considered, it is quite common to find groups of features and activity areas that represent single occupations (Mauldin et al. 1998; Miller 2007a). The ability to identify unambiguous and interpretable spatial patterning at Jornada sites is not as quixotic an endeavor as once thought.

Second, the geomorphic context and erosional status of many sites and landforms means that in certain areas, much of the archaeological record of basin landforms consists of surface or near-surface manifestations. In other words, the majority of the spatial distributions of artifacts and features across large expanses of terrain are readily accessible. Very large areas can be stripped of thin eolian overburden deposits and multiple feature clusters can be exposed. Surface collections can sometimes recover enough artifacts to allow for methods of point pattern spatial analysis. With a little vision, foresight, and planning, it may be possible to obtain some of the most detailed and dimensionally extensive spatial datasets of hunter-gatherer campsites available anywhere in the world. Thus, as emphasized in the introduction to this section, the archaeological research program at Fort Bliss has the potential to make profound contributions to the anthropological study of hunter-gatherer campsites and social and settlement organization.

Third, we can continue to lament the lack of chronometric resolution afforded by our reliance on radiocarbon dating or we can attempt to develop tools and methods to define relative age associations and evidence of multiple occupations. Statistical contemporaneity among radiocarbon age estimates is limited, under the very best circumstances, to a minimum of 100-year resolution. More often, the resolution is on the order of 150 to 250 years. Therefore, the presence of multiple, statistically contemporaneous dates cannot be used to establish contemporaneity among components with absolute certainty. While settlement contemporaneity cannot be unequivocally establish through radiocarbon dating, if multiple, contemporaneous dates are obtained from a group of spatially related features; at least the possibility that the features *are not* contemporaneous can be discounted. Working from this perspective, a renewed focus on comparing and contrasting the nature of spatial distributions associated with groups of contemporaneous and non-contemporaneous features may provide insights into whether or not spatial integrity is compromised by overlapping occupations. Numerous articles have been published that present creative means of examining site structure and partitioning various occupational episodes. The analyses range from distributional studies of different types of refuse found around and within pit house clusters to point pattern spatial analysis of individually plotted artifacts. Finally, additional dating methods, such as bone fluoride dating, are continually in development.

Fourth, it is critical that more detailed excavation and reporting methods be applied to the study of refuse deposits and disposal patterns. After all, most of the archaeological record at Fort Bliss and elsewhere throughout the world consists of one or another form of refuse. Refuse disposal patterns offer critical insights into site structure at both intensively occupied pit house settlements and even low-density hunter-gatherer campsites. Moreover, the composition of refuse deposits in chronologically ordered pit house fill and midden deposits can yield additional insights into changing subsistence and technological adaptations.

Finally, it was suggested earlier in this section that archaeologists reorient their focus from concerns with stratigraphic relationships and integrity to one more concerned with identifying horizontal patterning among distributions of prehistoric features and artifacts in the Hueco Bolson and Tularosa Basin. By doing so, we may begin to gain a broader appreciation of spatial relationships between features, artifacts deposition or discard patterns, and structural aspects of site formation and community pattern. This is not intended to discount behavioral considerations, for it is clear that many components of site structure, such as refuse disposal patterns and artifact toss zones, represent patterned human behavior. Moreover, a broader conception of how site structure (and even behavior) is formed and conditioned through various social relationships and modes of social production is proposed. In essence, one way of viewing the transition from site

formation to site structure is through a transition from behaviorally conditioned transformation and formation processes to more socially conditioned organizational aspects determined through kinship, social distance, settlement organization, anticipated residence duration, food sharing, and so forth. This is an oversimplification of course, in that behavioral and social factors are often interwoven.

It is instructive to consider the development of explicitly spatial approaches to archaeological investigation among Old World archaeologists. Although seldom credited or cited by North American archaeologists, much of the influence on Old World concerns with spatial analysis and reconstruction of site structure was through the work of Andre Leroi-Gourhan. Trained as an ethnologist, he became interested in applying broader anthropological studies and ethnographic models to archaeological contexts (Aduze 2002). As part of this emphasis, he developed several influential methods of both fieldwork and analysis, including the *decapage* approach to excavation and the *chain operatoire* method of technological analysis (see Chapter 12).

Rather than emphasizing the diachronic nature of culture change via stratigraphic excavation, Leroi-Gourhan's approach examined the synchronic nature of single occupations revealed through the exposure of horizontal living surfaces. His excavations at the Magdalenian period, reindeer hunter site of Pincevent (Leroi-Gourhan and Brezillon 1966, 1972) served as the model for his approach, and his excavation data has continued to be mined for spatial and behavioral data during the course of the following 30 years (Enloe and David 1992; Enloe et al. 1994; Simek and Larick 1983).

Decapage excavations are methodologically equivalent to what have been termed "horizontal exposures" or "block excavations" at numerous sites in the Jornada region. While horizontal exposures have been utilized since the mid-1980s (Miller 1989, 1994; O'Laughlin and Martin 1989), it appears the goals of such excavations were often phrased in terms of augmenting artifact samples and enhancing the recovery of features in an effort to overcome the typically low artifact and sample recovery rates of open-air sites in the central basins. The identification of site structure was occasionally mentioned as a goal (Miller 1989, 1990; O'Laughlin and Martin 1989), but research was not framed within an explicitly social or organizational structure. For example, Miller's discussion of site structure research was essentially a functionalist perspective of how different site layouts related to the larger dimension of settlement and land use.

In contrast, Leroi-Gourhan's approach was explicitly designed to identify spatial relationships among exposed "living surfaces" and thus ultimately provide a means of inferring forms of prehistoric social organization, or what he termed "paleoethnology". While the term paleoethnology did not receive widespread acceptance (as archaeology is generally implicitly understood), it is still a relevant concept. We are essentially attempting to reconstruct similar aspects of social structure and organization, group composition, technological adaptations, from spatial data at hunter-gatherer camps.

Ethnographic Analogy, Ethnoarchaeology, and Models of Site Structure and Spatial Organization

The identification of spatial patterning is not an end unto itself. As stated by Kent (1991: 56), "Only through understanding the principles behind patterns, rather than simply describing their presence or absence, it is possible to develop realistic and predictive models of the past." The spatial patterning identified at a particular site can be compared with those defined through actualistic research. Actualistic research, including ethnographic, ethnoarchaeological, and experimental approaches, offers important observations for the modeling and interpretation of spatial patterns.

Ethnographic studies of contemporary hunter-gatherer and horticultural groups provide invaluable insights for modeling the spatial structure of prehistoric sites. There is a tendency among Jornada archaeologists to consider or adopt ethnographic models solely from hunter-gatherer groups inhabiting arid environments, such as the various ethnic subdivisions of San Bushmen (Lee 1976; Silberbauer 1972; Tanaka 1976), Australian groups (e.g., O'Connell 1987; Spurling and Hayden 1984), or inhabitants of other arid lands (Taylor 1964). Of course, these are most appropriate for application to the semi-arid environment of the Fort Bliss region. However, spatial patterning can also be detected amongst hunter-gather settlements in other environmental contexts, such as more temperate forest and savanna environments or tropical forests (Fisher and Strickland 1989, 1991; Kaplan and Hill 1985; Kelly et al. 2005; Kent and Vierich 1991). As one example, ethnographic studies of Efe pygmy settlements identified interesting patterns of residential structures arranged around communal roasting features, as well as features "owned" by extended family groups (Fisher and Strickland 1991).

Aside from the classic ethnographic studies, ethnoarchaeological studies have also examined artifact and material distributions at abandoned hunter-gatherer settlements. Binford (1978, 1982), Murray (1980), Whitelaw (1983), Spurling and Hayden (1984), and O'Connell (1987) conducted influential studies that examined the behavioral patterns that created repetitive spatial relationships between features and various classes of material culture. Additional studies have built upon these initial efforts and applied them to other areas of the world (Enloe et al. 1994; Hayden and Cannon 1983; Koetje 1994; O'Connell et al. 1992; Yellen 1996), while other studies have expanded the behavioral perspective to also bring into focus the specific social contexts that affect the patterning of features and materials, such as kinship and food sharing (Kent 1991; Kent and Vierech 1991; Stevenson 1991).

The collective effort of these actualistic studies resulted in the identification of a consistent archaeological signature. Recurrent patterns among hunter-gatherer settlements include hearth-centered activity areas. Depending upon the length of occupation and size of the resident social group of the particular settlement, hearth-centered activity areas often have repetitive spatial associations with patterns of site maintenance and trash disposal. Additionally, correlations between feature and artifact patterning and the sizes of resident social groups and residential stability (duration of occupation) have been observed.

Hearths are typically located in relationship to shelters and living spaces. The numbers of hearths are correlated with the size of the resident social group and length of occupation (Kent 1991; O'Connell 1987; Stevenson 1991) an observation that has important implications for interpreting prehistoric hunter-gatherer settlements in the Jornada region. The clusters of multiple hearths observed at numerous ethnographically documented hunter-gatherer camps are highly reminiscent of the clusters of hearths commonly encountered at prehistoric sites in the central Hueco Bolson and Tularosa Basin, and offer important parallels for interpreting site use.

Patterns of artifact discard and loss are associated with hearth-centered activity areas, including the "drop and toss zones" defined by Binford (1978), and identified at numerous archaeological campsites (Enloe et al. 1994; Mitchell et al. 2006; Stevenson 1991; Timmins 1996; Vaquero and Pasto 2002). Longer-term or more intensive use of hearth activity areas results in the accumulation of various classes of debris, refuse, and discarded items. At camps occupied for longer durations, these areas are cleaned and debris is removed to the perimeter of the activity area, or what Stevenson (1991) terms the "displacement" zone. There is a selection bias in this process, in that artifacts removed or tossed tend to be larger or perceived as more hazardous (e.g., cores and lithic tools with sharp edges, rotted bone scrap, heating stones, broken ground stone) while smaller items such as small waste flakes tend to be overlooked and remain as primary refuse. This creates a clear size sorting among artifact classes (O'Connell 1987). The ultimate

expression of such discard patterns would be the formation of formal trash middens at intensively occupied residential sites.

In contrast, site maintenance is much less common at temporary camps (Binford 1978; Jones 1993; Yellen 1977, 1996), and thus lesser degrees of size sorting and differentiation among artifact classes is expected. This would also result in little or no distinction between peripheral displacement zones (if they exist at all) and the immediate drop and toss zones surrounding hearth activity areas.

The dimensions of hearth-centered activity areas have been found to correlate with the size of the resident household group and duration of occupation (Kent 1991; O'Connell 1987; Stevenson 1991; Yellen 1977). The dimensions of activity areas at !Kung San campsites occupied by small social groups for relatively short periods are significantly smaller than those occupied for longer periods by larger Alyawara household groups. This pattern tends to hold true in the broader cross-cultural analysis reported by Kent (1991).

In summary, spatial analysis and identification of variable forms of site structure at prehistoric Jornada hunter-gatherer and horticulturalist settlements may be used to make general inferences regarding the duration of settlement, size of resident social group, the systemic function and orientation of the site (i.e., residential forager, residential collector, task-specific collector).

The term general is used here because it is not proposed or assumed that such studies can by any means reconstruct the actual group composition and occupational history of prehistoric Jornada hunter-gatherer settlements. However, closer inspection of spatial patterning at these sites may offer a means of differentiating, on a heuristic level, among various settlement types representing different subsistence strategies. This will also be of immense use for refining technological and settlement models.

Trash and Refuse Deposits

Much of archaeological inquiry deals with what essentially consists of trash - the discarded remains of food preparation and consumption, structural remnants and building materials, fuel wood and hearth charcoal, the traces of various manufacturing processes, broken and worn out tools and containers, and all the other debris and detritus of human-material interactions. Most of the material culture recovered during excavation represents one or another form of de facto, primary, or secondary refuse that was abandoned, discarded, or lost through various behaviors or modes of social practice. As such, trash deposits and patterned refuse disposal practices are one of the key attributes to understanding site formation and site structure.

At many sites, trash contexts such as middens and pit house fills provide by far the bulk of artifacts and organic materials for analysis. Since these are deposits of secondary refuse, there are contextual problems involved when attempting to deal with primary contexts.

For example, radiocarbon dates obtained from trash fills in pit houses are dating the target event of post-abandonment use of the structure as a trash receptacle, as opposed to the occupation of the structure as represented by dates obtained from subfloor features. Yet, these dates may be of equal value by informing us of later use episodes at the site, and temporal changes in the composition of trash deposits may inform us about changing technological, subsistence, and social practices.

Two general approaches to the spatial study of refuse disposal practices are envisioned for research at Fort Bliss and the greater Jornada region. One domain involves the relatively low-intensity and low-density discard of tool manufacturing debris, broken and discarded tools, animal bone, and other materials at hunter-gather campsites. The second domain deals with the much more intensive and localized disposal patterns characteristic of longer-term pit house and

pueblo occupations by horticultural and agricultural groups. These are generalized approaches and are intended to facilitate a broader appreciation of spatial structure and hopefully serve to encourage additional studies.

Ethnoarchaeological studies have identified a positive relationship between the duration of settlement occupation and the distance between where trash is produced through various activities and where it is discarded (Hitchcock 1987; Kelly et al. 2005). In other words, as length of occupation increases, accumulations of trash are placed at greater distances from activity areas and residences. Additionally, trash disposal becomes more consistently and spatially localized. At short-term camps, trash is tossed within a few meters of domestic hearths.

Yet, ethnographic studies have observed that continual disposal of refuse at sites occupied for slightly longer periods often creates large, crescent-shaped scatters of debris around living spaces (Bartram et al. 1991; DeBoer and Lathrap 1979; O'Connell 1987; O'Connell et al. 1991). Meehan (1982) notes that debris dumped around the periphery of clusters of hearths at Australian hunter-gatherer camps sometimes formed quite dense mounds. While trash disposal tends to be more localized and consistent at longer-term residences, it is not necessarily any more patterned than at less-intensively occupied hunter-gatherer camps. As discussed above, ethnographic and ethnoarchaeological studies have identified consistent patterning among hearth-oriented artifact distributions, including drop and toss zones, displacement zones, and size sorting.

The dense accumulations at sites of more intensive occupations or ones of longer duration are of interest for understanding site formation and occupational history. As shown in Figure 10.9, the areas of greatest artifact density at the Mesilla phase Conejo and Tres Casitas sites were, for the most part, recovered from the fills of pit houses that had been abandoned and used as trash disposal areas. The highest material densities at the Tres Casitas Site were recovered from within and around one of the three pit houses at the site. Likewise, the majority of ceramic and chipped stone materials were recovered from pit house fills at the Conejo Site. It is also evident that several of the larger midden areas were formed through continual use of what was originally a pit house location. Once the pit house depression fills with debris, continual use of the location results in a horizontal expansion of the midden area.

Artifact densities and distributions vary according to material class. Ceramic densities are localized within pit house fills and two potential activity areas, while lithic artifact densities include several potential activity areas between and around pit houses. The composition of midden deposits at sites with long, complex occupational histories such as Conejo and North Hills may provide insights into changing technological and subsistence patterns.

For example, Figure 10.10 compares the densities of ceramics, chipped stone, and faunal bone in the refuse deposits of six pit houses and three midden areas at the North Hills I Site (Miller 1990, 2003). The densities of discarded chipped stone debris and ceramic sherds are generally correlated and both decrease through time. The most noteworthy pattern is the increasing quantities of animal bone deposited in dedicated midden areas later in time, suggesting the possible intensification of rabbit hunting and processing beginning in the late 1100s.

The cursory review of intra-site patterns of refuse disposal and midden composition demonstrates the value and importance of refuse deposits. When combined with a well-designed chronometric analysis, a detailed study of the variable composition, density, and distribution of refuse deposits can contribute a wealth of information on the processes of site formation and the occupational histories of prehistoric residential sites.

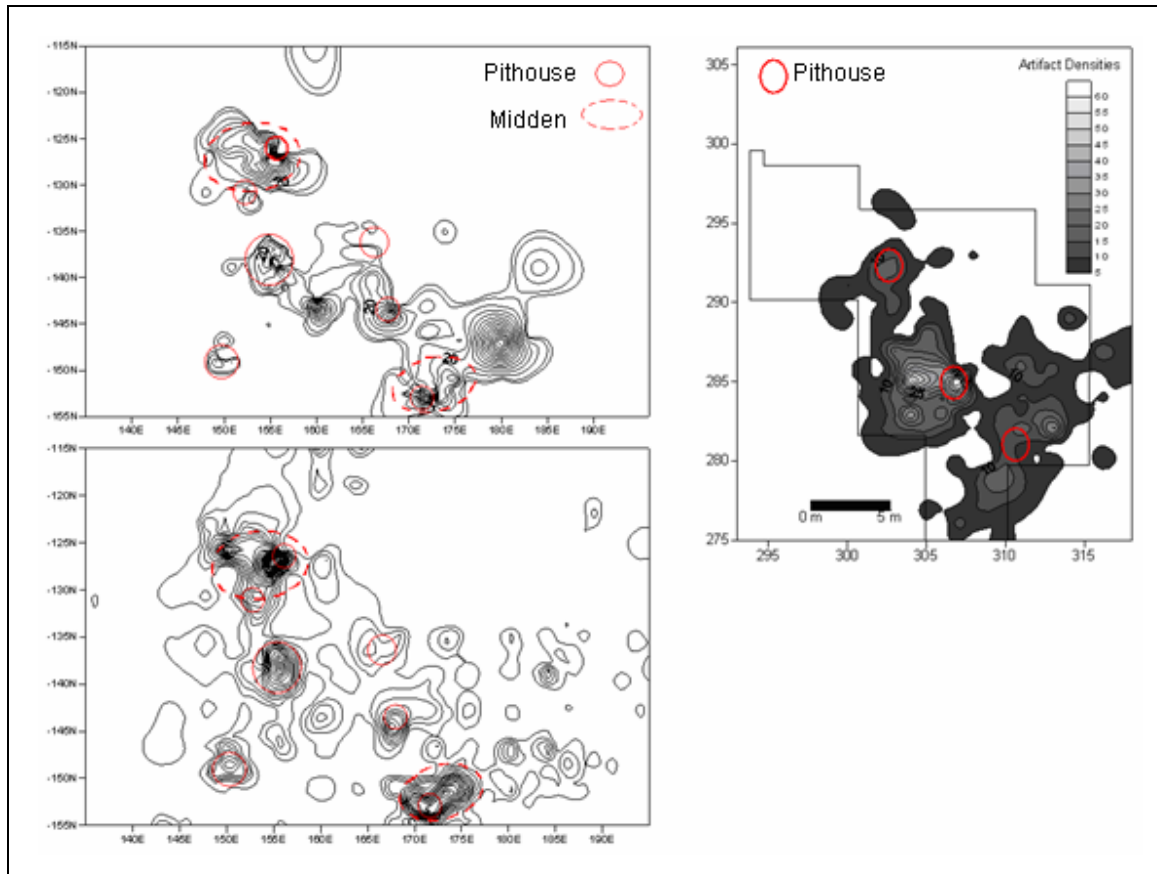


Figure 10.9. Contour plots of artifact densities at Mesilla phase pit house occupations on Fort Bliss.

Left figures: ceramic (top) and lithic (bottom) densities at the Conejo Site;

Right figure: total artifact densities at Tres Casitas.

Arrangements of Hearths and Structures

Small domestic hearths are by far the most common type of feature encountered throughout Fort Bliss and the greater Jornada region. By one estimate between 400,000 and 1 million hearth features are present across Fort Bliss (Mauldin 1996: 214). Linear and clustered distributions of hearths are one of the more consistent aspects of prehistoric occupations in the central basins, particularly among sites where broad horizontal areas (*decapage*) were exposed through excavation. Figure 10.11 shows several examples of hearth clusters with statistically contemporaneous radiocarbon dates from various block excavations around the Hueco Bolson and Tularosa Basin. Isolated and spatially segregated hearths are also common throughout most landforms. The settlement implications of these variable arrangements of isolated and clustered features should receive a renewed emphasis.

Hearths are the most prevalent of feature types at many prehistoric hunter-gatherer settlements, but house structures and living spaces are an equally important aspect of site structure. Indeed, it is the spatial organization of residences and living spaces that is the primary determinant of the locations of hearth activity areas in the first place.

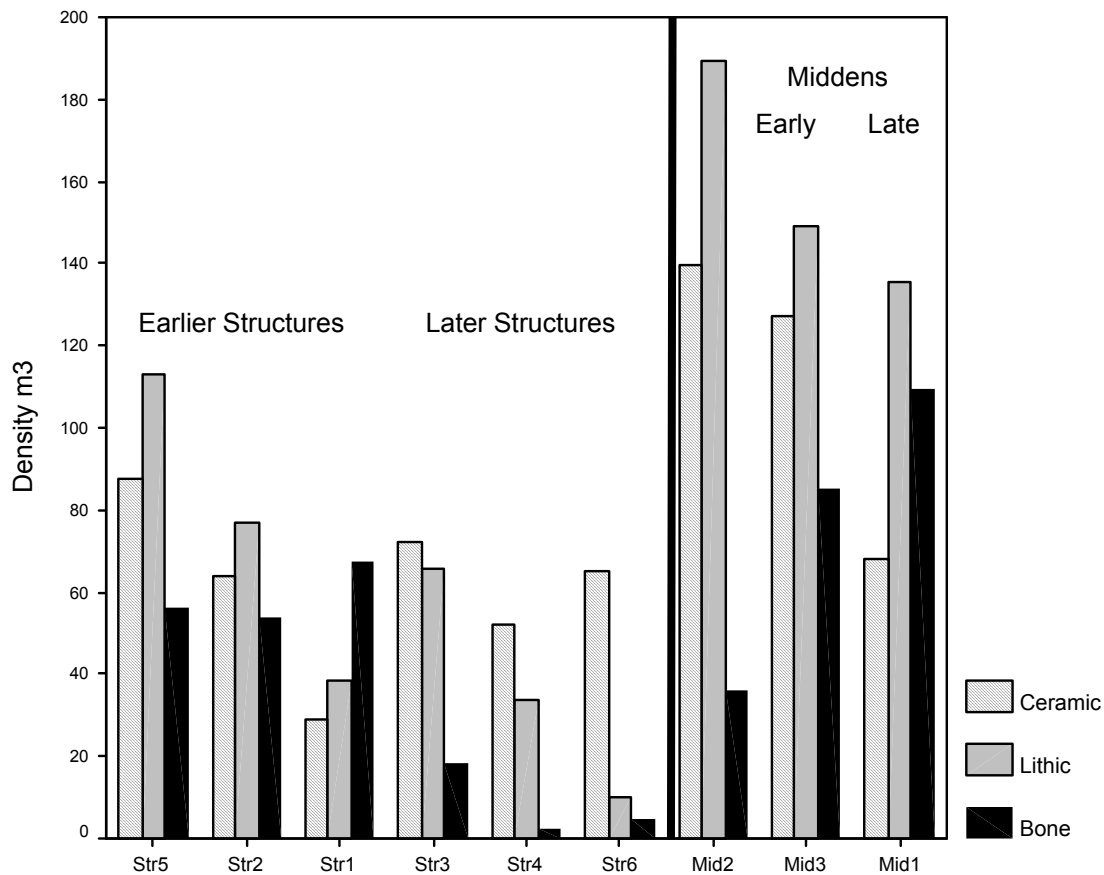


Figure 10.10. Densities of ceramics, chipped stone, and faunal bone in secondary refuse deposits at North Hills I.

Based on ethnographic observations throughout the world, there is a high correlation between the positioning of domestic hearths and the locations of house structures. Therefore, it can be assumed that ephemeral structures were associated with many or most hearth distributions in the Jornada region. Whether the hearth was internal or external to the structure is also of issue. In either case however, based on cross-cultural ethnographic and ethnoarchaeological studies, it is proposed that most hearth features were associated with some form of domestic structure, regardless of how ephemeral or transitory the structure may have been.

In this perspective, it is informative to compare the linear arrangements of prehistoric Jornada hearth features illustrated in Figure 10.11 (see figure 10.11) to ethnoarchaeological studies of modern hunter-gatherer camps. Figure 10.12 shows a seasonal campsite of the Kua San group of the Kalahari region (from Bertram et al. 1991). The parallels between the linear patterns of hearth features associated with domestic structures at the Kua camp and the inset figures to the left showing two examples of typical prehistoric Jornada hearth arrangements are intriguing.

Clustered arrangements of hearth features, including both circular and linear clusters, merit closer attention. Efforts should also be made to identify ephemeral house structures associated with hearth features, although this may not be possible given the combined factors of ephemeral construction and eolian erosion. At any rate, a more thorough understanding of these linear patterns of domestic hearth and inferred patterning of house structures is critical.

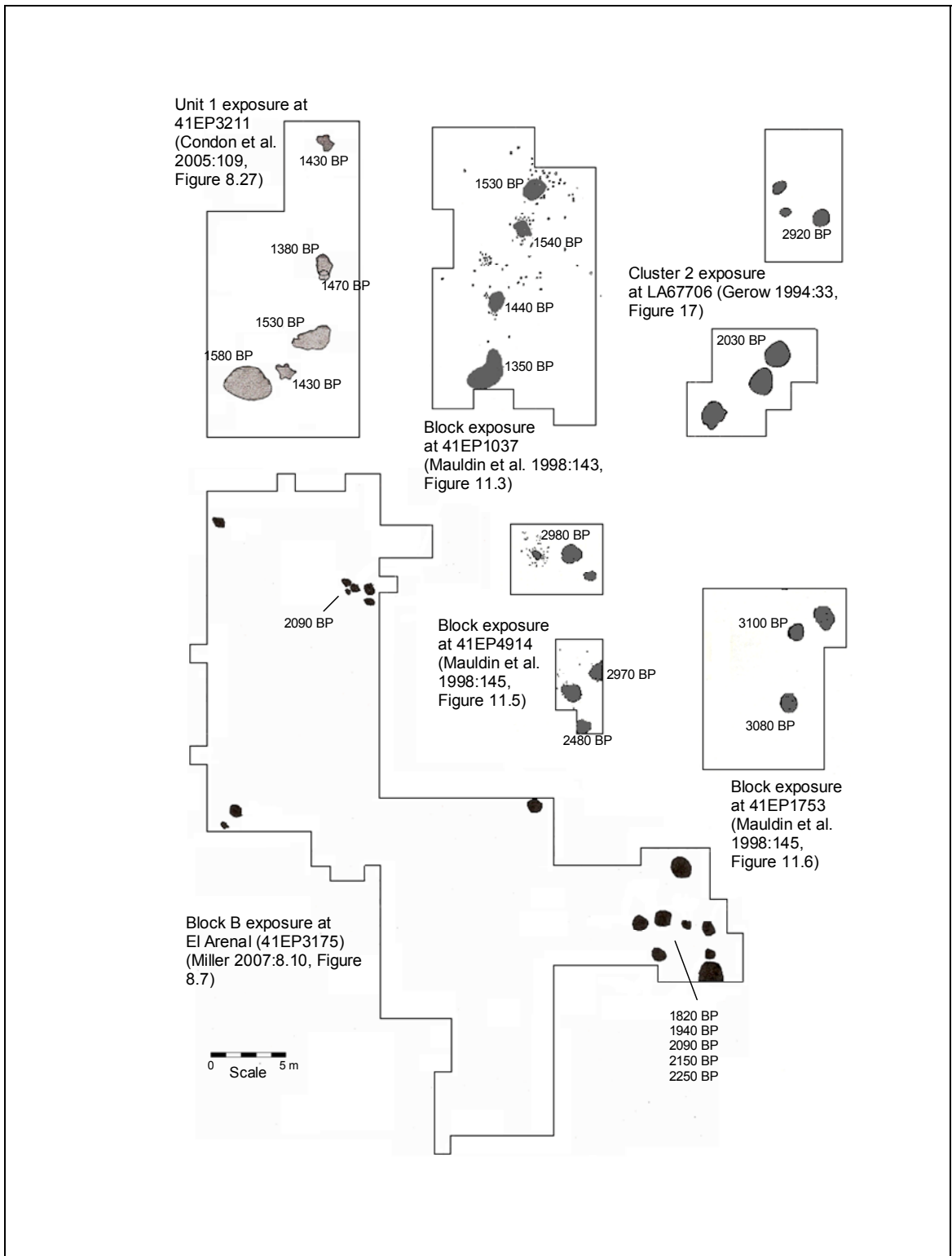


Figure 10.11. Examples of clustered hearths of contemporaneous radiocarbon age revealed in block excavations in the Hueco Bolson and Tularosa Basin. (Note the variety of clustered, semi-circular, and linear arrangements.)

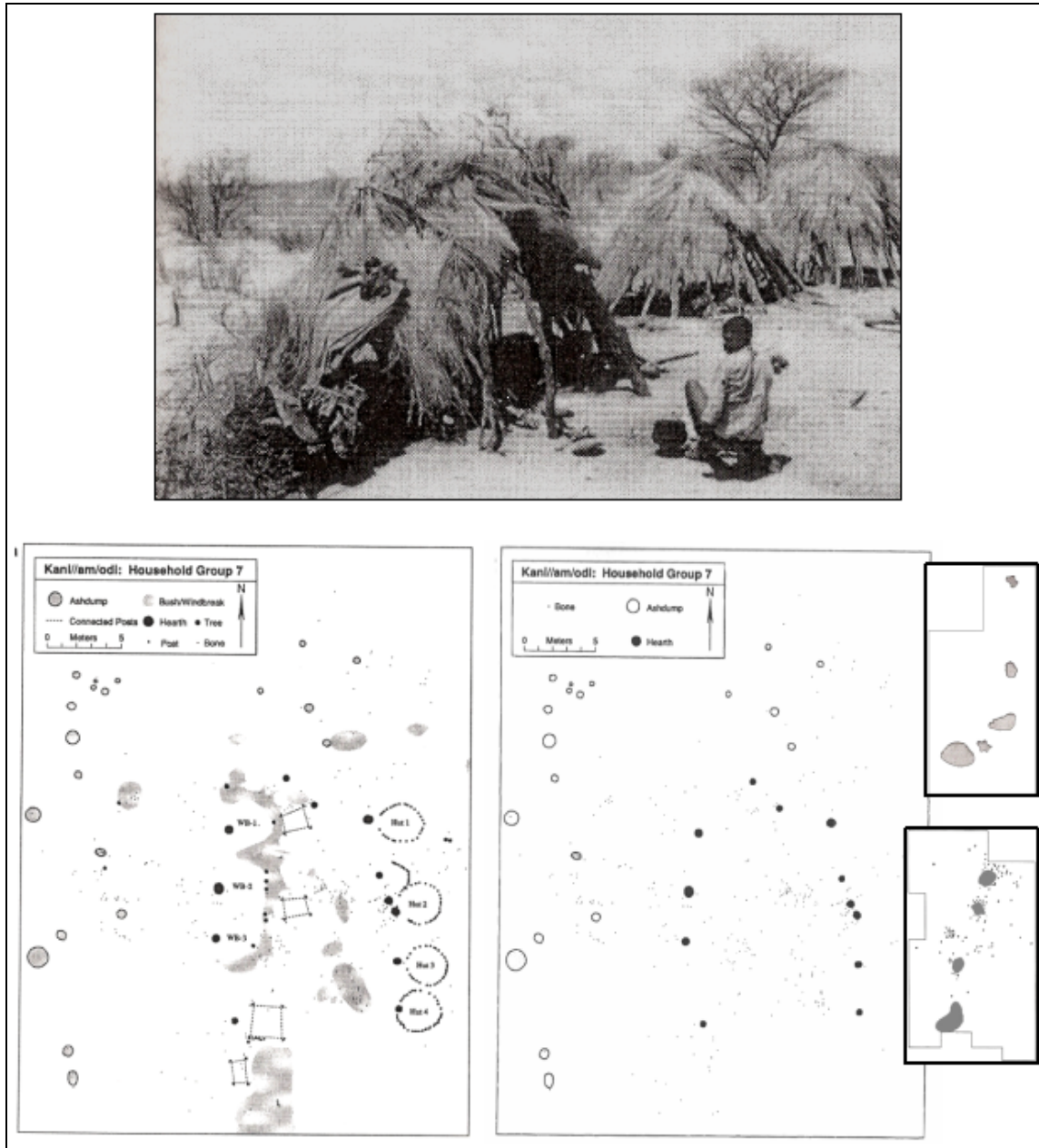


Figure 10.12. Site structure at a Kua seasonal camp.
(Photo in upper portion of the figure shows linear arrangement of brush structures and associated domestic hearths. Lower left figure shows locations of houses, windbreaks, and hearths during occupation; lower right figure shows ethnoarchaeological documentation of camp features and remains after abandonment [all three figures are from Bartram et al. 1991]. The two insets at the far right are from two of the prehistoric Jornada Mogollon sites illustrated in Figure 10.11. Compare the linear arrangement of hearth features at the Jornada sites with those documented at the Kua seasonal camps.)

The locations and distances of houses offer insights into the social organization of hunter-gatherer groups. Correlations between house spacing and such variables as social distance, group size, and predator avoidance have been observed in several studies (Binford 1991; Gargett and Hayden 1991; Hitchcock 1987; Kelly et al 2005; O'Connell 1987; Whitelaw 1983, 1991). Social relationships and modes of social production, particularly as mediated through practices of food sharing, can influence the arrangement of domestic household groups and thus the placement of house structures (Enloe and David 1992; Gargett and Hayden 1991; Kaplan and Hill 1985; Wiessner 1982). In this perspective, the widely scattered, isolated structures characteristic of many Archaic period sites in the Jornada region provide an interesting contrast with the typically clustered houses of Formative period settlements.

Courtyard Groups and Community Patterning

The preceding observation regarding the more highly clustered arrangements of Formative period houses is also of interest. One of the more critical issues for the study of Formative period residential settlements involves the analysis of site formation and occupational history in order to understand whether the habitation structures were occupied contemporaneously or represent a series of isolated, individual occupations.

As shown in Figures 10.13 and 10.14, groups of surface rooms at Late Doña Ana phase and El Paso phase settlements have several similarities with Hohokam settlements consisting of pit houses and surface jacal structures arranged around informal courtyards. Hohokam settlements have long and complex occupational histories, but the fundamental architectural component of nearly all Hohokam settlements is the courtyard group representing a cohesive and spatially-bounded social and economic entity (Cable and Doyel 1987; Doelle et al. 1987; Doyel 1991; Henderson 1987; Howard 1985; Sires 1987; Wilcox 1987; Wilcox et al. 1981).

In a similar manner, the determination that 41EP5276 at Fort Bliss and other such Jornada surface room clusters represent cohesive courtyard groups would imply the existence of structured settlements of some duration and stability. Moreover, the presence of adjoining rooms such as those identified at 41EP1602 on Fort Bliss and the Scorpion Site near Alamogordo, New Mexico, (Turnbow and Kurota 2007) suggest the presence of cohesive social groups.

Such settlements are a noteworthy contrast to settlements of the preceding Mesilla and Early Doña Ana phases. As shown in this section, many Mesilla and Early Doña Ana phase pit house villages with apparently clustered and circular house arrangements were formed through multiple occupations and do not necessarily represent coherent village settlements. The investigation of these changing patterns of site formation and site structure will yield important insights into changing modes of social organization.

RESEARCH ISSUES

Research Issues 10-1 through 10-4 are broadly phrased issues concerned with natural transformations and modern cultural transformations. These include how natural processes of soil deposition, erosion, and bioturbation and modern cultural practices have modified archaeological deposits.

Research Issue 10-1

Vertical and horizontal stratification in eolian contexts

This issue examines how eolian processes serve to bury, expose, and collapse natural and cultural stratigraphy and degrade cultural deposits. Integrated programs of geomorphic and archaeological work are needed to further define the age of the Holocene Q3 stratum and to refine

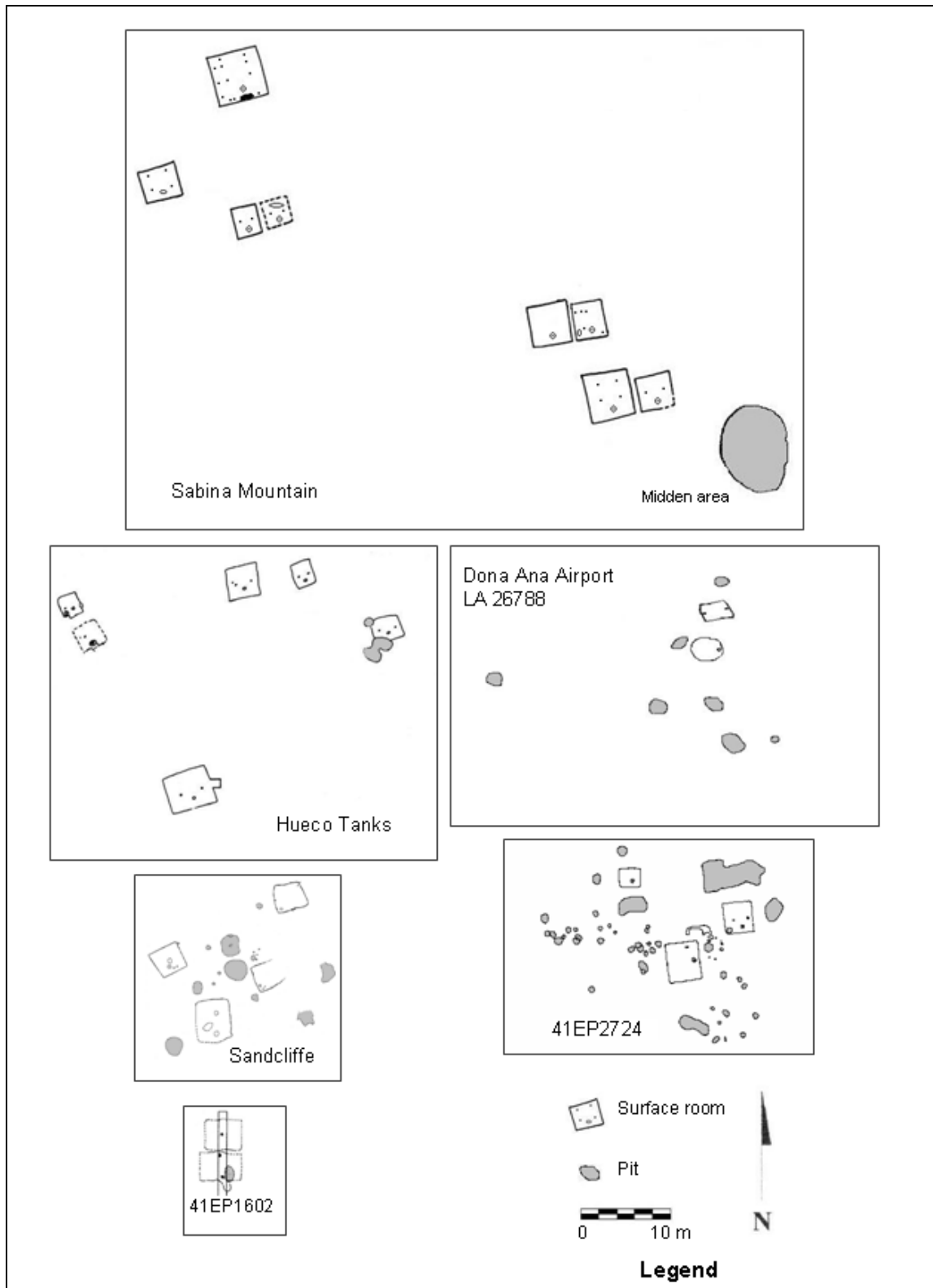


Figure 10.13. Examples of Late Doña Ana phase and El Paso phase surface room settlements of the southern Jornada Mogollon region.

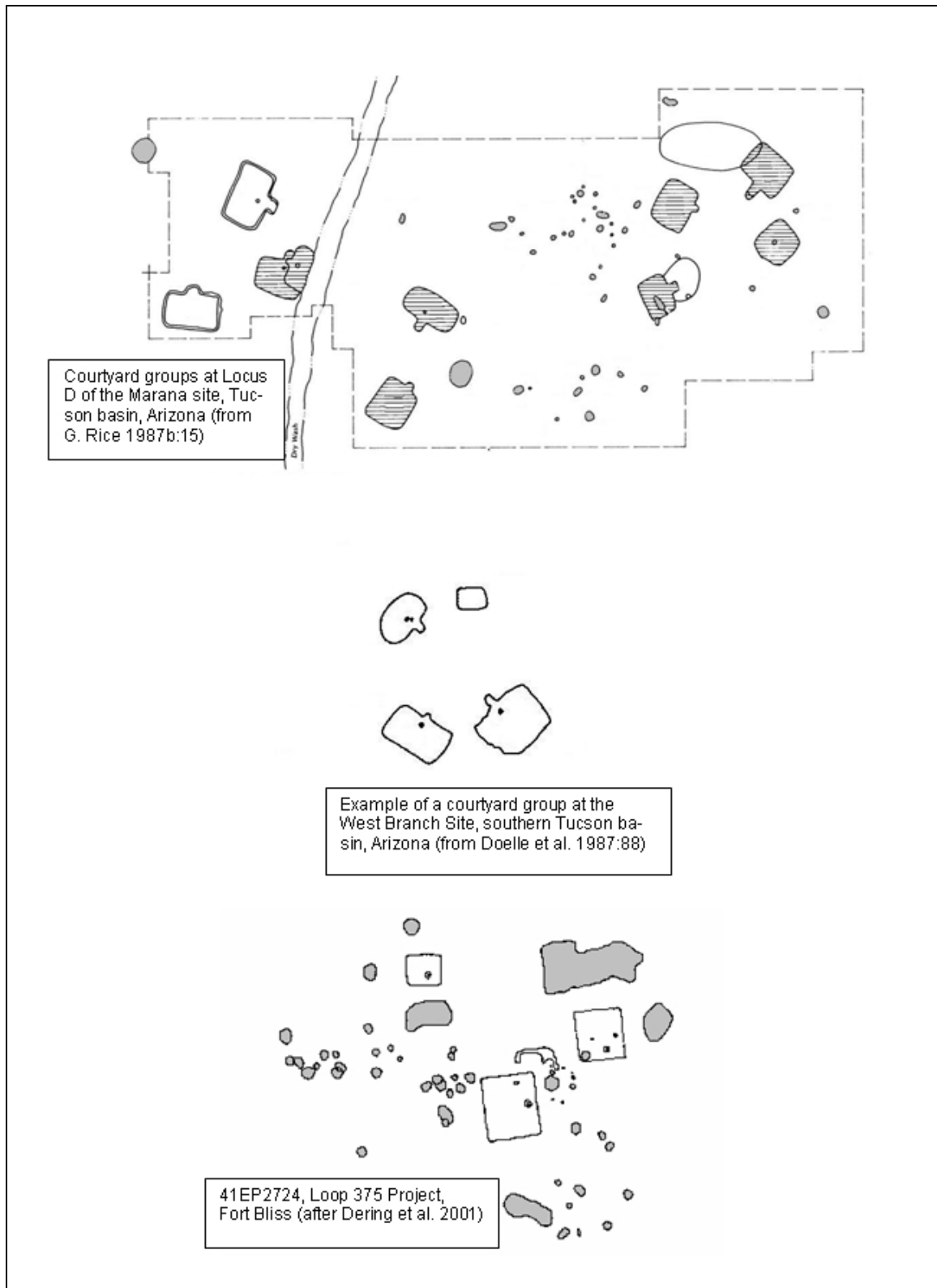


Figure 10.14. Comparison of site layout at 41EP2724, with examples of courtyard groups at Hohokam sites.

estimates of eolian aggradation rates in the central basins. In addition, the timing of periods of soil stability and erosional episodes needs to be further clarified. These data will contribute to a firmer understanding of site formation processes and whether or not features and artifacts deposited during widely separated temporal periods exist in stratified order within Holocene soil deposits. In the absence of clear natural or cultural stratigraphy in eolian environments, the issue of horizontal integrity merits further consideration. Geomorphologists and archaeologists addressing this research issue should refer to the background discussions on geomorphology and stratigraphic chronologies reviewed in Chapter 6.

Research Issue 10-2

Natural and cultural stratification in alluvial contexts

This research issue involves the processes by which alluvial deposition can result in the formation of stratified cultural deposits and how fluvial erosion via channelized or sheetwash flow can disturb cultural deposits in the alluvial fan and mountain foothill landforms. The potential for stratified features and refuse deposits in rapidly aggrading alluvial settings is underappreciated. Studies of stratified deposits can offer critical insights into site formation, occupational histories, and technological change. Moreover, stratified refuse deposits at complex residential sites in the alluvial fans offer one of the few opportunities for chronologically seriating El Paso brownware and non-local ceramic wares.

Research Issue 10-3

Effects of bioturbation on natural and cultural stratigraphy, site integrity, and stratigraphic chronology

The effects of badger, rodent, and insect burrowing were reviewed in this section, as well as in Chapter 6. The cumulative effects of years of such processes could potentially be enormous. Yet, it must also be noted that hundreds of intact pit house structures and hearths are common in the central basins, suggesting that the destructive potential of animal and insect burrowing may either not be as intensive and extensive as thought or that such disturbances may be localized in particular landforms. Research should focus on examining the extent of such disturbances. The analysis of artifacts recovered from badger burrow spoil piles described by Mauldin and Leach (1997) provides a useful example. One of the main issues is how bioturbation serves to obscure or erase the stratification of eolian soil deposits in the central basin. In addition, the potential effects of bioturbation on the accuracy and precision of OSL dating of eolian sands should be investigated.

Research Issue 10-4

Effects of modern cultural transformations on site integrity and assemblage composition

The results of the Fort Bliss Impact Study (Fort Bliss Project 94-02) have not been fully published. The original Impact Study included a compilation of Form 88 permit requests. GIS analysis of these data showed distinctive patterns where certain areas of the Hueco Bolson and Tularosa Basin were subjected to more intensive training use than other areas. It would be useful to compare the degrees of erosional exposure and site damage within these intensive use areas. In addition, the effects of increased military training on the integrity of cultural deposits and content of archaeological assemblages should be monitored over the course of the coming decade.

Research Issues 10.5 through 10.7 are broadly phrased issues concerned with prehistoric cultural and behavioral practices that formed and modified the archaeological record at Fort Bliss.

Research Issue 10-5

Recycling, scavenging, refuse classes, and site abandonment

The multiple and overlapping cultural site formation processes of artifact scavenging and recycling have been addressed by several studies at Fort Bliss and the greater Jornada region, but much more remains to be investigated. Given the long history of residential mobility characteristic of the region, it is proposed that the Jornada archaeological record has a great deal to offer for the study of recycling and scavenging behavior. Although much has been written about the process of site reoccupation in the region, the related processes of site abandonment have, for the most part, been neglected. A more consistent documentation and analysis of refuse deposits, including identification of de facto, primary, and secondary refuse, is needed. Consistent identification of these categories of refuse can contribute to a greater understanding of how sites were abandoned that, in turn, provides critical insights into whether locations, settlements, and regions were the subject of unplanned or planned (including ritual) abandonment.

Research Issue 10-6

Site formation and spatial patterning at Hunter-Gatherer Settlements

Hundreds of prehistoric sites on Fort Bliss provide very favorable contexts for the analysis of site structure. To reiterate the statement presented in the introduction to this section: the contribution of Jornada Mogollon site spatial analysis to the archaeological domain of hunter-gatherer settlement organization is potentially one of the most profound, yet presently unrealized, contributions of Jornada archaeological research.

The thousands of multiple hearth and artifact scatters lying exposed or slightly buried in broad interdunal deflation surfaces across Fort Bliss provide an ideal context to study hunter-gatherer site formation and settlement structure. In many situations, substantial and important aspects of settlement structure can be revealed through simple point plotting of surface artifacts and features. In cases of slight burial, the numerous hearth features can be chronometrically dated, providing both an overall temporal assignment for the site as well as allowing for a basic estimation of whether or not multiple hearth clusters represent contemporaneous occupations. Numerous methods of point pattern, grid, and contour spatial analysis are available and can be applied to archaeological data (Miller 2007a, 2007b, 2007c). Identification of the variability between settlement types and occupational histories of different temporal periods will provide critical insights into changing patterns of settlement and social organization.

Research Issue 10-7

Site formation and spatial patterning at horticulturalist/agriculturalist settlements

Jornada Mogollon pit house and pueblo sites offer rich and productive contexts for the analysis of site formation processes resulting from multiple occupations and abandonments. In addition, the clusters of pit houses and formal rooms have distinct occupational histories and may reflect different modes of social organization. The concept of courtyard domestic groups offers a productive means of investigating Jornada residential settlements.

CHAPTER 11. SETTLEMENT PATTERN AND LAND USE

Tim Church, Myles R. Miller, Trevor Kludt, and Patience Elizabeth Patterson

This chapter has been substantially modified and revised from the discussion of settlement patterns in the 1996 *Significance Standards* document. The modifications reflect information gained from a decade of work on prehistoric settlement and land use patterns on Fort Bliss and elsewhere in the Jornada region and efforts to interpret the data in a broader context (Church 2005; Church et al. 2002; Condon, Hall, et al. 2006; Kludt et al. 2007; Mauldin 1995, 1996; Mauldin et al. 1998; Miller 2001, 2005c, 2007b, Miller and Kenmotsu 2004). In addition, the discussion of settlement patterns has been broadened to incorporate the land use patterns as they are currently understood for agricultural groups in the region (Miller 2004b).

Many of the proposed analytical directions are designed to take advantage of the impressive amount of high-resolution information obtained during TRU surveys of over 100,000 acres of McGregor Range, Doña Ana Range, and Maneuver Area 1 on Fort Bliss. Finally, as noted in Chapter 4, the 1996 document focused on the cultural-ecological perspective. The focus has been expanded to include discussion of the social and political implications of mobility, territoriality, and other land use issues.

The material culture of past human groups in the El Paso area reveals a structured set of relationships. In the analysis of these structured relationships, several different levels of data (e.g., intrasite, intersite, landscape, and regional data) are examined. The sets of data required for settlement pattern analysis include distributional patterns of artifacts and features across the landscape made available from the recent emphasis on Transect Recording Unit (TRU) surveys, as well as basic site information such as site location, site characteristics and structure, and artifact variability. The analysis of the articulation of the environment, subsistence, and technology allow for recognition and explanation of adaptive strategies, and through these explanatory frameworks ultimately an understanding of how and why cultures change through time. These data allow settlement types and patterns to be defined (Struever 1968).

Researchers working at Fort Bliss, however, have recognized that the raw site information may not be particularly helpful in identifying these settlement types and patterns (Mauldin 1994, 1995; O’Laughlin and Martin 1989), making identification of site “types” or their respective time frames for settlement pattern analysis problematic. As noted in Chapter 3, an overwhelming majority of the sites (86 percent of + 18,000 sites) on Fort Bliss consist of an ashy stain accompanied by a few non-diagnostic artifacts. Several problems result from this sparse data set.

First, land managers seeking to make informed decisions have very little information on which to evaluate such a site because the majority of these sites have not been investigated beyond the survey or testing level. For example, in the survey of the alignment of Loop 375 across Fort Bliss land, 197 sites were recorded. Of these, 32 percent had no artifacts at all and were identified only by ashy or charcoal stains or burned caliche nodules and 112 sites could not be assigned to a time period (Shafer 2001: 16-17, 22).

Moreover, excavation of such features in the past has often recovered sufficient ash or charcoal for a radiocarbon assay, but little else (Shafer 2001). A date produced from the feature does corroborate broad land use patterns within a broad synchronic model, but if the feature does not contain macrobotanical or other material that allows interpretations of what the prehistoric people were doing at the site, the site contributes little to a meaningful settlement pattern analysis.

At the same time, it has sometimes been found during subsurface investigations that the assumptions about site “types” based on surface expressions can be quite misleading. In the Loop 375 project:

Large charcoal stains 2 m or more in width were assumed to represent the remains of structures. However, Phase II testing of such features proved that this assumption was often incorrect.... Three large surface stains at 41EP2805 (FB9895) proved to be small hearths that had deflated over a much larger area, and a small stain at 41EP2770 (FB9835) was found to be a pit house (Shafer 2001: 27).

Consequently, researchers and land managers struggle to categorize site survey data into meaningful “types” and to make informed decisions about which sites should receive further work and which are not eligible and merit no further work. In order to partially circumvent the problem with inaccurate and unrealistic site typologies, several researchers began to examine patterns of radiocarbon-dated thermal features and architectural forms across different landforms (Mauldin 1995, 1996; Mauldin et al. 1998; Miller 2001, 2005c; Miller and Kenmotsu 2004). These studies avoided many of the problems in data consistency and survey bias that hampered previous attempts to understand prehistoric land use.

Keeping in mind the limitations of the data set, to understand the prehistoric cultural systems that existed within the boundaries of Fort Bliss, the context in which they existed must be understood. That context is in part an environmental one, and what can be seen archaeologically are the remains of cultural adaptations to a highly variable, semiarid environment. Because it must be understood how cultural groups interacted with their environment, Chapters 2 and 7 provide detailed review of the current and past environments. In the following section, models of how groups in the past might have lived in and adapted to changes within that environment in order to meet their subsistence needs is presented.

Land-use models allow us to look at how a culture might have used the environment and how it was organized in order to live, thrive, and survive. Therefore, the ethnographically and/or ethnohistorically derived groups mentioned herein are groups directly associated with the El Paso area or they have similar environmental contexts the parallels of which can be extrapolated to make empirical generalizations to be incorporated in land-use models.

Taking a systemic approach (1964, 1965a, Clarke 1968, Flannery 1968), humans, culture, and nature are viewed as integrated segments of a system. Changes in one segment can (and often do) cause changes in other segments. The cultural ecological focus in this research design, the recognition of the interactions between humans and their environments, is kept at the forefront. A human sociopolitical organization, as part of an interactive system, has a repertoire of strategies for dealing with change. These range from immediate small-scale responses to longer-term pervasive changes in subsistence strategies.

Implicit in this interaction is the idea of "adaptive strategy." Kirch (1980: 129) broadly defines adaptive strategy as the set of culturally transmitted behaviors -- extractive, exploitative, modifying, manipulative, competitive, mutualistic, and the like -- with which a population interacts or interfaces with its natural and social environment. These patterns of behavioral variation can be linked to environmental characteristics, with implications for the archaeological record of settlement and subsistence systems (Jochim 1991: 308).

When viewing the archaeological universe we wish to explain and/or predict, all facets of the interconnections of the "system" must be understood. The system, in this instance, is the physical domain, the environment in which present-day Fort Bliss exists. The system consists of the past environment in which groups of people existed, as well as the people and how they interacted with each other and their environment. The system is not only the present physical environment

but the changes in that environment that have had a bearing on the archaeological manifestations of the past and what is seen now and how it is interpreted. This taphonomic process in this segment of the system will be dealt with subsequently.

Synchronic land-use models are hypothetical formulations of past cultural adaptations that provide a basis for further archaeological investigation. Models presuppose that humans are not a passive part of the environment. The situation is dynamic, and influences move from one segment of the system to the other. Models usually contain descriptions of how prehistoric peoples/cultural systems might have functioned at a given point in time and territory, and perhaps include some predictions as to the archaeological implications of those systems.

Strategies for acquiring at least the essentials to live and exist within an environment are part of those models. The "essentials" are activities that are repeated over and over, on a daily, seasonal, and yearly basis. These repetitive articulations of the component parts of the cultural system and the environment in which they take place allow archaeologists to identify, within the archaeological record, the causes and effects they wish to study (i.e., cultural changes through time). Although the strategies are repetitive in that water, food, and fuel must always be obtained, changing environmental factors (environmental variability) may require adjustments within the strategies in order to meet subsistence objectives.

Settlement patterns usually refer to the distribution and arrangement of specific sites or activity loci on or over a particular landscape (Kirch 1980: 139). There are several different factors that operate in decision-making regarding settlement placement. For hunter-gatherers, some of these factors are proximity of economic resources, shelter and protection from the elements, and a view for observation of game and strangers (Jochim 1976: 47-53). In the Fort Bliss study area, water is certainly a prime factor in settlement placement. Settlement patterns, then, are inextricably linked with the natural environment through subsistence strategies and other human decisions. Humans within different resource procurement strategies utilize their environments in different ways, adjusting to environmental fluctuations through mobility, scheduling, and technology. The two economic systems discussed here are hunter-gatherers and cultivators.

More recently, the theoretical perspective and analytical methods of "landscape" archaeology have been broadened to include a more holistic appraisal of prehistoric settlement and land use (Anschuetz 1995; Anschuetz et al. 2001; Ashmore and Knapp 1999; Crumley and Marquardt 1990; Marquardt and Crumley 1987; Snead 2008). Included in this new approach are considerations of the places and even archaeologically "empty zones" that constitute the locations of ritual performance and ceremonial acts, resource procurement, and social interaction among both individual actors and aggregate social groups.

Numerous accounts of historic Southwest puebloan groups mention the presence of ritual and sacred hills, springs, caves, mountains, plant gathering locations, and other locations of spiritual or cultural memory (Ortiz 1969; Parsons 1939). Trails, field houses and field shelters, and community shrines are part of prehistoric and historic landscapes (Snead 2008). While many such locations will be difficult or impossible to identify archaeologically, and additional sites will be located outside Fort Bliss, it is nevertheless important to consider these locations as part of the richer cultural heritage and land use of the prehistoric inhabitants of the region.

CONSTRAINING RESOURCES

In a discussion of land use by a group or groups, four basic criteria are involved. "The primary function of economic activities is the provision of the necessary sustenance for the population" (Jochim 1976: 16). We assume, as do others (e.g., Binford 1982; Gould 1980; Jochim 1976; Yellen and Lee 1976: 27-46), that the primary objective of the satisfaction of sustenance also

includes materials considered necessary for human viability. These four criteria are (1) water, (2) food, (3) fuel, and (4) shelter; each is necessary for long-term survival of any human group. Although these four necessities are fundamental requirements for survival, they are by no means the totality of all that was needed or desired by prehistoric groups and individuals.

The environment itself - its resource structure and climate - determines where and when the resources are available. Hunter-gatherers are one element in an ecosystem. Little or no buffering stands between them and the other components of the system. Their relationship to the land, to its flora and fauna, and to their fellow humans is intimate (Dunn 1968: 228). The interdependency of segments of the system, such as climate, elevation, soils, precipitation, and vegetation, create the ecosystem within which human groups operate. All these segments create a dynamic and temporally and spatially fluctuating environment with human groups as a segment of the system modulating their behavior.

Water

Hunter-gatherers must adapt to variables within an environment in order to gain what they need. Their behavioral flexibility and their adaptive strategy in the face of environmental fluctuation is the buffer between them and their environment. The timing of available resources and their placement within the landscape, to some degree, determine when, where, and for how long groups will place their camps. Water is an absolute necessity. Hunter-gatherer groups, their organization and placement, are partially determined by the availability of this resource (Gould 1980: 53; Jochim 1976: 51). In an arid to semiarid environment, there may be permanent, semipermanent, and/or ephemeral sources of water.

The locations of these sources play a role in the overall settlement choices made by both hunter-gatherers and small-scale agriculturalists. As discussed in Chapters 2 and 7, those sources in the Hueco Bolson and Tularosa Basin include rivers, streams (permanent and ephemeral), springs, and playas. Permanent sources such as rivers are usually at lower elevations along valley floors. Streams and springs are often located at higher elevations in mountains. Semipermanent sources, such as rainfall runoff streams and playas, usually occur on a seasonal basis. Ephemeral sources are precipitant runoff that drain into pools or catchment areas and shallow swales and bajos located on the desert floor.

Hunter-gatherers are "tethered" (Taylor 1964) to sources of water to some extent. In arid environments, this may require them to move from one source of water to another, depending upon its variability both spatially and temporally, or the depletion of the resource through evaporation and/or use. The Dobe area !Kung and the Kade pan area /Gwi and //Gana San, located in the Kalahari Desert in South Africa, are ethnographic examples of groups exhibiting this type of adaptational behavior (Lee 1976: 74-97; Tanaka 1976: 98-119).

Food

The distribution of plant and animal communities within the environmental milieu is as highly variable as is water. These resources make up the second basic necessity for human groups: food. Just as today, human groups during prehistory made choices about the foods they preferred, given the array that existed or could be grown in the environment where they lived. One food choice for hunter-gatherers is game. This resource provides both food and other items that might be referred to as manufacturing items, and nonfood resources, such as hides, bone, and sinew. Those portions of animals not consumed are utilized in other ways, such as for clothing, shelter, and weapons. Animals, small or large, move across the landscape, acquiring their own resources to survive.

Thus, hunter-gatherers that chose to consume select game that move across the landscape must be mobile in order to follow these resources when and where they are available. For such groups,

this necessary mobility pulls against the specifically sited water resources. Seasonal fluctuations can affect the presence or absence of particular game species or their relative numbers. For example, some species may migrate to another area during a given season, return at another, and some species may remain within the same environment but the population may be diminished during a season. Different species occupy different niches within the environment. Deer generally occupy upland, forested areas, while bison occupy grasslands. Study of the food choices made by groups in the Hueco Bolson and Tularosa Basin will allow inferences to be made regarding how settlement patterns land use changed over time, and how groups minimized the risk involved in environmental variability (Lee 1972: 339; Silberbauer 1972: 287).

Fuel

Another necessity is fuel, chiefly wood. In an arid environment, wood will be available in particular niches within a given range or territory of hunter-gatherers. Fuel sources, such as trees, may be confined to higher elevations where watered areas sustain their growth, and where temperatures and soil moistures are conducive to growth and viability. Ephemeral water sources are less likely to sustain considerable growth of any but the more xeric species. Fuel sources then would also have tethering effects due to their locality where water is more abundant (Tindale 1972: 244). When trees are not available, other more opportunistic sources of fuel, such as woody plants, and grasses may be gathered in areas where they are found (e.g., Ford 1977: 200).

Shelter

Shelter is the fourth and last of the basic necessities for survival discussed here. Shelter for highly mobile hunter-gatherers by necessity is nonpermanent. Their structures tend to have a minimum of constituents (i.e., made of hides or brush), which might be gathered on the spot during construction, given the appropriate environmental surroundings. The hides and poles that might make up a structure could be transported, assembled, and disassembled with relative speed and ease. Opportunistic shelter in the form of rock shelters, overhangs, or caves might also be utilized. The Tarahumara, for instance, have a preference for rock shelters (Pennington 1962; Hard and Merrill 1992).

Ritual and Social Needs

The four basic necessities described above constitute the *minimal* needs for survival. However, they by no means represent the totality of all that was needed or desired, unless we are willing to accept that prehistoric individuals and societies lived lives devoid of the spiritual dimension of human experience. An exclusive focus on these four variables reviewed above results in the exclusion of a significant aspect of human experience as well as the critical social and religious dimensions of settlement organization. Not all prehistoric resource procurement was concerned solely with food, water, shelter, and fuel, nor was all prehistoric landscape use arranged exclusively around the locations of these resources. Ceremonial Cave and other caves in the vicinity of Fort Bliss have unmistakable evidence of ritual use (Alvarez and Leach 1997; Creel 1997; Cosgrove 1947; Ellis and Hammack 1968), and rock art sites at Hueco Tanks, Three Rivers, and Alamo Canyon-Wilkey Ranch provide glimpses of a rich and complex ceremonial life. These types of sites show that specific locations across the landscape were used for ritual performance and religious pilgrimages. Moreover, medicinal and psychotropic plants were undoubtedly collected from special locations.

Unusual items of exotic stone and minerals are common at Formative period pit house and pueblo settlements. Most of these items were procured from mountain foothills and uplands at considerable distances from the settlements. Items of selenite (translucent gypsum) recovered from pueblos across Fort Bliss were obtained from Lake Lucero on White Sands Missile Range

and rock salt from the salt pans near Lake Lucero or Salt Flat basin was found at Twelve Room pueblo (Moore 1947). In fact, a consideration of the ubiquitous presence of minerals, crystals, pigments, fossils, turquoise, speleothems, and other exotic stone material at El Paso phase pueblos leads to the undeniable conclusion that puebloan groups participated in an extensive regional procurement and exchange system. The collection or extraction of these materials from mountains and playa margins across the region indicate that an extensive logistically organized procurement network was in place during the El Paso phase.

ENVIRONMENTAL CONTEXTS AND LANDSCAPE VARIABLES

The following section summarizes key aspects of the natural environment from the perspective of identifying and explaining prehistoric settlement patterns. Although this section parallels to some extent the discussions in previous sections, those discussions are recast and an environmental context for alternative models of adaptive use of the landscape is developed.

Hard (1983a) and Hard and Mauldin (1986) defined five major environmental zones for the region: (1) the Riverine zone is the Rio Grande drainage, floodplain, and adjacent valley-flanking terraces; (2) the Mountain zones include the bedrock uplands; (3) the Mountain Periphery zones are bands about 5 miles wide, adjacent to the mountain zones, that include alluvial deposits and also encompass several of the larger playas corresponding; (4) the Central Basin zone is the expanse of desert between the east and west mountain peripheries, and is a generally homogeneous plain consisting largely of mesquite coppice dunes; and (5) the Basin-Playa zones, defined as areas enclosed by a one-mile radius around smaller playas that dot the basin.

Each landform on Fort Bliss has its unique environment. Given this environmental variability, it is assumed that, as discussed in Chapter 2, hunter-gatherers and cultivators in their economic pursuits would have utilized these landforms differently. To understand the archaeological contexts of the present, we hypothesize regarding the past usages of those environmental components given subsistence needs, technological capabilities, and the strategies used to minimize risk in a highly variable arid environment.

Water is the most pivotal of all the resources, especially in an arid environment. As such, adaptive strategies that complement the wet and dry seasonal periods and take advantage of the florescence of plant foods in their own environmental niches seem most appropriate for the subsistence and maintenance of human groups. Efficient use of resources is achieved through placement of habitation areas (base camps) or short-term hunting/collecting camps where there is a congruence of resources. When that congruence is either nonexistent or variable, scheduling and logistical approaches to subsistence are necessary.

Within the Fort Bliss boundaries, the Mountain zone landform comprises those areas in the Organ, Franklin, Hueco and Sacramento mountains. Although most of the Jarilla Mountains lie outside the boundaries of Fort Bliss, they should be included in any consideration of regional land use, particularly since they contain one of the main sources of turquoise in the Southwest. The mountain landform contains the only areas that are forested (see Chapter 2 for a discussion of the flora and fauna in this zone). Juniper (*Juniperus monosperma*), piñon pine (*Pinus edulis*), ponderosa pine (*Pinus ponderosa*), and oak (*Quercus undulata*) are the major species occurring in the higher elevations of the Sacramento, Organ, and Franklin mountains, with extensive stands of ponderosa pine in Fillmore Canyon. Elm, hackberry, mesquite, cottonwood, and willow all occur in lower and well-watered elevations and in isolated draws.

Shrub communities that occur along with these species at lower elevations are agave, shaggy mountain mahogany, rabbitbrush, beargrass (*Nolina*), and broom snakeweed (Kenmotsu and Pigott 1977; Satterwhite and Ehlen 1980). Sources of water in mountainous regions would most

likely be streams and/or springs. Meat from deer and other small fauna whose habitat includes mountainous areas would be available. Other necessary elements, such as animal skins, and antlers would be derived from the faunal resources. Firewood would be available for fuel in this environmental zone. Additional resources available to hunter-gatherers and cultivators would have included water, wood from larger species of trees that was used for house construction, and food in the form of plants, nuts, berries, seeds, and meat.

Minerals, pigments, and other exotic materials were also procured from mountain zones. Both economic systems made use of all the environmental zones. It is a matter of proportional usage and scheduling. These mountainous environments would most likely be utilized during those seasons when food resources would be available (e.g., during the late summer and fall); piñon nuts and juniper berries would be collected in the higher elevations where those trees occur.

The Mountain zone had water available throughout the year in the form of streams or spring and perhaps catchment areas, which hold snow melt, etc. Resources available during the winter would include species such as deer and rabbit. Plant foods are unlikely to be available during the winter, especially in this highest zone. It is unlikely that base camps would be situated in this zone during the winter due to the scarcity of these resources. Fuel and water would be present year-round. Shelter in this zone would be the most critical during the winter months. Unless caves or deep rock shelters were available for habitation, with a water source nearby, it is likely that foraging parties would have utilized this zone during the dry winter months. This may be true for both hunter-gatherers and cultivators practicing a mixed subsistence strategy. Hunter-gatherers likely resided in camps at lower elevations in mountain peripheries or on or near the Rio Grande. Farmers would be more likely to reside at campsites located in an intermediate zone, such as the alluvial fans zone or near the river. Cultivators would subsist partially on stored foods and utilize the mountain zones in a logistical way (i.e., specific hunting parties) to pursue deer and/or rabbit or collect larger-sized fire and construction wood and exotic materials.

The Mountain Periphery zones consist of belts about five-miles wide, adjacent to the mountain zones that include alluvial deposits and also encompass several larger playas. This corresponds to Monger's (1993a) Fan-Piedmont landform. The Mountain Periphery zone is most likely the zone that has the most, if not constant, use. Its placement between the mountain and the central basin zones makes it optimally situated for the exploitation of all three zones. Anderson (1993: 54) contends that this zone contains no sites dating to MacNeish's first two phases of the Archaic (6000-2500 B.C.; cf. Carmichael 1986a: 147-148), but the apparent absence of early sites in this zone is more a result of their being buried and thus undetected during surface surveys (Miller and Kenmotsu 2004).

Plant resources are detailed for this zone in Chapter 2 and include mesquite (*Prosopis juliflora*), grasses, fourwing saltbush (*Atriplex canescens*), whitethorn acacia (*Acacia constricta*), datil (*Yucca* spp.), small-leaf sumac (*Rhus microphylla*), prickly pear (*Opuntia* spp.), *Agave* spp., Mormon tea (*Ephedra* spp.), sotol (*Dasyilirion wheeleri*), and other cacti. Plants such as mesquite beans, acacia, datil, sumac, Mormon tea, stool, and other cacti would be available from March through October in varying schedules of florescence. Grasses would be available for the longest period of time (i.e., April through October); others would have their greatest abundance from May through August (Anderson 1993; Kenmotsu and Pigott 1977; O'Laughlin 1978; O'Laughlin and Crawford 1977; Satterwhite and Ehlen 1980; Wetterstrom 1978).

Animal species available as resources would be jackrabbit (*Lepus californicus*), and cottontail (*Sylvilagus audobonii*). These animals would be available in this zone throughout most of the year. Their own productivity is much in concert with the availability of water (rainfall) and plant resources. Mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*) would be most available in the fall and winter seasons in the higher elevations of the alluvial fans zone

(Anderson 1993; Hard 1982; Mauldin 1993b; Mauldin et al. 1995; Whalen 1977, 1978). Hunter-gatherers would have likely employed a foraging strategy in this zone, while cultivators would have utilized the area for collecting or a logistical strategy. This zone was utilized in later periods (i.e., the Mesilla and El Paso phases) by cultivators as sites for planting crops in spring, harvesting in the fall, and as an area where residential camps were located year round. The larger playas located in this zone receive greater amounts of water in the form of runoff from the higher elevations. These likely were used for crop planting and cultivation (Carmichael 1986a; Hard 1982; Mauldin 1986). As noted in Chapter 2, some of these playas may have held water for periods of time.

The Central Basin is the expanse of desert between the east and west mountain peripheries and is a generally homogenous plain consisting largely of mesquite coppice dunes. This zone includes Monger's (1993a) La Mesa Basin Floor, Dunes, and Fault Complex landforms. Water is by far the most problematical resource in the basin. There are no permanent sources of it in the basin at all. The wet season is from May to September. What water there is collects in the small playas that dot the basin. Depending upon amounts collected, temperatures, and evapotranspiration, standing water may last only a few days to a few weeks.

As noted in Chapter 2, in modern times the most prevalent plant community in the basin consists of mesquite (*Prosopis glandulosa*), broom snakeweed (*Xanthocephalum sarothrae*), fourwing saltbush (*Atriplex canescens*), soap tree yucca (*Yucca elata*) and dropseed grasses (*Sporobolus* spp., *Muhlenbergia porteri*, and *Hilaria mutica*) (Satterwhite and Ehlen 1980). Studies show that prior to the late 1800s, there was significantly less mesquite in this zone (Kenmotsu and Pigott 1977). Annuals appear seasonally in the basin and were an important economic resource (Carmichael 1986a). Plant resources would be most abundant from April through July. Mesquite pods remain on the shrubs into the fall and are a most important resource (Basehart 1973; Opler 1983). Fuel available in this zone would be some smaller shrubs, such as mesquite. Animals available for hunting would be cottontail and jackrabbit, at their peak in the summer (Hard 1982: 20).

The greatest coincidence of resources, especially in this zone, is the summer. Hunter-gatherers could perhaps utilize a foraging strategy in the basin (Binford 1980) and camp where there are congruencies of water and other resources. Cultivators would most likely utilize a logistical strategy whereby they send out gathering or hunting parties for specific resources in this zone. Their base camps would probably be located closer to their planted fields (Hard and Mauldin 1986: 21).

As noted in Chapter 2, the Central Basin Playas include the numerous small playas which are scattered across the basin floor as well as several large playas, such as Old Coe Lake, that abut the alluvial fans. This zone corresponds to Monger's Youngest Basin Fill landform. The soils in the playas tend to have a higher clay content than the surrounding sandy soils in the basin. As such, these soils have a high moisture-retention factor, and this characteristic is an important factor in growth and distribution of plant species (Satterwhite and Ehlen 1980: 36).

Plants that are typically found in these playas (when not inundated) are grass, creosote, and saltbush (Carmichael 1986a: 49-50). Fuel, in the form of shrub-sized plants (mesquite), would be available in this zone to some extent; although studies have indicated that prior to the late 1800s, there was less mesquite in this zone (Kenmotsu and Pigott 1977). During wet periods (i.e., July through September-October), intensive but spatially variable rainfall occurs throughout the basin. The playas may fill with water but climatic conditions aiding evapotranspiration may dissipate these resources quickly. Cottontails and jackrabbits should be plentiful to hunt at their peak during the summer, and they may also be present in other seasons. The playa areas within the basin will clearly affect the placement of campsites.

Hunter-gatherers using a foraging strategy could utilize a playa and surrounding resources until they are depleted, then move on to the next available playa where water was evident. Cultivators likely used a collecting strategy and target specific resources in these areas. Late summer and fall would be the time of greatest resource congruence in these areas (Hard and Mauldin 1986).

In a semiarid environment such as the study area, there is high variability both temporally and spatially. Temporal variability refers to yearly changes in the types and amounts of resources. Spatial variability refers to changes in the location or types of location in which resources occur. Overall, environmental variability is directly related to behavioral variability (Gorman 1972; Jochim 1976, 1991; Yellen 1977).

In these instances hunter-gatherer populations exhibit high mobility profiles. The exigencies of infrequent and scattered rainfall require (in some cases perhaps) almost impromptu spatial or locational adjustments to meet subsistence needs. Water is the basic core of our integrated system. It is the dominant limiting factor. The productivity of a desert region is almost a linear function of rainfall (Odum 1975: 188). Water in this environment tends to have a "tethering" effect (Taylor 1964) upon a given population. The populations in the study area are tethered to the playas in the bolson or water sources in the mountains, Rio Grande, or at the base of alluvial fans where runoff may have accumulated. However, spatial variability in the availability of other resources requires a "pulling" against the tether by utilization of different mobility strategies to the benefit of the population (Binford 1980).

ETHNOGRAPHIC AND ETHNOHISTORIC ANALOGIES

Many known hunter-gatherer groups are/were located in semiarid regions (Gould 1980; Lee 1972, 1979, 1984; Silberbauer 1972, 1981; Tanaka 1980; Tindale 1972; Yellen 1977; Yellen and Lee 1976, 1978) and generalizations about hunter-gatherers have been offered (Bettinger 1977; Binford 1980; Jochim 1976; Yellen 1977). The use of ethnographic analogy and ethnohistorical sources from similar environments and past populations in the immediate area can be valuable tools as well (Yellen 1976: 47-72). While social, demographic, and geographical factors are different between some of our past cultures and the examples set out here, the environmental adaptations or the adaptational strategies may be very similar and therefore valuable in providing testable hypotheses. Binford, in his *Methodological Considerations of the Archaeological Use of Ethnographic Data*, states, "model building and testing can be related to ethnographic facts but verification of propositions would remain a problem to be solved by the formulation of hypothesis testable by archaeological data" (1968: 270).

The G/wi San of the Central Kalahari, a nonhierarchical society living in an arid region of Africa, live off the unimproved resources of their arid environment by hunting and gathering. They are largely dependent upon uncultivated, untended plants (Silberbauer 1981: 191). Due to several factors, the Kalahari where the G/wi-San live has few species of wild game. Thus, most of the meat consumed by the G/wi-San is in the form of cattle that they get in trade from the Bantu villages that reside at the edge of the Kalahari (Okihiro 1976; Wilmsen 1989, 1991). The G/wi's location is predisposed to those areas where plants, small animals, and water are necessarily sufficient.

Since these resources may vary over space and time, the G/wi exploitation range is by necessity fairly large (4,000 square km) (Tanaka 1980: 79), the groups or bands are relatively small and fluctuate given resource availability, and there is high mobility (Silberbauer 1981: 191). Plant foods are the mainstay of the diet, and with the exception of good tsama melon seasons (when they are gathered every other day), plant foods are gathered every day and consumed at the morning and evening meals following collection (Silberbauer 1981: 202). They are also the main source of fluids in all but the 6-8 weeks of the year during which rainwater can be found in pools

(Silberbauer 1981: 198). The foraging range for these daily activities is approximately 5 km. When closer areas have been depleted of edible plants and the round trip exceeds 10 km or so, the G/wi move with all their belongings to a fresh area where food plants are abundant (Tanaka 1980: 66).

Other hunter-gatherer groups such as the Dobe !Kung territory is only about 2,500 square km, almost half of that of the G/wi. HoKung San also live in the Kalahari. They reside in an area to the northwest of the G/wi San. However, the G/wi have no permanent source of water as do the Dobe !Kung. The Dobe are "tethered" around eight water holes surrounded by a belt of waterless, uninhabited country (Lee 1972: 331). The camp is the basic residential unit and the focus of subsistence activities. Membership at each water hole is very dynamic and changes constantly. During the dry season, the water holes are the centers of activity. As food supplies are exhausted in the immediate area, the Dobe move farther from the water hole and carry water with them. When that runs out, they rely on fluid-bearing plants.

The G/wi San and !Kung San (or Dobe) have high residential mobility, low-bulk inputs, and regular, daily food-procurement strategies. Binford (1980: 9) places the G/wi and the !Kung San in his category of "foragers," and notes that this type of system or strategy may be reflected in a variability of the contents of residential sites and result in a fairly low archaeological visibility.

Groups that have shifted from a purely foraging strategy to a more agriculturally based subsistence should reflect logistical strategies that accommodate the agricultural resource relatively near at hand. Required procurement of other critical resources will be operationalized by organizing specific resource procurement groups that collect and process the resources and return to the residential base (Binford 1980). These logistically based strategies have differing archaeological signatures from hunter-gatherer-based strategies. Increasing agricultural dependence is positively correlated with increasing population density and negatively correlated with levels of mobility (Mauldin 1983: 142). In one general way, greater ranges of intersite variability can be expected as a function of increases in the logistical components of the subsistence-settlement system (Binford 1980). Subsistence strategies that tend toward agricultural dependency (for the study area) are found to be archaeologically reflected in various lines of evidence, including shifts in settlement patterns, ethnobotanical data, and changes in the ceramic and ground stone assemblages (Mauldin 1986: 257-258).

Along the southern and eastern peripheries of the Greater Southwest, relatively sedentary puebloan economies based on small-scale farming give way to more nomadic hunting and gathering economies....Preserved in the archaeological record of the periphery, and documented in innumerable Spanish archival sources, is clear evidence that the boundary between these seemingly polar economic and social entities has been anything but sharp, and that over the centuries its nature and position have shifted repeatedly and often dramatically (Speth 1986: xiii).

Ethnohistoric accounts of cultural groups in the vicinity of the study area give us a small window into the past that proves to be useful in terms of observed patterns of subsistence and other behaviors. In the vicinity of El Paso, a number of cultural groups are mentioned in Spanish documents. These documents from the 1500s through the 1700s give a portrayal of settlement-subsistence patterns of the groups. Settlement and subsistence strategies of groups that are known ethnographically or ethnohistorically point to a mix of subsistence strategies that imply a collecting strategy as opposed to a strict foraging strategy and somewhat lessened mobility (Binford 1980). There are definite indications of populations that forage, and they would appear to have symbiotic relationships with other groups that exhibit more mixed subsistence strategies that include relying on some farming (Kenmotsu 1994).

The Patarabueyes, also known as the Otomoacos and Abriaches, were groups who were briefly described by Luxan in the official diary of the Espejo Expedition of 1592 (for a thorough review see Kenmotsu 1994). These groups were located around the confluence of the Conchos River and Rio Grande, some 200 miles southeast of El Paso. He described the Otomoacos and Abriaches as populous nations, living in adobe houses and farming along the Conchos and Rio Grande (Kenmotsu 1994: 203-208). They were primarily farmers but made much use of wild plants, bison, deer, small game, and fish. They cultivated maize, beans, squash, and may have practiced a certain amount of residential mobility, as indicated by Luxan's description of the houses they built in the fields, which they occupied during harvest time. They also hunted bison and deer away from their settlements. Meat, hides, and other foraged foods, such as mesquite beans, mescal, prickly pear fruit, and mushrooms, also were an indication of their mixed-subsistence strategies (Kenmotsu 1994: 206).

Their dwellings were described as being made of adobe and were rectangular and semisubterranean (Kenmotsu 1994: 206). Archaeologically, this structure has been borne out by Kelley's dissertation completed in 1949, and finally published in 1986. Their dwellings were *jacales* plastered with adobe, and were long east-west tiers of jointed rectangular houses with plazas (Kelley 1986: 71-85). Some researchers (Lehmer 1948, 1958; Mallouf 1999) believe the Patarabueyes were an admixture of Southwestern and Plains traditions. Kenmotsu (1994) gives an exhaustive account of the "Indian nations" that could be linked to the La Junta de los Rios, noting settlement-subsistence patterns of each group where possible.

The Jumanos, according to Kelley's documentary and archaeological evidence, were primarily traders and bison hunters. They probably consumed shellfish and certainly collected wild plants. The agricultural products they had were thought to be acquired through trade with the Patarabueyes. The Jumanos, although centered more in the region of the Pecos River and in Central Texas, interacted at times with a number of peoples living along the Conchos River and at La Junta. The land occupied by the Jumanos was within the historic range of bison, and nearly all researchers consider this nation to have been foragers (Kenmotsu 1994: 329). Foraged food included cottontails, fish, nuts, birds, grapes, plums, fish, mulberries, piñon nuts, and cacti *tunas*, and "the meals that the land will give them (because) they do not sow" (Kenmotsu 1994: 329). Jumano camps were located along streams and in rock shelters (Kelley 1986: 136). Archaeological evidence for tools and other utilitarian items noted by Kelley are evidenced in Trans-Pecos Texas by oval-bowl metates and one-hand shaped and unshaped manos. The Jumanos were known to have visited the El Paso area but their normal range was more to the east and south (see Kelley 1986 and Kenmotsu 1994).

The Sumas and Mansos are mentioned in Spanish documents of the 1600s and 1700s in the El Paso area (Forbes 1957: 319, 325). Benavides, in 1630, described these groups as being nomadic and nonagricultural (Ayer 1965: 89-90). They were hunter-gatherers who Benavides described as "warlike, barbarous, and indomitable, because they wander totally nude without house, and without crops; they live from what they hunt, which is all species of animals...thus moving from one set of mountains to another" (Kenmotsu 1994: 355). It is suspected that in the 1740s and 1750s the Sumas were still nomadic (Forbes 1957: 322). An indication of the settlement-subsistence pattern of the Sumas is evident in the comments of Benito, the Bishop of Durango in 1725, when he refers to their "nation which is so extensive that it occupies more than a hundred leagues in circumvallation without any fixed settlements" (Forbes 1957: 322). Kenmotsu (1994: 333) notes evidence that Mansos were hunter-gatherers. In the Benavides *Memorial*, the Mansos are described as not having houses, "but rather pole structures, nor do they sow. . .but all are nude and only the women cover themselves from the waist down with deerskins." He notes also that they eat rats and fish.

In El Paso del Norte in 1796, Lt. Col. Don Antonio Cordero set down a description of the "Apache nation" (Matson and Schroeder 1957: 335-356). The "Apache Nation" Cordero refers to consists of the various groups (he counts nine), "spread out in a vast space of the aforementioned continent (North America) from degrees 30 to 38 of north latitude and 264 to 277 of longitude from Tenerife." According to Matson and Schroeder, the location is quite accurate (Matson and Schroeder 1957: 336, footnote #2). Cordero notes that these groups do not compose one nation but posits they are alike in many ways given their various differences in locality, needs, and how much contact they had with the Spaniards (Matson and Schroeder 1957: 336). The groups referred to are the Tontos, Chiricaguís, Gilenos, Mimbrenos, Faraones, Mescaleros, Llaneros, Lipanes, and Navajos.

In reference to these people, Cordero mentions the "continuous movement in which he lives, moving his camp from one to the other location for the purpose of obtaining new game and the fruits which are indispensable for his subsistence..." (Matson and Schroeder 1957: 338). In regard to subsistence, Cordero notes, "besides the meat which is supplied by his continuous hunting and cattle stealing in the territories of his enemy, his regular food consists of wild fruits which his territories produce" (Matson and Schroeder 1957: 338). The fruits and game differ in the various regions they inhabit and there are, he notes, some common to all. Cordero provides a list of game animals and food plants that are prepared and consumed by the "Apache," and provides brief descriptions of the process of cooking agave, sotol, and maguey in roasting pits (Matson and Schroeder 1957: 338-339). As to settlements:

In general, they choose for dwelling places the most rugged and mountainous ranges. In these, they find water and wood in abundance, the wild produce necessary, and natural fortifications where they can defend themselves from their enemies. Their hovels or huts are circular, made of branches of trees, covered with skins of horses, cows or bison, and many likewise use tents of this type. In the canyons of these mountain ranges the men seek large and small game, going as far as the contiguous plains; and when they have obtained what was necessary, they bring it to their camp, where it is the work of the women, not only to prepare the foods, but also to tan the skins which are then used for various purposes, particularly for their clothing (Matson and Schroeder 1957: 339).

The joining together of many rancherías in one place is usually accidental and comes from all going to hunt for certain fruits, which they know are abundant in such and such a place at a particular time (Matson and Schroeder 1957: 342).

The Tarahumara (or Raramuri, as they call themselves) live in the mountains and canyons of the Sierra Madre Occidental in southwestern Chihuahua, Mexico, about 450 km south-southwest of El Paso, Texas (Hard and Merrill 1992: 602). The Tarahumara are well known both ethnographically and ethnohistorically (Hard and Merrill 1992: 602). Pennington (1962) has made use of the wealth of archival material in Jesuit records along with his personal observations of the Raramuri. He refers to these people as a semiagricultural folk who were clustered along stream ways of the upland meadows, valleys, and semiarid plains of southwestern Chihuahua. They were scattered over approximately 35,000 square km of territory (Pennington 1983: 276).

The Tarahumara region is one with a varied physiography containing steep canyons, uplands, foothills, plains, and basin and range country. Climatically, there is a good deal of variability as well, given the scope of environments present. The area is characterized by seasonal precipitation with summer and autumn being the wettest seasons. Seasonal variability is seen in streambeds that can be swollen in July, August, and September. They have low water during winter and spring, and some smaller streams have only isolated water holes (Pennington 1962: 28).

Archaeological material, historical records, and recent investigations demonstrate that the basic foodstuffs of the seminomadic Tarahumara have long been corn, beans, and squash. Maize

agriculture dominates the Tarahumara economy with approximately 70-80 percent of the diet based on maize (Hard and Merrill 1992: 603; Pennington 1962: 39, 1983: 278-280). These foods were supplemented in the past, as today, by a great variety of wild plant products as well as fish (Hard and Merrill 1992: 603; Pennington 1962: 39, 1983: 280-282). Hard and Merrill describe the residential patterns of these mobile agriculturalists, and as noted above, the Tarahumara derive about 75 percent of their diet from maize and depend on stored food year-round, yet they shift residences both during the growing season and during the winter (Hard and Merrill 1992: 601). The mobility strategies utilized by the Raramuri inhabitants of Rejogochi (the community and area foci of Hard and Merrill's research) are viewed from Binford's (1980) hunter-gatherer residential and logistical mobility strategies. The primary type of logistical mobility involves men traveling outside the valley without their families to work for wages (Hard and Merrill 1992: 605). The pattern of residential mobility during the growing season is a product of the use of sometimes widely dispersed fields outside the Rejogochi Valley area. This is due to local principles of land tenure, inheritance, and marriage restrictions. Households care for their fields by moving the residence to the dispersed fields for periods of a few days to several weeks. Often these fields have houses and grain-storage structures associated with them (Hard and Merrill 1992: 606-607).

The common residential strategy for winter involves moving all the household members and livestock in December to a nearby rock shelter or another house where they stay through February. Rock shelters are the preferred winter residence. This preferential form of residence has its beginnings in prehistory (Pennington 1962: 221-223; 1983: 287). They are generally located in the walls of small canyons off the main Rejogochi Valley. Rock shelters remain dry, usually have a southerly exposure, and receive direct sun much earlier than the valley bottom. They are usually located closer to firewood than the valley homes and some have springs located nearby. Most of these rock shelters are large enough to accommodate the family's sheep and goats on one end in a corral with low stone or log walls used as windbreaks and to divide sleeping and cooking areas at the other end (Hard and Merrill 1992: 607-608).

Hard and Merrill's analysis of growing-season mobility strategies employed by the Raramuri indicate there are three conditions that appear to motivate these patterns. Residential mobility at dispersed fields as opposed to logistical mobility is motivated first by the need to stay at the fields for extended periods of time; second, by the existence of tasks that require the attention of both men and women at distant fields, and third, by the need to consume the harvest there instead of transporting the crop back to Rejogochi (which does occur on occasion to replenish depleted supplies) (Hard and Merrill 1992: 609-613). In the case of dispersed or fragmented fields, it would also appear that these are maintained to produce additional yields of maize and to offset extremes of microclimatic variability (Hard and Merrill 1992: 609-612).

As to winter residential mobility, the strategy most commonly employed is that an entire household will move to a rock shelter, or sometimes, a house. This residential move involves moderate labor expenditure since food must be periodically transported to these shelters from their valley homes. However, this residential move oftentimes reduces risk of losing animals due to exposure and affords all family members the benefits of rock shelter living (i.e., warm, dry surroundings with convenient sources of firewood) (Hard and Merrill 1992: 613-614). As Hard and Merrill point out:

It is clear that neither mobility nor sedentism is an inherently better settlement strategy. Simply assuming that direct correlations exist between economic and settlement systems is counterproductive, because doing so precludes examining the basic issue of why one pattern exists rather than another. Different mobility strategies represent alternative solutions to the problem of bringing people and resources together in space and time (1992: 616).

This case points to the fact that our biases regarding settlement patterns and subsistence pursuits must be reigned in and our scope of strategies toward social and economic structures and their optimum use of the environment broadened.

The Western Apache are a group that practiced a mixed strategy of hunting/gathering and some agriculture. They utilized vast areas of territory. The approximately 90,000 square miles of their territory contained extreme ecologically diverse landscapes, from high mountains to arid deserts. These were the environments in which they subsisted by hunting and gathering (Basso 1983: 462-488). Their dependence on some agricultural products such as corn, beans, and squash, lessened only to a degree their high mobility (Buskirk 1986; Perry 1991; Pool 1985). Pool (1985) utilized the pre-reservation period settlement system taken from ethnographic accounts as a potential analog for the Early Mogollon period. This model characterizes the early period as semi sedentary, with a mixed subsistence strategy ranging over vast areas.

The Mescalero Apache cultural group is significant in that their range included the study area and encompassed approximately 100,000 square miles. Their territory was bounded on the west by the Rio Grande, and by the Pecos River on the east extending south into Texas. On the south, they ranged across the Rio Grande into the present Mexican states of Chihuahua and Coahuila (Opler 1983: 419) but not in large and concentrated populations. Topographically, their territory varied from 12,000-ft high mountains (Sierra Blanca) to hot and dry desert areas, such as the Tularosa Basin and Hueco Bolson, and the Organ Mountains to the west of the bolson.

This variation of climate and topography influenced their settlement and subsistence patterns. Their subsistence activities, population concentrations, and movements were conditioned to a considerable degree by available water supplies (Basehart 1973: 172). They were traditionally hunter-gatherers who were spread out over their vast territory in small groups (Opler 1983: 420). The geographical distribution of plants and animals that formed the basis of their subsistence required them to use vast areas of their territory. Also, both plants and animals were subject to periodic fluctuations in quantity so that different locations within the Mescalero territory afforded variable opportunities for subsistence from year to year (Basehart 1973: 147-148). Cordero noted:

They change their *rancherías* when, in the place in which they have been living, the foods necessary for them and their beasts become scarce, moving now from one mountain range to the other, now from a rock or cliff to another of the same range or mountain. Of much influence in these moves is the necessity of seeking places for the purpose of passing the different seasons of the year with more comfort" (Matson and Schroeder 1957: 342).

The Mescalero Apache in prehistoric times most likely practiced very little agriculture; Cordero mentions, "they were known to cultivate a few crops such as corn, beans and squash and tobacco, which the land produces more on account of its fertility than for the work which is expended in its cultivation" (Matson and Schroeder 1957: 338-339). Their limited efforts at agriculture exerted little influence on the hunting and gathering mode of the majority of Mescaleros (Basehart 1973: 174).

The hunter-gatherer groups noted above have similar high mobility signatures. These highly mobile patterns of subsistence and settlement are a reflection of the variable nature of their respective environmental settings. Archaeologically, these coping strategies generally have a low visibility factor given the small numbers of people in any one camp, the essential material possessions, and the frequency of moves. Groups noted above that practice some form of agriculture relinquish some of their mobility due to the investment of time required to insure successful crops. However, the highly variable nature of semiarid environments requires the flexibility within the system to maintain a certain amount of mobility that enables those groups to successfully meet their subsistence needs. Archaeologically, the hunting-gathering strategies employed, along with farming, should have a different and more visible signature than simply a hunting-gathering strategy. These adaptive strategies require storage of food products, a more complex or varied set of tools, and habitation sites that allow for larger groups conducting varied tasks for longer periods of time.

In discussing the land use of an agricultural economic system in an arid to semiarid environment, it is important to call attention to the supposition that nowhere in the Southwest were villages (especially during the earlier periods) sustained entirely on agricultural produce (Anschuetz 1995; Cordell 1984: 215; Nelson and Diehl 1999). Mixed subsistence strategies, necessitated by the vagaries of an arid environment, have been documented both ethnohistorically (Brooks 2002; Kelley 1986; Kenmotsu 1994) and ethnographically (Basehart 1973, Buskirk 1986). Farming, and hunting and gathering are strategies that are utilized in concert to meet subsistence needs. Adaptive strategies utilizing farming technologies result in certain effects upon both the environment and human groups.

Farming, by its nature, has a tethering effect upon its practitioners. Crops require water, which has a tethering effect on the placement of those crops as they must be planted in soils that have appreciable moisture content and located where water is available as a reliable source through rainfall runoff or some constructed device allowing for the watering of plants when needed. Another tethering effect of crops is the investment of time in one area to care for the plants and their success. Longer stays necessitate more substantial and permanent habitation structures. Farming requires larger numbers of individuals to prepare soil, and plant and harvest crops. Larger groups or aggregates of people remain (at least a portion of the time) in the same area. Larger groups necessitate a substantial investment in storage for excess of crops not consumed immediately after harvest. Territoriality becomes more of an issue as investment of time and labor for crops becomes necessary.

Climatic instability of arid environments necessitates relying on other resources as a proportion of diet. Hunting is a means of procuring meat and hides and other byproducts of animals for subsistence. Gathering alternate plant foods adds variety to diets and/or replaces depleted crop resources through a season. Wild plant foods are also sources of fiber and materials used for things other than food (e.g., medicine) (Castetter and Opler 1936; Castetter and Underhill 1935). A mixed subsistence requires scheduling of alternate procurement strategies such that they are accomplished around the farming schedule. This implies alternate strategies involving differential groups dedicated to target resources in particular procurement zones within the available environmental territory. All environmental zones are utilized in the pursuit of a mixed subsistence strategy, just as they are in a hunting-gathering economic system; however, they are utilized in different ways, thus their use presents a different archaeological signature (Binford 1980, 1982).

SYNCHRONIC MODELS FOR FORT BLISS AND THE SURROUNDING AREA

Due to the sampling and systematic survey of thousands of square kilometers of Fort Bliss lands (Beckes et al. 1977; Carmichael 1986a; Skelton et al. 1981; Whalen 1977, 1978) several land-use models have been developed with regard to the area of west Texas and south-central New Mexico. These have been developed as heuristic devices to organize and integrate research and include or are specific to the Fort Bliss area (Anderson 1993; Hard 1983a; Hard and Mauldin 1986; Mauldin 1986). Hard (1983a) and Mauldin (1986) have both utilized generalizations, taken primarily from Binford (1980), regarding resource acquisition and mobility strategies utilized by groups that are primarily hunters and gatherers. More recently, Church (2005, 2006) has developed models of prehistoric exploitation of playa environments derived from human behavioral ecology and Miller (2004b, 2005b) examined the potential issues of land tenure among mobile cultivators during the El Paso phase. An important premise remembered here is that environmental variability, adaptive mobility strategies, and social strategies of establishing and negotiating land tenure are inextricably linked.

For hunter-gatherers, the most critical strategy for obtaining the necessities is mobility. Resource availability in an arid environment is highly variable both temporally and spatially. That is, in an arid environment, the types and amounts of resources will change from year to year (and season to season); and there will be changes in the location or types of location of resources (Jochim 1991: 311-312). This factor of high environmental variability is dealt with through adaptive strategies of flexibility, opportunism, and variability. Effective strategies of mobility require efficiency in movement, best accomplished through small numbers of individuals working as a unit with few possessions. Consuming the acquired resources on a day-to-day basis creates no need for storage, thus reinforcing the effectiveness of high mobility.

Hard and Mauldin (1986: 45) stress the necessary interplay between the models of regional systems they present and the development of methods that can address relevant aspects of those models. The models identify which behaviors are relevant and critical for overall evaluation. They serve to differentiate what is interesting and possible from what is relevant and necessary (Hard and Mauldin 1986: 45). The Southwest in general has a considerable body of data for the Archaic period. Simmons and others (1989) indicate that the majority of these data come from northwestern New Mexico. Most of the various models developed for the Archaic rely on a consideration of subsistence strategies as site distribution determinants (Simmons et al. 1989: 39-74). Mauldin (1993a: 15) notes (in regard to the Fort Bliss area) that attempts to develop criteria recognizing elements of different cultural systems have focused on variability in site location, ceramic assemblages, ground stone assemblages, architecture, faunal remains, and some lithic assemblages.

Land-use patterns of late Pleistocene (Paleo-Indian) hunter-gatherers are not as well known in the study area as later economic adaptations of hunter-gatherers. A consideration of the environment is critical to understanding the earliest hunter-gatherer adaptations. As noted in Chapter 7, the data suggest that the region was already semiarid, albeit cooler, by 12,000 B.P. A significant difference from the semiarid conditions of the present, however, was a higher summer precipitation than today. Because of this higher rate of summer precipitation and cooler temperatures, much of the basins appear to have supported an oak-juniper woodland. These environmental factors would have drawn hunter-gatherers through the area (Carmichael 1986a: 41-42).

There are numerous playas on the basin floor within the bounds of the study area. These playas, given the wetter, cooler conditions during the late Pleistocene, may have held enough water to support short-term hunting and/or gathering camps. These playas may have acted not only as a source of water for both hunters and animals, but may have been utilized by the hunters as traps

for the water-seeking animals (Judge 1973: 195-197). The hunter-gatherers may have used these elements in opportunistic ways.

In a comprehensive review of Folsom occupations in the Jornada Mogollon region, including collections from Fort Bliss, Amick (1994a, 1994b; 1996) argues that Folsom settlement in the Tularosa Bolson and Hueco Basin involved a pattern of residential settlements oriented toward hunting game animals other than bison, a pattern that differs significantly from the Southern Plains where typical Folsom land use patterns involve logistical sites occupied during the course of bison hunts. In addition, Folsom occupations in the Tularosa Basin can be linked to extensive regional land use systems including the Southern Plains. In addition, work by Elyea (1988) suggests that a large site in the Tularosa Basin (LA 63880) could be considered a "base camp," as Judge (1973: 199-201) refers to them.

As a general characterization, Paleo-Indian hunter-gatherers formed themselves in small, highly mobile groups ranging over large territories in pursuit of game. These hunter-gatherers manufactured specialized tools, such as fluted points (Folsom points), which are found in association with now extinct megafauna. Most tools that have been recovered are appropriate for felling and butchering game, for processing hides, and working bone and wood (Carmichael 1986a: 7-8; Cordell 1984: 142-143). Plant foods were gathered and utilized as well. However, the degree to which these were incorporated in the earliest economies is not known (Cordell 1984: 145), especially in the Fort Bliss area.

The Archaic, as used here, is a term that refers to both a period of time and a way of life. The period of time follows the Paleo-Indian from approximately 6000 B.C.-A.D. 100. As a way of life, or an economic strategy, it is characterized as a continuation of hunting and gathering. There are, however, significant changes observed archaeologically in hunting and gathering strategies that serve to differentiate the Archaic peoples from their Paleo-predecessors. These differentiations are at least partly due to environmental changes that were on a global scale. The gradual warming trend that began in the late Pleistocene continued until about 6000 B.C. By that time, the scrub vegetation (which replaced the oak-juniper woodland) and desert conditions prevailed with somewhat higher winter and summer temperatures than today. Around 1000 B.C. all modern plant taxa had become established and modern climatic conditions prevailed.

The adaptive strategies of Archaic groups include a greater reliance on plant foods, as evidenced by the presence of small grinding stones to process those plant foods. The animals sought by these groups are all modern species. The other tools utilized reflect a more generalized economic strategy. Land use of these groups is also seen as more generalized. That is, Archaic-aged sites are found in all environmental zones. The previous discussion of hunter-gatherers, their needs, and their risk-reducing strategies to satisfy those needs through high mobility, are applicable here. The trends in the data from the region, however, do suggest a gradual population increase through the long 6000-year period of the Archaic. With this change, "it appears that increasing population levels coupled with more diverse subsistence economies led to an intensification of land use patterns as well as the exploitation of continually increasing environmental zones" (Miller and Kenmotsu 2004: 218).

An important event in the Late Archaic was the introduction of cultigens in the area around 1000 B.C. Little immediate impact upon Archaic lifeways was probably seen although the intensified use of selected environmental zones by individual groups may have contributed to the sustained use of cultigens (Miller and Kenmotsu 2004: 218). Certainly, during subsequent adaptations, cultigens played an increasingly important role.

Archaic period land-use patterns were modeled by Anderson (1993: 48-67; see also Hard 1983a; O'Laughlin 1980). Anderson divides her study area (Maneuver Areas 3-8 on Fort Bliss and sites from the Rio Grande and surrounding mountains) into landform areas: desert floor, low and high

alluvial fans, mountain, and riparian. Anderson utilizes 156 of the 240 sites from Carmichael's 1986 survey and places them in one of MacNeish's (MacNeish and Beckett 1987) Archaic phase designations: Gardner Springs (6000-4000 B.C.); Keystone (4000-2500 B.C.); Fresnal (2500-900 B.C.); and Hueco (900 B.C.-A.D. 250).

Anderson locates these sites with respect to the above-mentioned landforms and also assigns each site in one of the following three categories. The *macroband* category defines sites that have four or more hearths or large amounts of ground stone. The *microband* is distinguished by one to three hearths. Although sites in the *task force* category usually lack hearths, occasionally one may be present. Finally, Anderson includes, but does not define, *base camps*. These apparently have structures and are more intensively occupied than macrobands. They may represent occupation through one or more seasons in a year.

Given all these data, Anderson describes the land use for each phase. The Gardner Spring phase (6000-4300 B.C.) had a seasonally nomadic subsistence system with no base camps (as such), but moved constantly, with the pattern dictated by seasonally available resources. She posits that during the Keystone phase (4300-2600 B.C.), the settlement pattern is similar, but at the Keystone Dam sites at the end of the phase evidence of a pit house signals a shift to a system of base camps and special activity sites. The Fresnal phase (2600-900 B.C.), given the evidence of pit houses at the Keystone Dam Site, suggests the use of base camps and/or multiseasonal use of the Rio Grande area with special activity camps in other environmental zones. The implication of changing technology and subsistence bases is seen through greater numbers of grinding implements, cultigens, and the placement of sites on alluvial slopes. Anderson sees the continuation of these patterns in the Hueco phase (900 B.C.-A.D. 250). Anderson (1993: 67) also notes that this trend seems to continue into the ceramic Mesilla phase.

Hard's (1983a) model for the Late Mesilla phase (A.D. 750-1100) proposed that functionally differentiated sites existed during the Late Mesilla phase due to changing seasonal resource availability. Responsive to this variability, at least two types of residential sites were suggested to have been in use during the Late Mesilla phase: summer-foraging and winter-collecting base camps. Seasonal environmental variability and the related changes in land use and residential sites were taken into account (Hard 1983b: 41-51).

Mauldin (1986) presents a model of land use during the Pueblo period (A.D. 1150-1400) as an extension of Hard's model in the Fort Bliss/El Paso region. His model focuses on resource acquisition and mobility strategies employed by Pueblo period populations. Two major residential types, primary and secondary habitation sites, are postulated. Mauldin considers primary habitation sites to be well-watered locations, principally the mountain slopes and river margins, which were occupied throughout the year. Agriculture was considered a major activity at those locations. He considers logistical forays, primarily deer hunting and plant collection, to have been launched from those primary site locations. Secondary sites, located in the same zones as primary sites as well as in the central basin, were those probably occupied only during the summer after the initiation of the summer rains and before the harvesting of the agricultural crops at the primary village sites; foraging for seasonally available plants and animals was the focus of activities at the secondary sites. The site types and their expected characteristics are considered in his model (Mauldin 1986: 255-269).

The land-use models presented above were developed to provide frameworks in which further investigations could be conducted. They are a partial response to the lack of developed methods that could allow accurate identification and interpretation of site variability within the El Paso region. These models are set within the culture-historical framework of phase and/or periods, and they assume lesser or greater dependence upon agriculture (Hard 1983a: 9; Mauldin 1986: 257). They deal with environmental variability and propose that functionally differentiated sites existed

during particular time periods due to changing resource availability (Hard 1983b: 44; Mauldin 1986: 257-258). Also, both Hard and Mauldin's models allow for a mixed subsistence strategy given the vagaries of the semiarid environment. These mixed strategies are viewed within the same cultural and adaptive system.

ALTERNATIVE EXPLANATIONS OF SETTLEMENT VARIABILITY: ADAPTIVE DIVERSITY

During the 1980s, several researchers proposed alternative schemes in which either distinctive adaptive trajectories were represented, or ones in which a fluctuation between a dependence on wild foods and a dependence on farming occurred (Carmichael 1983, 1985a, 1986b; Johnson and Upham 1988; Kauffman and Batcho 1983, 1988; Stuart and Gauthier 1984; Upham 1984, 1988). The common presence of small "nondiagnostic" sites was seen as evidence for that cultural variation. Alternative schemes were eventually suggested in which the archaeological record was argued to reflect either distinctive adaptive systems or economic fluctuations between a dependence on wild foods and a dependence on farming. For example, Upham (1984, 1994) suggests that data identifying the kind of adaptive diversity above have already been collected by archaeologists. He refers here to limited-activity sites, or artifact scatters. These sites are identified and assigned a temporal and cultural affiliation on the basis of ceramics or diagnostic lithic material without clear understanding of their structural relationship to the settlement-subsistence system (Upham 1984: 239).

Carmichael (1986a: 239-253) discusses the discovery of ephemeral residential structures dated to the Pueblo period (A.D. 1100-1400) in the west El Paso area. He notes that the characteristics of the houses and the artifact assemblage suggest that they functioned as a short-term base camp in an adaptive strategy of high residential mobility. The late dates imply that such a mobile strategy may have been in operation during the same general period as more logistically organized, pueblo-based, adaptive strategies. Carmichael suggests that there is a need to cope with the potential for identifying "Archaic-like" adaptive strategies at other times besides the Archaic period. He further notes that, "Many late foraging sites have probably been misidentified as preceramic sites, or as logistic camps associated with one of the Formative phases" (Carmichael 1986a: 253). Carmichael (1990: 122-134) notes that present data suggests that sedentism appeared later in the Jornada area (A.D. 1100) than in other parts of the Southwest. He also notes that there is evidence that sedentary strategies were not sustained for long periods, even during the Pueblo period and, "The coexistence of, or oscillations between, mobile and sedentary strategies may be indicated" (Carmichael 1990: 122).

Young (1994: 141-154) takes Upham's (1984) proposition that prehistoric populations frequently oscillated between mobile and sedentary adaptive strategies and his argument of limited-activity sites as the remains of hunter-gatherers rather than sedentary agriculturalists. She suggests that differences in lithic technology provide a better method for distinguishing the remains of highly mobile groups from those of sedentary populations. Young examined the methodological problems she saw in Upham's arguments but affirms the correctness of his calling attention to the diversity of adaptive strategies within the Southwest (Young 1994: 152). Upham's model of adaptive diversity predicts that oscillation between adaptive strategies by different southwestern groups was common after A.D. 700 (1994: 157). He notes that, "some archaeologists have chosen to focus on the economic relationships between gatherer/hunters and village agriculturalists during this and the immediately preceding time periods and have generated some very interesting results (e.g., Spielmann 1991a, 1991b)" (Upham 1994: 157).

Kenmotsu (1994), undertaking a study of the interaction between small-scale foragers and cultivators, developed a model of mutualistic interaction and tested the model with data contained in Spanish documents dating from A.D. 1545-1750 that relates to the La Junta de los Rios region

of Mexico and Texas. She notes that there is abundant documentary evidence of the existence of close relationships between the nations of La Junta de los Rios and the foraging nations that occupied various territories around the Presidio Bolson. There is substantial documentation that these interactions were based on relationships that had been in existence for a long time and that they were activated during periods of stress, such as war and famine (Kenmotsu 1994: 509).

These are competing adaptations and/or mutualistic interactions between hunter-gatherers and agriculturalists across the landscape, and workable methods must be devised that allow the true context and function of any archaeological sites, let alone limited-activity sites to be ascertained. Land-use models can accommodate those suppositions by altering the hypotheses so that viable methodologies that will identify and come to terms with the archaeological record and the explanations archaeologists seek can be found.

The function of any of these models is to provide a framework upon which to ask questions, to test assumptions, and to develop alternative hypotheses or ways of addressing the data. In order to test the implications inherent in these models, the data must contain spatial and more importantly temporal boundaries (Carmichael 1986a: 21). Surveys conducted on Fort Bliss (Beckes et al. 1977; Carmichael 1986a; Skelton et al. 1981; Whalen 1977, 1978) have documented thousands of small artifact scatters or isolated features that cannot be assigned any temporal placement (Mauldin 1994: 1). Seaman and others (1988) and Doleman and others (1991) encountered similar occurrences to the north in the Tularosa Basin. Mauldin (1993a) points out that the "temporally unknown" sites with their low artifact inventories, small size, and low frequency of diagnostics are not generally the focus of archaeological investigations. However, some work has been accomplished on these types of sites (Doleman et al. 1991; Mauldin et al. 1994; O'Laughlin and Martin 1989; Whalen 1980, 1986). The work of Mauldin and others (1998) suggests that there are different patterns of behavior within the basin. One is a hunting-gathering, high-mobility residential pattern (short-term residences), and the other, later in time, is a use of the area as foraging zones or locations for resource collection (logistical strategies, see Binford 1980).

Often these small sites or features are relegated to the Archaic period due to a lack of temporally diagnostic materials. An association is assumed, given the lack of diagnostic data. Ironically, an association is often assumed for a whole site due to a temporally diagnostic artifact or sets of artifacts. However, as noted in the beginning of this chapter, surface expressions with or without diagnostic artifacts and/or ashy stains can be misleading. Given the dynamic nature of the environment, it is dangerous to assume temporal associations for whole sites when a palimpsest of data that defies separation into obvious temporal periods based on the present cultural-historical context is present.

Methodologies must be developed that will allow the associations of the cultural materials currently on record and that which continues to be discovered and recorded to be understood. Comprehension can only be advanced by continuing to acquire solid chronological data for as much of the material as possible. Without detailed attention to and the understanding of the chronometric factors, as well as the associations of materials within features and sites, the vast amount of archaeological data cannot be brought together into a substantive picture of the past, let alone used to assess the significance of that data.

NEW APPROACHES TO SETTLEMENT PATTERN ANALYSIS UTILIZING GEOMORPHIC MAPPING AND TRU SURVEY DATA: LANDSCAPE COMPONENTS AND RESOURCE DISTRIBUTIONS IN THE JORNADA

The discussion of landscape components and resources reviewed above and in the 1996 *Significance Standards* focused on four broadly defined landforms, providing an extensive list of

the plant and animal resources found in each. In conjunction, likely patterns of exploitation by hunter-gatherers and cultivators within the landforms were offered. The following section expands on this discussion, and is intended to enhance understanding of settlement and land use patterns as they are affected by resource distributions across the various landforms on Fort Bliss. Note that the following discussion presumes that analysts are familiar with and will be using computer-based GIS software for their analyses.

Major work has been done over the past decade regarding landforms on the McGregor Range portion of Fort Bliss. This work was intended to provide “simple and reasonably accurate” (D. Johnson 1997: 10) geomorphic surface maps of the Quaternary landscape across the study area. A series of 13 basic landform mapping units were defined, including four alluvial surfaces, four dune surfaces, two playa surfaces, pediment and bedrock surfaces, as well as a Bolson Floor complex.

While these 13 basic landforms form the basis of the analysis, detailed maps of the study area delineate some 70 distinct landform ‘complexes’. These complexes, which combine up to five of the basic landform elements, reflect the complicated nature of the geomorphic processes responsible for the present landforms, and the difficulty of mapping some of the more complicated landform interfaces found within the study area. For each of the complexes, the most dominant landform is given prominence, followed by the additional landform components found within the zone, in descending order.

The detailed mapping units discussed above (available in digital format from Fort Bliss Environmental Division upon request) provide an improved basis for understanding land use and settlement patterns on McGregor Range. Preliminary inspection of these coverages, with recent TRU survey data overlain, suggests that high-level correlations between artifact/feature distributions and landform complexes are likely. For instance, in the northern reaches of McGregor Range, artifacts and features appear to be highly correlated with the various dune complexes where these dune areas inter-finger with distal fan alluvial deposits, and are all but absent in the active, aggrading alluvial channels that run through the dune areas toward playa basins in the valley bottom. At this point, it is not clear whether this general pattern is the result of differential site placement within the dune regions, or whether the aggrading alluvial surfaces have covered and masked use of these alluvial regions during the recent past.

Further research would be required to validate general land use patterns such as those outlined above and to determine whether buried cultural deposits are found within the active alluvial channels mentioned. Nevertheless, research of this nature, focused on the distribution of cultural materials within geomorphically-defined landforms, provides a more enhanced sense of landscape and context than has previously been the case. Of particular importance for this discussion, since the landforms are fundamentally geomorphic, research based on these landforms has the potential to illuminate the effects that surface stability, erosion, and aggradation have on the patterns visible in the data. Patterns can now be calibrated in terms of surface stability and visibility rather than taken at face value.

The landform maps described above apply specifically to McGregor Range, and do not extend into Doña Ana Range or the southern Maneuver Areas. Monger (1993a) defined and mapped ten different surfaces geomorphic landforms or surfaces for these portions of Fort Bliss. The La Mesa basin floor surface covers most of these portions of Fort Bliss, followed by the Fault Complex surface, and the Petts Tank alluvial surface. Organ eolian and alluvial surfaces, Lake Tank basin floor deposits, Fort Selden erosional surfaces, Jornada I and Jornada II alluvial surfaces cover minor portions, while Isaack’s Ranch fan deposits do not occur within Fort Bliss proper, but are found just west of the western boundary of Doña Ana Range. It is not known whether the surfaces defined by Monger have been digitized, and whether these coverages are

available from Fort Bliss Environmental Division. The utility of this dataset for settlement and land use studies cannot at present be evaluated, but once it has been digitized and made available, should provide much the same enhanced sense of landscape and context as the coverage generated by Johnson.

Resource Distribution

To better incorporate resource distributions within the current settlement and land use research and strengthen the analytical utility of this work, moving beyond generalized landscape characterizations is imperative. In most instances, resource discussions have been limited to lists or rosters identifying the significant plant, animal, and other key resources found within Fort Bliss. These rosters often include some indication of the seasonal availability of these resources and where these resources may be found (e.g. alluvial fans, playa edges, proximal alluvial fans, etc), but such characterizations do not approach the level of detail necessary to offer anything more than generalized expectations regarding land use and settlement decisions and the distribution of subsistence resources.

To a large extent, settlement and land use studies are driven by an underlying assumption that patterns in the distribution of cultural materials are influenced by the distribution of what are considered important resources; people differentially select locations on the landscape to undertake various tasks, and their selection is influenced by the distribution of the resources needed to fulfill or accomplish the specific tasks. Resource rosters can provide clues into the likely focus of the various activities, but are inadequate for untangling the spatial challenge associated with resource procurement and landscape utilization. Addressing patterns in landscape utilization requires spatially referenced datasets that embed the knowledge contained in the various resource rosters within a spatial framework to fully appreciate the spatial challenge of land use and resource procurement activities.

A number of spatial datasets relating to resource distributions across Fort Bliss are available, including a detailed vegetation map created by the Nature Conservancy. This dataset maps the distribution of 35 different biotic zones, including five basin, eight foothill, one forest, two lower piedmont, two upper piedmont, four mesa, three montane, three plains, and two woodland zones. The dataset also maps out which of these regions constitute either deer or antelope habitat. This coverage could be further enhanced by linking the listed biotic communities to the individual plant and animal species found in the extant resource rosters, and by including return rate values for each of these resources (Raven 1990; Raven and Elston 1989).

As with all landscape coverages that delineate the present distribution of biotic communities, the utility of these coverages for understanding resource procurement activities in the past are somewhat problematic. The degree to which these mapping units reflect the distribution of resources in the past is not clear. Nevertheless, they provide a more refined characterization of the distribution of biota than the coarse landform zones generally used.

Further relevant datasets are also available, including soils maps by the Soil Conservation Service, and the geomorphic maps discussed above. In combination with standard GIS datasets such as elevation models from the United States Geological Service (USGS), these coverages can, for example, be used to identify specific locations that combine the appropriate hydrological, geomorphic, and soil attributes necessary for different forms of rainfall based agriculture. The distribution of cultural materials can then be analyzed in relation to these potential agricultural fields.

Analytical Methods

The most prevalent landscape scale analytical technique found in the literature is the predictive site location model (see contributors in Westcott and Brandon 2000). Predictive site location

models are primarily used to project known patterns or relationships from surveyed space into neighboring regions that have not yet been surveyed. Spatial correlations between site locations (the dependant variable) and environmental parameters such as vegetation community, landform, slope, aspect (the independent variables) are calculated for the study area, with the expectation that these relationships hold true for regions outside of the study area. Probability maps generated by this technique are then used to map the statistical likelihood that archaeological sites will be found at any given location, allowing researchers to ‘predict’ where sites will be found (and where they will not be found).

Predictive site location models have been popular with archaeologists for a number of reasons, including their (relative) ease of implementation and their potential to predict the location of sites across large regions, including regions that may never be surveyed. Predictive models have also been of interest to resource managers, with the expectation that these studies will enhance their ability to protect the resources under their care, and to predict in advance the likelihood that the presence of cultural materials will impact facility placement. Recent implementations, based on more refined datasets and sophisticated statistical analyses, suggest that predictive models will remain a mainstay of archaeological settlement and land use analysis (Westcott and Brandon 2000).

While large-scale predictive models predominate, microregional analysis of settlement patterns at the community level offers an alternate scale of analysis. Community level research focuses on defining small-scale residential human groups or aggregates, and the spatial ‘footprint’ that these communities have across the landscape (see Adler 2002; Kolb and Snead 1997; Peterson and Drennan 2005; Wells et al. 2004). Integral to the notion of community employed in these studies is the importance they ascribe to community space and the need for detailed, microregional data recording methods to fully appreciate the activities that occur between villages and residential locations. The examination of prehistoric communities across the landscape also requires the incorporation of social theories regarding land tenure and broader considerations of how prehistoric societies viewed the landscapes in which they resided (Adler 2002; Varien 1999). A more detailed discussion of community level studies is provided elsewhere, but it should be noted that the standard survey method used at Fort Bliss, the TRU method, is ideally suited for community level analysis.

Finally, agent-based simulation models have begun to appear in the literature, and are worth mentioning. Agent-based simulation modeling is an inductive approach in which multiple ‘agents’ (often referred to as ‘cellular automata’) act and react within a simulated setting. Agents follow simple decision rules (e.g. ‘after consuming resource, move to nearest resource patch’), and with each iteration of the simulation, the action of the agents generates patterns of movement and resource exploitation, based on their decision rules. Depending on the number of agents involved in a given simulation, and the number and diversity of their individual decision rules, highly complex interactions can be generated. The ability to generate complexity from simple decision rules is seen as the methodological strength of this modeling technique (see contributors in Gimblett 2002 and Kohler and others 1996).

Agent-based simulation models are significantly more difficult to implement than the predictive models mentioned above, but offer the potential to explore the underlying behavioral correlates to patterns noted in the archaeological landscape. Relatively simple models can be constructed that focus on specific topics or questions, and the patterns generated by the simulation can then be compared to patterns noted in the record. For instance, an agent-based simulation of lithic raw material procurement and transport, based on very simple rules of procurement and discard, generated assemblage patterns similar to archaeological assemblages described in the literature. The similarity of the assemblage patterns call into question some basic assumptions regarding the

significance of assemblage level measurements of raw material richness and transport distance (Brantingham 2003).

A final issue that needs to be addressed is that of pattern recognition. When ‘sites’ are the focus of analysis, spatial patterning across the various environmental attributes is fairly straight forward: where are the sites located? With the adoption of the TRU survey method, analysis need no longer be limited to site locations, and the potential number of spatially-relevant patterns within the rich datasets is dramatically increased. Finding patterns within the new TRU-derived datasets is, however, a challenge. For each grid location, upwards of a dozen assemblage observations are available, and any given project may contain hundreds, if not thousands of such records. When combined with the landscape datasets discussed above, we are faced with discerning spatial patterns across dozens of attributes over hundreds if not thousands of locations.

A number of techniques have been developed to discern patterning within large, rich datasets. The process of searching for such patterns, often referred to as ‘data mining’, is intended to find ‘hidden’ relationships that would either be missed or overlooked by traditional methods. Data mining techniques include neighborhood analyses and clustering methods, neural networks and related methods, decision trees, and rule induction, among others (Berson et al. 1999). To date, data mining techniques have not been used to identify spatial patterns within survey data at Fort Bliss, a situation which will undoubtedly change in the coming years as the sheer volume of TRU based survey data accumulates. These rich, complex datasets all but require sophisticated data mining procedures to fully explore the potential relationships contained within, and the uncovering of ‘hidden’ spatial relationships in the surface assemblage should open up exciting new avenues of research. On the other hand, data compiled during TRU survey can also be used to provide simple count or locational data for simple location-based analyses

Suggested readings for predictive modeling include Altschul and others (2004), Raven 1990, Raven and Elston (1989), and Westcott and Brandon (2000). For agent-based simulation modeling, see Brantingham (2003), Gimblett (2002), and Kohler and others (1996). Berson and others (1999) provide a useful overview of data mining procedures.

SETTLEMENT PATTERNS, LAND USE, AND THE TRU SURVEY METHOD: NEW ANALYTICAL PERSPECTIVES

One of the most significant changes to settlement pattern and land use studies at Fort Bliss over the past 10 years has been the refinement and widespread adoption of the TRU_survey method. As implemented at Fort Bliss, the TRU method entails recording field observations by reference to 15-m by 15-m grid locations. From these initial observations, spatially isolated aggregates of artifacts and features (‘sites’) are routinely defined and delineated. The adoption of the TRU method has fundamentally shifted emphasis onto empirical observations (the recording of artifacts and features) to characterize the spatial distribution of artifacts and features, as opposed to interpretive synopses of sites and site assemblages that have long been integral to traditional recording methods. Following Arnold and Applebaum (1996), changes associated with the adoption of the TRU method can be discussed in terms of added functionality at three levels: doing simple things that have always been done; doing complex things that are seldom or never done; and, doing new things that revolutionize the current thinking and create new hypotheses.

The most basic tasks undertaken during survey work are associated with finding, delineating, and recording archaeological sites. TRU data can readily accomplish these tasks, and thus provide this most basic level of functionality. Computer routines have been developed to search through the spatially-referenced tabular datasets generated during fieldwork, delineating spatially isolated artifact/feature aggregates that meet empirical criteria that distinguish archaeological sites from

(generally low density) isolates. Once defined, assemblage characterizations and site maps are readily generated.

More complex analyses are also possible with TRU data sets, although not all projects are large enough to warrant these analyses. For instance, site-based settlement pattern research generally requires large block coverage encompassing multiple landforms and environmental zones to adequately characterize regional patterns (e.g. Whalen 1978). Although they may be adequate for confirming patterns noted during larger scale projects, smaller survey projects are not the ideal platform from which to generate regional site distribution patterns. While the above generalization may be valid, the adoption of the TRU survey method can go a long way to alter this unfortunate limitation.

Because TRU data sets consist of assemblage tallies referenced to individual 15 m grid locations, they are inherently flexible and amenable to re-analysis and the generation of an endless series of novel thematic groupings. While this is certainly true of individual project data sets, multiple data sets can also be merged and analyzed in the same manner. As database parameters are standardized, the ability to link surveys of any size or scope into an ever growing regional database is enhanced, leveraging the analytical relevance of each new project by the sum of the preceding projects. For any given project, novel analytical techniques can be developed and tested without being limited to the specific project location. In this manner, larger scale regional settlement and land use pattern research, generally the subject of large block survey projects, could be initiated during smaller projects, increasing the frequency at which these larger scale patterns are investigated, evaluated, and analyzed.

Finally, the adoption of the TRU survey method has the potential to enable archaeologists to see things in the surface record that we have never seen before, or even looked for. In the TRU method, sites are defined and delineated after the surface distribution of artifacts and/or features has been recorded. Whether artifacts/features at a given location fall within a site is not known while they are being recorded. There is no distinction made between site/isolate contexts during the recording process; all artifacts and features are potentially part of a site, and are treated equally. As a consequence, 'isolate' locations are unavoidably integrated within project databases, and are available for later analysis. Site-based recording methods, on the other hand, de-emphasize low-density scatters, and these 'isolates' are generally given little consideration.

An example of the suitability of TRU data for community-based analysis is the identification of footpaths and/or trails in northern McGregor (Kludt et al. 2007; see discussion below). While the footpaths described above are a fairly simple example of potential new avenues of research accessible within TRU data sets, they do beg the question: "What else has remained invisible simply due to the way empirical observations have been recorded? What else has been unseen?" The footpaths were always there. That they weren't observed before is more an indication of the inadequacy of the former recording methods than of a lack of attentiveness or diligence. What else will be noticed in the new datasets? Can more extensive path/trail systems be identified by tracking low-density ceramic distributions? Can patterns be seen within large palimpsest site assemblages that suggest the activities responsible for their creation?

REVIEW AND CRITIQUE OF USING SITE 'TYPES' FOR SETTLEMENT PATTERN ANALYSIS

In general, settlement pattern analysis involves an assessment of the distribution of sites in relation to variables such as landform, soils, exposure, view shed, and other environmental parameters. As part of the analysis, sub-groups of the various sites under study are often defined, and differences in the distribution of the sub-groups are used to draw conclusions and interpret aspects of settlement and subsistence that differ among the defined groupings.

Partitioning of sites into groupings, or site ‘types’, can be based on various lines of evidence. Temporal indicators such as projectile points and ceramic types can be used to distinguish Paleo-Indian, Archaic, and Formative sites. Site size can be used to define villages, hamlets, and base-camps, and used to investigate apparent hierarchical relationships. Sites can be grouped in terms of site function, such as residential sites, base camps, extraction sites, quarry sites, and special activity areas. Assemblage composition can also be used to define groups such as aceramic sites, sites with low artifact diversity, sites with diverse assemblages, sites with middens, etc. Depending on research orientation, multiple lines of evidence can be combined to produce a complex typology of sites within a given study area.

The results of any analysis are fundamentally affected by how the different groupings are defined, and care must be exercised when constructing site typologies for settlement pattern research. Palimpsest sites are common within the basin, and site boundaries can contain multiple activity areas from different temporal periods representing different functional occupations. Overlapping occupations of this kind can generate unexpected temporal and functional juxtapositions that may confound simple typologies and generate spurious patterns.

The vagaries of surface processes can also influence the number and kind of artifacts that are visible on the surface, and the same site can look radically different after major rain or windstorms. This is particularly true of the ever-shifting basin sand sheets, and less true of the upper reaches of the relatively stable alluvial fans and pediment zones. Depending on where a given site is located and when the site was recorded, counts and assemblage components can be expected to differ, suggesting that some variation noted in the surface record is a reflection of surface geomorphic processes rather than some underlying behavioral difference (for more, see the discussion in Chapter 6). In short, a certain amount of ‘noise’ in artifact counts and assemblage constituents should be expected, and these counts are probably best viewed as approximations or indications of magnitude, rather than as absolutes (Bailey 2007; Mauldin et al. 1998). Typologies should avoid overly fine distinctions based solely on these attributes (cf. Raven 1990).

The above observations also apply to assemblage data recorded during TRU surveys. Jumbled palimpsest assemblages will be recorded, and surface dynamics influence what items are ultimately recorded at any given location. TRU datasets, however, offer the potential to actually investigate these confounding factors. The splitting of palimpsest assemblages into discrete, spatially referenced grid locations means that small-scale spatial relationships in these jumbled surface assemblages are open to investigation. By comparing the recorded surface assemblage with geomorphic setting and landform, these same data can also be used to analyze the influence that surface dynamics have on the reliability of surface tallies. In short, while TRU survey data are not immune to the confounding effects of repeated reoccupation and surface dynamics, they are better suited to investigate these phenomena than traditional site-based datasets. Investigation of these phenomena should, over time, lead to more reliable typological categories and site classifications.

The broader issue of ‘site types’ and settlement pattern analysis, TRU based survey data provides a widened field of potential categorization and classification opportunities when it comes to the selection of ‘types’. The fundamental spatial unit of observation is the grid unit, and these grid units can be grouped into larger spatial aggregates that correspond to traditional ‘sites’. Significantly, the generation of spatial aggregates that correspond to traditional sites is not the only manner in which the grid units can be grouped. Novel spatial ‘types’ can be devised that have little or nothing in common with the traditional site concept, and analyses run on these novel assemblage constituents.

For example, all grid locations with ground stone implements can be identified, and the over-all assemblage characteristics of these locations can be compared and analyzed. Next, neighboring grid squares can be aggregated with these locations, assemblage characteristics re-calculated, and the resulting spatial aggregates re-analyzed. This aggregating process can continue, encompassing an expanding concentric ring around the focal locations, for as long as desired. The above example is extremely simple, but with more complex selection criteria and aggregation methods, an almost infinite series of spatial aggregates can be generated and analyzed. And while many (most?) of these novel spatial 'types' may fall within traditional 'site' boundaries, the interpretive significance of such novel aggregates is solely due to the specific attributes used to define them, and this significance may have little to do with traditional notions of 'site'.

LAND USE, SETTLEMENT PATTERNS, AND AGRICULTURAL SOCIETIES: COMMUNITY BASED ANALYSIS.

The nature of agriculturally based societies on Fort Bliss is an on-going topic of research. The advent of food production entails the altering of fundamental landscape relationships, and patterns associated with agricultural societies should be expected to differ from those noted for highly mobile hunter/gatherer societies of the preceding periods. Understanding and analyzing these differences requires an appreciation of the key determinants of agricultural production at the landscape scale, in addition to societal factors that generally gain prominence when mobility is supplanted by storage, food production, and sedentism.

One of the key issues concerning the analysis of agriculturally based societies is that of scale and spatial extent. Dwellings and high-density artifact scatters, the focus of most site based analyses, may represent components of agriculturally-based societies, but other significant components such as agricultural fields or plots, transit corridors, and buffer regions, may not be as readily identifiable (Wells et al. 2004). Depending on how they are defined, sites may not include important community space extending beyond artifact scatters and dwellings, and a focus on such spatially isolated high-density areas can act to splinter the view of agricultural societies. One way to ensure that the spatial context of agricultural landscapes is not inadvertently missed is to select a spatial unit of analysis large enough to encompass the range of anticipated activities and related facilities.

It has been argued that a more appropriate level of analysis of agriculturally-based societies is that of the community, a scale intermediate between site and region (Adler 2002; Kolb and Snead 1997; see also Peterson and Drennan 2005). Under this conceptualization, a community is seen as a territorially based aggregate large enough to ensure social reproduction, subsistence production, and self-identification. A community consists of a minimum of individuals who interact regularly and share a sense of local identity, where community relationships act to mediate many economic activities. By focusing analysis at the community level, a more holistic view of regional landscapes is created and significant novel land use patterns may be highlighted.

From a community and landscape perspective, the identification of potential agricultural fields or plots offers a potentially significant tool for identifying likely agricultural communities and their associated cultural inventories. Using standard GIS techniques, available datasets such as USGS Digital Elevation Models (DEM), the Soil Conservation Service (SCS) soil coverages, and Johnson's geomorphic landforms identify potential agricultural areas, and in conjunction with TRU based survey data, define micro-regional aggregates associated with these potential agricultural lands. The degree to which these aggregates represent agricultural based communities can then be investigated, and relevant landscape patterns defined.

While the identification of potential agricultural fields is a fundamental first step in the analysis of community-based agricultural societies, Kolb and Snead (1997) discuss additional avenues of

investigation, including differential labor investment, community level spatial relationships, and boundary maintenance. Labor investment is evident in construction projects such as monumental architecture, extensive residential structures, agricultural systems, and water control features. Labor investment is often quantified in terms of volume calculations and labor per day estimates, but care must be given to these estimates and to the organizational aspects of the labor force.

In the Jornada region, the dearth of large-scale, labor-intensive architectural features and facilities suggests that labor investment analyses will be difficult to implement (see discussion of this investment in G. Johnson 1989). Defining and delineating water control features associated with potential water harvesting techniques will likely provide the best avenue for studying labor investment at the community level. Various techniques are described in the literature (Critchley and Siegert 1991; Prinz and Malik 2002) while Field (1992) provides a detailed discussion of prehistoric alluvial fan agriculture in the Tucson region. Due to the high rate of erosion and deposition in areas favored for run-off based agriculture, surface survey data alone may not be sufficient to define and delineate water-harvesting features, and backhoe trenches may be needed to trace out suspected water-harvesting features.

Spatial analysis at the community level is an attractive alternative to research on labor investment. Once communities have been identified, analytical strategies can focus on relationships with these communities such as the spatial organization of dwellings and secondary refuse disposal areas, residential location, and distance to fields or water. In addition, relationships between communities and available resources can be analyzed at the macro-regional scale, and can include indications of community level hierarchical differentiation or similarity, and measures of inter-community spacing such as aggregation or dispersal.

Inherent in a community level analysis is a consideration of land tenure and boundary issues (see Chapter 12). If a community is conceptualized as a bounded spatial aggregate, at some point questions must be considered, such as: how the members of these communities interact with one another; how labor and activities are structured and scheduled; how these communities interact within regional hierarchies; how territorial boundaries affecting resource access and land tenure are established and enforced at the various levels; and how these various aspects change over time.

Many of these questions were once thought to be difficult to deal with archaeologically, as they entail aspects of social dynamics not commonly visible in the archaeological record, but recent research has demonstrated that it may be possible to examine the formation and maintenance of social boundaries (Miller 2005a, 2005b). Detailed ethnographic research on small scale agricultural societies and recent work on buffer zones and ‘common pool’ resources suggest that ecologically based analyses of territoriality and boundary parameters can be informative at the community level (Adler 2002; Eerkens 1998; Stone 1996; Varien 1999).

Advocates of community level analysis stress the need for detailed survey methods that consciously monitor the spatial distribution of cultural materials throughout a given region. Such a ‘micro-regional approach’ is thought to increase the likelihood that all aspects and activities associated with a given community will be available for analysis (Kolb and Snead 1997; Peterson and Drennan 2005; Wells et al. 2004). The TRU survey method, now standard for survey projects on Fort Bliss, represents just such a ‘micro-regional’ approach to documenting the surface record, and survey data recorded in this manner should facilitate the implementation of community-based analyses.

The identification of communities however, is not something that can be derived solely from a black box approach (e.g. computer/GIS). Communities are social constructs, influenced by both the natural and social environment. Therefore, heuristic models of “communities” should be built from appropriate anthropological parameters, which can then be operationalized via GIS or

though simulation modeling. Recent work suggests a uniformity, or self-organizing, aspect to human communities (Eglish 2005; Hamilton et al. 2007; Zhu et al. 2005) that may be conducive to analysis using scale sensitive techniques (e.g., Bellier et al. 2007).

RECENT EXAMPLES OF SETTLEMENT AND LAND USE PATTERN ANALYSIS UTILIZING GIS, SPATIAL ANALYSIS, AND DATA COMPILATIONS

A perfect example of TRU data providing novel insights into the surface archaeological record can be seen in the series of footpaths recently discovered in the northern reaches of McGregor Range (Church et al. 2005; Kludt et al. 2007). Quite by accident, low-density linear ceramic scatters were noted in the project data when it was displayed on-screen (Figure 11.1). To reiterate, the linear scatters were eventually interpreted as footpaths, most likely associated with the transportation of water. These footpaths extend a fair distance (in one case over 3 km), cross a number of sites, and include low-density ceramic scatters between the recorded sites.

No one involved in the project had anticipated these linear ceramic scatters, and had not even considered the possibility of their existence as the data were inspected. That these footpath segments were distinguishable within the overall scatter and across a number of sites is due to the fact that, under the TRU method, 'isolates' are accorded significance equal to higher density areas. It is doubtful that the low-density ceramic scatters would have been recognized as segments of longer footpaths as they crossed the sites had traditional site-based recording strategies been used.

To the extent that this interpretation is correct, the identified footpaths provide direct empirical evidence of travel and mobility at the community level. Further analysis of these data would help to delineate aspects of the communities associated with the various path segments, including the distance that people were willing to travel from these communities to obtain water, and whether the water source was shared among multiple communities or controlled by a single community. In addition, by tracing out the paths evident in the surface data, the relationship between settlement pattern and water procurement (e.g. labor investment?) at the various communities can be investigated.

Another example of settlement pattern research utilizing TRU survey data is based on the results of spatial analysis of data generated during survey of two widely separated one square kilometer parcels on McGregor Range (Miller 2007b, 2007c). Several spatial analytical procedures were brought to bear on the TRU data collected from the two parcels, but for simplicity of presentation, the graphical results of nearest neighbor analysis are presented. Figure 11.2 shows the multidimensional scaling plots of nearest neighbor *R* coefficients among nine major artifact or feature categories.

The most striking pattern of both figures is the wide separation of Chupadero Black-on-white and El Paso Polychrome ceramics from other data classes along Dimension 1. This clearly reflects the high nearest neighbor *R* coefficients between these ceramics and other data classes. The fact that the nearest neighbor values for this ceramic class are uniformly elevated indicates that these two ceramic types are spatially segregated from most of the other data classes across on these two survey parcels

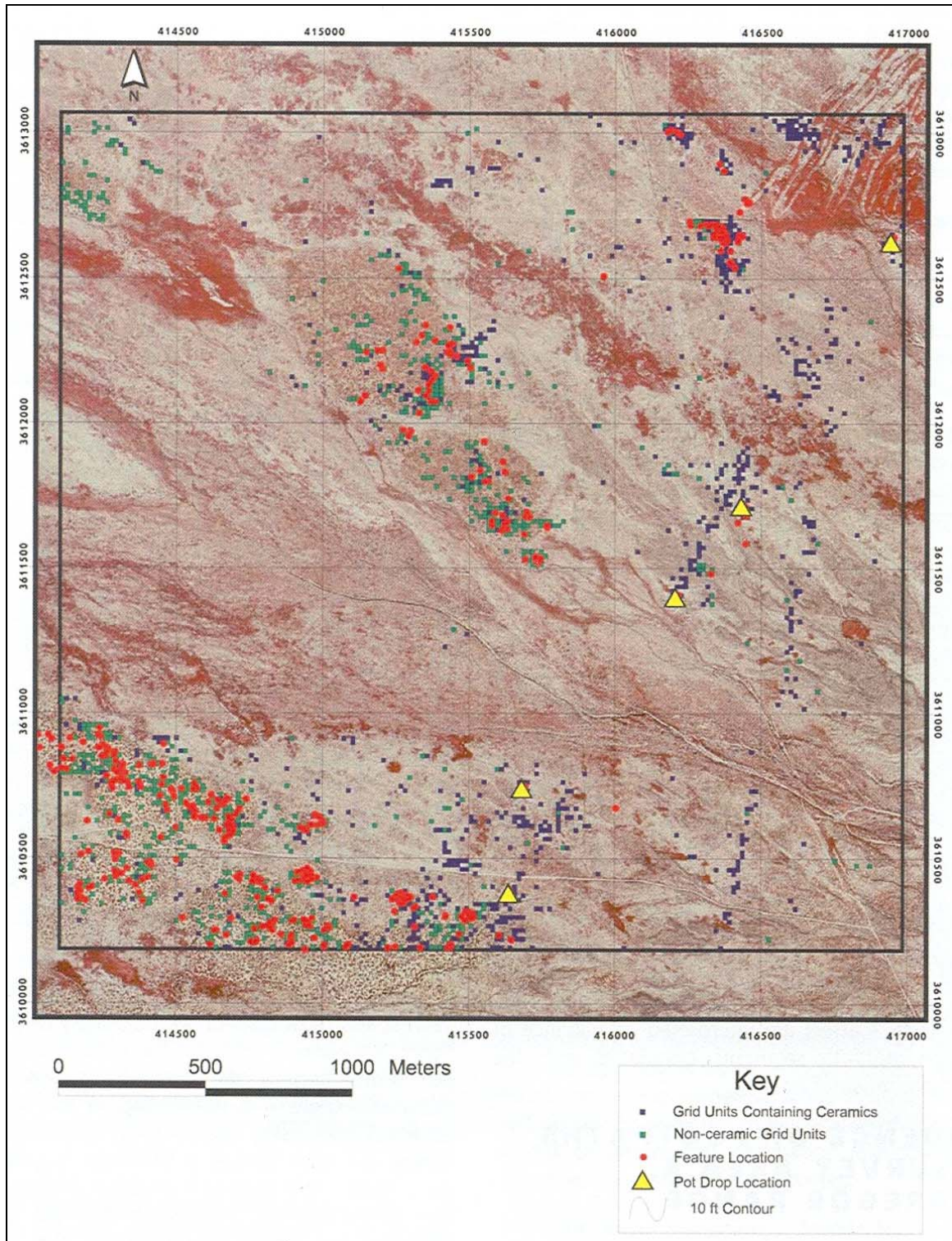


Figure 11.1. Linear distributions of ceramic artifacts and pot breaks denoting prehistoric trails on McGregor Range. (from Kludt et al. 2007: 176; Figure 6.2).

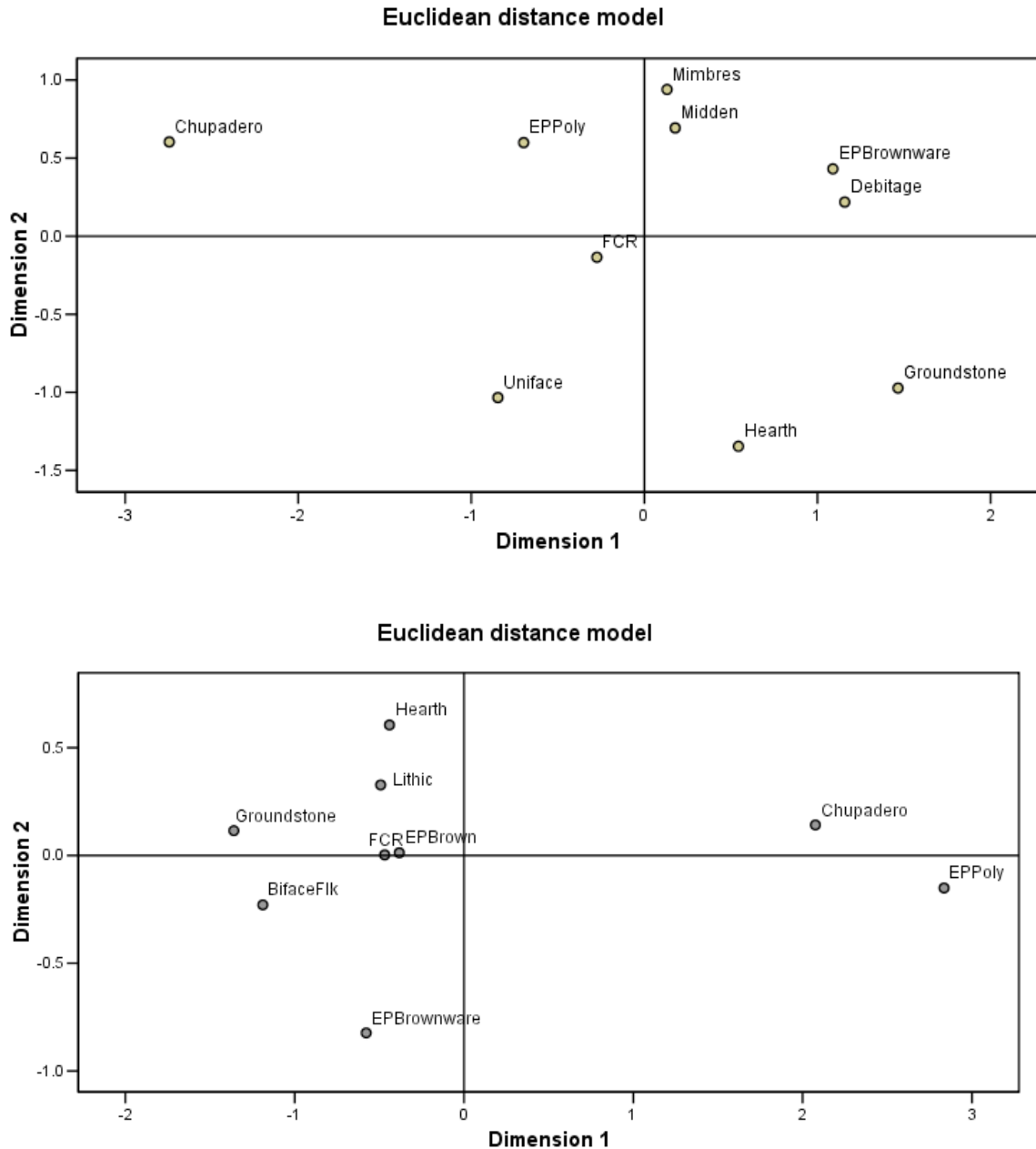


Figure 11.2. Multidimensional scaling plots of nearest neighbor R statistics for data classes from TRU survey parcels on McGregor Range. (from Miller 2007b: Figure 6.3 and 2007c: Figure 7.3)

The consistent separation of the two late ceramic (Late Doña Ana or El Paso phase) wares - Chupadero Black-on-white and El Paso Polychrome - from the remainder of the data classes signifies the presence of a distinct temporal and functional dimension among ceramic distributions in both survey parcels. The widespread segregation of Late Formative ceramic sherds from other data classes suggests a different organizational pattern was involved in the creation of these landscape distributions.

It is proposed that much of this ceramic patterning is a result of Late Formative period logistical use of the landscape, and hints at a substantial degree of vessel transport during a period when most populations were living in relatively stable pueblo and surface room settlements. The

widespread distribution of ceramics may have resulted from a range of settlement strategies, agricultural needs, technological adaptations, and social factors. These may have involved water transport for agricultural and domestic use, the collection and transport of particular food or plant materials, the transport of fermented beverages, the use of ceramic sherds as tools, and the transport and caching of ritual or status items (Miller 2007c).

While further research is needed to evaluate the various explanations for such widespread vessel transport and breakage patterns, for the present time it is intriguing how this analysis and the aforementioned discovery of prehistoric trails were arrived at independently, but clearly the two findings compliment each other. Both analyses of TRU landscape survey data reveal distinctive ceramic distributions across different terrains and suggest that ceramic vessels were used to transport water and other foods or commodities across large expanses the Jornada region.

Finally, examples of diachronic patterns are presented. While examining groups of radiocarbon and obsidian hydration dates from the Hueco Bolson, Mauldin (1994, 1995, and 1996) noted that a substantial shift in prehistoric landscape use from intensive use of the central basins to an increasing exploitation and settlement of the alluvial fans occurred at approximately A.D. 600. Mauldin (1995, 1996) further noted that this major change in settlement pattern was not accompanied by visible changes in artifact morphology and thus could not be detected through temporally or functionally “diagnostic” artifacts.

Using a larger compilation of radiocarbon dates and associated contextual information compiled during the Fort Bliss CRCP report (Miller 1996), Miller and Kenmotsu (2004; see also Miller 2005c) review several significant changes in landscape use, technology, and architectural form during the Late Archaic period and the Late Formative period. An example of landscape changes based on radiocarbon date frequencies is presented in Figure 11.3 (see Miller and Kenmotsu 2004 for further discussion). The settlement pattern changes in this figure are noteworthy on their own, but attain even greater significance when compared against other data. These changes in landscape use are contemporaneous with dated changes in architectural form and site structure, changing proportions of wild and domesticated plant foods, the presence of storage facilities, and technological changes in the use of formal and intensive roasting facilities. Of further significance is that most of the major intervals of change at ca. A.D. 650, 1000, 1150, and 1275/1300 correlate with periods of widespread environmental, demographic, and culture change across the Southwest (Miller 2005c).

RESEARCH ISSUES

Research Issue 11-1

Potentials and pitfalls of predictive modeling

The spatial and distributional analysis of TRU survey data can offer several advantages for cultural resources management. One of the more useful attributes of the TRU method is the flexibility it provides for examining material culture distributions at different scales. The basic unit of observation and data collection is the 15-m by 15-m TRU cell. These units can be examined as individual entities or can be grouped together to form aggregate units, or “sites,” encompassing increasingly larger spatial scales.

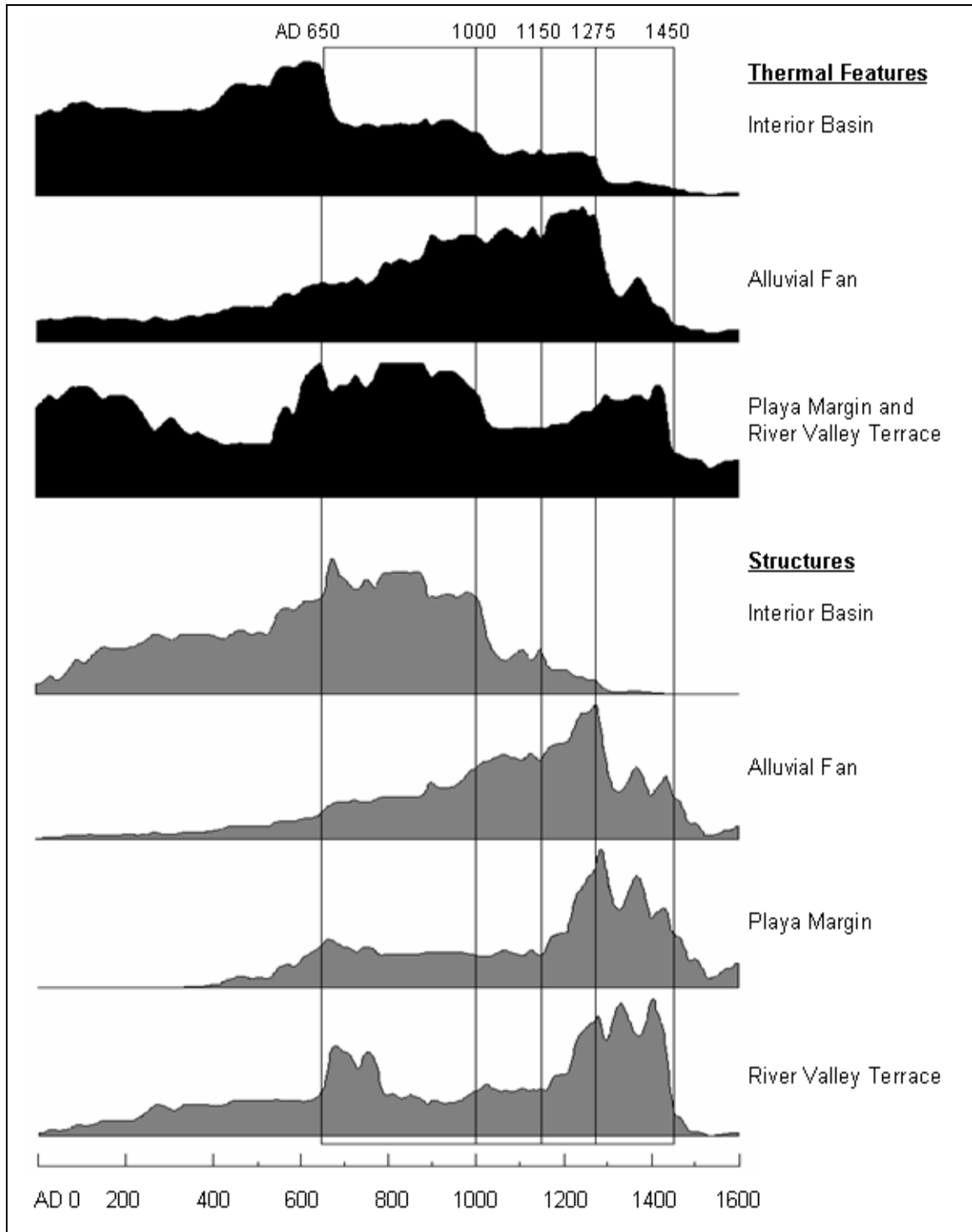


Figure 11.3. Summed radiocarbon probability histograms illustrating changing land use patterns in the Jornada Mogollon region. (from Miller 2005c; Miller and Kenmotsu 2004).

In addition, the Fort Bliss Environmental Division and its archaeological consultants may be able to identify discrete, patterned, and repetitious associations of material culture (i.e., “sites”) at various measurement scales and correlate these patterns with environmental, topographic, geomorphic, and other natural parameters. Thus, it may be possible to identify and recover important patterns and spatial relationships at relatively discrete and empirically justified measurement increments on the landscape. This may allow us to reduce the degree of ambiguity in determining site boundaries, cell criteria, and other factors. These are potentially productive means of refining predictive models, determining site boundary criteria on a firmer empirical and behavioral basis, and identifying archaeologically significant landscapes for possible preservation.

One goal of this integrated program is to develop a series of robust and consistent parameters for predicting the general probabilities of cultural materials, and various densities or clustering levels of cultural materials, being present under a specific set of environmental and geomorphic parameters. In other words, the intent is to develop predictive models that will allow Fort Bliss to better evaluate and predict the potential for significant (NRHP eligible) archaeological sites being present within a various landforms and survey parcels. The TRU method offers the most productive means of achieving these goals.

Much work needs to be done, however, before this goal can be realized. It is strongly cautioned that the use of predictive modeling for estimating or predicting the locations and numbers of specific *site types* in the Jornada Mogollon region is an entirely unrealistic proposition at this time. While archaeologists have obtained a general idea of the locations of some site types and time periods, the present knowledge is limited to a small period of time. Moreover, a firm understanding of the range and variety of site types is still lacking. Given the inability to correctly “predict” what a single site contains, the development of predictive models describing the locations and counts of site typologies is not possible at the present time.

On the other hand, the landscape distributional data obtained from TRU surveys across McGregor Range and several of the maneuver and training areas offer a different means of developing predictive models. As noted in this section, when combined with geomorphic mapping, vegetation maps, and landform categories, GIS analysis of archaeological distributions can provide a different approach to predictive modeling. Based on GIS analysis of these layers, it may be possible to refine our ability to estimate where variable densities of material culture are located, and under what geomorphic conditions such distributions are likely to represent buried, high-integrity deposits or exposed and eroded contexts. In other words, it may be possible to predict, with a measurable and consistent degree of error, areas where archaeological deposits of variable density and integrity are located.

These allow cultural resources managers at Fort Bliss to identify geomorphic contexts, landforms, and proximity values to certain variables (playas, fans, etc.) to develop predictions of which contexts and locations have the potential to have (1) intact, high-density buried deposits; (2) intact low-density deposits; (3) disturbed high density deposits, and (4) disturbed low density deposits. In the latter case, with sufficient ground-truthing, it may be possible in the future for CRM managers at Fort Bliss to determine whether archaeological work is required for a proposed undertaking in an area designated as “low integrity/low density.” This approach is similar to the development and implementation of Potential Archaeological Liability Maps (PALM) such as that developed by James Abbott for the Houston District of the Texas Department of Transportation (Abbott 2001).

The definition of “high density” areas, clustered artifact distributions, and even “sites” may also be refined for both management and research purposes. Miller (2007b) examines the potential of applying density-dependent analysis to the study of spatial clustering and site definition as an

alternative to distance-dependent site definition criteria. Miller contrasts the results of density-dependent and distance-dependent analyses using the group of methods spatial analysis by distance indices (SADIE; after Perry 1995, 1998; Perry et al. 1996, 1999) for the definition of spatial aggregates of material culture (i.e., “sites”). As illustrated in Figure 11.4, this approach results in the formation of different patterns of clustering, or “sites.” Whether or not the SADIE cluster indices effectively and realistically translate into behaviorally meaningful artifact patterning remains to be determined. Nonetheless, the study suggests that non-parametric, density-dependent indices at least provide an alternative way of forming and evaluating behaviorally meaningful aggregate material distributions. Future investigation will focus on comparing the assemblage content and site dimensions based on TRU distance criteria against those derived from parametric and non-parametric SADIE analyses.

In summary, one of the main pursuits of the coming decade should involve the quantitative and qualitative analysis of GIS layers and cultural material distributions in order to develop predictive models. In addition, these studies will significantly enhance our understanding of prehistoric land use and settlement organization.

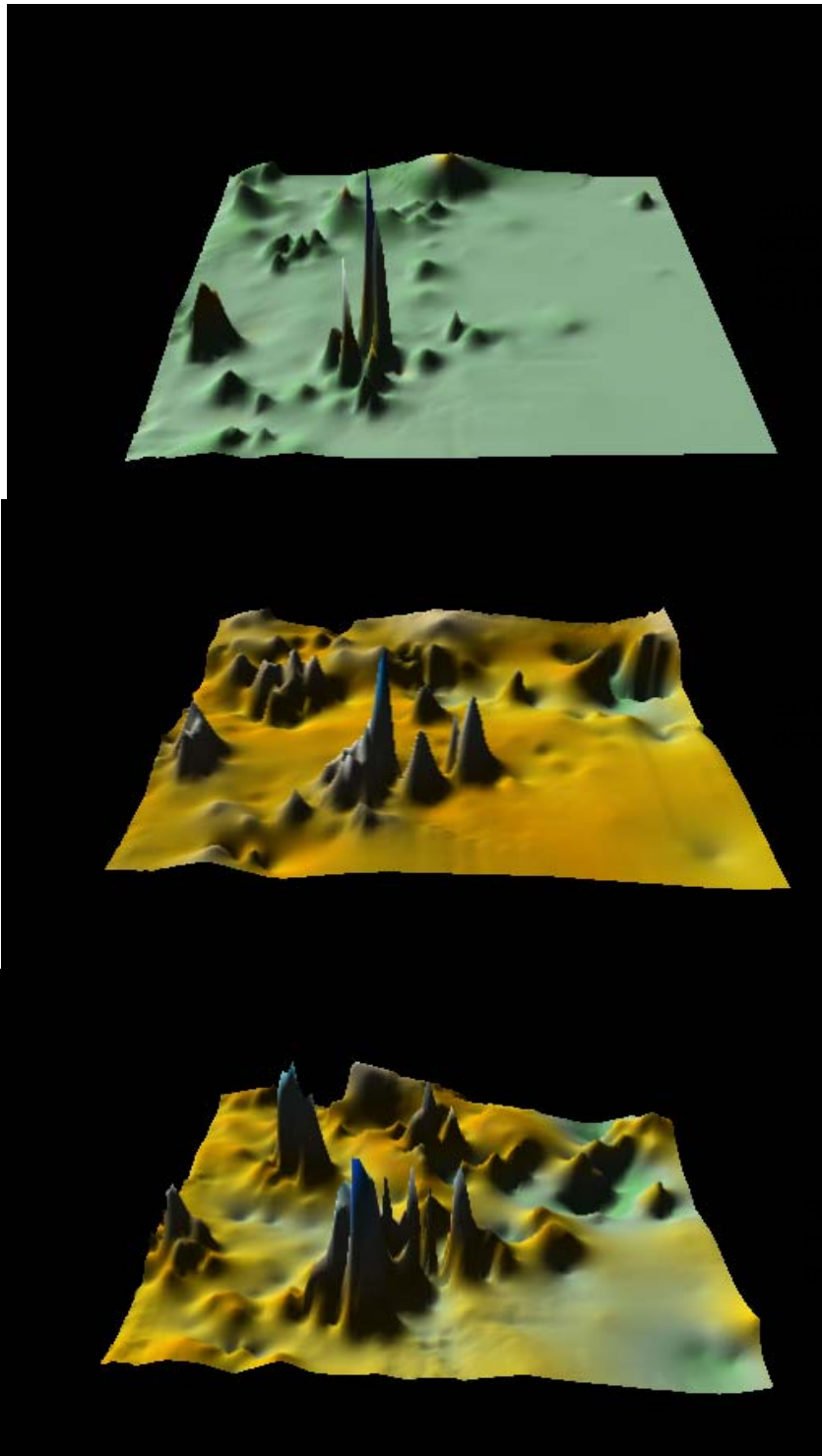
Research Issue 11-2

Bounding landforms and defining scales

To effectively pursue the goals of predictive modeling and landscape settlement analysis, the following data are needed. As noted previously, a variety of geomorphic schemes have been used to classify landforms on Fort Bliss. The most detailed of the earlier schemes is that of Satterwhite and Ehlen (1980) who identify four primary landforms (mountains, alluvial fans, basin areas, and washes) and subdivide these into 13 secondary forms.

More recently, Monger (1993a) and D. Johnson (1997) have developed geomorphic mapping units for the southern maneuver areas and McGregor Range. Additional mapping schemes based on the distribution of vegetation communities, soils, and elevations are available. Several of these schemes have been converted to digital format, geo-referenced, and thus can be incorporated as GIS layers. The following questions involve specific archaeological information within each of these mapping divisions.

- What are the material culture densities in each division of each mapping scheme?
- What patterns of material remains exist among the mapping schemes? Can these be treated as analytical units? What degree of non-random clustering or dispersion can be observed?
- What are the types of sites or cultural event loci and what spatial patterns exist within the mapping scheme?
- Is there a relationship between the presence of surface structures and mapping scheme?
- During what seasons was the mapping scheme occupied or exploited?
- Can post-depositional transforms (e.g., erosion) be identified and can these contexts be controlled for during GIS analysis?



Surface density map showing artifact densities in a 1 km² survey block based on original, unmodified TRU artifact counts

Surface density map of SADIE density-dependent cluster indices

Surface density map of cluster indices using non-parametric rank-cell counts

Figure 11.4. Surface density plots for a 1 square km survey parcel on McGregor Range comparing original TRU artifact densities against density-dependent SADIE cluster distance indices.

Note the more even distribution of density peaks provided by the SADIE density-dependent clustering methods that more accurately reflect artifact distributions. (from Miller 2007b: Figure 6.8)

Research Issue 11-3

Spatial and distributional analysis and evaluation of landscape distributional patterns

Developments in GIS, hand-held computers, GPS, and the integration of these technologies within the TRU survey method offer unprecedented means of recording high-resolution spatial data across landscapes. At the present time, archaeological analysis of these data is in an exploratory and developmental stage. Over the coming decade archaeologists and cultural resource managers will continue to explore the potential of spatial (quantitative) and distributional (qualitative) analysis (including GIS-based routines and methods independent of GIS) to contribute to a broader understanding of prehistoric land use. The potential of agent-based modeling, random walk analysis, quantitative studies of point pattern and grid provenience data, and even traditional pattern recognition based on visual study of TRU survey data, should all be explored in depth.

The issue of prehistoric trails merits a particularly focused research effort. Graves and others (2002: 458) describe another linear arrangement of ceramic artifacts crossing Limited Use Area L between the Jarilla and Organ mountains, and it is likely that more trails will be discovered. Future studies should focus defining these important features - their beginning and end points, distances, and whether they served as communication and exchange corridors, for water transport, or led to specific and important resource procurement areas or agricultural fields.

Perhaps the most daunting issue for this form of analysis is the enormous quantity of database information produced by TRU field recording methods. A typical 1 square km UTM survey parcel will contain 4,444 individual 15-m by 15-m TRU cells. In some cases over 50 percent of the cells will be positive for cultural material and the data file for such a parcel will thus contain over 2,000 records. The PDA recording system includes over 100 data entry fields. Thus, a typical data file for a single 1 square km UTM survey parcel may contain upwards of 200,000 individual data entries. Isolating relevant data fields and preparing such large databases for use by GIS and statistical software programs can involve substantial time expenditure. Methods of streamlining database preparation and data mining should be applied to TRU survey data.

Can the immense quantities of data generated by TRU surveys be manipulated and reduced to manageable proportions? Can data mining procedures be used to effectively search for patterns among multiple data files?

Can one or more of the quantitative and qualitative methods of spatial and distributional analysis be applied effectively to TRU survey data?

Can higher and lower-resolution patterning be detected and interpreted? Miller (2007b) notes that the structure of TRU survey data within 15-m grid cells imposes some scalar restraints on high-resolution studies of 30-45 m or less. However, it is further suggested that broad patterning on the scale of multiple kilometer survey parcels is likely to be seen. The patterning of material culture across geomorphic and topographic landforms is of particular interest for settlement pattern analysis and predictive modeling.

Can additional prehistoric trails be identified? Can the extent of the trails be traced among multiple TRU survey parcels?

Research Issue 11.4

Can Temporal and Functional Trends in Prehistoric Landscape Use be Expanded and Refined?

General trends of land use among basin, alluvial fan, and playa margin/river terrace landforms and associated trends among architectural form and burned rock features have been identified by Mauldin (1994, 1995, 1996; Mauldin et al. 1998) and Miller and Kenmotsu (2004). These

patterns establish a basic framework for understanding the relationship between the exploitation and occupation of major landforms and changes in the subsistence base and technological organization.

Can our knowledge and understanding of such diachronic changes in settlement and land use be further expanded and refined? Our knowledge of prehistoric occupation of Otero Mesa and the mountain foothill and uplands regions remains limited, although this situation has recently improved with the publication of the results of surveys and excavations on Otero Mesa (Graves et al. 1997; Quigg et al. 2002) survey of the southern Sacramento Mountain escarpment (Knight and Miller 2003), the survey of rock shelters in the Hueco Mountains (Alvarez and Leach 1997). Nevertheless, the range of site types and time periods represented by archaeological remains in these areas remain very poorly known, compared to the central basin and alluvial fans of the Tularosa Basin and Hueco Bolson.

Even within the comparatively well-known basin, alluvial fan, and playa-margin zones there is room for much more refined conceptions of settlement and land use. These could include, for example, additional associations among finer-grained landform classifications and various feature and artifact classes. Additionally, the possibility of identifying landform changes on the basis of other attributes beyond radiocarbon-dated features should be explored. For example, analysis of ceramic data (Miller 2004b, 2007c) and obsidian hydration dates (Mauldin 1995, 1996) from the central basin landform show a distinct pattern of logistically organized land use during the Late Formative period.

Research Issue 11-5

Linkages between models and site typologies

Research Issue 11.4 is essentially a corollary of Issues 11-1, 11-2, and 11-3 above. The concern here is with the feasibility of developing site typologies and whether such typologies can be refined and applied with any degree of confidence.

The issue of site types has been addressed throughout this section. At the present time, it is nearly impossible to determine whether an El Paso phase residential component consists of a pueblo room block, a cluster of individual formal rooms, or a combination of both architectural forms. Determining whether hut structures are present among a cluster of Late Archaic or Early Formative period, Mesilla phase artifacts and thermal features is equally difficult in the absence of excavation data, and sometimes even with excavation data from sites in eroded settings. A substantial amount of careful excavation and scrutiny of past and present excavation results will be required before the use of site typologies based on surface inspection or minimal testing will be acceptable.

The consistent identification of material remains of logistically organized landscape use is equally problematic. Many or most traces of logistically organized procurement or processing tasks may be so ephemeral that they simply can't be identified in the archaeological record. One may ask whether an entity such as a "hunting camp" or cacti procurement area can be identified on the basis of the Jornada archaeological record. On the other hand, certain logistical procurement sites may be identified by the nature of the material extracted or procured. Deposits of limonite and hematite are present in several locations in local mountains (Church et al. 1996). Can evidence of working and extraction be seen among the deposits? Can mining tools be identified? Numerous rock-lined pits on alluvial fans are isolated from residential settlements and likely represent logistically organized bulk processing of cacti and other plants. Finally, evidence of logistically organized settlement has been provided through the isolation of broad landscape distributions of specific artifact classes, individual artifact types, and even specific artifact subtypes, such as

dated obsidian artifacts and varieties of El Paso brownware ceramics (Mauldin 1995, 1996; Miller 2007c).

Settlement pattern models continue to be based primarily on residential occupations. Identification of the logistical procurement component of prehistoric settlement will significantly enhance and broaden our understanding of prehistoric land use and economy, resource procurement, and social organization.

Research Issue 11-6

Community analysis

Archaeological spatial analysis is not confined to cultural-ecological and settlement pattern research; on the contrary, the use of spatial studies adopted from geography have often been used to examine larger dimensions of human social organization. Macroregional and microregional analyses of social and community organization across the landscape can be undertaken. We may also be able to better conceive of landscapes – not only in an ecological view, but in social and ritual terms. Integrated analyses of settlement organization and social production across the landscape can be pursued. For example, a study of Johnson's (1997) geomorphic mapping units and differing agricultural and hydrological potentials of the soil types in these units could be integrated with a distributional analysis of material culture. In particular, the role of small El Paso phase settlements with a single pit house or two could be critically evaluated.

The consideration of this research issue generates numerous questions: Can analyses of distributional patterns (TRU data or otherwise) identify material patterning that can be used to interpret communities, social networks, or social boundaries? Can linkages between settlements and settlement areas – the usual scale – be linked to broader land use, including agricultural fields, trails, and resource procurement areas? Can prehistoric trails be traced to specific pueblo settlements? Can trails linking two or more settlements or settlements to important resource areas be identified? Is there any way that prehistoric agricultural fields can be identified? Can geochemical sourcing studies provide insights into prehistoric territorial exploitation ranges and social networks? These and other studies can serve to expand our conception of community formation and dynamics among Jornada social groups and their settlements.

One of the great challenges of the TRU data is exploring for appropriate techniques to unravel the patterns inside. At present there is no cookbook to guide us, and it would be unwise to place too much stock, too quickly, in the patterns that are sure to emerge. Patterns aplenty there probably are, differentiating between epiphenomenal patterns and anthropological meaningful patterns is the trick. The most likely place to start for most will be the available computer routines and techniques that currently exist. Unlike the situation just a mere decade ago, sophisticated software is widely available today and, much of it is free via the internet. A wide range of possible research avenues and tools is available through the internet, but care should be taken before their application. One must be familiar with the nature and limitations of the data. TRU data is mix of data types and the work of Schneider (1994) is recommended place to begin.

Research Issue 11-7

Achieving a broader conceptualization of the prehistoric landscape: Ritual, Place, and Memory

Much of the research in the Jornada Mogollon (as well as the greater Southwest) continues to be focused on the site as the primary analytical unit. Even landscape or non-site archaeology has primarily been concerned with hunter-gatherer mobility and deciphering the resultant overlapping (palimpsest) artifact distributions (e.g., Camilli et al. 1988; Rossignol and Wandsnider 1992). More recently, the method and theoretical perspective of "landscape" archaeology has been broadened to include a more holistic appraisal of prehistoric settlement and land use (Ashmore

and Knapp 1999; Crumley and Marquardt 1990; Marquardt and Crumley 1987). Included in this new approach are considerations of the places and even empty zones that constitute the locations of ritual performance and ceremonial acts, resource procurement, and social interaction among both individual actors and aggregate social groups.

Numerous accounts of historic Southwest puebloan groups mention the presence of ritual and sacred hills, springs, caves, mountains, plant gathering locations, and other locations of spiritual or cultural memory (Ortiz 1969; Parsons 1939). Several caches of small ceramic vessels, fossils, and other ritual items have been recovered from hilltops in the Jornada area (Achim 1984), including the small sand hills just south of Maneuver Area 1 (Hedrick 1997; Moore and Wheat 1951). While many such locations will be difficult or impossible to identify archaeologically, and additional sites will be located outside Fort Bliss, it is nevertheless important to consider these locations as part of the richer cultural heritage and land use of the prehistoric inhabitants of the region. Moreover, a consideration of such sites will lead to a greater degree of attention paid to the discovery and documentation of such sites during surveys of mountain foothill and upland zones during future undertakings at Fort Bliss.

CHAPTER 12. SOCIAL, RITUAL, POLITICAL, AND ECONOMIC ORGANIZATION

Myles R. Miller, Robert J. Hard, Patience E. Patterson, Cynthia L. Tennis,
and Belinda Mollard

The following section is intended to considerably expand and augment the “Cultural Interaction” section of the 1996 *Significance Standards* document. The information base for studies of interaction has increased dramatically since 1996. Several thousand ceramics have been submitted for NAA and the past 20 years of obsidian sourcing have been reviewed and the presence of imported obsidians from northern Chihuahua has been documented. Equally important, the theoretical contexts for investigating social interaction have been expanded. Simply stated, the practice of “cultural interaction,” whether involving exchange, ritual performance, or group movement and migration, between human groups and individuals is demonstrably and inherently a social process. Accordingly, the original Cultural Interaction domain has been modified into this new section encompassing Social, Political, Economic, and Ritual Organization.

It was believed that the original Cultural Interaction domain was defined too narrowly and restrictively. As defined within an essentially cultural-historical and materialist framework, it dealt primarily with exchange relationships between Jornada groups and those in adjacent regions. The scale of reference should be expanded to examine patterns and processes within the Jornada region at a broader geographic scale of reference, as part of understanding relationships between long-term change in adaptive systems and pan-regional social and economic systems. This would allow for issues such as demographic change, territoriality and boundary maintenance, reciprocal exchange relationships, and other topics to be readily incorporated into current research. Conversely, smaller scales of reference should also be considered. Under the rubric of “Cultural Interaction” only inter-regional patterns and processes were considered (i.e., Mimbres and Jornada, Jornada and Casas Grandes). Examination of intra-regional relationships between hunter-gatherer and/or agricultural groups could also prove to be a highly productive avenue of inquiry. For example, issues of land tenure are of particular interest for agricultural periods. Given the high degree of residential and logistical mobility, and highly variable and uncertain resource base, it is clear the specific social arrangements must have been present to facilitate the widespread movement of populations during the agricultural periods in the region (Late Doña Ana and El Paso phases).

The following discussions cover several topics, including political organization and leadership strategies, land tenure and territoriality, social boundary maintenance, feasting, and ritual. It should be noted that these topics are almost always interrelated and it is difficult to compartmentalize them. The act of communal feasting, for example, may involve ritualized behaviors, actions, and agents, may serve to solidify or signal leadership status, can be used to define social boundaries, can help to form and maintain social alliances, and may even have a notable affect on economic organization and subsistence practice. In particular, the economic domain is highly integrated within the social, political, and ritual spheres, and for purposes of modeling and interpretation it may prove more efficient to incorporate this subsection into the other three.

SOCIO-POLITICAL ORGANIZATION AND LEADERSHIP STRATEGIES

The evolution of social and political organization among prehistoric Southwestern societies has been one of the more contentious areas of debate among archaeologists during the past 20 years. The debate reached its apex during the 1980s with sharp divisions between those who detected hierarchical and stratified socio-political structures among Southwest pueblo groups (Cordell and Plog 1979; Upham 1982; see Upham et al. 1989 for a compendium of articles representing proponents of this position) versus those who viewed precontact Southwestern social formations as predominantly egalitarian (Graves et al. 1982; Reid 1985; Reid and Whittlesey 1990; Vivian 1989).

As noted by Feinman and others (2000), part of the debate was laid to rest with the publication of Gregory Johnson's (1989) critique of Southwestern socio-political structure. Asked to serve as a discussant for a 1983 School of American Research seminar, Johnson provided a review of Southwestern social organization and complexity from the vantage point of his experience with the highly complex urban, stratified, and sedentary societies of southern Iran. Johnson's fundamental conclusion was that the marginal environments of the Southwest and correspondingly limited potential for agricultural surpluses imposed severe economic limitations that could not have supported the development of stratified, hierarchical organizational structures.

Since the acrimonious period of the 1980s, the discussions over Southwestern political organization have evolved into a more nuanced and constructive stage. The egalitarian/hierarchical dichotomy has been replaced by less polarized (and polarizing) conceptions of social organization. As noted by Mills (2000) in her introduction to the volume *Alternative Leadership Strategies in the Prehispanic Southwest*, these include a greater appreciation of ethnographic record of pueblo societies. More recent appraisals of the ethnographic and ethnohistoric record have changed the traditional view of post-contact pueblo societies as egalitarian (Brandt 1994; Levy 1992; Whiteley 1988). These studies have helped to challenge the view, based analogies derived from earlier interpretations of pueblo societies as egalitarian, that precontact societies were also organized in such a manner. Second, it is now recognized that political organization, kinship, economy, and ritual within a society may be organized in different ways: some may be controlled via hierarchical authority while others may be managed through various forms of modular egalitarian structures (Brandt 1994; McGuire and Saitta 1996; Plog 1995). Further, it is recognized that there are different sources of power that can be marshaled by leaders to obtain and maintain their status and authority. Power may be derived through control of sectors of the political economy such as the subsistence base, craft production, or land tenure. Equally important, power may be derived from control of aspects of ritual and ideological performance. This too is overly simplistic, as these different components may interact and crosscut each other, such as the ritual control of a sector of the political economy via ritualized procedures of communal feasting.

Scalar Stress and the Formation of Hierarchies

Gregory Johnson (1978, 1982, and 1989) produced a series of influential articles that examined the information capacity of human groups and corresponding development of organizational structures. Johnson proposed theories of "scalar stress" and hierarchical organization based on empirical studies of social groups that indicated when a number of "information sources" reached or exceeded an average number of six entities, the capacity to organize and process information deteriorated. The "information sources" referred to by Johnson could include any number of organizational units such as individuals, social groups, households, or even territories. Through a detailed argument incorporating studies in social psychology, organizational sociology, ethnology, and archaeology, Johnson demonstrated how the biological constraints on human

information processing capabilities resulted in the creation of structures to help manage such information.

Johnson (1978, 1982) proposed two forms of organizational structures that arise in response to scalar stress: simultaneous and sequential hierarchies. A simultaneous hierarchy is the traditional pyramidal structure where social integration and control are consistently maintained throughout the structure. Johnson (1982: 396) proposed that development of sequential hierarchies was the “egalitarian alternative” to simultaneous hierarchies. In this organizational mode, the decision-making process operates at multiple, sequential levels. For example, members of several household groups may come together to mediate an issue. A representative of that household cluster then joins with representatives of other household clusters to reach a higher-level consensus on the issue. This pattern may be repeated at multiple levels and can effectively integrate large groups and diverse groups.

Several aspects of this model proved attractive to Southwestern archaeologists. The consensus decision-making process served to suppress the development of inequality, thus explaining the absence of formal, hierarchical decision-making polities. Sequential hierarchies were seen as rather fluid and impermanent, often serving to organize groups for intermittent periods of time. Leadership positions were also seen as shared and provisional. The modular nature of the process was also of interest since it provided a means of explaining the aggregation and dispersion of populations so prevalent in the Southwest archaeological record. Of perhaps even greater significance to Southwestern archaeologists familiar with studies of historic pueblo societies, Johnson, referring to studies of nomadic Amazonia groups described by Gross (1979), demonstrated how sequential hierarchies were often maintained and coordinated through ritual structures and performance, particularly in the process of integrating modular segments of the hierarchy.

Johnson’s theory of scalar stress and the formation of organizational hierarchies proved enormously influential, not only among archaeologists interested in the development of social and political organization and inequality, but was also one of the success cases of archaeological theory reaching a broader audience and influencing such varied fields of study as business management, political science, computer science, and other fields of social theory. In archaeological practice, several important interpretations of pueblo social organization were based on Johnson’s conceptions of sequential hierarchies (e.g., Kintigh 1994; Spielmann 1994).

Agency

Recent theorizing on prehistoric social organization has incorporated the concept of human agency and an acknowledgment that internal social dynamics may be a foundational cause of culture change (Dobres and Robb 2000). Agency theory demonstrates that human agents and actions are a fundamental source of cultural change. This perspective has led to a growing recognition that ideology, as expressed through ritual and symbolic acts, serves to legitimize and sustain power structures and social relations. A focus on human agency and dialectical relationships between social groups – the “lived experience of past peoples” (McGuire and Saitta 1996: 198) - can provide a more nuanced understanding of social and political organization in prehistoric societies.

Dual Processual Theory, Communalism, and Shamanic Leadership

Johnson’s work laid the foundation for more recent studies of political dynamics and leadership strategies. These refinements continue to grapple with the apparent contradictions in leadership strategies that Johnson’s work set forth – that different forms of consensual and hierarchical social relations appear to co-exist among Southwestern pueblo societies.

An alternative approach to understanding different forms of political leadership proposed by Blanton and colleagues (1996) has been termed dual-processual theory. Dual processual theory proposes two modes of political organization and leadership: network and corporate. Table 12.1 outlines the typical tendencies associated with each mode. Conceptions of human agency underlie the expression of dual-processual theory (Blanton et al. 1996; Feinman et al. 2000), in that the formation and perpetuation of one or another political organization depends on different sources of social power (detailed background discussions of the theories and influences underlying dual processual theory are provided in Feinman 2000; Feinman et al. 2000; and Mills 2000).

Table 12.1.
Tendencies of Network and Corporate Modes of Political Organization
(after Feinman 2000: 214, Table 12.2; Feinman and others 2000: 453, Table 1)

Network	Corporate
Concentrated wealth	More even wealth distribution
Individual power	Shared power arrangements
Ostentatious consumption	More balanced accumulation
Prestige goods	Control of knowledge, cognatic codes
Patron/Client factions	Corporate labor systems
Attached specializations	Emphasis on food production
Wealth finance	Staple finance
Princely burials	Monumental ritual spaces
Local kinship system	Segmental organization
Power inherited through personal glorification	Power embedded in group affiliation
Outstanding elite adornment	Symbols of office
Personal glorification	Broad concerns with fertility and rain

Many of these tendencies are more commonly found among complex, state-level societies; yet several also apply to societies in the Southwest, including the social groups inhabiting Jornada Mogollon pit house and pueblo settlements. Of particular interest is the prevalence of the corporate mode of political organization throughout prehistoric and historic societies in the Southwest.

Another alternative means of viewing Southwestern social formations proposed by McGuire and Saitta (1996) has been termed communalism. McGuire and Saitta (1996: 201) define a communal society as one that “exists when constituent social groups hold the means of production – the land, game, plants, fish, tools, technical knowledge, and other resources needed to sustain life = in common, and where surplus appropriation is *collective* in form [emphasis in original].” McGuire and Saitta also view social organization and leadership among historic Southwestern pueblo societies as having both hierarchical and consensual, egalitarian structures that were highly fluid and contingent upon historical circumstances.

Each of the alternative modes of political and social organization – corporate, communal, and sequential hierarchies – take into account the fact that these social relations formed through the “manipulation of scarcity (McGuire and Saitta 1996: 209).” For example, Feinman (2000: 224) suggests that the prevalence of corporate leadership strategies through the precontact Southwest “... may in part be related to the frequency of migration and long-term propensity toward

demographic fluidity. Corporate formations may have been more successful at the sociopolitical integration of diverse demographic groups that tended to share the sometimes economically marginal Southwestern landscape.” Given the risk and uncertainty involved with playa and alluvial fan runoff agriculture reviewed in Chapters 2 and 7 of this document, the Jornada would represent one of the most marginal environments in the Southwest. The presence of fluid social formations and political structures should therefore be anticipated among Jornada agricultural settlements (Miller 2004b).

Another alternative form of political leadership has recently been proposed that involves the role of shamans as both religious practitioners and in leadership roles (VanPool 2003; VanPool and VanPool 2007; Whiteley 2000, 2001). Shamans as religious practitioners are a nearly universal aspect of hunter-gatherer societies. As societies increased in complexity, their control of esoteric knowledge, ritual, and exotic goods positioned them in increasingly powerful roles as political and religious leaders. It has been proposed that the primary leadership roles at Paquimé and outlying settlements were filled by shamans (VanPool and VanPool 2007).

Jornada Research

Most of the debate and theorizing over Southwestern political and leadership organization has focused on the large, complex pueblo settlements of the Mogollon Rim, Colorado Plateau, and northern Rio Grande. These pueblos offer multiple lines of evidence for the study of social organization, including large burial samples, inventories of decorated ceramics, complex architectural blocks, and elaborate ritual or socially integrative facilities such as kivas and plazas.

In contrast, one might question whether the Jornada Mogollon region can offer any particular insight into the debate of Southwestern social and political organization, given that sites in region typically involve small settlements and resident social groups, few or no burials, and small ceramic inventories having limited stylistic variation. Jornada groups have also been perceived as “simple” societies with the social and organizational complexity equivalent to that defined for bands and, in later times, tribes (using the evolutionary structures of Fried [1967] and Service [1975]). Thus, under the definitions of social complexity defined by these terms, it would be inferred that political structures did not exist or simply would have been egalitarian in nature. Moreover, such organization would have been of such limited magnitude that no corresponding expression would exist in the local archaeological record.

The views expressed above run counter to Johnson’s demonstration that sequential hierarchies can form even in simple, “egalitarian” social groups. Johnson (1982: 406) suggests that ritual is “scale dependent” and thus may be more elaborate and pervasive among larger social aggregates. In turn, the process of ritual cohesion and integration among small social units may be relatively muted (and thus we may anticipate that it will not manifest or be obtrusive in the archaeological record of simple societies). However, Johnson also notes that the apparent absence of evidence of ritual does not by any means imply evidence of its absence. Taking this argument further, Paynter (1989) and Flanagan (1989) provide compelling arguments that egalitarian social arrangements are exceptionally difficult to maintain and thus any apparently “simple” society will be much more complex than supposed.

Moreover, Miller (2004a) suggests that, in fact, many Jornada residential settlements offer a highly productive context for the analysis of socio-political organization, and particularly those involving the incipient development of corporate leadership strategies. Miller refers to comments by Wills and Crown (2004: 164) that large aggregated settlements may not be particularly suitable places to search for evidence of communal feasting because such settlements often experienced continual cleaning, remodeling, and changing functions of rooms and space. In contrast, special ceremonial places with fewer disturbances and transformations may be more likely in dispersed and more mobile settlement systems. Shifting this argument from evidence of

feasting to evidence of leadership strategies, it is suggested that the less intensive and shorter-duration habitation of Jornada settlements provides less disturbed contexts for identifying architectural correlates of social organization. The communal and other socially integrative facilities at Jornada settlements were not subjected to the degree of remodeling, dismantling, superimposed construction, and changing functions typical of more complex and longer-lived pueblos. Miller proposes that the study of architectural and settlement layout at Jornada residential sites offers particularly rewarding contexts for detecting incipient patterns of social aggregation and political organization and their accompanying architectural expressions.

Unfortunately, issues of social organization and leadership strategies have not been widely addressed in Jornada research. This is intended not as a critique, but rather as an observation that few complex residential sites have been excavated in the region and that much of the research on leadership strategies and political organization is relatively recent. However, it does seem that the Jornada region was for the most part bypassed by the debates of the past twenty years. Despite this apparent neglect, a few interpretations of social organization have been offered. For example, O’Laughlin (1980) suggested that the arrangements of parallel, linear room blocks typical of El Paso phase pueblos may have been inhabited by corporate descent groups. Whalen (1994a: 143) used Johnson’s conception of scalar stress to interpret a communal structure at Turquoise Ridge as an architectural expression of the need for group coordination. By far the most comprehensive discussion of social and political organization has been provided by Railey and Holmes (2002) who examine several aspects of Formative period social organization in terms of the dual processual theory of Feinman and others (2000) and the communalism of McGuire and Saitta (1996).

Miller (2004a, 2005b) examined the relationships between architectural form, communal rooms, and social organization at El Paso phase pueblos. Communal rooms are absent among modular room blocks having four or fewer rooms but are a common feature of room blocks averaging six to seven rooms – a pattern it will be recalled that matches the threshold number of communication units at which sequential hierarchies tend to form (G. Johnson 1982). With the construction of additional rooms and increased population, new communal rooms tend to be constructed. These rooms have larger floor areas and often contain two floor hearths positioned along the north-south axis. The positioning of the hearths and subfloor pits (often containing the majority of “wealth”) are evidence that the communal rooms are architectural expressions of sequential hierarchies.

LANDSCAPES, TERRITORIALITY, LAND TENURE, AND BOUNDARY MAINTENANCE

One of the more uncontested views of prehistoric Jornada settlement organization is that populations were highly mobile throughout almost the entire prehistoric and early historic sequence. Several issues come into play when considering prehistoric social organization at broader landscape perspectives and scales. First, the interplay between mobility ranges and territoriality, as well as agricultural land use and historical patterns of land tenure, need to be taken into account (Adler 1994, 1996b; Hitchcock and Bartram 1998; Kim 2003; Varien 1999).

Boundary Maintenance

Boundary maintenance refers to the influential social theories and mode of analysis developed by Fredrik Barth (1969), although the actual term “boundary maintenance” was applied by later social theorists. Barth essentially views ethnicity as the “social organization of cultural differences” in that ethnic groups are often formed and maintained as a result of interaction with others. That is, the process of forming and maintaining social boundaries serves to confirm the integrity and uniqueness of one’s ethnic group by marking and signaling cultural differences with other groups. Rather than attempting to understand ethnicity and identify it by focusing on

interior social relationships or aspects of material culture within groups, Barth suggested how the boundaries and frontiers between social groups serve to establish and maintain a sense of social [ethnic] identity. Therefore, this boundary and how it is maintained, rather than the cultural traits it encloses, becomes the focal point of inquiry in the study of ethnic groups.

The social boundary serves an important function in that it structures and channels behavior and social relations. Having an identity as a member of a social or ethnic group includes a common and shared means of communication and interaction. In contrast, the identification of outside individuals or groups as strangers or “others” implies a lesser capacity for shared knowledge and understanding. These social boundaries arise and persist despite a continual flow of people, information, and material culture across them. Despite this permeability, there remains a structured flow of interaction and information that sustains awareness of cultural difference and group identity. Therefore, a second point of Barth’s study is that, while cultural attributes may change, the ethnic group will persist if its members continue to perceive of themselves as different from others. This perspective on culture change is quite interesting for it sometimes may explain the common flux and fluidity of archaeological material traits across archaeological “cultures.”

While the boundaries theorized and studied by Barth and his followers are social in nature, they quite often have territorial and spatial counterparts. This territorial aspect often may be visible in the patterning of material culture and thus may be investigated through archaeological study. Given that much of the study of boundary maintenance involves shared cultural and behavioral norms and membership standards, as well as methods of signaling or other forms of symbolically conveying such practices, it is not surprising that for archaeologists the most common and effective means of viewing the processes of boundary maintenance and identity is through the analyses of stylistic expression and variation in material culture. Several advances have been made in the identification of boundary maintenance in prehistory by using middle range constructs derived from ethnographic and ethnoarchaeological studies (Dietler and Herbich 1998; Hodder 1979; Lightfoot and Martinez 1995; Sinopoli 1991; Smith 1999; Stark 1998). While stylistic studies have been predominant in such research, the results of compositional analysis of ceramic materials have also been applied successfully to studies of boundary maintenance and identity formation (Cameron 1998; Duff 2002; Stark et al. 2000).

Indeed, a significant but heretofore underappreciated component of spatial and geographic patterning in the archaeological record may be best explained through reference to boundary maintenance. For the Jornada region and greater Southwest, social relationships between mobile hunter-gatherer groups and increasingly sedentary agriculturalists have long been a topic of interest. As noted by Lightfoot and Martinez (1995), ethnic identification and boundary maintenance will intensify in situations where people are competing for space and resources. The expansion of agricultural groups into regions traditionally exploited by hunter-gatherer groups (or vice-versa) would result in such competition and tension over land tenure. Increased territorial competition and intrusion among hunter-gatherer groups would have also placed pressures on social boundaries (Kelly 1995; Kim 2003). During such periods of subsistence, social, and economic change, ethnic and corresponding territorial boundaries would have been under increasing pressure and it is proposed that more conspicuous forms of boundary maintenance would have emerged during such times (Lightfoot and Martinez 1995).

Jornada Studies

Processes of boundary maintenance have recently been explored in a small number of studies using Jornada material culture. Although part of a larger scale investigation of the southern Southwest, McBrinn (2005) uses cordage and projectile point data from the Jornada region to

examine the relationships between stylistic variation and different forms of social relations at different scales across the Southwest.

Miller (2005a) proposes that processes of social boundary maintenance provide the most parsimonious means of explaining the technological, contextual, and distributional patterns of Mimbres whiteware ceramics in the Jornada region. Miller finds little evidence that Mimbres whiteware ceramics functioned as status or power objects in prestige goods or peer-polity exchange systems, as well as little indication of alliance formation as would be indicated by the predominance of single chemical composition groups at individual sites. Instead, he suggests that the distributional and compositional data indicates a more fluid process of exchange and social interaction during the continual cycling of various Jornada groups in contact with Mimbres populations along the Rio Grande river valley. These exchanges served to create and perpetuate social relationships between sedentary Mimbres settlements encroaching further towards the east and the mobile Jornada populations who were finding access resource patches to be increasingly restricted. This concept of territorial marking via exchange is compelling because under conditions of emergent boundary tensions and increasing complexity of social relationships, the exchange of various distinctive items – such as Mimbres Black-on-white and El Paso brownware vessels – may have allowed individuals and social groups to profess and display membership and to symbolically convey their presence within a region.

Conflict and Warfare

The ultimate expression of boundary maintenance - or perhaps also stated as an expression of the *failure* of boundary maintenance - is conflict and warfare (LeBlanc 1999, 2000). Social conflict and warfare has been a continual aspect of human prehistory and history (Keeley 1996), and it is likely that Jornada groups were either the victims or perpetrators of social conflict at one time or another. The potential for conflict may have been greatest during the latter periods of the local sequence, as reflecting the larger conflicts throughout many regions of the Southwest during the Late Prehistoric (LeBlanc 2000).

Clear evidence of conflict is most consistently detected among human remains, including mass burials, the presence of human remains in burned structures, and evidence of physical trauma. Less ambiguous evidence may include the intentional razing of house structures, presence of weapons, minor physical trauma, careless treatment of the dead, and other factors (Table 12.2).

Table 12.2.
Indicators of Warfare in the Prehistoric Southwest
(adapted from Kuckelman 2002: 234)

Population aggregations
Use of defensible locations
Defensive architecture and site configurations
Development of unoccupied areas separating clusters of settlements
Burned structures
Postmortem neglect of human remains
Weapons
Evidence of scalping or other forms of trophy taking
Artifact representations of warfare
Oral traditions of warfare
Physical evidence of violent death
Anthropophagy (cannibalism)

The presence of such indicators of social conflict in the Jornada region is vague and equivocal. A few instances of burned pit houses and pueblo rooms have been encountered but they are exceptionally rare when considered in light of the several hundred structures excavated during the past 50 years. Room 17 at Hot Well Pueblo contained the remains of burned roof and superstructure elements and several reconstructable El Paso Polychrome vessels were on the floor (Lowry 2005). Embree Pueblo in the Rio Grande Valley north of Las Cruces, New Mexico presents one of the strongest cases for large scale burning (Magers 1973; Fort Bliss CRCP field notes). Based on extensive test pits placed across the site, almost all contexts appear to have been burned or contain scattered burned structural elements and corncobs. In addition, two rooms contained extensive de facto floor and subfloor assemblages of burned ceramics, stored foodstuffs, and tools (Magers 1973; O'Laughlin 1985), indicating catastrophic burning of the pueblo. Moore (1947) describes similar findings at Twelve Room House where several floors were covered by deposits of charred roofing material. Several rooms at Madera Quemada Pueblo were burned.

It remains conjectural whether one or more of these cases reflect accidental burning, intentional burning during ritual abandonment, or the intentional destruction of pueblo settlements by marauding groups. Seymour (2002) suggests that the burning of pueblo rooms combined with the presence of Fresno-style projectile points indicate that El Paso phase pueblo inhabitants throughout the region were displaced by raiding nomadic groups. However, it should be noted that the basis for this argument rests on questionable contexts for radiocarbon dates at site LA 91220 on Fort Bliss.

More recently, intensive excavations at Madera Quemada Pueblo on Fort Bliss suggest that rooms may have been ritually burned upon abandonment of the pueblo (Miller and Graves 2006). Several advances in understanding the effects of fire on habitation structures have been made recently (see Lally 2005). Based on experiences at Madera Quemada Pueblo, the process of parsing out the evidence for accidental, ritual, or intentional burning requires very careful excavation and close attention to detail.

Tim Church and Trevor Kludt (personal communication 2007) have described evidence for possible conflict at an unusual site on northern McGregor Range that has an uncharacteristically high number of broken grinding tools and shattered ceramic vessels. At the present time, information is based solely on surface survey and thus details are sketchy. Kludt suggests that these sites represent intentional destruction of subsistence technology. The geographic aspect of these sites is also interesting because these areas are in closest proximity to the Sacramento-Capitan uplands. Demographic pressures between the upland and lowland Jornada regions would be expected to be manifested in this boundary region. Moreover, incontrovertible evidence of warfare has recently been identified at Bloom Mound at the eastern limits of the Sacramento region (Speth 2004a).

One of the more reliable means of identifying social conflict - burial data - also provides ambiguous insights into the existence of warfare in the Jornada. Virtually no trauma or wounds attributable to weaponry or warfare are evident among the nearly 120 El Paso phase pueblo and pit house burials, and no evidence of burned or carelessly buried bodies have been found within rooms. However, two burials at the Late Doña Ana phase, Jaca Site were missing hands (Jones-Bartholomew et al. 2002), although whether this indicates some form of social conflict or a form of ritual during interment remains unresolved.

At a larger scale of reference beyond the feature and site, social conflicts and warfare may be reflected in settlement patterns. LeBlanc (2000) notes the presence of clusters of large pueblos throughout the Late Prehistoric period of the Southwest, suggesting the formation of alliances for defense and protection (see also Spielmann 1994). From the earliest regional surveys, it has been

known that Jornada pueblo settlements are clustered around playa landforms (Whalen 1977, 1978). However, the preponderance of current evidence on El Paso phase settlement does not support the interpretation that such clustered settlements represent defensive postures and alliances. It is doubtful that all pueblos comprising such a settlement cluster are contemporaneous and there is strong evidence of short-term and episodic occupations at many of these pueblos.

Feasting and Commensal Political Economies

One of the more rapidly expanding dimensions of archaeological inquiry of the past decade involves the search for evidence of feasting and analysis of the social functions performed by feasting among societies of varying complexity (Blinman 1989; Crown 2000; Graves and Spielmann 2000; Potter 2000). Feasting is not a new concept - the ethnographic literature is replete with descriptions of competitive feasting ranging from the famous potlatch celebrations of the Northwest Coast of North America to the “Big Man” feasts of Papua, New Guinea. As noted by Wills and Crown (2004: 153) “Feasting provides the central analytical focus for archaeological approaches to commensal politics” or, in other words, the study of feasting provides an effective means of operationalizing the archaeological study of political and social organization. Table 12.3 lists several archaeological indicators of feasting.

Table 12.3.
Archaeological Indicators of Feasting
(adapted from Hayden 2001: 40-41, Table 2.1 and Wills and Crown 2004: 155, Table 9.1)

Rare or especially labor-intensive foods
Special recreational food and drink such as alcohol or hallucinogens
Unusually large quantities of foods
Unused and wasted portions of food
Unusual types of food preparation tools
Unusually large or large numbers of food preparation tools
Unusually large size, large numbers, or quality of food-serving utensils (primarily ceramic vessels)
Specialized food preparation facilities
Unusual size, number, or location of food preparation facilities
Special structures and ritual architecture or spaces associated with feasting events
Unusual food disposal patterns (e.g., dense concentrations of animal bone)
Imagery of feasts

While it may be a relatively forthright process to observe and document these indicators in the ethnographic and ethnohistorical record, isolating evidence of feasting in the archaeological record has proven a more difficult proposition. First of all, problems of equifinality must be considered, in that many of the phenomena listed in Table 12.3 (see Table 12.3) could have been produced by several other behavioral or site formation processes other than feasting. Secondly, many of the criteria listed in the table are more apt to be recovered or detected among more complex societies than the typical horticultural and hunter-gatherer groups of the Jornada region.

Dietler and Hayden’s (2001) compilation unfortunately does not include archaeological examples from the American Southwest and for such information it is best to refer to a compilation of recent articles from the 2002 Southwest Symposium (Mills 2004). Potter (2000) and Crown (2000) provide additional useful overviews using case studies from the Southwest. Archaeological visibility of feasting tends to be limited in the Southwest and detection of feasting events and behavior is difficult for several reasons (Potter 2000; Potter and Ortman 2004).

Nevertheless, evidence of feasting may be examined and modeled with carefully constructed models from other areas. It may require more than one linking argument or multiple lines of

evidence. One such study is provided by Lindauer's (2000) analysis of roasting facilities at the Schoolhouse Mound Site in the Roosevelt basin of southern Arizona. Otherwise, much of the evidence for feasting in the Southwest and other regions of North America has been identified through analyses of ceramics and faunal remains. For example, based on the immense quantities of deer bone and broken ceramics recovered from household middens, it has been suggested that large-scale feasts involving social groups from multiple communities were conducted at Cahokia. Based on MNI calculations from recovered deer bone, some estimates place the number of deer consumed during major feasting events between 300-3,000 deer (Pauketat 2004).

Various interpretations of the role of feasting in social contexts and the practice of social reproduction have been proposed. For example, in Southeast Asia feasting generally functions in the production and maintenance of status (Junker 2004). In contrast, interpretations of feasting in the Southwest and other less complex societies focus on the role of communal feasts in establishing and reinforcing social ties. Of course, it is evident that the framing of these arguments has larger implications for interpretations of egalitarian and hierarchical political formations.

Jornada Studies

Despite the problems of identification and equifinality, there are nevertheless several potential avenues of inquiry for the Jornada region. As with other research in the Southwest, these are primarily limited to subsistence remains, roasting facilities, and ceramic vessels. For example, mass quantities of rabbit bone have been observed in numerous studies of Mesilla and Early Doña phase, midden deposits (Bartlema 2003; Duncan et al. 2002; Hanson 1990; Miller 1989; Presley and Shaffer 2001; Russell and Hard 1987; Shaffer 1999). The fundamental problem of interpretation lies with determining whether the quantities of bone in these middens resulted from the discards of communal feasts or reflect broad-scale resource intensification and changing diet breadth during periods of resource stress, demographic changes, or other factors. In one sense, it could be suggested that communal feasting is a process that combines both social integration and economic or subsistence intensification, and therefore the argument of whether feasting differs from intensification is spurious in the first place. While this helps to envision feasting and subsistence intensification as a coterminous process, it does not resolve whether subsistence intensification took place under other economic or social contexts aside from the performance of feasting. Such issues are especially critical when considering the evidence that Mesilla and Doña Ana phase settlements with such extensive deposits of rabbit bone refuse may have been occupied by relatively small social groups (Miller and Burt 2007; Miller 2003).

Developing analytical methods and procedures to examine the structure and composition of refuse deposits would offer a point of departure for addressing these issues. For example, a careful and detailed excavation of midden deposits could reveal whether bone was deposited in high density, discretely bounded areas suggestive of individual mass disposal episodes as would be expected from the deposition of feasting debris. Or, in contrast, bone accumulation in midden deposits could represent more uniform and continual deposition as would result from continual, long-term discard of food remains. The remains of foods recovered from discrete trash pits common at pueblo and historic sites could be examined to see if high status or unusual food remains were present. For example, peach pits were commonly recovered from Spanish Colonial period refuse pits at a Pueblo Revolt settlement in Ysleta (Miller and O'Leary 1992).

Specialized roasting facilities are often viewed as a locus of large-scale food production (Lindauer 2000; Lowell 1999; Whalen and Minnis 2000; Wills 1996). The use of the facilities appears to be particularly common across the southern Southwest, including the Jornada region. As with the issue of rabbit bone, whether the use of these facilities in the Jornada represented bulk food processing for purposes of feasting distribution or reflect resource intensification

remains ambiguous. Whalen and Minnis (2000) suggest that roasting pits at several small pueblo sites in the Casas Grandes region were used for large-scale food preparation for feasts or other socially and ritually distributive functions. However, it should be noted that the typical roasting facilities investigated by Whalen and Minnis (2000: 177) are several meters in diameter and thus much larger than earth ovens typically encountered at Jornada settlements (see also the immense cobble-lined roasting pits at Paquimé illustrated in Di Peso and others (1974). In contrast, the extensive Hohokam agave fields and associated roasting facilities have more commonly been viewed in terms of resource intensification in response to settlement and demographic factors (Van Buren et al. 1992; see also Miller 2005d for the Jornada), although some more recent work does reference the potential use of such features during the production of feasts (Lindauer 2000).

Finally, the functional role of large El Paso Polychrome vessels should be examined. It is proposed that such vessels may have been used to ferment corn or cacti (Jackson et al. 2004; Shafer 2003). Studies that have identified bimodal size distributions among vessel orifice diameters (e.g., Ortman and Bradley 2002) are used to suggest that two categories of vessels were manufactured: smaller vessels for domestic use and large vessels for communal feasting. Such bimodal patterns have not been observed among El Paso brownware rim assemblages, although this may be due to the fact that so few whole vessels are available for study. Moreover, an interesting observation is that the strong bimodal pattern observed by Ortman and Bradley was from what is by far the largest pueblo in the study area; in comparison such bimodal patterns were significantly reduced or absent among other pueblo collections. Perhaps similar bimodal patterns of vessel sizes would be observed among El Paso Polychrome bowls and jars from large, plaza-oriented pueblos such as Alamogordo Site 1, Cottonwood Spring, and Indian Tank pueblos, as opposed to the present collections of sherds from relatively small room blocks.

Political Economy

Investigation of the conditions and consequences of intersocietal contact have been based on the examination of various types of trade, warfare, and other forms of interaction as archaeologists have struggled to assess the role of intersocietal contact in culture change. In the past two decades, Southwestern archaeologists have been searching for conceptual tools that consider the regional context of local cultural change (e.g., Cordell and Gumerman 1989; Gumerman 1994; Mills and Crown 1995). For example, Plog (1995) suggests that interaction develops for an array of demographic, social, economic, religious, and political factors, and that exchange is an expected characteristic of almost all societies at all levels of organizational complexity. Several recent studies (see Hegmon 2000) have shown that interaction and exchange can be quite complex, and note that individuals, rather than sites or regions, interact. The personal nature of such interaction can lead to quite different alliances with one village or family in a region interacting with groups to the east and another family in the same region interacting with groups to the south.

The economic organization of any society is intimately connected to the nature of social, political, and ritual organization of a group. Recognizing this, research focusing on the economic organization can reveal much about the ways in which changes in the economic organization of a group can affect other elements of the society. Trade, with its focus on the peaceful movement of goods between two or more societies, can be empirically verified with an array of compositional analyses summarized below. The identification of nonlocal material confirms the existence of interaction, but determining the nature of the relationship between societies is a far more complex issue (Hegmon 2000; Schortman and Urban 1987:50).

Various models of trade have been proposed; the most relevant to the Jornada Mogollon region involve hunter-gatherers, village agriculturalists, and middle-range or chiefdom-like levels of political organization. Buffering exchange provides economic security against stochastic

environmental change by spreading the risk of subsistence failure across a large region (Spielmann 1991a: 4-5). The exchange of craft and ritual items maintains intersocietal relationships that can be relied upon to gain access to resources in times of scarcity. Buffering models include the exchange of durable items for food in times of need (Spielmann 1991a: 4). However, climatic extremes and resulting environmental productivity frequently affect large regions, resulting in low levels of spatial variation. As a result, all communities in a region may experience shortages, simultaneously reducing the effectiveness of buffering exchange (Dean et al. 1985; Spielmann 1991a:4).

Mauss (1967) emphasized reciprocal gift exchanges that maintain useful alliances at several organizational levels, including intersocietal. These alliances may serve numerous purposes including buffering mechanisms and devices for maintenance of prestige. For example, South African Bushmen participate in reciprocal gift giving among trading partners (Kelly 1995: 188-189). Gifts are not retained but are traded in-turn to other partners. Among the Bushman, most trading partners live within 40 km of each other, but partners may live as far as 200 km apart (Kelly 1995: 188). Ethnographic evidence from several hunter-gatherer groups suggests that in times of resource scarcity families go to live with trading partners (Kelly 1995; Spielmann 1982).

Mutualistic exchange may emerge when resource distributions are heterogeneous. Societies exploiting different ecological settings may emphasize the production of complementary resources for exchange for mutual benefit (Spielmann 1991a: 5). High resource abundance and predictability coupled with low production costs favor the formation of some degree of specialization and mutually beneficial exchange.

World systems theory, first proposed by Wallerstein (1974), offers a set of conceptual tools providing a systemic approach to macroregional interactions while considering multiple causations and variables that contribute to cultural change, all within an economic framework (Schortman and Urban 1987). The interrelationships among cores, semiperipheries, and peripheries are the analytical focus of world systems theory and lead to an understanding of the growth of cores at the expense of peripheries. A number of Southwestern archaeologists have attempted world systems analyses, including consideration of Mesoamerican-Southwestern interactions (e.g., Whitecotton and Pailes 1986; Wilcox 1986). With the growing acceptance among Southwestern archaeologists of the notion that interaction occurs among individuals rather than groups (see Duff 2000; Habicht-Mauche 2002; Zedeno 1994), world systems theory is now considered an umbrella theory while researchers struggle to unmask the complexities of trade and interaction. Nonetheless, regardless of which model is used to study interaction, all are dependent upon documenting the movement of materials across space. Our analytical tools for identifying nonlocal materials and their origins are substantial, but our ability to infer the nature of the interaction in behavioral terms is not well developed.

Rock Art

Rock art provides a rich source of ideographic, symbolic, and ritual meaning. A variety of rock art styles are found within the boundary of Fort Bliss. Sites within the installation contain rock art from the Archaic through Historic periods. Below is a summary of the styles found within Fort Bliss and the time periods they are attributed to. For a detailed overview of rock art styles and the context of the various cultures that produced them, the reader is referred to Polly Schaafsma's *Indian Rock Art of the Southwest* (1980).

Rock Art Styles

Great Basin Abstract: As described by Steward (1929) and later by Heizer and Baumhoff (1962), Great Basin Abstract is a general style with regional variations in the Southwest. It consists of art that is abstract in nature and some researchers (Heizer and Clewlow 1973; Whitley 2000) suggest

the production of this style involved magic and ritual activity (e.g. shamanism). This general style was created by hunter-gatherers from the Archaic through the Protohistoric periods. Local variations of this style are found most often on Fort Bliss, along with historic rock art.

Variations of the Great Basin Abstract style found within the confines of Fort Bliss include the Desert Abstract, Chihuahuan Abstract, and Mogollon Red styles. The Desert Abstract Petroglyph style has its origins with the hunter-gatherers of the Archaic period, with continuity evident between the Archaic and the pre-1000 A.D. Jornada Mogollon time period (Schaafsma 1980: 43). The elements commonly found in this style include, zigzags, wavy lines, parallel lines, rectilinear or curvilinear components, circles (some with dots), grid patterns, rakes or “nets.” A general characteristic of this form is that the petroglyphs are usually found on all sides of the boulder or rock surface. Natural rock features are often incorporated into the design, and superimposition (overlying of elements) is common. The petroglyphs are sometimes irregular and superimposition is often so severe that the individual elements cannot be described. A large number of these petroglyphs are found near natural springs (Schaafsma 1980: 45).

A variation of the Desert Abstract Petroglyph style is termed the Chihuahuan Polychrome Abstract pictograph style. This style represents a form of pictograph designs concentrated in small caves and rock shelters in the Chihuahuan Desert. Elements are usually independent of one another and include short parallel lines, zigzags, chains, nets, rakes, circles, dots and “sunbursts”. The colors used in these pictographs include yellow, red, white, orange, and black. The Jornada Mogollon additions to these two styles include small reptiles, quadrupeds, stick-figure anthropomorphs, and animal tracks. In addition, a style very specific to the El Paso area, including Fort Bliss, is the miniature “life forms” sometimes found with Chihuahuan Polychrome Abstracts (Schaafsma 1980: 55-61). These are small, crude human figures (1-3 inches tall); some are winged. The cultural affiliation of these figures is unknown, although they closely resemble the work of Archaic hunter-gatherers. They are believed to date before 600 A.D. and represent an unknown cultural group (Bilbo and Sutherland 1975). The Mogollon Red style is usually found in the mountains of the Mogollon region west of Fort Bliss, but is occasionally found in the Jornada region (Bilbo 1985). This style consists of small elements painted in red, although white paint is occasionally used. Each design seems to be a separate entity and include simple stick-figure humans, wavy lines, zigzags, and simple circles. Superimposition is rare and the sites that contain this style of pictograph are often small rock shelters or sites that have protected overhangs.

Jornada Style: Probably the most common style found in the El Paso area, the Jornada style flourished after 1050 A.D. Notable elements include masks, faces, feathers, horns or pointed caps. Flying birds, cloud terraces, animals with bent legs (to show movement), and horned serpents are also common. Fish depictions are highly realistic (Schaafsma 1980: 203) and human forms are usually reasonably portrayed. This style includes both petroglyphs and pictographs and superimposition is not common. The Eastern branch of the Jornada Mogollon added elements to include goggle-eyed figures, abstract faces/masks, birds, and animal tracks. The “plumed” serpents, with forward-facing horns or conical caps are distinct to the Jornada style (Schaafsma 1980: 217). There is evidence of ceremonial activity or ritual behavior portrayed in the Jornada rock art that has possible ties to Mesoamerica (including Tlaloc and Quetzalcoatl personages) (Schaafsma 1980; Sutherland 1996). The advent of the Jornada style of rock art coincides with changes in cultural systems, including a rise in population, large, aggregated villages, and a greater reliance on agriculture. Jornada-style petroglyphs and pictographs are found at sites across Fort Bliss.

Apache Style: This style is found among rock art sites from southern Arizona through southern New Mexico, west Texas, and northern Chihuahua, Mexico. The sites contain both petroglyphs and/or pictographs, and are relatively recent in origin. Black pigment is most common, although

colors are used occasionally (especially white). Frequent elements include horses, riders (some with wide-brimmed hats), Euro-American weapons, shields, bison, snakes, lizards, masks, and mythical beings. Solidly painted anthropomorphs, thick white paint, dance scenes, and polychrome paintings are attributed to the Apache in this area (Kirkland and Newcomb 1967). These elements are sometimes associated with the Comanche as, historically, they also occupied this area. The Comanche and Apache styles are so similar that it is difficult to distinguish between the two. One motif that has been verified ethnographically by the Mescalero Apache is the “hourglass” design. This is a common Apache motif and represents “Child-of-Water” for both the Mescalero and Chiricahua (Opler 1942; Schaafsma 1980: 335). Many ceremonial or shamanistic scenes are portrayed in Apache rock art (Opler 1946).

Rock Art Research

The study of rock art has gained increasing attention by archaeologists over the past 25 years. Most of the early research was done by professionals in other fields (e.g., Schaafsma) or by avocational enthusiasts who wanted to document these important sites before they disappeared. Although researchers in other fields have made valid contributions to rock art research, the dominance in this field by non-archaeologists has created an atmosphere of mystery and sensationalism. For many years, archaeologists hesitated to enter the field of rock art research for fear their professional reputations might be negatively affected. It may be because of this that no clear set of guidelines exist that clearly define rock art or how it should be recorded.

What can we hope to learn from the rock art, about the people who made it, or about the landscape it sits on? Rock art is a direct manifestation of prehistoric human thought systems. It was sometimes used as a form of communication, or a means of recording oral traditions. Contrary to popular belief, rock art can be interpreted, even in the absence of the original artists (Whitley 2005). Rock art, like all symbolic systems, had a social function. That function was to communicate ideas and concepts to others in the absence of the artist (Layton 2001). Identifying the social meaning of the rock art is the goal of the interpretation. To do this, we must understand how the symbolic system operated. As Geertz (1973: 17) points out, the meaning of symbols are inferred from human *behavior*, not from what people *say*. Therefore, the archaeological record, as a record of human behavior, should be analyzed to determine how the rock art in this region functioned. For example, rock art may serve as a territorial boundary or sacred site marker (Barton et al. 1994: 200).

A recent formal analytical approach to rock art involves neuropsychological models (Francis and Loendorf 2002; Keyser and Klassen 2001; Lewis-Williams 2003; Lewis-Williams and Dowson 1988; Sundstrom 2004). This model is very specific in its analysis of “trance” rock art. The neuropsychological model concerns itself with altered states of consciousness and is based on the fact that modern humans are all neurologically “hard-wired” the same way, thereby reacting to such altered states in similar ways. It is concerned with the origin of the art, not its symbolism. This theoretical framework has seen success in different parts of the world to explain certain types of rock art, but it does not apply to all rock art. It often invokes a shamanistic experience and common elements portray metaphors of trance states such as death, magical flight, and bodily transformation.

Rock art sites on Fort Bliss have not been well researched due to the location and inaccessibility of the sites. With few notable exceptions (Bilbo 1985; Sutherland 1976, 1996; Sutherland and Giese 1992), the documentation of rock art sites has been primarily descriptive. Only 37 sites of the more than 17,000 archaeological sites documented in the Fort Bliss site files contain mention of rock art. Unfortunately, these site files often only contain a notation of presence or absence.

There are a few problems associated with rock art research. One of the difficulties in studying rock art is that at an archaeological site, the rock art is a feature. Unlike a thermal feature, you cannot excavate it and transport it back to the lab for analysis. This means it is very important to be as thorough as possible when recording a site. Details within the natural rock surface are often incorporated into the design. These details may help in the interpretation of the rock art. Another problem is that rock art is often distributed across the landscape, in difficult terrain, making recording and analyzing it an investment in both time and labor. More often than not, funding is not available to conduct the amount of research required to sufficiently document and analyze the rock art within the archaeological site using traditional methods. A third concern is that there is a common misconception that “only panels that depict items recognizable to modern viewers, are archaeologically useful...abstract forms...are beyond comprehension” (Turpin 1990: 263). As Lewis-Williams states, “before we can learn from the art, we must first learn about it” (1986: 171). We must reconstruct its archaeological and social context to be able to learn from it.

Finally, there is the issue of classifying “styles”. Styles pertain to particular time periods. As chronometric abilities improve, classification will improve, giving better chronological control of the rock art. A major failing of the use of style as a temporal/cultural marker is the presumption that all stylistic variability is cultural-historical in nature. If two rock art sites are stylistically different, are they necessarily of different age, or from different cultures? This “denies the possibility of functional or social variability in a culture’s rock art” (Whitley 2001: 25).

Documenting Rock Art

Rock art sites are being destroyed at a rapid rate. The need to document these images before they are gone has become urgent. There have been attempts at standardizing rock art recording (Loendorf et al. 1998) but as of yet, no one standard has been accepted. There are dozens of suggested techniques in the literature, but many are now known to damage the rock art.

Some recording methods will probably always be acceptable, but due to expense or time expenditure, are becoming outdated. Newer methods and advances in existing technology will improve documentation and allow new avenues of research. Photography, especially with scale, is still one of the best methods to record rock art; it is non-intrusive and produces accurate representations. Several different mediums can be used to photograph rock art, including color, black and white, and infrared film, as well as digital cameras. Since different elements of rock art images may be more visible under different lighting conditions, taking several photographs at different times of the day is recommended. When the color of the petroglyph lines is very similar to the rock varnish, it may be necessary to use side lighting to enhance the lines using shadows. With advances in digital photography, even amateur photographers can produce exceptional records of rock art images.

Digital photography is becoming the recording method of choice, as the application options are numerous. Digital images can easily be enhanced to show different details or emphasize certain elements of the rock art. It is clear that computers have significantly changed the way we are recording rock art sites. Recent advances in technology have improved photography and allowed for a unique form of image preservation. Several recent publications discuss these advances (Walt and Brayer 1994; Mark and Billo 1999) and software is now available that offers the ability to record images and detail the order they were created for superimposition studies. Mark and Billo (1999) discuss how “stitching” photos together to create mosaics or panoramas can be used to illustrate changes in a site over time due to vandalism or erosion. Using this method, they were able to overlap images taken in 1977 of a panel at Inscription Point, Arizona, and then rectified to overlay an image taken during a rock art recording project at the same site in 1993. The results showed temporal changes at the panel, pre-vandalism and post-vandalism. This method has also had very positive results at nearby Hueco Tanks State Park (Mark and Billo 2001, 2006).

ANALYSIS OF SOCIAL, POLITICAL, RITUAL, AND ECONOMIC INTERACTION: CHEMICAL AND PHYSICAL CHARACTERIZATION AND SOURCING

Numerous chemical and geological techniques are available to determine the characteristic chemical composition of specific sources. Some of these methods have been employed in the study area and will continue to be used; others perhaps can be usefully applied in the study area to understand its interaction with regions beyond. Discussions of the methods pertinent to the study area are taken from Renfrew and Bahn (1991) and Parkes (1986), unless otherwise cited. While a variety of geochemical and physical characterization methods were outlined in the 1996 *Significance Standards*, a much more restricted set is recommended for continued use. The use of standardized and accepted methods such as NAA and X-ray fluorescence (XRF) help ensure that analyses conducted by different individuals and institutions are comparable.

Petrographic Analysis

The study of the rock or mineral structure of ceramic artifacts has been common for some time (Shepard 1956). By cutting a thin section of an object and examining it under a microscope, it is possible to identify specific mineralogical characteristics of the sample. Examination of a thin section of a potsherd can reveal the constituents of its temper, thus allowing specific clay and/or temper resources to be identified. To be effective, samples from all possible clay sources also need to be analyzed to build a database against which samples of artifacts are compared. Petrographic analysis is one of the more common studies carried out on ceramics in the area. This type of analysis lends itself to answering questions regarding settlement, subsistence, and interaction (and changes in those systems) on local and regional levels (see Hill 1988, 1989, 1993; Rugge 1986, 1988; Smiley 1977; Southward 1979).

Trace Element and Isotopic Analysis

The basic composition of many materials is quite consistent. Obsidian, for instance, is broadly similar in its makeup of silicon, oxygen, calcium, etc. The trace elements (representing only parts per million in the stone's makeup) vary according to their source and can be geographically differentiated. The methods used to measure these concentrations are listed below.

Neutron Activation Analysis: NAA is a method of trace-element characterization that came into widespread use in the 1970s and has been used for obsidian, pottery, metals, and other materials. With pottery, it is a destructive process as the sample is ground into a coarse powder. This disadvantage is typically overcome by submission of part of a sherd or artifact while the curatorial institution retains the remainder of the sampled artifact. The method depends on the excitation of the nuclei of the atoms of a sample's various elements when these are bombarded with slow neutrons. In order to do this, the samples (about 50 mg) are placed in a metal can in a nuclear reactor and bombarded with a beam of neutrons. The irradiation transforms the atomic nuclei of the elements in the sample into unstable radioactive isotopes (nuclides), which release gamma rays as they decay into stable isotopes. The energy levels of the gamma rays are characteristic of the particular element excited. Measuring the gamma-ray energy emitted by a sample therefore indicates the elements present. The intensity of each spectral line shows the quantity of each element. This method has the advantage of measuring concentrations ranging from 1 part per million (ppm) to 100 percent, and it can be automated, so that numerous results can be achieved relatively quickly.

The first characterization of turquoise in the Southwest was conducted by Sigleo (1975) using NAA on turquoise from 24 mines in the Southwest, including samples from Orogrande, New Mexico, in the Jarilla Mountains near Fort Bliss. Weigand and others (1977:15-34) adopted neutron activation as an analytical procedure in their work on turquoise sources and source analysis in Mesoamerica and the Southwestern United States. Bentley (1994), working on Fort

Bliss, has utilized Instrumental Neutron Activation Analysis (INAA) in a geochemical characterization of clay sources in the study area. This technique has been employed on a large volume of El Paso brownware and Mimbres Black-on-white ceramics from sites in the Jornada region to better understand regional social interaction and ceramic production technology (Miller 2005c; Miller and Burt 2007; Miller et al. 1997). Chupadero Black-on-white and several varieties of Mogollon and Mimbres ceramics from regions adjacent to the Jornada have also been sourced (Creel, Clark, and Neff 2002; Creel et al. 2002).

Inductively Coupled Plasma Mass Spectrometry: Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) is based on the same principles as optical emission spectrometry where a mass spectrometer is used to identify elements but the sample is atomized and excited in plasma rather than in a carbon arc. A much higher temperature can be reached, which reduces problems of interference between elements. ICP-MS has been largely automated, so that an extremely high volume of assayed samples can be achieved. This method has been used in the characterization of pottery, chert, obsidian, copper, and bronze. Recent use of ICP-MS on ceramics and clay samples from the Grasshopper Plateau in eastern Arizona (Zedeno 1994) aided in identification of local and nonlocal ceramics. Coupled with other techniques, the data led to interpretations of patterns of interaction and settlement in the region during the late thirteenth century.

X-ray Fluorescence Spectrometry: Known as XRF, X-ray Fluorescence Spectrometry utilizes a sample irradiated with a beam of X-rays that excite electrons in the surface. The electrons revert to their original positions when the X-ray beam is switched off, but as they do, they emit secondary or fluorescent X-rays. The energies and wavelengths of these secondary X-rays correspond to the concentrations of elements in the sample (each element emits X-rays of a characteristic energy). XRF analysis is usually accurate to ± 2 -5 percent. This method has been used on materials such as metals, obsidian, and pottery. It has been particularly useful for examining glazes on pottery. Bradley and Hoffer (1985: 161-177) utilized XRF to assess patterning in the chemical content of Playas Red sherds from different sites in the Jornada Mogollon and Casas Grandes regions. XRF is the method of choice for characterizing and sourcing obsidian artifacts (Miller and Shackley 1997).

The application of isotopic chemistry to metal sourcing has produced very successful results. It has become the most important characterization technique for metal objects because it successfully distinguishes lead from different sources in a way that trace-element analysis has failed to do. The method is of direct use not only for lead artifacts, but also for silver (lead is usually present as an impurity) and copper. Copper sources always contain at least a trace of lead, and it has been shown by experimentation that a large proportion of that lead passes into the copper metal produced during smelting. The obvious impact of this type of study on the copper bells found in the region would illuminate further the ideas of spheres of influence from the south and Southwest.

Recently, isotopic analysis has been undertaken to characterize the differences among turquoise mining districts, including Orogrande, New Mexico (Mathien 1995). Initial results indicate that there are differences in the amount of lead in turquoise samples from mines in the Southwest and one source from Chihuahua, Mexico. Additionally, differences are seen in lead isotopes (^{208}Pb / ^{207}Pb) from the Cerrillos mining district and five other mining districts in the American Southwest. Future research efforts can perhaps bring light to the role of the Orogrande mining district in cultural interaction with Paquimé to the south during Formative times.

Oxygen isotope ratios have proved useful for the characterization of marine shell. Temperature, salinity, species type, calcite-to-aragonite ratio, and geological environment affect the chemical composition of marine shell. The majority of factors, except for species, are environment related. Differing trace elements in the shells of mollusks of the same species would be expected to reflect

geographically based differences in the environment given their difference in water temperature, salinity, and sedimentological- and/or geological-related discrepancies or differences (Bradley 1992: 142). Another technique is determining source areas for shell from the Gulf of California. This chemical analysis uses the technique of emission spectroscopy (Bradley 1992: 140).

RESEARCH ISSUES

A limited but representative sample of research issues for the study of social, political, and ritual organization in the prehistoric Jornada region is provided below:

Research Issue 12-1

How did social arrangements facilitate conflict resolution over territories and land tenure among mobile hunter-gather groups and agricultural groups? Did Jornada populations have particularly fluid kinship and lineage organizations that reflect the need for populations to disperse on a seasonal or annual basis because of resource stress?

Research Issue 12-2

Can examples of corporate and network modes of political organization (Feinman et al. 2000) be identified among Jornada populations of various time periods? Do the material correlates for these organizational modes support the model of Feinman and his colleagues?

Research Issue 12-3

Can evidence of scalar stress (after G. Johnson 1982, 1989) and resultant social and political organizational responses be detected among the patterns of site structure and occupational histories identified in the region?

Research Issue 12-4

Can archaeological evidence of ritual actions, such as communal feasting or exchange, be identified? Did ritual actions serve to ameliorate social tensions and maintain social ties among mobile groups in the Jornada? Can different scales of ritual activities be detected, both among social groups with the Jornada proper and between Jornada groups and those of adjacent regions?

Research Issue 12-5

Does the increasing frequency of Mimbres whiteware and wider range of production zones through time as indicated by NAA data indicate an increasing emphasis on boundary maintenance between the two regions, a means of continuing access to resources, or other factors?

Research Issue 12-6

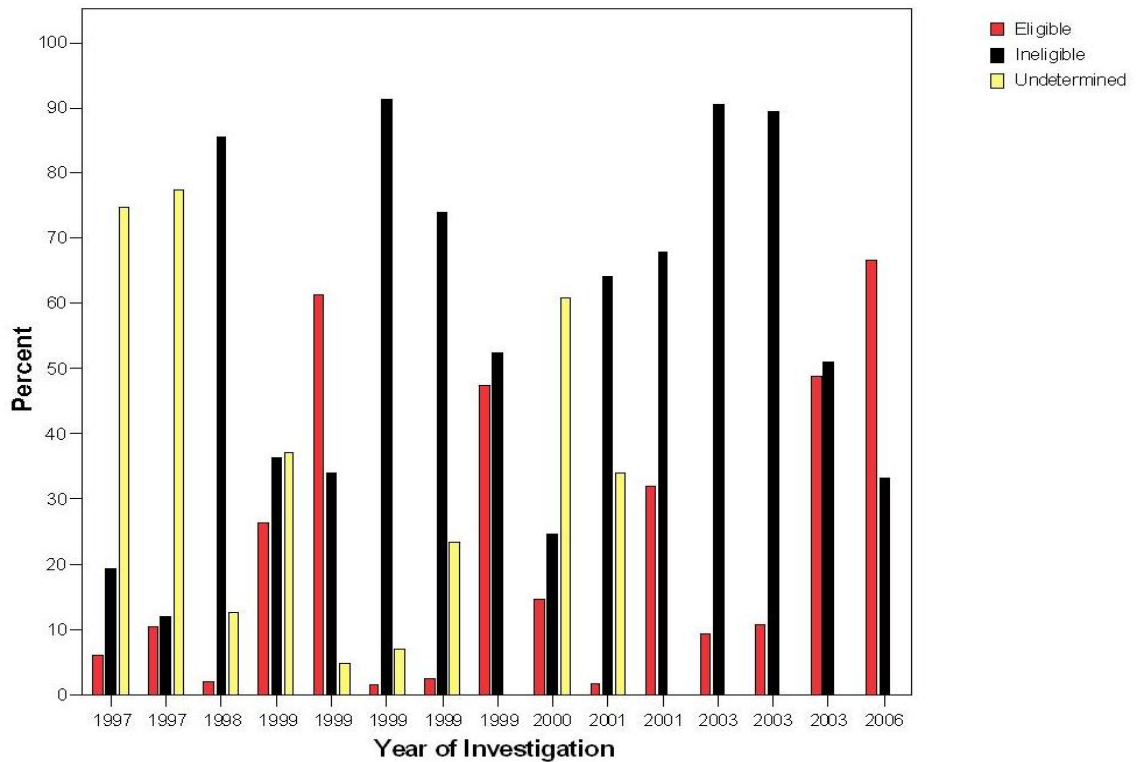
How do the distributions of extra-local obsidian and other materials reflect differing territorial ranges or modes of exchange?

The preceding list offers but a small sample of productive and meaningful research pursuits. It should be noted that these topics involving ritual, social, and political organization, boundary maintenance and land tenure, and other topics are relevant to the greater Southwest. The Jornada region can offer important data and insights into these studies.

Research Issue 12-7

Can rock art sites provide insights into aspects of prehistoric symbolism, ideology, and ritual? Are shamanic and trance episodes encoded in the iconography. Can these elements be related to larger patterns of the kachina religion? Are particular landscape contexts associated with rock art elements?

PART IV. MANAGEMENT AND RESEARCH PROCEDURES FOR NRHP ELIGIBILITY EVALUATION AND THE DESIGN OF MITIGATION PROGRAMS



Proportion of sites recommended as eligible, ineligible, and of undetermined eligibility for inclusion in the NRHP, 1997 - 2006

CHAPTER 13. REVIEW AND CRITIQUE OF QUANTITATIVE NRHP ELIGIBILITY EVALUATION PROCEDURES

Myles R. Miller, Nancy A. Kenmotsu, Tim Church, Brian Knight, and Sue Sitton

Section 106 of the National Historic Preservation Act requires that federal agencies take into account the effects of their undertakings on properties “listed on or eligible for the National Register of Historic Places” (NRHP). Properties that are not listed on or eligible for the NRHP do not require consideration or preservation prior to federal action. In 1982, the Advisory Council on Historic Preservation (ACHP) published 36 CFR 800 that details how federal agencies determine if properties are eligible and, if they are, how to determine if the actions of the federal agency will have adverse impacts on those properties. The regulations have been revised several times since 1982, but the process is still largely unchanged. As noted in Chapter 1, Fort Bliss has streamlined the eligibility process through development of a Programmatic Agreement (PA) that tailors the process for Fort Bliss, its unique resources, and its mission. This PA is signed by the ACHP, the New Mexico SHPO, the Texas SHPO, and Fort Bliss. With regard to eligibility, Fort Bliss Standard Operating Procedure (Fort Bliss SOP) 4 of the PA states:

Evaluation of eligibility is a judgment process based on established criteria and guidance developed by the [NRHP]. The process relies on two key concepts: significance and integrity. Both of these thresholds must be met to establish NRHP eligibility....For prehistoric archaeological sites, the thresholds established for eligibility on Fort Bliss are based on the document *Significance Standards for Prehistoric Archaeological Sites at Fort Bliss: a Design for Further Research and the Management of Cultural Resources* (Abbot et al. 1996)...Once the SHPOs have concurred [on these new revised Significance Standards], this document will become incorporated into this PA and will be the basis of future eligibility decisions (Section 4.4.2 of Fort Bliss SOP 4).

Given the size of Fort Bliss and the quantity of prehistoric archaeological sites on the base, other SOPs within the PA further streamline the eligibility decisions. SOP 6 states that if Fort Bliss determines that no historic properties will be affected by an action or that historic properties are present but will not be affected or not affected adversely, the determination will be reported in the annual report to SHPO or the relevant National Environmental Policy Act (NEPA) documentation. This procedure allows such decisions to be handled as routine matters. If, through consultations with SHPO, Fort Bliss determines that a site is eligible for the NRHP and requires standard mitigation procedures, Fort Bliss can proceed without further SHPO review of the research design.

While the discussion above sets forth the procedures for making a determination of eligible or not eligible, as noted in Section 4.4.2 of the PA, in the real world of day-to-day decisions eligibility is a judgment process. As a judgment process, not every eligibility decision will be agreed to by all parties. For this reason, the system has checks and balances. In the case of Fort Bliss, these checks and balances include the requirement that their contractors be familiar with the regional archaeology and that they use these revised *Significance and Research Standards* in developing research designs and in making NRHP eligibility recommendations to Fort Bliss. Another embedded balance is that the respective SHPO will review and comment on decisions of eligibility and data recovery plans/research designs for proposed mitigation of adverse effects.

Finally, in this Part IV of the revised *Significance and Research Standards*, an attempt is made to critique the eligibility standards that have been employed for prehistoric sites at Fort Bliss since 1996 and provide in Chapter 14 a series of revised procedures based on the new research domains discussed in this document and in the critique that follows.

This chapter reviews the past decade of NRHP eligibility evaluation procedures, including ranking systems and how the *Significance Standards* were incorporated into such programs. The review and critique of NRHP eligibility ranking procedures includes the following topics:

- Origin and development of NRHP eligibility ranking procedures
- Review and critique of NRHP eligibility ranking procedures
- Broader frames of reference for developing NRHP eligibility determinations

ORIGIN AND DEVELOPMENT OF NRHP ELIGIBILITY RANKING PROCEDURES

The 1996 *Significance Standards* document advocated the development and use of a ranking system to bring organization and consistency to the NRHP eligibility process. The rationale and process was set forth in the summary section of Chapter 11:

Both new survey and remedial survey should be designed to make explicit observations about the nature, frequency, and ubiquity of the key data sets needed to address the natural context research domains and the cultural content research domains. The use of newly developed and standardized data forms is indicated to collect meaningful, replicable, and accurate information. For each site (whether newly recorded or archivally documented), a series of filters are then applied to evaluate overall research potential. These filters sequentially pose a series of minimum rejection criteria; at each filter, those sites not meeting the minimum criteria are rejected as having no research potential.

First, the data sets bearing on the four cultural content research domains are reviewed and scored. These domains are technology, settlement patterns, subsistence, and cultural interaction. The scoring system used should be comparable to that devised for the natural context research domains [outlined below]. The total score for each site is then compared to the minimum "rejection threshold" as specified in the CRMP. If the site does not meet the minimum threshold, it has no significant research potential and is not eligible for inclusion to the NRHP. If the recorded observations bearing on cultural content do not permit a clear rejection of the threshold criterion, then collection of additional data is warranted. Such data are generally collected by means of a subsequent "testing" phase. If however, the site significantly exceeds the threshold, it proceeds to the next filter.

The site is then assessed for chronometric potential, according to the data needs presented in [the chronometric chapter]. If it does not contain any chronometric potential, it has no significant research potential and is not eligible for inclusion to the NRHP. If the recorded observations do not permit a clear determination, then collection of additional data is warranted. Again, such data are generally collected by "testing" the site. If however, the site has clear and promising chronometric potential, it proceeds to the final filter.

Finally, the site is assessed for context and integrity. The data sets bearing on the two natural context research domains, geomorphology and paleoenvironment, are reviewed and scored. The total score for each site is then compared to the minimum "rejection threshold" as specified in the CRMP. If the site does not meet the minimum threshold, it has no significant research potential and is not eligible for inclusion to the NRHP.

Again, if the recorded observations bearing on natural context do not permit a clear rejection of the threshold criterion, then collection of additional data by means of testing is warranted. If however, the site significantly exceeds the rejection threshold, then it has passed all rejection filters and has significant research potential and is eligible for inclusion to the NRHP. By law, the site must be preserved and protected. If adverse impacts to the site cannot be avoided, then these must somehow be mitigated (Trierweiler et al. 1996: 252-254; statements in brackets have been added).

Based on these recommendations, Requests for Proposal (RFP) issued by the Fort Bliss Directorate of Environment between 1996 and 2003 included the following language as part of one or more enumerated task requirements:

Review *Significance Standards for Prehistoric Archaeological Sites at Fort Bliss* (Abbott et al. 1996) and recent eligibility evaluation studies conducted at Fort Bliss and incorporate them into a research design to guide the work. Develop an objective ranking system for evaluating the NRHP eligibility of the sites using the Fort Bliss significance standards and similar eligibility studies conducted at Fort Bliss. Rank each site's research potential and physical integrity with reference to *Significance Standards for Prehistoric Archaeological Sites at Fort Bliss* (Abbott et al. 1996) and recent eligibility evaluation studies conducted at Fort Bliss

Archaeological contractors were thus contractually obligated to develop quantitative NRHP eligibility ranking systems as part of the survey and evaluation projects they performed at Fort Bliss.

REVIEW AND CRITIQUE OF NRHP ELIGIBILITY RANKING PROCEDURES

The design and intent of the ranking system, as set forth in the 1996 *Significance Standards*, did represent a concerted and dedicated effort to both systematize and standardize NRHP eligibility review procedures for use at Fort Bliss. This was particularly germane to the circumstances of the time at Fort Bliss where multiple cultural resource management contractors and individuals were conducting NRHP survey and evaluation projects. One of the fundamental problems was that no single consensus ranking system was developed, and that the use of ranking systems has fallen into disfavor. It should be noted that the goals of the effort, consistency and organization, remain valid. It was the implementation that failed.

In addition, there are several theoretical, methodological, and even philosophical issues that were not fully taken under consideration while proposing the original concept of quantitative ranking systems, as well as during the development of the individual ranking systems used between 1996 and 2004. Four of the most prominent methodological and theoretical issues are reviewed below.

1. There was no objective consistency in the design and implementation of the NRHP ranking system.

The ultimate intent of the ranking procedure proposed in the 1996 *Significance Standards* was to develop and establish an “objective” quantitative NRHP evaluation system for use by all archaeologists working at the installation. The quantitative ranking system and numeric eligibility thresholds were to be established under a CRMP, but in practice no single consensus ranking system was developed. Instead, individual Principal Investigators or Project Directors working for a given contractor developed their unique quantitative system. Unsurprisingly, these ranking systems were subject to quite a bit of latitude in design and interpretation and the efforts were not as coordinated as anticipated (although see Sale 1999), partly due to the volume of archaeological work needed at Fort Bliss with its new mission. The result was that each contractor used a different set of criteria and thresholds that changed over time.

The inconsistencies and problems of this historical approach are examined in the following graphs. Figures 13.1, 13.2, and 13.3 illustrate the relative proportions of NRHP eligibility recommendations for prehistoric archaeological sites proposed among a sample of 15 major survey and evaluation testing projects published between 1997 and 2006. The first graph (see Figure 13.1) illustrates the proportion of sites recommended as eligible for inclusion in the NRHP, ineligible for inclusion in the NRHP, and of uncertain or undetermined eligibility. The trend of proportional values is arranged from left to right in order of increasing proportions of “eligible” recommendations, although it is apparent that proportions of sites recommended as eligible are negatively correlated with proportions of sites recommended as ineligible.

It should be cautioned that these graphics are not based on entirely unbiased data, and several mitigating factors should be considered during their interpretation. Some of the projects included in Figure 13.1 (see Figure 13.1) dealt with landforms such as alluvial fans or the margins of major playas generally known for having more intensive, Formative period settlement and these sites tend to have good geomorphic integrity. Therefore, the projects may have encountered higher numbers of large, dense, and complex (i.e., NRHP eligible) sites. Some projects were designed to evaluate the “undetermined” sites of earlier projects.

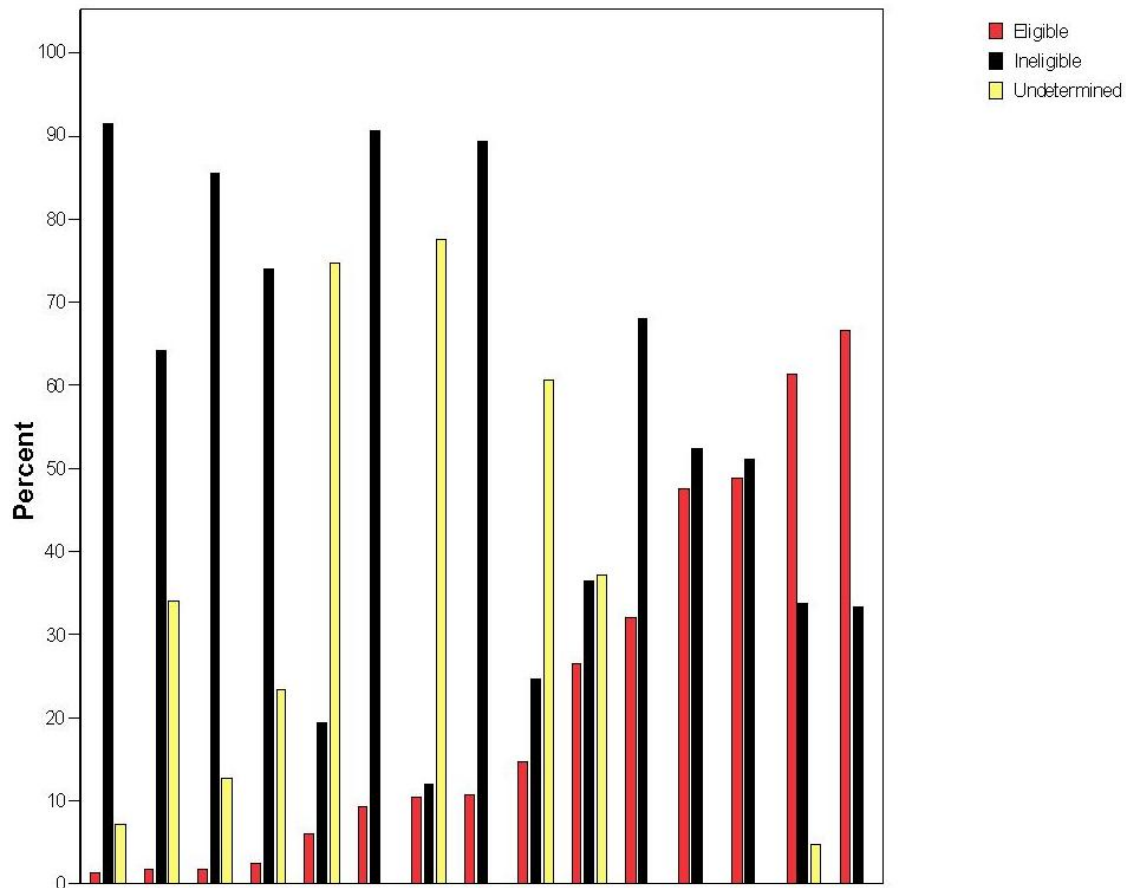


Figure 13.1. Proportion of sites recommended as eligible, ineligible, and of undetermined eligibility for inclusion in the NRHP among a sample of 15 NRHP evaluation projects at Fort Bliss.

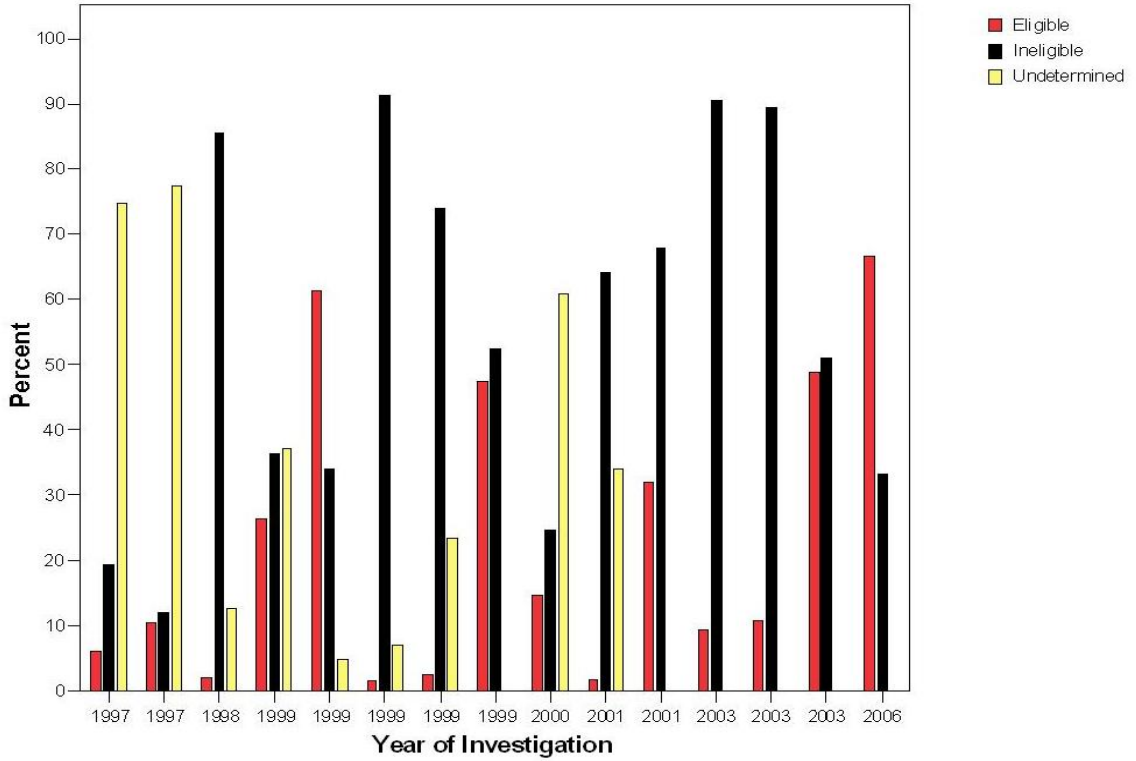


Figure 13.2. Proportion of sites recommended as eligible, ineligible, and of undetermined eligibility for inclusion in the NRHP arranged in chronological order.

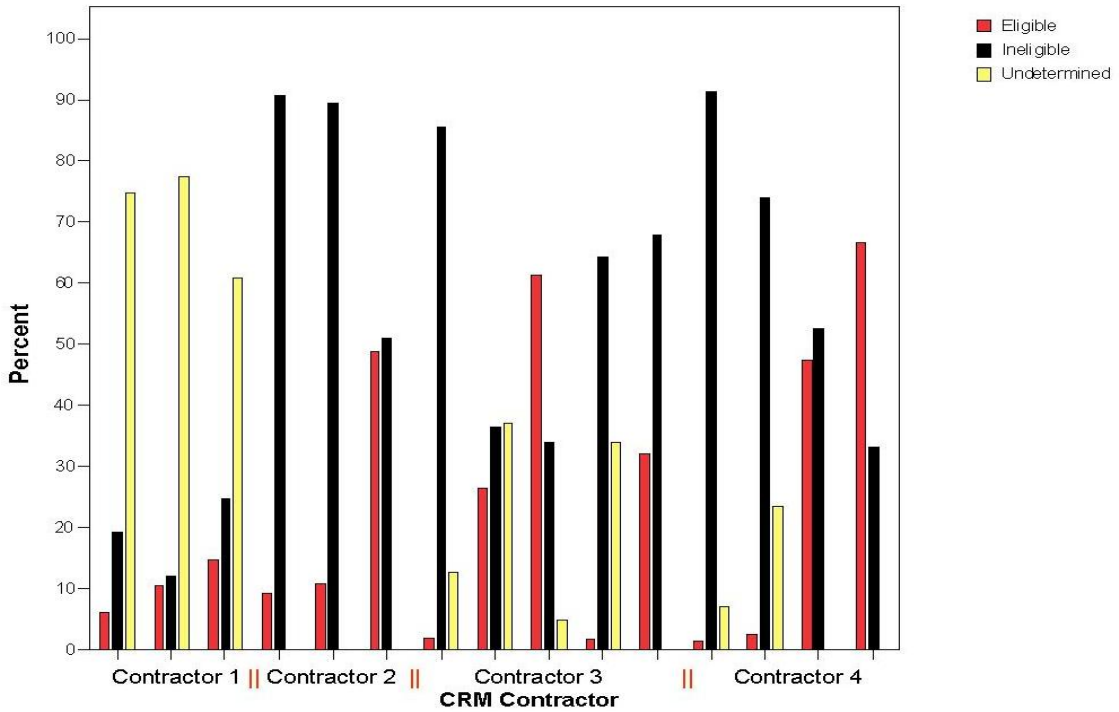


Figure 13.3. Proportion of sites recommended as eligible, ineligible, and of undetermined eligibility for inclusion in the NRHP arranged by CRM contractor.

Thus, the proportions of NRHP eligibility recommendations for such projects were already biased in terms of fewer eligible sites simply because the group of “eligible” sites within the specific project area had already been evaluated and removed from further consideration.

Nevertheless, these factors cannot entirely explain the dramatic range of variability among the NRHP eligibility recommendations proposed in this sample of 15 projects. The recommendations for sites being eligible for inclusion in the NRHP range from proportional highs of nearly 70 percent to lows of less than 2 percent. Correspondingly, the proportions of sites recommended as ineligible for inclusion in the NRHP range from over 90 percent to slightly over 10 percent. The proportions of sites with undetermined eligibility recommendations range from a high of 80 percent to less than 10 percent (the apparent 0 percent values for this category are explained below).

As shown in Figure 13.2 (see Figure 13.2), the only clear chronological pattern among the series of NRHP eligibility recommendations involves the proportions of sites recommended as having undetermined NRHP eligibility. There appears to be a much higher proportion of such recommendations during 1997, but as illustrated in the Figure 13.3 graph (see Figure 13.3), this actually reflects an institutional bias of a particular CRM contractor. At the other end of the temporal scale, undetermined eligibility recommendations are absent between 2003 and 2006. This reflects the fact that, beginning in 2003, Fort Bliss began to issue instructions in RFPs that recommendations for sites being of undetermined NRHP eligibility would not be accepted. Evaluation of sites during survey and testing projects had to provide a recommendation of either eligible or ineligible for inclusion in the NRHP.

The final and perhaps most enlightening pattern is revealed in Figure 13.3 (see Figure 13.3) where eligibility recommendations are presented according to four cultural resources management contractors who conducted archaeological work at Fort Bliss between 1997 and 2006. It is clear from an examination of this figure that, despite the intended objectivity of ranking procedures, a substantial degree of institutional and even individual (Principal Investigator/Project Director) bias existed.

Contractor 1 recommended unusually high proportions (60 percent to nearly 80 percent) of sites as having undetermined eligibility and requiring additional testing. In contrast, archaeologists with Contractor 2 tended to recommend from 75 percent to over 90 percent of the sites they documented as ineligible for inclusion in the NRHP. Contractors 3 and 4 have highly variable series of eligibility recommendations. In each of these cases, much of the observed variation is directly attributable to the influence of two or more Principal Investigators or Project Directors and the variations in the individual ranking systems they developed during their employment with these firms.

A second criticism of the quantitative ranking procedure is that the NRHP eligibility thresholds were set at numeric values. For example, under a hypothetical quantitative ranking system, a site having a cumulative numeric ranking of 20 or more points would be recommended as eligible for inclusion in the NRHP; sites with between 10 and 19 points would be of uncertain eligibility and require additional testing; sites having 9 or fewer points would be recommended as ineligible for inclusion in the NRHP.

The selected cut-off values were often based on examination of a histogram of cumulative numeric rankings. The actual cutoff numbers were supposed to be established in a CRMP. However, given the fact that multiple ranking systems were developed, it would have been impossible to establish a single numeric cutoff value for partitioning eligible and ineligible sites.

A more pressing fundamental problem with the use of numeric NRHP eligibility thresholds was never addressed. That is, while ostensibly designed as an objective system, the establishment of a numeric threshold for determining NRHP eligibility was a purely subjective decision.

Under a given ranking system, what specifically made an archaeological site with a ranking of 20 points eligible for inclusion in the NRHP, while a site having 19 points required additional test investigations?

No explicit rationale linking numeric thresholds to research potential was developed in the 1996 *Significance Standards* or among the various ranking systems, aside from subjective references to some form of relationship between research potential of a site and its location on the frequency histogram of cumulative rankings for a specific project.

The eventual outcome of the history of quantitative NRHP eligibility evaluation systems and their problems reviewed above is that a mosaic of at least nine different ranking systems was developed and applied across the Fort Bliss maneuver areas during the evaluation of hundreds of sites. No single consensus ranking system was developed and implemented for use, and thus the intended goals of consistency and objectivity could not be realized.

2. Adjustments were required to make certain classes of sites or sites of particular temporal periods “significant” and thus represented among inventories of NRHP eligible historic properties.

Many of the ranking systems had provisions and internal adjustments that artificially inflated the numeric point totals for sites having evidence of rare or under-represented site types or temporal periods. For example, several ranking systems artificially inflated the point values for certain assemblage attributes or chronologically diagnostic artifacts affiliated with the rarely encountered Paleo-Indian or Protohistoric temporal periods. Accordingly, the presence of a Protohistoric ceramic sherd or Paleo-Indian projectile point would automatically result in additional points for the site. Some systems contained an internal adjustment granting additional points if ceramics were absent, with the intent of ensuring Archaic period sites were not under-represented.

The result of these adjustments often guaranteed and bestowed *de facto* NRHP eligibility on such sites, or at least a recommendation for additional test excavations. Such status was granted regardless of ambiguous or unfavorable data on the absence of intact deposits, lack of corroborative chronological or chronometric information, insufficient technological data for incorporation into larger settlement studies, or any other indications of significant data potential. A more troubling issue was that the inflated numeric rankings (and by extension the research potential and NRHP eligibility) were often based on the presence of a single item such as a single Paleo-Indian point in an eroded site that had little potential for yielding information on the Paleo-Indian or any other period. There was often no indication of whether the “diagnostic” item was truly associated with other material culture and features at a site, or simply represented an isolated case of loss or discard across the landscape.

The intent of these adjustments and inflated rankings was to ensure that sites or certain time periods were included in numbers that the researchers thought necessary to adequately represent them among inventories of NRHP eligible historic properties within a given project area. The numbers of Paleo-Indian and Protohistoric sites are exceedingly rare in comparison to the thousands of Late Archaic and Formative period sites present across the central basin and alluvial fan landforms of Fort Bliss. Therefore, the goal of ensuring that sufficient numbers of these sites would be preserved or mitigated was, at the outset, a seemingly proper course of action.

However, this masks an important underlying issue for broader programmatic considerations of NRHP eligibility. Why did sites of certain time periods or certain types of sites require artificial inflation of their numeric rankings to be determined eligible for inclusion in the NRHP? Did they

not contain sufficient integrity, chronological potential, and analytical potential to be considered eligible without reference to their rarity? The concept of rarity, in and of itself, does not constitute a criterion for evaluating NRHP eligibility and must be considered within the usual contexts of integrity and data potential. Moreover, the underlying goal of obtaining some arbitrary count or proportion of rare site types should be evaluated in greater depth. First, the modification and adjustment of ranking systems to achieve this goal constitutes another violation of the proposed objective process of the ranking systems. Second, there is no compelling statutory or procedural reason for a site type or period to be represented solely on the basis on its rarity, nor is there a sound reason to determine some arbitrary number or proportion of such sites that reflects a suitable level of their representation among the inventory of historic properties at Fort Bliss. The issue is whether a given site, regardless of its type or time period, can provide information on prehistory in a meaningful way.

In the method and practice of CRM, the concept of rarity should be an issue for consideration in the management and treatment of archaeological historic properties, not in the evaluation of their eligibility. Once a site is determined eligible and thus warrants management and treatment as an historic property, the issue of its rarity or uniqueness should be a factor in decisions regarding its management and treatment. For example, if it was determined that only one, NRHP eligible, Mesilla phase pit house site remained intact among the Doña Ana Firing Ranges of the Organ Mountains alluvial fan piedmont, cultural resource managers at Fort Bliss might want to give greater weight to treatment options that avoid and preserve the site rather than excavate it.

3. The research basis for individual ranking criteria was often poorly conceptualized or missing entirely.

The relationships between rankings based on the basis of the presence or absence of certain items or classes of material culture, and the analytical utility of the presence of such materials were poorly conceptualized. The presence/absence criterion did not take into account whether the presence of an item truly represented some level of analytical or interpretive potential. For example, the presence of a single Mimbres or Chupadero Black-on-white sherd on a small single hearth site would result in the addition of several points for the Cultural Interaction domain. None of the various ranking systems offered an explicit analytical or theoretical rationale that would demonstrate how a single Mimbres whiteware sherd would illuminate how prehistoric populations in the Jornada Mogollon region interacted with groups residing in the Mimbres Valley. The variety of unresolved potential site formation processes, including artifact recycling, loss, and discard and landscape settlement patterns were not factored into the ranking.

A second shortcoming of this approach was that no provision was made for whether the artifact type or class was present in sufficient sample counts amenable to any form of quantitative analysis. Other examples include the presence of one or more ground stone items would result in the addition of points to the subsistence domain, given the proxy information on subsistence practice based on relationships between mano size and agricultural dependence (Hard et al. 1996). The presence of a formal chipped stone tool would result in the addition of points for the technology domain. However, the presence of one or two of such items did not provide sufficient sample counts for any form of comparative quantitative analysis, and NRHP eligibility evaluations based on such presence/absence criteria were often unrealistic.

4. Ranking systems inherently forced a compartmentalized research program using individual domains of the 1996 Significance Standards. No coherent research focus was developed.

The final and most critical issue is that the majority of the ranking systems tended to create and impose a structure under which the research domains of the 1996 *Significance Standards* were perceived as separate and unrelated research pursuits. The most fundamental flaw in the design of the quantitative ranking systems is that the practice of using point values for each of the seven

research domains created an artificial, yet nevertheless operationalized, perception of each domain as a separate entity. Each of the seven research domains – chronology, geomorphology, paleoenvironment, subsistence, technology, settlement pattern, and cultural interaction – was considered individually without reference to its intrinsic relationship to other domains.

This often resulted in a lack of a coherent research focus incorporating broader, interrelated themes of subsistence practice, settlement pattern, technology, and social theory. Archaeological and anthropological theory – whether derived from cultural ecological, processual, behavioral, social, or evolutionary schools of thought – examines human behavior within several of these frameworks. Chipped stone technology (i.e., technological organization) is inherently linked to settlement organization and subsistence economy. Settlement patterns (i.e., settlement organization) are contingent upon the seasonal subsistence round, resource availability, and subsistence economy. Cultural interaction is manifest among issues of territoriality and land tenure associated with hunter-gatherer and agriculturalist settlement patterns.

By focusing on individual research domains, the more expansive and regionally-relevant research potential of sites was often underemphasized in NRHP eligibility ranking procedures. In an altogether too typical case, a site situated in a partially intact Holocene Q3/Organ deposit that contains a shallow, eroded hearth stain, two chipped stone debitage items, an imported ceramic sherd, and a flake tool could be assigned points for subsistence, technology, settlement pattern, cultural interaction, chronology, and geomorphology. Provided that the histogram cutoff points were not set too high, such sites often met the numeric threshold values and therefore were recommended eligible for inclusion in the NRHP, or at least for additional testing. Yet, when Fort Bliss cultural resource managers consider the true analytical potential of such a site for modeling and interpreting regional settlement and technological adaptations, its deficiencies become readily apparent. The site has minimal assemblage content for analysis of reduction technology and tool utilization, has unsuitable sample sizes for comparative quantitative analysis of lithic technological attributes and ceramic exchange, and has a low potential for subsistence data to be extracted from the stained soil deposit. In fact, the site would therefore contribute little to regional analyses of subsistence practice, technological organization, settlement pattern, or cultural interaction.

This compartmentalization of the seven *Significance Standards* research domains was one of the main conceptual weaknesses of the quantitative NRHP eligibility evaluation programs under the 1996 *Significance Standards* and as operationalized by CRM contractors. The practice tended to inhibit the development of a coherent, regional research focus based on the integration of multiple data sets, thus allowing the rich and varied archaeological record of Fort Bliss to be applied to research issues of broader archaeological and anthropological significance.

BROADER FRAMES OF REFERENCE FOR DEVELOPING NRHP ELIGIBILITY DETERMINATIONS

As demonstrated in the preceding discussions, there has been a general failure to integrate the specific research domains of the *Significance Standards* and regional or pan-regional archaeological research issues with the NRHP evaluation process. For example, a practice not advocated by the 1996 *Significance Standards* - but long in use in the Jornada region - is that if a site such as that described in the preceding section has a single cultural feature it has automatically been determined eligible for inclusion in the NRHP. On the surface, this practice seems to be a simple 'yes/no' objective criterion. In reality, the practice: a) avoids entirely the issue of integrity and data potential as individual surface features often lack depth or association with artifacts that will allow for interpretation of meaningful cultural patterns; and b) results in the expenditure of large sums of money to mitigate marginal sites. The revised procedures for

eligibility determinations for prehistoric sites have to reach a balance. That is, some of these marginal sites may merit further investigation but not all of them. Such sites are part of larger cultural system and they should not be short-changed on *a priori* grounds. Yet, there is a need to develop a way to approach these sites as a group, with a clear rationale for how many marginal sites will be mitigated and what research goals will be achieved through this mitigation. There is a pressing need to develop research programs that effectively complete and integrate the data within current theoretical models of prehistoric landscape use.

Some discussions have been held about establishing management thresholds that, once reached, would result in a reduction of types of sites needing treatment. The typical example again involves single feature sites. Does each and every one have to be excavated? If not, how do we decide how many to dig? The articulated scenario is, once X number of a given site type are dug, then only XX percentage of the remainder need to be dug. Of course this scenario begs a number of questions: how is 'X' determined? Does each site type have an individual 'X'? Does each site type within each temporal period have a separate 'X'? Does each site type within each temporal period and within each of the topographic landforms present at Fort Bliss have a separate "X"? These and other questions are not easily resolved.

Part of the above issue involves sampling. When the 'XX' number of sites has been mitigated, how much of the remainder of sites need to be dug and which ones? One of the conditions of sampling is a knowledge of the population's parameters, which goes back to the question "what is the population of X when less than 100 percent of Fort Bliss has been inventoried"? While there are no easy answers to the issue, there are some methods available to tackle it. One possible answer may be an investigation of the use of uncertainty analysis (e.g., Knapp et al. 2003; Moilanen 2007; Moilanen et al. 2006; Prato 2004).

Again, we return to the issue of broader archaeological and anthropological research frames. Eligibility decisions should not start with the sites on Fort Bliss. They should start with a series of regional research issues and even pan-regional issues of relevance to archaeologists working in other regions of the world. Then, based on those issues, we need to identify the sites or site types that have the potential to answer those research issues. For example, many archaeologists would automatically state that El Paso phase pueblo sites that have reasonable integrity are eligible for the NRHP. In fact, in and of themselves, they are not eligible - not unless there are one or more research issues that they can address. If the mitigation is simply centered upon "this is a pueblo and we need to recover information," the result will simply be another accumulation of data on excavated rooms, content of features, and numbers of artifacts with no net increase in an understanding of how groups in the El Paso phase coped with each other, their environment, and outsiders. Thus, part of the solution is to begin with regionally relevant research issues, such as those laid out in revised *Significance and Research Standards*, not with the single feature in site X. Once the research issue is known, the next step is to determine if site X within a specific undertaking can contribute to the understanding of that research problem. Those are the sites that rise to the level of significant.

NRHP eligibility evaluation procedures should also incorporate the broader appreciation of landscape scales, the effects of site boundary definition in eolian settings, and geomorphic landforms gained over the past decade. Mauldin and others (1999; see also O'Leary et al. 1997) show the effects of different site boundary definition criteria on aspects of site and assemblage content, temporal assignment, and resultant NRHP eligibility determinations and potential archaeological interpretation. Depending on the distance criterion used to partition the discontinuous distributions of cultural material across the Fort Bliss maneuver areas, a given distribution can be bounded within a single large site or multiple small sites. The large site will contain multiple features, temporally diagnostic artifacts, and high artifact assemblage counts, and therefore will be considered as having significant research potential and be considered

eligible for inclusion in the NRHP. In contrast, the multiple small sites will contain few features, low numbers of artifacts, and will often lack temporally diagnostic items. Many of these sites may not be considered as having significant research potential, despite the fact that they represent the same landscape artifact distribution as incorporated within the large site.

This issue has been partially resolved by use of the TRU survey method (see Chapter 1) employed by the Fort Bliss Environmental Division, that requires that a consistent, GIS-based site definition routine be used by all archaeological contractors at Fort Bliss. The subjective nature of site boundary definition has been considerably lessened through the implementation of this procedure.

However, with the increased awareness and understanding of scale prehistoric settlement organization and landscape use gained during the past two decades, it can be assumed that almost any site boundary definition in the central basin will subsume a distribution of material culture that represents multiple overlapping and overprinted occupational events of differing durations, functions, and time periods. As a result of the detailed studies of small sites and intensive dating programs conducted at Fort Bliss during the 1990s (Burgett and Poche, in prep; Dering et al. 2001; Lowry and Bentley 1997; Mauldin et al. 1998), archaeologists gained an appreciation of the extent of multicomponency among sites in most of the landforms at Fort Bliss. While widespread patterns of site multicomponency were recognized from some of the earliest investigations in the region (e.g., Carmichael 1981, 1982), the true extent and nature of such processes were revealed during the 1990s.

Given these issues of site boundary definition and landscape-scale approaches to understanding prehistoric settlement organization, the assessment of research potential and design and implementation of NRHP eligibility evaluation procedures should consider that many sites – particularly those in the central basins - consist of different components and therefore may reflect multiple research domains.

Another key point that has become clear over the last decade is that NRHP evaluation based on the abundance of surface artifacts as a measure is often inappropriate. As shown above, low sample numbers of artifact types or classes create analytical and interpretive problems. On the other end of the spectrum, the presence of an abundance of surface artifacts or numerous features exposed on the site surface has been equated with research potential and NRHP eligibility. The practice resulted in eligibility recommendations for numerous deflated sites that offer poor data potential. Yet, sites with lesser assemblages of surface artifacts but excellent subsurface potential were written off as ineligible. It is for this reason that the revised *Significance and Research Standards* stress the need to understand the geomorphic landscape and the implications for site preservation.

It should be pointed out that considerable effort is now being directed toward this issue and this should be continued and expanded. However, ancillary issues need consideration. First, while upper level staff among archaeological consulting firms and Fort Bliss all agree on the need for better understanding of the geomorphic landscape, the crew chiefs (whose responsibility is often the preparation of site forms) need to be enlightened on the issues of artifact counts and research potential. Along with this is a growing requirement that field personnel need to have some level of geomorphic training so they can recognize situations and landforms that have high potential to contain subsurface cultural material. Most, but by no means all, field personnel know that sandsheets are a good indicator of preservation. However, few know the difference between an old sandsheet and a newer sandsheet of blow sand. Likewise, the growing evidence indicating that there are likely two or more paleosols occurring sporadically across Fort Bliss also needs to be relayed to field workers.

Previous efforts at education using workshops were not focused on quick and basic identification of such geomorphic features, but such a workshop might benefit Fort Bliss by bringing some level of consistency to NRHP evaluation. It does little good to have the people who spend the least amount of time in the field knowledgeable, while those who spend all their time in the field remain in the dark.

These expanded frames of reference serve as a preface for the discussions to be presented in Chapter 14. In the following section, a revised procedure for evaluating NRHP eligibility is outlined and set forth for implementation at Fort Bliss.

CHAPTER 14. PROCEDURES FOR NRHP ELIGIBILITY EVALUATIONS AND THE DESIGN OF RESEARCH

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This chapter outlines the approach for evaluating the NRHP eligibility of prehistoric sites at Fort Bliss. The development of this section has been a corroborative effort among the staff of the Environmental Division of Fort Bliss, and GMI, LMAS, and TRC. As in any collaborative process, however, not all parties reach the same conclusions or necessarily concur with the proposed procedures. Concerns have been expressed about the potential to under-represent or discount so-called “small sites” and sites representing rare or unusual types or temporal periods. As will be demonstrated in the following discussions, such concerns are unfounded. The revised evaluation procedure ensures that representative sites of all types and periods are considered equally. Furthermore, the procedures impose certain review and evaluative criteria that require archaeologists to consider research potential in a much more comprehensive manner.

TWO-TIERED NRHP ELIGIBILITY EVALUATION PROCEDURE

The 1996 *Significance Standards* advocated a multi-tiered NRHP evaluation process. The proposed process was for a given site to be evaluated for its potential to contribute to one or more of the archaeological research domains (subsistence, technology, settlement pattern, cultural interaction). If the site passed this data potential threshold, it was then evaluated for chronological potential and its natural attributes of geomorphic integrity and ability to yield paleoenvironmental data. In actual practice, however, the process was not implemented in the recommended sequence. Instead of a two-tier or two-phase process, the ranking systems developed for use at Fort Bliss tended to evaluate all seven research domains simultaneously. A modified version of the two-tiered evaluation procedure was resurrected for use during several NRHP evaluation projects conducted between 2002 and 2004 (Knight and Miller 2003; Knight et al. 2003; Lowry et al. 2003, 2004). This served as a template for discussion among representatives of the Fort Bliss Environmental Division and its archaeological contractors attending the February 2007 meeting on NRHP evaluation procedures.

The current NRHP evaluation program differs from the 1996 *Significance Standards* procedure in two ways. First, quantitative ranking systems have been replaced by a consideration of how the data potential of a site can address one or more historic contexts. A historic context is an organizational format that incorporates information about related properties based on a theme, geographic limit, and chronological period (Figure 14.1). In the present application, a “theme” represents a major research issue that subsumes one or more of the five research domains described in Part III of this document.

Second, the sequence of evaluation procedures has been reversed. In the current manifestation, sites are first evaluated for their chronological potential and geomorphic integrity based on Part II of these revised *Significance and Research Standards* and then for their potential to address one or more of historic contexts that integrate multiple research domains derived from Part III of this document.

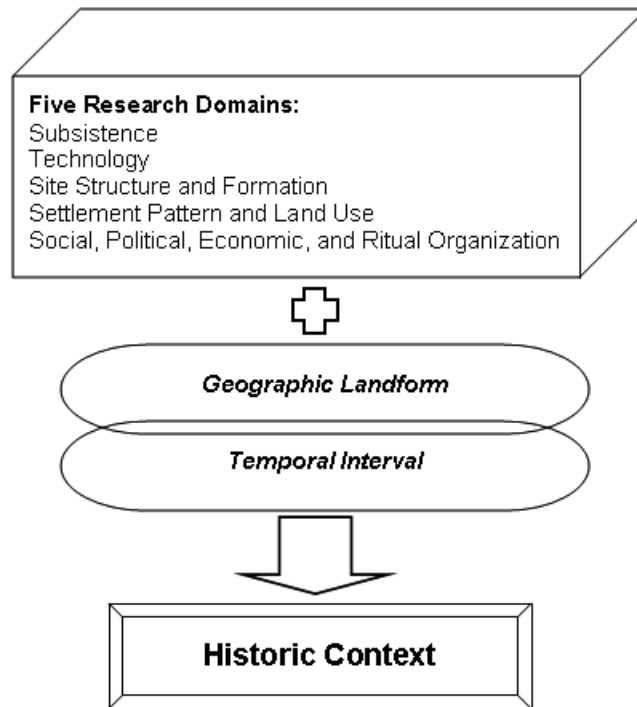


Figure 14.1. Development of Historic Contexts.

The process for evaluating the NRHP eligibility of prehistoric sites is graphically illustrated in Figure 14.2. In order for a site to empirically address any research question, the site must have something that allows researchers to place it in a temporal framework. But passing that threshold is not sufficient in and of itself to make the site eligible for inclusion in the NRHP. In addition to having chronometric potential, the site must also retain some level of geomorphic and spatial integrity and, even more importantly, have the type of data that will inform on one or more research issues relevant to the prehistory of Fort Bliss and the greater Jornada Mogollon region.

THE FIRST EVALUATION TIER: EVALUATING SITE INTEGRITY AND CHRONOLOGICAL POTENTIAL

The first evaluation tier involves two criteria that are critical for determinations of eligibility: site integrity and chronological data potential. The backgrounds of these criteria are described in greater detail in Chapter 6 (Geomorphology and Geoarchaeology) and Chapter 5 (Chronometrics and Chronology) of this document.

These attributes represent fundamental physical attributes of archaeological deposits and intrinsic site qualities that establish the integrity and temporal context of cultural deposits. Sites that lack good horizontal and/or stratigraphic integrity and chronometric potential simply do not have data useful to interpret mobility patterns, changes in subsistence practices, or other aspects of the prehistory of the Jornada Mogollon. It is well known that many sites in the central basin have been seriously deflated from both wind action and military maneuvers. Deflation can cause comingling of discrete occupations at a site, and can also adversely affect the spatial integrity of materials from a single occupation or component. Even if the site retains carbon staining and has chronological potential, excavation of such a site produces little other than a date and a few artifacts that cannot be confidently associated with one or multiple occupations.

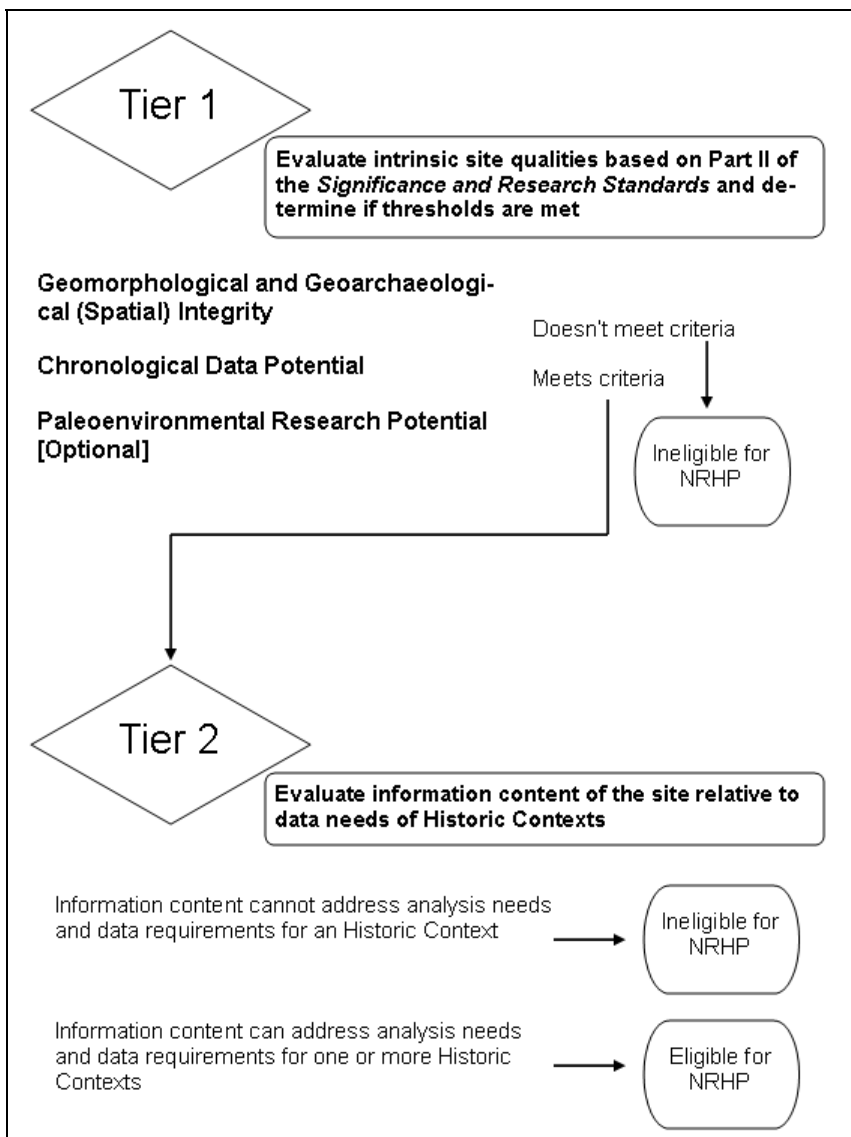


Figure 14.2 NRHP eligibility evaluation procedure for prehistoric sites at Fort Bliss.

Similarly, when the site retains its integrity but has no chronological potential, data recovery will result in a net accumulation of more artifacts (undifferentiated brownware sherds, chipping debris, non-diagnostic stone tools, and so forth), but an inability to place it in a time frame that would lead to a net increase in the understanding of how such tool and material assemblages relate to specific settlement and technological adaptations or other research issues of concern in the Jornada region. In sum, the first tier in evaluation of sites for the NRHP is an accurate assessment of whether the site possesses both integrity and chronological potential.

Chronometric Data Potential

As noted at the beginning of this section, chronometrics and chronology is not considered as a research domain or issue *per se*. We know that people lived in the Jornada Mogollon region for the past 11,000 years. Dating more hearths or burned caliche features just because they contain sample material suitable for dating will not improve on that basic bit of information. However, the presence of chronometric materials at a site, whether they are based on relative, sidereal, or

isotopic methods, is an important threshold in the evaluation of the site's eligibility for inclusion in the NRHP. Simply stated, in order for any site to empirically address any research question the site must have something that allows researchers to place it in a temporal framework.

It is also important to keep in mind that the ambiguities in incorporating chronometric research questions into the process of evaluating NRHP eligibility need to be resolved. The research issues set forth in Chapter 5 are designed to determine whether a given site has the data potential to address various chronometric research questions (e.g., can ceramic luminescence dating be used successfully?). However, these questions are difficult to incorporate into an NRHP eligibility evaluation process because, if a given site has potential to conduct experimental research on chronometric methods and address one or more chronometric research questions, *then the site clearly has substantial chronometric and chronological data potential in the first place*. For example, Research Issue 5-3 of Chapter 5 asks if the use of archaeomagnetic dating can be expanded and whether recent statistical refinements can enhance the interpretive potential of this method. In order to empirically address this research issue, it is clear that a given site and its constituent features must retain some degree of chronological potential for both archaeomagnetic and corroborative radiocarbon dating.

The distinction between chronometrics as a research domain, and chronometric data potential as an intrinsic site characteristic and NRHP evaluation standard, must be made explicit and the specific criteria for each need to be clarified. Chronometric research issues are relatively straightforward and are enumerated in Chapter 5. If a site has information that can address one or more of the chronometric and chronological research issues in Chapter 5, it has *de facto* chronometric data potential.

The dilemma arises when none of the chronometric research issues can be addressed using the collection of features and artifacts at a particular site. This is a common scenario among the low-density and low-intensity prehistoric occupations characteristic of the central basin landforms across Fort Bliss. In such situations, chronometric data potential is evaluated in terms of the prospective ability to place the archaeological contexts, features, and materials at a site within a secure temporal framework. Note that this judgment is independent of, and not contingent upon, the ability to address a particular chronometric research issue.

In such cases, how should chronometric data potential be defined in terms of the NRHP eligibility evaluation process? For purposes of NRHP evaluations at Fort Bliss, the basic definition is that chronometric data potential refers to *the presence of one or more interpretable associations of datable archaeological contexts and material remains at a site*. Under this definition, it becomes clear that chronometric data potential does not apply to isolated hearth features that can be dated via radiocarbon but are otherwise not associated with other contexts or material culture that serve to establish an *interpretable association*. While the hearth may contain organic material that can be radiocarbon dated, it lacks any association with other contexts or "items" of material culture that establish an interpretable relationship. Moreover, this definition establishes a higher evidentiary threshold for establishing chronological potential based on the presence of very small numbers of chronologically diagnostic artifacts. The mere presence of a single projectile point or ceramic sherd should not be routinely used to establish a dateable context or association. A more critical appraisal of the association or relationship between such items and other contexts, aspects of assemblage content, and corroborative chronometric or chronological data must be presented.

Geomorphic and Geoarchaeological (Spatial) Integrity

Chapter 6 of Part II of this document presents several discussions about site integrity. The issue of geomorphic integrity sounds simple, but in practice it is actually one of the more difficult concepts to operationalize for purposes of NRHP evaluations. The potential visibility and integrity of prehistoric cultural deposits varies widely among the eolian environments on Fort

Bliss and the potential effects of eolian processes on surface artifact visibility and patterning must be carefully considered. The mapping of eolian strata by Monger (1993c) and Johnson (1997) provides useful tools to adjust for geomorphic bias in the distribution of sites detected by pedestrian survey. When combined with GIS analysis of TRU survey data, correlations between eolian units and densities of material culture become readily apparent.

Assessments of site integrity should include geomorphic observations on the micro-topographic context of the site (presence of advanced coppice dunes with interdunal erosional surfaces, the presence or absence of lag gravels in surface sands of limited depth, and presence of sheet sands or dune piles) and the presence, absence, depth, and extent of Holocene soil deposits and subsurface cultural deposits. In addition, observations of natural and cultural disturbances are important and require a judgment of the degree to which disturbances have compromised the research potential of a site. The process described above is designed, among other things, to evaluate the integrity of site deposits through geomorphic, geoarchaeological, and specific disturbance information that will be collected during site evaluations.

Site integrity may be most effectively evaluated through a two-level hierarchy. The two-level approach is essentially based on whether or not unambiguous evidence of buried cultural deposits can be documented during survey or test investigations.

The first level of evaluation is based on a determination of whether intact subsurface cultural deposits are present. *It is important to note that there is a general correlation between geomorphic integrity and chronometric data potential.* The presence of preserved organic deposits in feature fills is often a useful and reliable measure of integrity in terms of absence of erosion and disturbance. If cultural features with dateable organic materials are observed on the site surface or through subsurface testing, a strong case can be made that the site or intrasite context retains some level of integrity. Such integrity may be present even in advanced coppice dune microtopographic settings. Advanced coppice dune zones are characterized by high, steep-sided dune formations surrounded by interdunal deflation areas. Such landforms are often severely deflated and all organic deposits have been eroded. However, in other cases remnant Q3/Organ deposits are present and multiple prehistoric features with organic deposits remain intact. These may be preserved at the surface or may be buried under a thin layer of Q4 eolian sands.

It must be emphasized that the presence of subsurface cultural deposits must be further evaluated through other information regarding the extent of natural and cultural disturbances and the overall size of the site. Integrity may often be observed for a relatively small area or single feature within a larger site. Likewise, it is not uncommon to find one or two remnant feature stains in sites that have been severely damaged by erosion and/or military vehicle maneuvers. In such cases, care should be taken not to extend the integrity observed within a small part of a site to account for the entire site.

If the small area contains an important prehistoric occupation and presents significant research potential *because it can contribute to one or more historic contexts*, the site may be recommended as NRHP eligible with the provision that only a certain area contains the characteristics contributing to its eligibility. This recommendation can be taken into account during subsequent management and treatment programs by the Fort Bliss Environmental Division. On the other hand, if the small area with chronometric data potential and geomorphic integrity does not have assemblage and spatial data that can contribute to an historic context, and the remainder of the site lacks integrity, a judicious recommendation would be that the site is ineligible for inclusion in the NRHP.

The second level of evaluation should be implemented if the evidence for subsurface cultural deposits is ambiguous or unresolved. For example, in a situation analogous to that described above for damaged or eroded sites, it is not uncommon to find one or two remnant feature stains in a deflated or exposed surface surrounded by extensive surfaces of eolian sheet sand deposits across the larger site area. The difference is that, instead of the remaining site areas being eroded or damaged, the remaining site areas are covered by sheet sands and obscured from surface inspection. A very low-density scatter of artifacts and isolated fire-cracked rocks may be present across the sheet sands, suggesting that buried occupational surface may be present. On the other hand, the artifacts may represent the typical palimpsest landscape distributions of artifact loss and discard present across the central basins of Fort Bliss.

In such situations where the subsurface potential for cultural deposits is ambiguous or unresolved, a second level of evidence based on the presence of a paleosol or the intact, upper horizons of the Q3/Organ stratigraphic unit must be evaluated. It is clear that the second evaluation level will often require some amount of subsurface testing and geomorphic assessment. Testing should focus on identifying whether intact paleosols are present. In addition, testing should establish whether the Q3/Organ unit is present and, more importantly, should demonstrate whether upper (Ab and Bw) or lower (Bk) horizons are present. As reviewed in Chapters 6 and 10 of this document, recent studies have shown that the majority of prehistoric occupations are associated with the upper formations. The presence of Q3Bk deposits generally indicates a low probability of cultural deposits.

If subsurface testing through shovel testing or backhoe trenching can demonstrate that the potential for cultural features deposits and artifact-bearing deposits extend below the eolian deposits obscuring portions of a site, a stronger case for site integrity can be made. Should testing encounter intact organic cultural deposits and/or artifact-bearing occupation levels below eolian deposits, this would confirm that the cultural deposits observed in exposed areas do extend beneath sheet sand deposits and, accordingly, would also establish evidence for site integrity.

Finally, the issue of geoarchaeological – or spatial – integrity needs to be taken into account. Much has been written about collapsed stratigraphy and lag deposits of artifacts representing different temporal periods. It is generally assumed that eolian erosion of natural stratigraphic units in the central basins has had the corollary effect of collapsing cultural stratigraphy. The ultimate effect of such erosional transformation processes is the so-called “lag” deposits of cultural materials of different time periods and occupational events intermixed within a single horizon. As noted in Chapter 10, the emphasis on stratigraphic integrity of cultural deposits in the central basin landforms has perhaps been misguided. Chapter 10 outlines the implications of different aggradation rates on the formation of natural and archaeological stratigraphy in the central basin landforms.

Based on these findings, archaeologists should focus more on elucidating patterns of *horizontal* integrity among distributions of prehistoric features and artifact distributions in the basin landforms. This involves a fundamental reorientation of our conception of site structure, in that evaluations of research potential are based on whether isolable temporal and occupational components can be differentiated across the horizontal dimension of basin landscapes. While this is by no means a simple proposition, a revised emphasis on the horizontal dimension of spatial integrity may help simplify the often difficult conceptual relationship between geomorphic (i.e., stratigraphic) integrity and chronometric potential as set forth in Part II and described above. Both chronometric data potential and site integrity may be demonstrated in tandem provided that a sufficient portion of the upper levels of the Q3/Organ stratum is present

Research at the El Arenal Site (Miller 2007a) has established that meaningful and interpretable spatial patterning can be recovered from large, complex, and multicomponent occupations that

lack depth and stratification. Furthermore, hunter-gatherer residences are usually not placed in the same location as previous residences owing to the presence of sharp chipped stone debris, discarded and decaying bone, and other safety, health, and comfort issues (see Chapter 10). Instead, residences at reoccupied locations tend to be positioned in a sequential fashion across the land. Evidence of such settlement patterning is evident among prehistoric sites occupied by hunter-gatherer and horticulturalists across the Jornada, including Keystone Dam, Turquoise Ridge, North Hills I, and El Arenal (Carmichael 1985; Miller 1990; 2007a; Whalen 1994a). Therefore, the issue of “spatial integrity” should receive greater consideration during site documentation and evaluation procedures

Paleoenvironmental Data Potential as a Criterion for NRHP Eligibility: The Paleoenvironment research domain of the 1996 *Significance Standards* has proven to be a problematic subject for NRHP eligibility evaluation programs. The basic issue is that “Paleoenvironment” is very rarely an intrinsic attribute or quality of a prehistoric site, but rather is a characteristic of the natural environment in and around the location in which a site is situated. In other words, paleoenvironmental data and study contexts may be fortuitously associated with the spatial boundaries of an archaeological site but not intrinsically with the prehistoric occupation or cultural materials of that site. For example, backhoe trenching conducted at pit house villages in alluvial fans offers an opportunity to obtain pollen columns from Holocene and Pleistocene-aged alluvial deposits and to study aggradation or sedimentation rates. Eolian and carbonate deposits around and under prehistoric sites in the central basin can be studied for pollen, phytoliths, carbonate morphology, and isotopic signatures.

It could thus be argued that the location of almost any prehistoric site has the potential to yield some form of paleoenvironmental data. Conversely, for these studies and most of the paleoenvironmental research questions presented in Chapter 7, almost any prehistoric site can be bypassed and the needed study contexts can be found off-site. For example, the vast majority of backhoe trenches examined during Monger’s (1993a) geomorphic mapping studies of Fort Bliss were excavated in non-site areas. Additionally, recent paleoenvironmental and environmental studies conducted at Old Coe Lake Playa and Snail Playa described in Chapter 7 took place outside the boundaries of prehistoric sites surrounding the playas.

There are some obvious exceptions. Rock shelters with prehistoric occupations offer a multitude of contexts and materials for a wide range of paleoenvironmental studies. However, rock shelters generally have rich and well-preserved cultural deposits and thus the NRHP eligibility of such sites is seldom an issue. Moreover, military training at Fort Bliss seldom impacts this site type. It should be noted that there are also some occasions where archaeological data may inform directly on paleoenvironmental conditions. Wood charcoal, if present in sufficient sizes and numbers at a site, may be examined for patterns of prehistoric wood resource depletion (after Dering 2001). In addition, ¹³C isotope data may be obtained in tandem with radiocarbon dates to potentially examine Holocene precipitation and temperature regimes (Miller 1996; see Chapter 7). These studies are usually incidental to radiocarbon dating and macrobotanical analysis. Therefore, for a given site to have research potential for these paleoenvironmental studies, it must first have sufficient preservation and data potential for chronometric and subsistence analyses.

In summary, for purposes of evaluating NRHP eligibility, the Paleoenvironment research domain is usually either inapplicable or is redundant with other research domains. Accordingly, it should be eliminated as a standard contributing research domain for NRHP evaluation programs. However, under certain conditions where clearly outstanding paleoenvironmental data is present within a site it should be considered, along with the Chronometric and Geomorphology domains, as an intrinsic site characteristic. Under such circumstances, it should be used as an optional criterion for eligibility, as well as for subsequent treatment and management decisions.

THE SECOND EVALUATION TIER: RESEARCH SIGNIFICANCE AND POTENTIAL TO ADDRESS HISTORIC CONTEXTS

If a site has demonstrable geomorphic and spatial integrity and chronological data potential, it will be further evaluated through reference to the five research domains described in Part III of the revised *Significance and Research Standards*. These domains are not reviewed individually, but instead are integrated into a series of higher-order historic contexts that are derived from - and thus specifically tailored to - the nature of the prehistoric archaeological record of Fort Bliss and the greater Jornada region. By doing so, we can avoid the practice of evaluating the five research domains as isolated subjects of inquiry that, as discussed in Chapter 13, results in an overly compartmentalized research and evaluation program. The historic contexts incorporate the research questions and issues of the subsistence, technology, site formation, settlement pattern, and social organization research domains set forth in earlier chapters. The use of historic contexts allows for the development of comprehensive evaluation criteria that incorporate these multiple research domains and can be applied to groups of sites representing distinctive site types and time periods associated with specific geographic or topographic landforms and time periods. Based on the archaeological work completed at Fort Bliss over the past 10 years, a series of historic contexts tailored for Fort Bliss has been developed. A representative sample of historic contexts is provided in the following section.

Establishing Quantitative Standards for Artifact Counts

A fundamental evaluative criterion of the revised NRHP evaluation procedure is based on the *explicit quantitative and statistical qualities* of artifact assemblages, in terms of their ability to address specific technological and cultural research issues. In basic terms, this criterion mandates that sufficient numbers of artifacts of relevant material classes (chipped stone, ceramic, ground stone, faunal bone) must be present and in association with a dateable context in order for information from a site to be applied toward the study of one or more of the historic contexts.

The term “sufficient number” of artifacts can be a rather nebulous concept, and the determination of what exactly constitutes a “sufficient” number of artifacts traditionally has been an arbitrary process. To provide a more robust and sound methodology, a decision grounded in statistical probability and sampling theory offers an explicit and defensible alternative.

Most parametric statistical sampling procedures are based on the Central Limit Theorem (CLT). In layperson’s terms, the CLT posits that, as sample size (N) increases, the shape of the sampling distribution (variance and standard deviation, or s and s^2) of the mean more closely approximates the shape of a normal distribution (Blalock 1979; Kallenberg 1997; Thomas 1976). In other words, there is a greater likelihood of obtaining or at least approximating a normal distribution with the use of larger sample sizes (i.e. larger artifact counts). Since a basic assumption and requirement for most parametric statistical procedures - including regression and correlation analysis, difference of means tests (t-test and analysis of variance), and such multivariate routines as discriminant and principal components analysis - is that the data being analyzed are normally distributed, the importance of sufficient sample sizes become readily apparent. The CLT forms the basis of most inferential statistics based on sample populations.

Many statisticians adopt a general rule that a minimal sample size of 30 items or objects is preferred to obtain a minimally robust normal distribution (Blalock 1979: 187; Weinberg and Abramowitz 2002:241). The value of 30 has been determined through numerous simulation studies based on different population parameters and distribution shapes. In reality, however, there is no absolute or universal minimum sample size. Sample sizes also depend on the level of confidence desired and margin of error that can be accepted. Sample sizes are also affected by the shape of the original distribution. Distributions having small tails (small standard deviations)

or small skewness measures can require a small sample; distributions with wide tails or skewed shapes may require larger sample sizes. Unfortunately for our considerations, archaeological data distributions often resemble the latter case and are frequently skewed.

It is also possible to examine small sample sizes using non-parametric statistical tests. However, these tests are not as powerful (i.e., using the statistical definition of the term¹) as parametric methods. Moreover, even several of the more common non-parametric statistical procedures such as chi-square, Kolmogorov-Smirnov, and difference of median tests based on distributional and probability theory require minimal sample sizes, or 20 or more items. Even a basic chi-square analysis of a 2 x 2 cell matrix requires that each cell contain a minimum of five members, thus requiring a minimum sample population of 20 objects (actually more should any cell contain more than 5 members). Based on these statistical requirements, it is recommended that a preferable sample size minimally consist of at least 30 items for certain artifact categories.

Archaeologists and cultural resource managers familiar with the archaeology of Fort Bliss will recognize an immediate issue with an NRHP-eligibility criterion requiring a minimal sample size of 30 items. A substantial proportion of the small, low-density archaeological sites on Fort Bliss do not have 30 chipped stone or ground stone artifacts in association with one or more thermal features or discrete activity areas. Even fewer such sites have multiple activity areas where most or all contain 30 or more artifacts. The implementation of such a threshold would effectively eliminate a sizeable proportion of the small sites on base from future management and treatment programs.

In these and all situations, the nature of the material class and goal of the proposed technological analysis must be considered. If the intent of a chipped stone technological analysis is to compare flake size distributions among different material types, then minimal sample sizes of 30 artifacts for *each* material type will be required. On the other hand, if the intent is to compare general assemblage content among one or more sites or intra-site activity areas, a minimal sample of 30 total artifacts per site may suffice. The threshold of 30 items is preferred and recommended, but it is possible in rare and special circumstances that 20 items can be accepted. In such cases, however, the CRM consultant must consult with Fort Bliss staff on the reduced sample size.

If one wishes to compare the range of chemical compositional groups (and production areas) among Mimbres whitewares between two sites, again a minimal sample size of 30 sherds is preferred (taking into account that sherds from a single vessel do not count as multiple specimens). In certain cases, 20 items may suffice as long as one takes into account the reduced utility of the dataset for statistical analysis and considers this factor when considering acceptable confidence intervals. Analysis of faunal assemblages may require even higher sample numbers because of the high percentage (usually 70-80 percent) of unidentifiable items among Jornada faunal collections.

Ceramic and ground stone artifact classes offer different analytical potential than chipped stone. A site may contain 20 or 30 El Paso brownware sherds, but in reality, such collections often represent a single vessel – and thus a sample count of one. This holds particularly true when the sherds are clustered. Ground stone is another difficult artifact class to quantify. The preferred sample threshold of 30 items will seldom be found among low-density sites in the central basins. Moreover, the majority of the items, if not all of the items, will be fragmentary and cannot be used for comparative quantitative studies of mano size (e.g., Hard et al. 1996) and metate size.

¹ In the theory and practice of inferential statistics, power is defined as the possibility of correctly rejecting the null hypothesis and avoiding Type I or Type II errors (see Blalock 1979 and Thomas 1976 for non-technical discussions).

It is often difficult to even identify basic types among the fragmentary assemblages typical of the Jornada region. Therefore, some artifact classes such as ceramics may be evaluated for their potential to contribute to qualitative analyses. If one wishes to compare qualitative data – such as basic frequencies of recycled ground stone items in hearth features of different time periods, a single recycled artifact may suffice. The rationale for using qualitative measures to address the historic contexts must be presented in detail to Fort Bliss.

In a realistic and pragmatic sense, however, it must be acknowledged that the archaeological study (and, by extension, NRHP-eligibility evaluation) of most prehistoric sites at Fort Bliss is based on chipped-stone technology and technological organization. A subset of Formative period sites offers ceramics and faunal remains for study. A very small number of sites may have ground stone assemblages of sufficient size and completeness for detailed analysis. Otherwise, as with most regions of the world, chipped stone artifacts are the most common and durable items of material culture recovered from prehistoric sites of all time periods and all landforms at Fort Bliss. The minimal sample size requirement of 30 artifacts for chipped stone assemblages is designed to yield useful information from this class of material culture. Archaeologists should consider the implications of small sample counts on proposed or future research endeavors. How many mitigation reports contain research designs that propose detailed and intensive analyses of chipped stone artifacts and other materials, but then proceed to state in the summary chapters that no such analyses could be undertaken because too few artifacts were recovered? Most analytical pursuits and procedures cannot effectively integrate samples of less than 30 chipped stone items. Therefore, with certain rare exceptions, a minimal count of 30 chipped-stone items is required to address issues of chipped stone technological organization discussed in Chapter 9 and as set forth in the following section with examples of historic contexts.

Establishing Spatial Association

Developing a consistent and realistic definition of the term “association” is a complex endeavor. As demonstrated in Chapter 10, hearth-centered activity areas and the resulting formation of hearth-centered artifact distributions are a near-universal aspect of ethnographic and archaeological hunter-gatherer settlements. The spatial extent and composition of such distributions can vary widely depending on such factors as settlement duration (both anticipated and actual), size of the resident social group, social distance and house spacing, food sharing, and subsistence base. However, there are some consistent patterns apparent among the ethnographic and actualistic research on spatial patterning at hunter-gatherer settlements. Moreover, recent quantitative spatial analyses of point pattern artifact distributions and TRU survey data from the Jornada region offer empirical evidence for establishing a threshold at which hearth-artifact associations may be consistently monitored and recorded.

Analysis of TRU survey data from a 1 km parcel on McGregor Range revealed several spatial scales at which hearths and cultural materials exhibit non-random patterns of clustering and segregation (Miller 2007b). It should be noted that TRU data is recorded within 15-m by 15-m cells and the nature of these data creates peculiar scalar conditions and constraints in that only spatial patterns at scales of 15 m intervals can be discerned. Figure 14.3 presents the results of the analysis and illustrates the scales at which hearth features are associated with three classes of material culture: ceramics, ground stone, and lithic debitage. Hearths and ground stone are closely associated at spatial scales of 15 m, a finding that is not surprising given the common use of recycled ground stone items as cookstones in thermal features. Chipped stone debitage is strongly clustered with hearths at scales of up to 15 m and shows a continued non-random clustering, albeit much weaker, at 30-m scales.

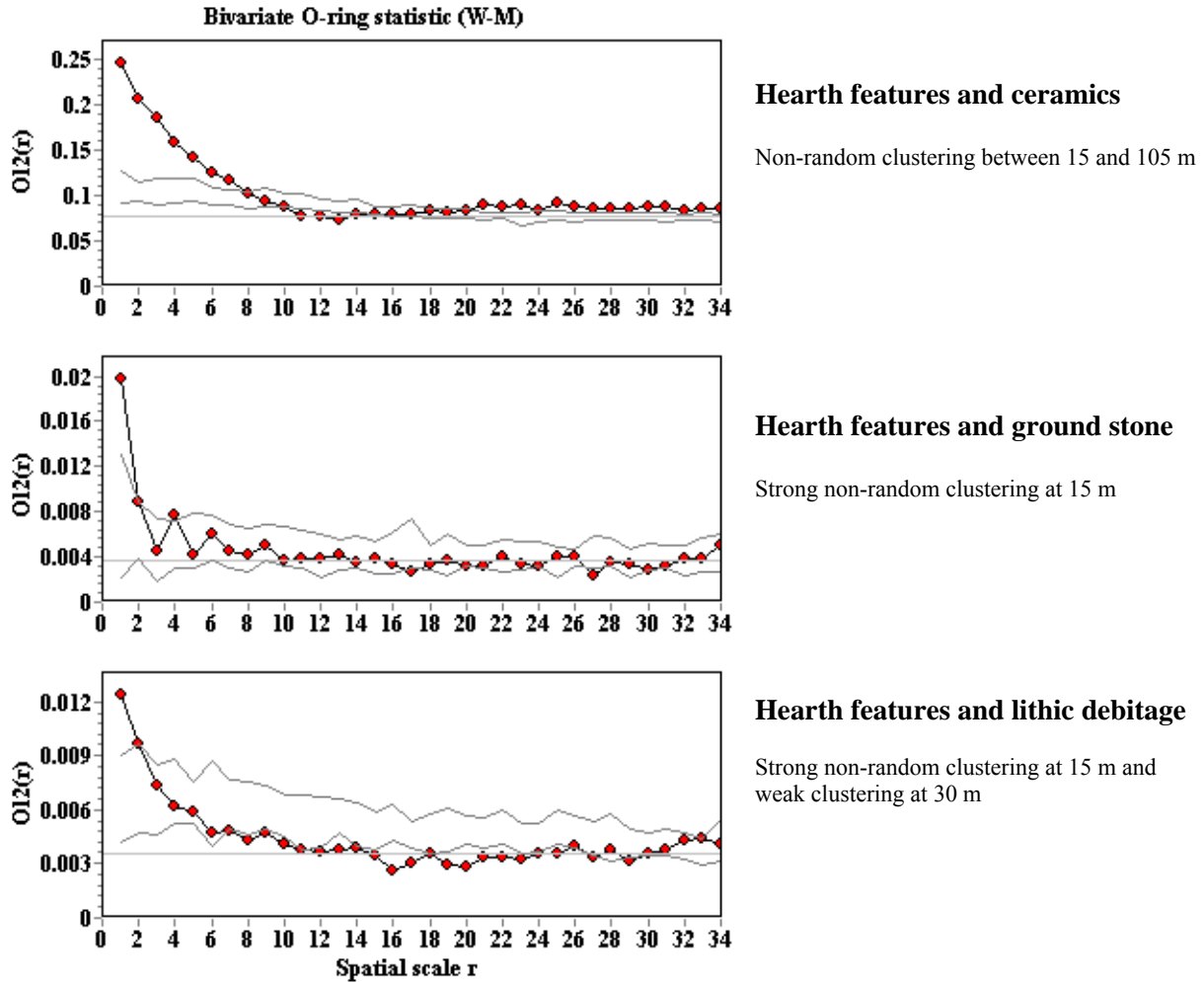


Figure 14.3. Bivariate O-ring statistic for spatial relationships between surface hearth features and other data classes across a 1-km survey parcel on McGregor Range. Graphics illustrate scalar trend of the O-ring statistic with radius r calculated at 15 m intervals (based on TRU recording cell increments) For example, $r = 2$ would indicate a radius of 30 m. Light lines denote 95% confidence intervals around the null model and denote random associations between data classes (adapted from Miller 2007b; Figure 6.6).

Ceramics show broad levels of clustering across the landscape. The ceramic patterns most likely reflect patterns of logistically organized settlement resulting in the widespread loss and discard of ceramic sherds and vessels. Overall, the predominant and strongest patterns of spatial aggregation across this particular landscape occur within scales of less than 30 m and primarily at 15-m intervals.

Point-provenienced artifact plots at the El Arenal Site provided insights into finer-grained intrasite spatial associations. Spatial point pattern analyses identified significant non-random artifact patterning at scales of less than 5 m and additional weaker spatial clustering at scales of up to 14 to 20 m. Based on this combined evidence from landscape and intrasite analyses of spatial association, a useful empirical threshold for documenting the association of hearths and major artifact classes is a 15-m radius.

Sites Representing Rare Types or Temporal Periods

Prehistoric sites of several time periods have been considered “rare event” samples because of their rarity in the archaeological record of Fort Bliss. Time intervals rarely encountered at Fort Bliss include the Paleo-Indian, Early Archaic, and Protohistoric periods. In addition, a continual fear expressed among some archaeologists is that certain site types, particularly so-called “small sites,” will be ignored, underrepresented, or discounted due to personal bias or other causes.²

However, as noted in Chapter 13, there is no statutory or procedural reason for a site type or period to be represented solely on the basis on its rarity, nor is there a sound reason to determine some arbitrary number or proportion of such sites that reflects a suitable level of their representation among the inventory of historic properties at Fort Bliss. Rather, the issue is whether a given site, regardless of its type or time period, can inform us on prehistory in a meaningful way and thus is eligible for inclusion in the NRHP. In the method and practice of CRM, the concept of rarity should be an issue that is considered in the management and treatment of archaeological historic properties, not in the evaluation of their eligibility.

ADVANTAGES AND IMPROVEMENTS OF THE REVISED NRHP EVALUATION PROCEDURE

The revised NRHP eligibility evaluation procedure offers several improvements and advantages over quantitative ranking systems. First and foremost, each historic context incorporates multiple research domains from Part III of the *Significance and Research Standards*. As such, the new approach compels archaeologists to consider the research potential of each site within a broader and more comprehensive analytical and theoretical framework. As shown in Chapter 13, ranking systems tended to impose a perception and appraisal of a site as an assortment of separate data categories, each of which was then related to an equally separate research domain.

For example, a datable feature + a ground stone fragment + chipped stone flakes were seen as equivalent to chronometric potential + subsistence + technology. If such a site was to receive enough ranking points, was determined to be eligible, and was subsequently mitigated without consideration of broader historic contexts, the only result is a chronometric date that adds nothing of substance to our understanding of prehistory.

The present approach revises this perspective and requires that we consider the interrelationship of data and research domains. From this perspective we must then inquire: “how can this occupation consisting of a thermal feature associated with a ground stone fragment and chipped stone reduction debris inform us on chipped stone technological organization and ground stone recycling in relation to changing patterns of subsistence and settlement organization during the Late Archaic/Early Formative period?”

Corollary issues must then be considered: is the ground stone item unambiguously associated with the scatter of cookstones? Are the chipped stone materials present in sufficient sample numbers to allow for comparative quantitative analysis with assemblages from sites of similar function and time periods? Are the materials associated with the feature, or are they scattered across a 50-m by 50-m area and potentially represent multiple episodes of artifact discard and loss across the landscape and not associated with the thermal feature? In sum, it is apparent that the current approach forces a more holistic and expansive consideration of a site’s research potential.

² Actually, the issue of rarity does not apply to “small sites” (low-density and low-intensity occupations) since these are by far the most common archaeological manifestation across Fort Bliss.

These questions serve to establish more standardized and productive field and laboratory observations during the eligibility evaluation process. In this regard, we enumerate specific considerations that are required for field documentation and evaluation:

- (1) The chronological potential, integrity, and research potential of features and activity areas, both individually and cumulatively as potential indicators of complex occupational histories;
- (2) The spatial arrangements and relationships of these features, activity areas, and artifacts;
- (3) The research potential and explicit quantitative and statistical qualities of artifact assemblages in terms of their ability to address specific technological research issues.

Finally, the procedure should result in a more unified and unbiased appraisal of sites. Contrary to the concerns expressed by some archaeologists that certain types of sites will be under-represented or ignored, the current approach actually ensures representation of significant sites for all temporal periods and site types. As reviewed in the following section of this chapter, multiple historic contexts are available for the most common temporal periods of the prehistoric sequence represented among the archaeological record of Fort Bliss: Paleo-Indian, Middle Archaic, Late Archaic, and Formative periods (including Mesilla, Doña Ana, and El Paso phases).

Additional historic contexts can be developed for the Early Archaic, Protohistoric, and Early Historic periods. Additionally, site types ranging from complex residential sites and isolated structural sites to small, low-density occupations and burned rock features are included among the historic contexts. While we can never completely eliminate personal and institutional bias in considerations of research significance and NRHP eligibility, the current procedure helps to mediate potential biases by compelling archaeologists to equally consider sites of all types and time periods and ensure that they will be accorded due consideration.

One possible drawback of the revised NRHP evaluation procedure is the same drawback that can take place for any procedure. In a similar fashion to what often transpired with quantitative ranking systems, there is a possibility that archaeologists will come to rely on formulaic eligibility evaluation checklists – e.g., are there more than 20-30 flakes? If yes, then the site meets minimal requirements for quantitative assemblage content.

This is particularly acute among large-scale surveys and evaluation projects involving hundreds of sites. What often occurs is what could be called “evaluation fatigue” resulting from a combination of the sheer numbers of sites and the often high-level of redundancy of site types, as well as certain time and budgetary constraints. In such situations, it may be tempting to quickly review a group of sites using a small number of simple - and perhaps overly simplistic - criteria.

A review of the recent survey literature finds that some sites continue to be recommended as NRHP-eligible solely because they consist of a feature with preserved organic material and have a scatter of artifacts. There has been some notable improvement in the consideration of artifact sample sizes, and fewer sites with two or three items are being recommended as eligible.

Yet, in some cases the critical spatial aspect is not being taken into consideration. An assemblage of 40 chipped-stone items may constitute a sufficiently robust sample size. But, if those 40 items are scattered throughout a 3,000-4,000 square-meter area without any apparent clustering or association with features or activity areas, the requirement that assemblages be spatially associated with datable contexts may not be met. It is necessary for CRM professionals at Fort Bliss and its archaeological contractors to ensure that NRHP eligibility recommendations do not become formulaic, but rather are based on systematic and thoughtful deliberation.

HISTORIC CONTEXTS, DATA NEEDS, AND THRESHOLD CRITERIA FOR NRHP ELIGIBILITY EVALUATION

Historic contexts are theoretical and thematic constructs for purposes of evaluating NRHP eligibility (see 48 Federal Register, pp. 44717-44720 and *Secretary of the Interior's Standards and Guidelines for Preservation Planning*). A historic context is an organizational format that incorporates information about related properties based on a theme, geographic limit, and chronological period. Numerous historic contexts for the NRHP eligibility evaluation have been developed for prehistoric sites at Fort Bliss over the previous five years (Knight and Miller 2003; Knight et al. 2003; Lowry et al. 2003, 2004; Stowe, Arford, et al. 2007; Stowe, Martinez, and Miller 2007) along with the development of programmatic research designs for the mitigation of those sites. In the following discussion a selection of historic contexts are presented that deal with sites in major several landforms and including the Paleo-Indian, Early Archaic, Middle Archaic, Late Archaic, and Formative periods (as well as the specific Mesilla, Dona Ana, and El Paso phases).

The theoretical perspectives outlined in Chapter 4 are represented among the selection of historic contexts. Cultural ecology, human behavioral ecology, behavioral archaeology, and social theories are well represented. Evolutionary archaeology is an exception, as this theoretical approach has not been applied to prehistoric research problems in the Jornada Mogollon region. Its exclusion also reflects a general absence of linking arguments and material culture analyses for this body of theory. In contrast, the pervasive influence of processualism and cultural ecology is readily apparent, as the majority of historic contexts include components from the subsistence, technology, and settlement pattern research domains. The influence of Steward's concept of culture core and its relationship to environmental conditions is apparent among these historic contexts.

The selection of historic contexts is based on the assignment of a site to one of the temporal periods of the Jornada Mogollon taxonomic sequence. However, many sites have chronometric data potential but may otherwise lack diagnostic artifacts such as a ceramics and projectile points, and thus cannot be assigned to a temporal period on the basis of information recorded during survey or test investigations. This is common among sites with surface stains that can yield radiocarbon data but otherwise lack diagnostic materials. Based on the overwhelming proportions of Late Archaic and Early Formative sites in the central basins, a reasonable assessment is that such sites are from these time periods. In the absence of other chronological information, such sites should be evaluated under historic contexts developed for the Late Archaic and Early Formative periods. Nevertheless, it should be acknowledged that such temporal assignments are based on a statistical probability and are not a certainty. A small proportion of such sites will also represent Middle Archaic or Late Formative occupations, and the potential for Early Archaic and Protohistoric features and associated materials cannot be ruled out (preserved organic deposits and radiocarbon dates from Paleo-Indian period occupations are almost non-existent). However, unless radiocarbon dates are obtained from most or all features during survey or testing programs – an immensely costly proposition – archaeologists must make good faith estimates based on statistical probabilities.

Certain provisionally unassigned sites may be evaluated under a subset of subsistence and technological research questions that span multiple time periods. Two such programmatic proposals involving chipped stone reduction technology and ground stone use and recycling are provided as examples. It should also be emphasized that the historic contexts presented in this section do not represent an exclusive nor comprehensive selection. Additional historic contexts merit study and others will be developed as some of those in the following segment are answered and new information suggests other avenues that need research.

HISTORIC CONTEXT FOR THE PALEO-INDIAN PERIOD

Historic Context: Folsom Settlement Adaptations in the Central Basins - Mobile High-tech Foragers or Semi-sedentary Low-tech Foragers?

Research Domains: Subsistence / Technology / Site Formation / Settlement Pattern / Ritual, Social, Political Organization

The following historic context examines the cultural-ecological and behavioral dimensions of Folsom and late Paleo-Indian settlement adaptations in the Jornada Mogollon region. The context takes into account the nature of Paleo-Indian occupations and archaeological data typical of Fort Bliss and the Jornada Mogollon region. Amick (1994a, 1995) observes that Folsom assemblages in the Jornada region differ in several regards from those of the Great Plains. These differences may offer important insights into the relationship between the resource structure of Late Pleistocene and Early Holocene environments of the Jornada region and the nature of prehistoric technologies.

No kill sites, or for that matter any faunal remains at all, have been recovered from Paleo-Indian contexts at Fort Bliss or in the southern Jornada region. Another factor is that many Paleo-Indian occupations in the Jornada lack the high numbers of bifaces typical of sites on the Plains. A third factor is that Paleo-Indian sites are often overprinted by and mixed with materials deposited during later occupations. Accordingly, by default the main interpretive focus of Jornada Paleo-Indian studies has involved chipped stone artifacts and inferences of technological organization derived thereof. The absence of faunal assemblages and rarity of stratified or unmixed assemblages does not mean that nothing can be learned from Paleo-Indian sites in the Jornada. Several issues of importance based on a broader perspective of the different resource structure and environment of the semi-arid Jornada region can be addressed.

Meltzer (2006) presents a current overview of Folsom research issues (see also Amick 2000). Of the extensive series of issues presented in his monograph, the following issues may be addressed through an examination of the site types and material culture typical of the Jornada region: lithic resource procurement, the organization of technology, and settlement organization. Folsom chipped stone tool assemblages and projectile weapons have long been known for containing stone materials transported across great distances.

The nature of these raw material distributions have been the subject of increasing attention over the past two decades, and have been used to infer mobility and territorial ranges, (Amick 1994b, 1996; Hofman et al. 1991) and more recently the possible social dimensions of geographic subregions apparent among material distributions (Amick 1994a; MacDonald 1998; Stanford 1999). The organization of Folsom technology has been interpreted primarily in terms of the practices of retooling and gearing up (Amick 1996; Hofman 1992; Ingbar 1994; Sellet 2004) in the context of different modes of settlement organization, mobility, and strategies of risk minimization or avoidance. The overarching issues of settlement organization have been considered under the two oppositional models reviewed below.

Data obtained from Paleo-Indian sites at Fort Bliss may contribute a Jornada Mogollon perspective to one of the more current and spirited debates regarding the nature of Paleo-Indian technological and settlement organization in the western United States: whether Paleo-Indian settlement organization and subsistence economy are best viewed as mobile, high-tech foragers or as sedentary, low-tech foragers. For much of the early part of the early period of research, Paleo-Indian groups were portrayed as highly mobile big game hunters (e.g., Sellards 1952; Willey 1966; Wormington 1957).

With data accumulated over many years of work, divergent interpretations have arisen over the past two decades or so. One perspective generally follows the conventional mobile big game hunting model, viewing Paleo-Indian groups as very highly mobile and specialized hunters following herds of bison and mammoth throughout the year. Such groups had a high investment in technology, utilizing flexible and reliable tool kit based on bifacial cores (Goodyear 1989; Hofman 1992, 1994; Hofman and Todd 2001; Waguespack and Surovell 2003). Such an adaptation would have been technology oriented rather than place oriented (after Kelly and Todd 1988), whereas the groups would have practiced similar hunting and settlement strategies across the landscape regardless of the season or the topographic setting. Group movement was continual, food storage was minimal, and residences were occupied for short periods of time (Hofman 1992). Bamforth (2002b) makes a notable distinction in that the big game model was originally conceived to account for early Paleo-Indian (Clovis) settlement adaptations, but was subsequently extended to Folsom and late Paleo-Indian periods.

This standard model has been the subject of several critiques based on examination of faunal assemblages (Cannon and Meltzer 2004), settlement scale and site types (Amick 1994a, 1996, 2000) and technological organization (Amick 1994a; Bamforth 2002b; Bamforth and Becker 2000). Bamforth (2002b, 2003) has proposed an alternative explanation that Paleo-Indian foraging groups (especially Folsom and later) were more sedentary and place-focused, intensively and repeatedly occupying key locations of high environmental diversity or in proximity to multiple ecological zones. Bamforth sees the chipped stone technology and organization of that technology in a much different manner, noting that there is little evidence for the widespread use of bifacial cores (see also Bamforth and Becker 2000), that most tools consist of informal forms made of local materials, and that patterns of tool resharpening typical of highly mobile groups are limited to extractive tools such as projectile points and end scrapers but are not present on maintenance and production tools. Additionally, Bamforth questions the universal importance assigned to distant raw materials, noting that most Paleo-Indian sites outside the Great Plains (where materials are highly localized) do not have large quantities of distant materials.

Based on our current understanding of late Pleistocene and early Holocene paleoenvironments and resource structure in the Jornada region, it is suggested here that the low-tech forager model would best explain the patterns of settlement and material culture of the Jornada region. This is in basic agreement with Amick's (1994a, 1996) interpretations regarding the distinctive nature of Folsom subsistence and land use in the basin and range region, including the southern Jornada. His comprehensive review of Folsom occupations in the Jornada Mogollon region was based on a sample of over 500 point specimens and several hundred preforms and channel flakes, including a large number of Folsom points and preforms from Fort Bliss. Amick (1994a, 1996) has argued convincingly on the basis of assemblage content and raw material sources that Folsom settlement in the Tularosa Basin and Hueco Bolson involved a pattern of residential settlements oriented towards hunting game animals other than bison, a pattern that differs significantly from the Southern Plains where typical Folsom land use patterns involved logistical sites occupied during the course of bison hunts. Amick (2000) also observes that the Jornada and Great Plains had different organizational strategies due to the very different resource structure of each region.

However, things are not all that neat and simple. Contrary to Bamforth's model, distant stone sources have been identified in Jornada Paleo-Indian assemblages, albeit often not in substantial numbers. The presence of such distant raw materials among Paleo-Indian assemblages in the Jornada region leads Amick (1994a) to the conclusion that Jornada groups participated in settlement or social systems at broader geographic scales. The presence of non-local and distant raw material sources offers insights into broader issues of territorial mobility and home ranges, and potentially some aspects of social relations with Paleo-Indian bands in adjacent regions.

Edwards Plateau Chert has been detected among Folsom assemblages on the Great Plains at distances of up to 575 km from the source in central Texas (Hofman et al. 1991).

Geographic distributions of materials have been identified, leading some to conclude that such raw material distributions denote the “boundaries of traditional areas of exploitation by independent Folsom bands (Stanford 1999: 303).” MacDonald (1998) proposes several social interpretations of Folsom mobility based on raw material distributions, including the search for sexual mates as well as small-scale exchange of materials for purposes of maintaining alliances. It is also possible that stone material exchange could signal boundary maintenance. However, Meltzer (2006) expresses doubts on raw material exchange for social purposes during the Paleo-Indian period. At the present time, the nature of subsistence practices, settlement organization, and social interactions of Paleo-Indian groups of the Jornada region remain unresolved.

Analysis Requirements:

- (1) For multicomponent sites, spatial analysis designed to determine whether distinctive Paleo-Indian tools and debitage (e.g., lanceolate projectile forms and preforms, transverse or “snub-nose” scrapers, channel flakes, and denticulate radial break tools) show non-random spatial clustering distinct from assemblages or materials of other time periods;
- (2) Analysis of raw material distributions among artifact classes, with particular emphasis on the accurate differentiation of local, non-local, and distant raw material sources;
- (3) Analysis of technological organization representing various levels of mobility and logistical organization.

Raw material identifications will assist in two important aspects of the project. First, patterns of raw material selection for the manufacture of formal tools, and patterns of use, maintenance, and discard of such tools, are inherent components of current theoretical models examining the relationships between hunter-gatherer land use, economic risk, raw material availability, and the organization of technology. Several studies of raw material variability among tool forms at Paleo-Indian occupations in the Jornada region have identified distinctive patterns indicative of retooling and “gearing up” for anticipated group movements (Mauldin and Amick 1998; Mauldin and Leach 1997; Mauldin and O’Leary 1994). Given current theoretically-oriented conceptions of chipped stone technological organization reviewed above, it may be expected that the specific resource structure and settlement organization of Paleo-Indian groups in the Jornada region should be reflected in different strategies of lithic raw material provisioning and reduction, as well as patterns of tool production, transport, and discard. An intriguing but seldom addressed aspect of Jornada Folsom technology is the common occurrence of very small Folsom points. Does this represent size constraints imposed by the small nodule sizes typical of Jornada lithic procurement areas? Or does it reflect material conservation and functional considerations, in that smaller game was procured? Analyses of raw materials, tool forms, and other aspects can provide additional insight into these research issues.

Data Requirements / NRHP Eligibility Threshold

- (1) Isolable Paleo-Indian chipped stone assemblage, including caches, debitage, and tools; and
- (2) Sufficient sample counts for examination of subsamples of raw materials and quantitative analysis of flake and tool sizes; and
- (3) Identification of specific regional and extra-regional raw material types.

HISTORIC CONTEXT FOR THE EARLY ARCHAIC PERIOD (6000 TO 4000/3000 B.C.)

Historic Context: Early Archaic Settlement Organization and Technological Organization: The Transition from Paleo-Indian to Archaic Lifeways

Research Domains: Subsistence / Technology Settlement Pattern/

The following historic context involves the organizational and technological dimensions of Early Archaic period settlement adaptations in the Jornada Mogollon region. This context takes into account the fact that the Early Archaic period is perhaps the most poorly-known interval of the Jornada and Trans-Pecos prehistoric sequence (see Mallouf 1985, 1990 and Miller and Kenmotsu 2004 for summaries), as well as throughout much of the greater Southwest (Vierra 2008). The intensive surveys of Fort Bliss and adjacent areas conducted over the past 30 years have recorded several surface finds of Early Archaic projectile point types, but only rarely have features or substantial settlement locations of this period been identified. The lack of information on technology and settlement necessitates the development of a generalized historic context for this time period.

Regional paleoenvironmental data (see Chapter 2) indicate a pronounced drying trend beginning at about 6,000 B.C. Vegetation shifts in the region include the appearance of desert scrub and succulents, including *Opuntia* sp. and honey mesquite, and the disappearance of temperate taxa. Van Devender (1990) argues that the shift at 6000 B.C. represents the onset of dramatically higher summer temperatures, continued frequent winter freezes, and a shift to dominantly summer precipitation. Geomorphic activity on the alluvial fans and in the bolsons (Blair et al. 1990a; Gile et al. 1981; Monger 1993b) increased markedly, presumably in response to these climate changes.

Several aspects of Early Archaic technology provide insights into changing technological adaptations. The use of rock or caliche as heating elements or as cookstones in thermal features first appears during this period, as does the widespread use of ground stone tools. The presence of large burned rock features positioned on alluvial fans establishes a land use pattern that persists throughout the remainder of the Archaic and much of the Formative period. These technological additions indicate an increased emphasis on plant processing. Projectile technologies involved a change from narrow, lanceolate forms of the preceding Paleo-Indian period to stemmed forms with broader blade elements such as Jay and Bajada.

With the adoption of stemmed forms comes a marked change in the use of coarser-grained raw materials for the manufacture of projectiles. In contrast to the common use of high quality, fine-grained materials for the manufacture of Paleo-Indian tools, the majority of Bajada and Jay specimens consist of coarse-grained igneous, metamorphic, and sedimentary rock types (Miller and Kenmotsu 2004; Wills 1988). Factors underlying these changes in projectile design and raw material use are unclear. Whether they reflect changes in prey selection and hunting practices, a reduced emphasis on tool maintenance combined with a greater emphasis on durability, different strategies of settlement mobility and territorial ranges, or a combination of these factors is unknown given the current lack of knowledge regarding Early Archaic settlement location, mobility, and subsistence. Nevertheless, these observations do mark a distinct technological change from the preceding Paleo-Indian period and suggest a broad spectrum foraging strategy.

These differences may offer important insights into the relationship between the resource structure of Early Holocene environments of the Jornada region (and adjacent regions as well) and the nature of prehistoric technologies and settlement organization. Early Archaic settlements seldom have substantial occupational deposits. Most sites consist of small hearth and artifact scatters distributed among a variety of environmental zones. Technological changes over the preceding Paleo-Indian period are apparent by different hafting methods and patterns of raw

material utilization for projectiles, the utilization of rock for heating elements in thermal features, and use of ground stone

Accordingly, the historic context for Early Archaic sites examines how technological and settlement adaptations changed in response to the increasingly dry, Early Holocene environment. However, it should also be noted that, given the paucity of Early Archaic remains in desert regions of the Jornada Mogollon and eastern Trans-Pecos, it may be productive to consider Early Archaic occupation of the Jornada region within a broader scale of hunter-gatherer mobility across the Southwest and Plains. In this sense, the low frequency of Early Archaic use of the Jornada may reflect a broader pattern of drought-induced migration of hunter-gatherer groups out of the lowland deserts of the Southwest to higher-elevation environments (Huckell 1996).

Analysis Requirements:

- (1) Integrated analysis of subsistence economy, including macrobotanical and faunal remains (if present) and associated ground stone, projectile, and cookstone technologies.
- (2) Analysis of raw materials with particular emphasis on the accurate differentiation of local, non-local, and distant raw material sources;
- (3) Analysis of technological organization representing various levels of mobility and logistical organization.

At the present time, virtually nothing is known of Early Archaic subsistence. It is likely that this pattern will continue unless a substantial Early Archaic settlement is discovered. Most likely such a site will be buried in alluvial sediments or in the basal cultural deposits of a rock shelter. Therefore, as with Paleo-Indian period settlements, inferences of Early Archaic subsistence may have to rely on insights obtained from durable technologies (chipped stone, ground stone, burned rock features).

As with the study of Paleo-Indian adaptations, raw material identifications will assist in two important ways. First, patterns of raw material selection for the manufacture of formal tools, and patterns of use, maintenance, and discard of such tools, are inherent components of current theoretical models examining the relationships between hunter-gatherer land use, economic risk, raw material availability, and the organization of technology. In particular, the dramatic shift in projectile design and raw material use needs to be placed within a broader settlement and technological context, with corroborating data from other material culture and settlement pattern analyses. In addition, the presence of thermal features and ground stone assemblages can offer insights into the proportional dependence on hunting versus plant processing.

Data Requirements / NRHP Eligibility Threshold

- (1) Isolable Early Archaic chipped stone assemblage, including debitage and tools, of sufficient sample size in a dateable context; and
- (2) Identification of specific regional and extra-regional raw material types; and
- (3) ground stone and cookstone materials associated with the chipped stone assemblage.

HISTORIC CONTEXTS FOR THE MIDDLE ARCHAIC PERIOD

With the exception of the excavations at Keystone Dam (O'Laughlin 1980), the broader nature of Middle Archaic period settlement and technology was for the most part unknown in the Jornada region prior to 2004. Miller and Kenmotsu (2004) attempted to remedy this situation by summarizing all available evidence for the period, including feature types, settlement patterns (topographic contexts of dated features), and lithic and projectile technologies. Despite this comprehensive review, it must be emphasized that information on this period outside of the single

site of Keystone Dam is very meager. Therefore, a fundamental problem is that any attempt to provide interpretations and models of Middle Archaic period settlement and adaptation are based on extremely limited datasets. Summaries by Miller and Kenmotsu (2004) and Lowry and others (2003) have noted that occupations of this period tend to be situated in proximity to well-watered landforms, such as the margins of playas and the Rio Grande Valley. Otherwise, Middle Archaic period components are rare.

Despite these shortcomings, Miller and Kenmotsu (2004) summarize the available data from Middle Archaic settlements and technologies and identify several intriguing patterns in material culture, technology, and landscape use that suggest that Middle Archaic lifeways may have differed from subsequent Archaic periods. These interpretations are, in part, dependent upon the data set analyzed. Two comparative data sets – one based on the identification of distinctive projectile forms and the other based on radiocarbon dates – are available for measuring the nature and intensity of Middle Archaic period land use at Fort Bliss and across the southern Jornada Mogollon region

Radiocarbon-dated contexts of the Middle Archaic period are rare. Dated features of this period represent less than 3 percent of the total summed radiocarbon record of the region (Miller 1996). Recently, three of five dated features in the vicinity of Old Coe Lake Playa have radiocarbon dates in the range of 3800-4100 B.P. (Lowry et al. 2003), indicating the presence of Middle Archaic occupations. Otherwise, the majority of Middle Archaic dates from the southern Jornada region have been obtained from sites in the Rio Grande Valley margins. This consistent occurrence of Middle Archaic features near riverine and playa landforms suggests that settlements of this period may have been tethered to permanent or semi-permanent water sources (see discussion in Miller and Kenmotsu 2004).

Overall, however, a cursory examination of the radiocarbon record suggests only sporadic or low-intensity use of the central basin landforms during the Middle Archaic. At the very least, these data suggest that adaptive strategies involving thermal features or other subsistence and economic activities resulting in the deposition of dateable materials within the central basin zones of the Tularosa Basin and Hueco Bolson were uncommon (although the occurrence of several deeply buried Middle Archaic thermal features along alluvial fans suggests that use of the fan environments may have been more common).

A different conclusion, however, may be reached with an examination of the projectile points recorded in the area that are representative of each Archaic period time interval. When projectile point frequencies are examined, it is found that Middle Archaic projectile forms represent between 25-30 percent of the points collected during surveys within the Tularosa Basin and Hueco Bolson. These proportions are in marked contrast to the radiocarbon record, where less than 2 percent of the radiocarbon dates from these basins represent Middle Archaic occupations. The disparity between the two measures of intensity of land use during this time interval is of interest, particularly when compared to other data.

For example, another observation of importance is that obsidian from distant sources in northern Chihuahua are represented in much higher proportions among Middle Archaic lithic assemblages than for other time periods, with the sole exception of the Protohistoric period when regional populations and land use intensity were similar to the Middle Archaic period (Miller 2001; Miller and Shackley 1997). Furthermore, a review of projectile points found a markedly higher proportion of patterns of blade and edge modifications during the Middle Archaic, including serrated, beveled, and heavily reworked blades (Miller and Kenmotsu 2004; Vierra et al. 1999).

Historic Context: Technological and Settlement Organization of Middle Archaic Populations in Playa Margin and Basin Landforms

Research Domains: Subsistence / Technology / Settlement Pattern

This is a broadly phrased context given that aspects of Middle Archaic period subsistence, technology, and settlement organization in the Jornada Mogollon region are so poorly understood. Miller and Kenmotsu (2004) propose several alternative (but not mutually exclusive) interpretations regarding Middle Archaic period settlement and land use that may be used to guide future research programs involving Middle Archaic components.

The disparity between proportions of projectile points and dated features may indicate that Middle Archaic adaptations involved a greater emphasis on hunting across the central basins. In this sense, the rarity of thermal features may be viewed in a similar manner to the Paleo-Indian period, in that some specialists in burned rock cooking technologies have proposed that cookstone technology was not part of Paleo-Indian settlement or subsistence practices (Thoms 2003). However, this does not preclude the use of informal hearths for cooking, warmth, and light.

Occupations of this period may have involved low-intensity logistical use of the central basins (primarily for hunting) with more substantial occupations tethered to alluvial fans, playa margins, the Rio Grande Valley, and other well-watered landforms. In contrast, as suggested by obsidian sourcing studies and projectile point blade modifications, Middle Archaic settlement and land use may have involved a high degree of residential mobility across broader territorial ranges than for populations of the subsequent Archaic and Formative periods. The distinctive patterns of blade modifications indicate that Middle Archaic projectiles reflect a distinctive technological interval in the Archaic sequence - one that had a specific emphasis on raw material conservation and highly maintainable, multi-function bifacial tools characteristic of highly mobile populations. In addition, the relatively high proportions of Chihuahuan obsidian identified among Middle Archaic projectile point collections suggests that populations exploited broad territorial regions that extended up to 200 km or more across the basin-and-range physiographic region of southern New Mexico and northern Chihuahua.

Analysis Requirements:

- (1) Identification and characterization of thermal features constructed and utilized during the Middle Archaic period;
- (2) Analysis of projectile point technology, hafting, and reworking with reference to technological and settlement organization;
- (3) Comparative analysis of artifact density and diversity.

Burned rock features are rare among features dated to the Middle Archaic period in the central basins, as opposed to the common presence of burned rock and caliche in Late Archaic and Formative period thermal features. To further evaluate whether Middle Archaic technological organization did not involve cookstone technology, Middle Archaic features will be examined for the presence of fire-cracked rock or burned caliche.

Attributes of lithic assemblages should be examined to corroborate the projectile point data. The projectile technology of the period is characterized by a much greater incidence of beveled and serrated blades, suggesting an emphasis on raw material conservation and multiple uses of the tools. Based on these projectile point data, which admittedly represents only one facet of chipped stone technological organization, Middle Archaic projectile technology indicates a greater emphasis on maintainability and durability of tool edges compared to other Archaic and Formative period time intervals, and overall constitutes a highly portable and versatile tool kit that may reflect broad patterns of territorial mobility.

If a debitage or a non-projectile tool assemblage is identified, the collection will be examined for corroborative evidence. Such evidence should be present in the debitage assemblage in the form of small waste flakes resulting from resharpening and maintenance of formal tools and bifacial manufacturing debris. The non-projectile tool assemblage should have similar attributes to the projectile tools, with formal and durable tool forms (bifacial knives and scrapers, retouched unifaces, multi-function core tools), evidence of on-site retooling and maintenance, and low numbers of informal flake tools.

The rarity of Middle Archaic components and low artifact counts may indicate that residentially mobile groups used the central basin primarily for extractive logistical resource procurement as opposed to foraging bases. Several integrated analyses may be brought to bear on this issue. Artifact counts and densities will be compared to Archaic and Formative occupations in the central basin. In addition, logistical sites should have chipped stone assemblages consisting of debitage resulting from isolated resharpening of tool edges, low diversity among tool forms, and the presence of special purpose tools. Ground stone assemblages, if present, should consist of small, durable, and multi-functional forms (for example, examination of dual use as battering stones will prove to be of interest).

Data Requirements / NRHP Eligibility Threshold

- (1) A statistically quantifiable assemblage of chipped stone and/or ground stone items in unambiguous association with a feature or context securely dated to the Middle Archaic temporal interval through absolute (radiocarbon) or relative (projectile point styles) methods; and
- (2) Presence of formal tools and projectile points; and/or
- (3) Presence of associated thermal features or residential structures for comparative analysis of morphology and function.

**Historic Context: Territorial Ranges and Extra-Regional Contacts
of Middle Archaic Populations**

Research Domains: Subsistence / Settlement Pattern / Social, Ritual, Political Organization

Obsidian of Chihuahuan origin has been identified as a common raw material used to fashion Middle Archaic projectile points. Although the sample is small, Middle Archaic, contracting stem projectile forms (Pelona and Augustin types or the “Gypsum Cluster” of Justice 2002) tend to be particularly pronounced in these Chihuahuan compositional groups. The presence of these sources, located as far as 200 km from the Hueco Bolson and Tularosa Basin, most likely reflects the territorial ranges of Middle Archaic populations across the Basin-and-Range province of north central Chihuahua, southern New Mexico, and west Texas (Miller and Shackley 1997). However, the possibility that projectile points or the raw materials used in their manufacture arrived in the region via exchange must also be considered.

Analysis Requirements

- (1) Geochemical and visual sourcing of raw materials used to manufacture projectiles and formal tools, and the materials observed among debitage collections will help further define Middle Archaic mobility and raw material procurement patterns;
- (2) XRF analysis of obsidian artifacts from Middle Archaic occupations is strongly recommended;
- (3) Analysis of raw material distributions among tools and debitage to identify patterns of technological organization.

Obsidian items may have been procured at source locations and transported with mobile groups or may have been obtained through exchange. Differentiating between these two processes may be difficult. Chipped stone analyses should include attributes and attribute states that are aimed at clarifying the differences between raw material and finished artifact procurement. These include attributes tailored toward the identification of various artifact types such as cores, early- and late-stage reduction debitage, and biface thinning and rejuvenation pressure flakes that, when combined with material type identification, can be used for differentiating the form in which non-local materials and artifacts were obtained. Miller and Shackley (1997) observe that statistically higher proportions of finished bifacial tools and projectile points are represented among Chihuahuan obsidian, and that isolated waste and production flakes, informal tools, and cores are comparatively rare. This suggests that obsidian tools were transported as finished objects and discarded during the process of retooling and “gearing up.”

Data Requirements / NRHP Eligibility Threshold

- (1) Sufficient sample sizes and raw material variability in chipped-stone tool and debitage assemblage; and
- (2) Presence of formal tools and debitage.

Historic Context: Middle Archaic Settlement Organization and Projectile Technology

Research Domains: Technology / Settlement Pattern

Further documentation of Middle Archaic projectile point forms and curation practices will contribute to our understanding of larger patterns of tool use, function, and raw material conservation in relation to settlement strategies.

Analysis Requirements:

- (1) Analysis of patterns of use wear, retouch, reworking, and distinctive blade modifications (serration, beveling) on Middle Archaic projectile points.

Data Requirements / NRHP Eligibility Threshold:

- (1) Middle Archaic projectile points in association with a dateable feature and activity area.

HISTORIC CONTEXTS FOR THE LATE ARCHAIC PERIOD (1000 B.C. TO A.D. 200/400) AND THE EARLY FORMATIVE PERIOD (A.D. 200/400 TO 1150)

Analysis of over 1,700 radiocarbon dates and several hundred radiocarbon-dated features have demonstrated unequivocally that the prehistoric occupation of the central basin was predominantly during the Late Archaic and early Formative. The first evidence of cultigens occurs during the Late Archaic period and a pronounced increase in the numbers of features and radiocarbon-dated contexts begins between 1200-1000 B.C., a time period corresponding to the appearance of cultigens. Another more pronounced rise in date frequencies across all feature types and contexts occurs near the close of the Late Archaic between 200 B.C. to A.D. 1, particularly for the numbers of dated house structures and cultigen dates (Miller and Kenmotsu 2004).

There is a general correlation between the appearance of cultigens and an increase in the number of radiocarbon-dated contexts that could suggest a linkage between changing demographic patterns and the adoption of cultigens. Whether the appearance of cultigens is a cause or effect of increasing population levels and/or land use intensity as represented by much higher numbers of dated features and components is uncertain.

Mauldin (1996; see also Mauldin et al. 1998) notes another major shift in landscape use in the central basin at A.D. 600. This shift is marked by a significant decline in the numbers of features radiocarbon-dated to this time period compared to the Late Archaic period and the first several centuries of the Formative period. In contrast, the number of features and sites in alluvial fans show a marked increase during this period. This major shift in settlement and feature construction within the central basin does not appear to have any distinctive correlate in artifacts and diagnostic materials, although, the question of whether the inception of the El Paso brownware tradition occurs at this date or at an earlier time remains unresolved. Miller (2007a) observes distinctive changes in site structure and chipped stone technological organization between Late Archaic and Early Formative, Mesilla phase occupations in the Hueco Bolson. These changes appear to reflect changing mobility and hunting practices, particularly a decrease in medium and large game hunting and increase in plant processing during the latter period.

Despite the immense quantity of archaeological data produced on central basin sites over the past decade, the period is surprisingly poorly known. Late Archaic period subsistence economies in the lowland desert zones are almost completely unknown. Faunal data is poorly preserved in basin contexts, as are most macrobotanical data. Late Archaic period subsistence will most likely have to be addressed through sophisticated applications of proxy indicators (see Chapter 8), and it is evident that much more refined and dedicated efforts towards the analysis of chipped stone assemblages and early ceramic technologies are needed.

Historic Context: Late Archaic and Early Formative Period Site Structure and Settlement Organization in the Central Basin and Playa Margin Environments

Research Domains: Site Formation / Settlement Pattern

The major changes in regional subsistence economies at ca. 2000 to 1000 B.C. and A.D. 600 should be reflected by differing patterns of residential and logistical mobility and group movement, including changing group composition, increased seasonal patterns of movement among the interior basin, playa margins, and alluvial fans, and by different levels of occupational duration and intensity at habitation sites. These changes in mobility, scheduling, and group composition should, in turn, be manifested in different forms of site structure such as multiple hearth and activity area loci, single and multiple residential structures, and spatial distributions of artifacts and features.

Analysis Requirements

- (1) Chronometric dating of multiple features and statistical analysis of chronometric data to identify contemporaneous and non-contemporaneous site areas;
- (2) Spatial analysis designed to explore relationships between site occupational histories and artifact and feature distributions reviewed in Chapter 10;
- (3) Analysis of raw material variability and identification of source locations to assess territorial mobility ranges.
- (4) Analysis of different technological and settlement aspects of sites with habitation structures versus those with more ephemeral or short-term residence.

Data Requirements / NRHP Eligibility Threshold

- (5) Presence of discrete activity areas associated with dateable features; and
- (6) Ability to correlate activity areas via spatial and chronometric analyses; and
- (7) Suitable surface artifact distributions for distributional plotting; or
- (8) The presence of habitation structures and associated activity areas is needed for the study of analysis requirement #4.

Historic Context: Technological Responses to Changing Late Archaic and Early Formative Period Subsistence Economies in Multiple Landforms

Research Domains: Subsistence / Technology / Settlement Pattern

The major shifts in regional landscape use, mobility, and subsistence that occurred during these periods are undoubtedly reflected in adaptive changes in technological organization. Chipped stone technologies offer the most productive means of studying changing subsistence and settlement organization, as well as representing the most common artifact class available from sites of this period. Raw material provisioning, tool curation practices, and the use of formal versus expedient reduction and tool production strategies should reflect different settlement adaptations and land use patterns. Whether or not ground stone technologies change is open to debate, although it appears that the recycling of ground stone tools as cookstones and heating elements in thermal features may take place during these periods.

The adoption of ceramic containers is another critical issue of this period. The demarcation point between the Late Archaic and Formative periods has conventionally been based on the appearance of ceramic technology in the region. However, this remains poorly dated, with estimates ranging from A.D. 200 to 600 (Perttula et al. 1995). Earlier inception dates for the El Paso brownware ceramic tradition at A.D. 200 to 400 are based on rather insecure associations between sherd scatters and isolated thermal features. The latter date of A.D. 600 would accord well with the major settlement changes observed in the radiocarbon record at that time. While the dating is of interest for correlation with other technological and settlement changes, as well as the issue of phase and period boundaries, it is really secondary to the more critical issue of why ceramics were incorporated in the Late Archaic/Early Formative technological inventory. Miller and Burt (2007) explore several functional reasons, including the possibility of increased containment security for collecting seeds and use for boiling the seeds. They also demonstrate intriguing parallels between the earliest Jornada ceramic technology and similar ones associated with early agricultural societies in southern Arizona.

Fire-cracked rock and burned caliche offer additional insights. The increasingly intensive and sedentary settlement systems employed during this era may be reflected by more intensive use of burned rock thermal features. These and other technological research issues are critical for understanding the changing economic and settlement roles of Archaic and Early Formative groups during major intervals of change and provide a distinctive diachronic perspective on Jornada Mogollon prehistory.

Analysis Requirements

- (1) Analysis of raw material distributions among artifact classes, with particular emphasis on the accurate differentiation of local, non-local, and distant raw material sources;
- (2) Analysis of technological organization representing various levels of mobility and logistical organization (including concepts of curated and expedient chipped stone reduction strategies, gearing up and retooling, the portability of ground stone and ceramic tools, and other aspects of technological organization);
- (3) Corroborative radiocarbon dating of hearth or structural features and thermoluminescence dating of ceramics in unambiguous association;
- (4) Comparative analysis to determine if increasingly intensive use of features can be detected via analyses of morphological attributes (pit dimensions, fill deposits, artifact associations, and rock weight, size, type, and fracturing patterns);
- (5) Functional and technological analysis of ceramic temper, finish, firing, and other design attributes;

- (6) Examine potential of residue analysis on chipped stone tools, ceramic sherd interiors, ground stone tools, and burned rock or caliche.

Raw material identifications will assist in two important aspects of the project. First, patterns of raw material selection for the manufacture of formal tools, and patterns of use, maintenance, and discard of such tools, are inherent components of current theoretical models examining the relationships between hunter-gatherer land use, economic risk, raw material availability, and the organization of technology. Recent studies of raw material variability among tool forms at Archaic period occupations in the Jornada region have identified distinctive patterns indicative of retooling and “gearing up” for anticipated logistic hunting forays group movements (Miller 2007a). Given current theoretically-oriented conceptions of chipped stone technological organization, it may be expected that the specific resource structure and settlement organization of Archaic and early Formative groups in the Jornada region should be reflected in different strategies of lithic raw material provisioning and reduction, as well as patterns of tool production, transport, and discard.

Data Requirements / NRHP Eligibility Threshold

- (1) Artifact assemblages of sufficient sample counts in association with one or more dateable features or contexts; and
- (2) one or more of the following attributes:
 - a. Sufficient chipped stone sample counts for quantitative analysis of flake and tool sizes among subsamples of raw materials;
 - b. Early El Paso brownware ceramics in association with dateable feature and in sufficient sample numbers for technological and functional analyses;
 - c. Ground stone items for quantitative analysis of size and type or qualitative analysis of recycled ground stone in dated features.

Historic Context: Correlation of Decreasing Territorial Ranges of Late Archaic and Early Formative Groups with Increasing Mutualistic Exchange Relationships with Extra-Regional Populations

Research Domains: Settlement Pattern / Social, Ritual, and Political Organization

Patterns of nonlocal obsidian sources show proportions of Chihuahuan sources decreasing markedly during the early Formative period. This observation suggests that territorial ranges of Jornada hunter-gatherer groups were becoming increasingly circumscribed (Miller and Shackley 1997). Conversely, during the Early Formative, Mesilla and Early Doña Ana phases increasing varieties of nonlocal ceramics and items such as marine shell and turquoise begin to appear, indicating that wider social networks were maintained, perhaps as a means of maintaining access to resources in areas that were once part of the territorial range of Jornada groups. This pattern may also be detected during the Late Archaic if the proliferation of projectile point forms is taken to indicate signaling of social and territorial boundaries (McBrinn 2005) resulting from increasing contact with extra-regional groups or occupation of the Jornada region by a greater number of social groups.

Lehmer (1948) and O’Laughlin (1981) report the finding of fragmentary *Glycymeris* shell bracelets and other shell items at the Roth Site and Los Tules sites. Otherwise, exotic items such as shell, minerals, and jewelry are generally rare at Mesilla phase sites, indicating that the Jornada Mogollon region may not have been a primary participant in broader, pan-Southwestern exchange systems during the period of A.D. 600-1000. However, the presence of Mimbres whiteware, Mogollon redware, and occasionally Viejo period decorated and textured wares, suggests that

Jornada populations may have participated in active, yet geographically restricted, exchange systems during this period (Baugh and Lukowski 2003; Miller 1989, 1990).

The Mesilla and Early Doña Ana phases in the Jornada Mogollon region were a period of increasing population aggregation within small settlements comprised of two or three household clusters. Distinct changes in regional land use have been detected, particularly between A.D. 650 and 1150 (Mauldin 1995, 1996; Mauldin et al. 1998; Miller and Kenmotsu 2004). Several variables indicate that, during the latter part of the Mesilla phase, territorial mobility ranges may have become increasingly restricted by extra-regional population growth (Miller 2002, 2007a). These patterns become more pronounced during the subsequent Early and Late Doña Ana phases (A.D. 1000 to 1150 and A.D. 1150 to 1275, respectively). Interestingly, there appears to be a linear relationship between the increasingly restricted territorial ranges and the greater variety and quantities of non-local ceramics appearing in the region – a pattern suggesting that access to critical resources was maintained through increasingly formal and reciprocal exchange relationships.

Social, ritual, and economic exchanges are generally approached through the study of non-local material culture (items that do not occur naturally within a group's territorial range) such as obsidian, turquoise, shell, and certain ceramic types. Such items are usually acquired through various exchange systems such as peer-polity and prestige exchange networks, bride price, or ceremonial or political tribute. It should be noted that increasing mutualistic relationships is only one potential explanation for the increasing variety and quantity of nonlocal materials appearing at Early and Late Formative period residential sites. Other explanations include greater levels of social differentiation and status among increasingly sedentary populations as reflected in the acquisition of prestige goods (Braun and Plog 1982, 1984), an increasing participation in pan-regional peer-prestige exchange networks (Bradley 1993, 2000), or increasing delineation of social boundaries and social identities among wide-ranging foraging groups (McBrinn 2005) and between agriculturalists and mobile hunter-gatherer groups. For example, Miller (2005a) has proposed that the distributions of Mimbres whiteware ceramics during the Early Doña Ana phase are best explained through social processes of boundary maintenance.

Analysis Requirements

- (1) Chemical characterization and source identification of obsidian;
- (2) Chemical characterization or visual identification of source locations for rare and unusual materials (turquoise, shell, minerals);
- (3) Chemical and visual identification of ceramics;
- (4) Raw material characterization of chipped stone assemblages;
- (5) Comparative morphological and stylistic analysis of projectile points.

Data Requirements / NRHP Eligibility Threshold

- (1) Presence of high numbers of obsidian artifacts and particularly projectile points; or
- (2) Presence of rare or unusual items in secure context and associated with other material culture yielding corroborative territorial and social information; or
- (3) Projectile points in unambiguous association with dateable contexts that, through stylistic, morphological, or chemical analysis may yield corroborative information on territorial mobility ranges and social interaction; or
- (4) Identification of geochemical compositional groups among El Paso brownware and nonlocal ceramic assemblages.

HISTORIC CONTEXTS FOR MESILLA PHASE (A.D. 200/400 TO 1100) AND EARLY DOÑA ANA PHASE (A.D. 1000 TO 1150) RESIDENTIAL OCCUPATIONS

Historic Context: Settlement Structure and Site Formation at Mesilla and Early Doña Ana Phase Residential Sites

Research Domains: Site Structure / Settlement Pattern / Social, Ritual, Political Organization

Mesilla and Early Doña Ana phase pit house sites are often conceived of as integrated villages. A reappraisal of excavations conducted at the Conejo Site suggest that this site, as well as many Mesilla and Early Doña Ana phase pit house sites, were formed through several occupations (Miller 1989, 1990; Miller and Burt 2007; Railey et al. 2002; Shafer et al. 1999). An understanding of site formation processes and site structure first and foremost establishes baseline data for subsequent archaeological analyses and interpretations of such settlements.

Site layouts at Mesilla and Early Doña Ana settlements include isolated houses, clusters of two or three houses, and semi-circular arrangements of houses. Mixtures of these patterns are also common. The degrees of settlement intensity and duration represented by these different layouts are equally variable. Moreover, inferences regarding group composition and social interaction may be derived from the number and arrangement of contemporary households at a particular settlement. One of the fundamental questions involving site structure and layout at Mesilla and Early Doña Ana phase sites is whether the household clusters were occupied contemporaneously or represent individual episodes of occupation and reoccupation.

Analysis Requirements

- (1) Geomorphic and archaeological identification of natural and cultural stratigraphy in alluvial contexts and determination if pedogenic surfaces are correlated with prehistoric occupations;
- (2) Chronometric dating of multiple features and statistical analysis of stratified chronometric data to identify contemporaneous and non-contemporaneous site areas;
- (3) Analysis of refuse patterns in pit house fills and trash middens to further explore site formation and occupational history.

Data Requirements / NRHP Eligibility Threshold

- (1) Two or more residential structures with good integrity; and
- (2) Evidence of stratification among cultural and natural deposits; and
- (3) Presence of refuse deposits of good integrity.

Historic Context: Settlement Organization and Subsistence Economies of Mesilla and Early Doña Ana Phase Residential Occupations along the Alluvial Fan Piedmont and Playa Margins

Research Domains: Subsistence / Settlement Pattern

Issues of settlement mobility are intrinsically related to subsistence economies. A relatively substantial body of flotation and other paleobotanical data has been compiled from Mesilla and Early Doña Ana phase occupations, and the subsistence economies of these periods are the best known of the Jornada prehistoric sequence. Nevertheless, while the subsistence base is relatively understood for these periods, several questions regarding the nature of settlement organization remain unresolved. Issues of seasonality, occupation duration, and mobility are only partially understood.

Mesilla and Early Doña Ana phase sites situated along the lower flanks of alluvial fan piedmonts are uniquely positioned to take advantage of fauna and cacti present along the higher elevations and rockier soils of the alluvial fans and mountain flanks, while also being located near the margins of well-watered playas. Chronometric analyses of feature distributions among different topographic landforms have identified occupation patterns (Miller and Kenmotsu 2004), indicating that subsistence economies at sites so positioned involved exploitation of both domesticated and undomesticated plants.

Direct evidence of subsistence practices in the form of macrobotanical and faunal data are often recovered from Mesilla and Early Doña Ana residential settlements. The preservation of faunal remains at sites buried in alluvial fan settings also tends to be much better than sites in eroded interior basin landforms. Accordingly, patterns of faunal resource exploitation may be explored with some success. Other indicators of seasonality and mobility should be investigated. Architectural form and morphology may relate to seasonality of occupation (Condon and Hermann 2007) with deeper pit house structures offering increased insulation during winter months (Gilman 1987). Ceramic compositional data may demonstrate patterns of ceramic (and group) movement.

Analysis Requirements

- (1) Comparative analysis of the relationships between architectural form and formality and patterns of settlement duration and seasonality in the Jornada region;
- (2) Analysis of faunal bone, macrobotanical samples, and possibly residue analysis;
- (3) Geochemical data on El Paso brownware ceramics.

Data Requirements / NRHP Eligibility Threshold

- (1) Architectural structures with good integrity; and
- (2) Preserved organic and refuse deposits for recovery of botanical and faunal material; and
- (3) El Paso brownware ceramics in association with dateable contexts and in sufficient sample numbers for geochemical compositional analysis.

Historic Context: Mesilla Phase and Early Doña Ana Phase Technological Responses to Changing Settlement and Subsistence Organization

Research Domains: Subsistence / Settlement Pattern / Technology

As with the Archaic-Formative transition, the major shifts in regional landscape use, mobility, and subsistence that occurred during the Mesilla and Early Doña Ana phases are undoubtedly reflected in adaptive changes in technological organization. In addition to chipped stone technologies, analysis of sites of these periods can incorporate studies of ceramics and ground stone to a larger extent. In addition, studies of fire-cracked rock offer important insights. Increasingly intensive and formalized use of burned rock roasting facilities becomes more common during the Early Doña Ana phase.

Additionally, the increasing formality and labor investment of different architectural forms such as huts, pit houses, and formal rooms can be used to infer aspects of settlement duration or seasonality (after Gilman 1987; Hard 1983b). These and other technological research issues are critical for understanding the changing economic and settlement roles of early Formative groups during major intervals of change and provide a diachronic perspective on Jornada Mogollon prehistory.

Simple expedient core technologies are an almost universal feature of Jornada Mogollon, Formative period settlements. As such, they are characterized by a limited range of formal and

informal tool forms and low morphological variation. Attempts to discern changes in reduction strategy and formal tool types through the Early (and Late) Formative period have generally proven unsuccessful.

The production of El Paso brownware undergoes some technological changes during this period. While some have proposed that changing vessel and neck forms reflect the need for containment security for boiling corn (Hard et al. 1994; Whalen 1994a), other functional and technological pressures and alternative explanations have not been fully explored.

Direct evidence of subsistence practices in the form of macrobotanical and faunal data are often recovered from Mesilla and Early Doña Ana residential settlements in alluvial fan settings. These data allow the utility of ground stone, ceramic, and chipped stone tool forms as proxy indicators of subsistence practices to be evaluated.

Analysis Requirements

- (1) Comparative analysis of the relationships between architectural form and formality and patterns of settlement duration and seasonality in the Jornada region;
- (2) Analysis of chipped stone technological organization and core technologies with reference to specific functional requirements brought about by changing subsistence economies;
- (3) Comparative analysis to determine if increasingly intensive and formal use of burned rock features and pit roasting facilities can be detected via analyses of morphological attributes (pit dimensions, fill deposits, artifact associations, and rock weight, size, type, and fracturing patterns);
- (4) Functional and technological analysis of ceramic temper, finish, firing, and other design attributes with a focus on investigating whether ceramic tempering materials reflect greater emphasis on strength, thermal shock resistance, or porosity;
- (5) Analysis of ground stone assemblages for morphological and size differences.

Data Requirements / NRHP Eligibility Threshold

- (1) Artifact assemblages of sufficient sample counts in association with one or more dateable contexts; and
- (2) one or more of the following:
 - a. Sufficient chipped stone sample counts for quantitative analysis of flake and tool variability among subsamples of raw materials;
 - b. El Paso brownware ceramics in association with dateable contexts and in sufficient sample numbers for technological and functional analyses;
 - c. One or more intact and dateable structures;
 - d. Ground-stone items for quantitative analysis of size and type.

HISTORIC CONTEXTS FOR LOW-DENSITY/LOW-INTENSITY OCCUPATIONS OF THE LATE FORMATIVE PERIOD (LATE DOÑA ANA PHASE [A.D. 1150 TO 1300] AND EL PASO PHASE [A.D. 1300-1450])

Distributional studies of projectile points, ceramics, obsidian hydration dates, and radiocarbon dates provide clear evidence of extensive logistical landscape use across most topographic

landforms (Mauldin 1995, 1996; Mauldin et al. 1998; Miller 2002; Miller and Kenmotsu 2004), including the central basin. Unlike other topographic zones, such as alluvial fans and playa margins, there is little evidence of residential use of the central basins during the Late Formative period. Recent spatial and distributional analyses of TRU survey data from McGregor Range has found that Late Formative ceramic types such as El Paso Polychrome and Chupadero Black-on-white often have distributions that are spatially segregated from other artifact types (Miller 2007c), indicating widespread logistical landscape use based on transport of ceramic vessels and whatever materials were contained in the vessels.

Logistical mobility, representing one side of the residential-logistical duality of hunter-gatherer studies of the past several decades, has received much attention in the modeling and interpretation of hunter-gatherer material remains and settlement adaptations worldwide. When it comes to agricultural societies, though, it is interesting to note that logistical mobility is seldom referenced in discussions of either short-term resource procurement or longer-term population movements and patterns of landscape use. Despite the widespread evidence, both ethnographic and archaeological, of various forms of special use or task specific sites and material distributions representing logistically organized behavior among agricultural groups, few studies have been undertaken to examine the nature of such sites and the implications for population aggregation, resource procurement, and resource stress.

Furthermore, most models posit test implications of logistical and residential sites solely based on the hunter-gatherer perspective, and make little or no distinction between non-agricultural and agricultural groups. In opposition to this perspective, it is maintained here that the resource structure and nature of the “base” residence of agricultural groups, as well as various forms of social organization reflected by aggregated settlements, differ fundamentally from hunter-gatherer groups, and therefore patterns of mobility and sedentism among agrarian societies cannot be understood using the ecological assumptions – nor the temporal and spatial frameworks – underlying hunter-gatherer models.

A general rule among such models is that, as the frequency of residential moves decreases (or, as residential duration and stability increase), the logistical procurement of both primary and critical subsistence resources will be increasingly emphasized. Variations of this model have been used to study hunter-gatherer groups in a multitude of environmental and temporal contexts. The majority of models in the southern Southwest – and particularly within the Jornada region – focus on residential sites of varying duration and intensity and are generally contingent upon a distinctive seasonal component that clearly falls within the hunter-gather cultural ecological paradigm (e.g., Anschuetz et al. 1990; Church and Sale 2003; Dering et al. 2001; Doleman et al. 1992; Ennes 1999; Hard 1983a; Mauldin 1986; Mauldin et al. 1998).

However, the structure of resource procurement differs among agrarian societies. Logistically organized tasks among hunter-gatherer groups serve to collect and transport both primary and auxiliary subsistence, production, and maintenance items to the base residence. In contrast, among agricultural groups it may be presumed that logistical procurement systems were not designed to collect and transport *primary* subsistence items, those items being the cultigens grown in prepared and maintained agricultural fields.

Moreover, unlike hunter-gatherer groups, the physical and social nature of agricultural settlements and land tenure would have imposed certain restrictions on the range of residential movements. Hunter-gather models are generally environmentally deterministic, where residential and logistical mobility are interpreted by reference to the temporal and spatial distribution of resources (although see Bender 1985; Wiessner 2002 for insights into social dynamics of hunter-gatherer groups).

Movement by agricultural groups, occurring under conditions of greater local population densities and restricted territorial ranges from extra regional population growth, would involve problems of land tenure (Adler 1996b; Kohler 1992; Varien 1999) and access to resources. Thus, movement of individual households, small groups, or larger communities in agricultural societies involves a distinctive social component. In addition, the construction of surface rooms and pueblo residences required a significant time and labor investment, thus further constraining the options for residential mobility among agriculturalists.

As noted by several researchers, the introduction and adoption of agriculture is thought to have provided greater control and predictability over the environment (Matson 1991; Minnis 1992; Wills 1988). Interestingly, in opposition to the somewhat greater control over food production, it is proposed here that the sedentary lifestyle actually entails less control over the immediate environment and local catchment areas when it comes to secondary and auxiliary resources (such as fauna, fuel and construction wood, wild subsistence and economic plants, sources of stone and clay, and other materials) due to the depletion of resources resulting from aggregated populations.

As agricultural settlements had a much more pronounced effects on local resource availability than mobile hunter-gatherer groups, the range of options to compensate for such effects utilizing strategies of residential mobility would have been more circumscribed. Therefore, it is probable that logistical forays would have involved increasingly wide procurement zones. Upon the initial occupation of a location by a large social group, many subsistence and economic items could be gathered within the general foraging radius of the site. Ongoing residential occupation would quickly reduce or deplete these local resources, requiring logistical procurement from more distant locations, with continued residential occupation resulting in logistical use of increasingly distant landscapes.

Last but not least, the utilitarian, social, and ritual aspects of puebloan lifeways required the use of a wide range of materials and items. Based on the variety of materials recovered from Jornada pueblo settlement – a list that minimally includes minerals, pigments, fossils, stone for grinding tools, and wood for construction beams – puebloan settlement and social adaptations required the employment of logistical procurement systems of equal or perhaps sometimes greater extent and frequency than many hunter-gatherer groups.

Historic Context: Extractive Technologies of the Late Formative Period in Multiple Landforms

Research Domains: Subsistence / Technology

There is substantial evidence that low-intensity logistical use of the alluvial fan, central basin, and mountain landforms occurred during the Late Formative period, but the nature of much of this logistical use remains speculative. The few features associated with this time period that have been investigated in the central basins have not been thoroughly described, so it is unknown whether substantial morphological differences exist among thermal features with earlier time periods. Formal rock-lined pit roasting facilities and large burned rock accumulations have been documented in alluvial fan contexts and mountain zones, but the nature of associated chipped stone, ground stone, and ceramic technologies are poorly understood.

The question of whether specific tool assemblages or morphological tool forms are associated with Late Formative period extractive tasks in the basin, fan, or mountain zones requires further investigation. In addition, technological data from ceramic samples may provide insight into the nature of resources collected in the basin and transported to residential sites along the alluvial fans and playa ridges bordering the central basin.

Analysis Requirements

- (1) Dateable features or contexts in association with statistically suitable samples of artifacts:
- (2) Integrated analysis of thermal features and technological analysis of associated tool assemblages (chipped stone, ground stone, ceramics)
- (3) Compilation of locational and distributional information on Late Formative material culture across the landscape.

Data Requirements / NRHP Eligibility Threshold

- (1) Suitable sample counts of artifacts for technological and compositional analysis in association with dateable features or contexts; and
- (2) Morphological data on dated thermal features (associated with artifacts).

Historic Context: Late Formative Period Logistic Exploitation of Multiple Landforms

Research Domains: Subsistence / Technology / Settlement Pattern

This is a broad context subsuming a wide range of logistical procurement behaviors and resultant site types across the major landforms of Fort Bliss. Many Late Formative period sites documented in these environmental zones are small, consisting of a few thermal features and low-density artifact scatter. These sites differ fundamentally from the large Formative period habitation sites found along the distal alluvial fans and margins of playas. In the central basins, analyses of radiocarbon dates and dated features have determined that, with the exception of landforms adjacent to the larger playas, residential settlement of the central basin essentially terminated at approximately A.D. 1000 (Miller 2002; Miller and Kenmotsu 2004). However, Late Formative period ceramic materials, projectile points, and scattered hearth dates indicate that Late Formative groups continued to pursue a logistical exploitation of the central basin (Mauldin 1996). The range of logistic forays and territorial catchment zones within the central basin may be examined through general geochemical analysis of El Paso brownware ceramics and raw material identification of projectile points.

As noted in the introduction to this series of historic contexts, there is clear and unequivocal evidence of multiple and extensive logistical procurement systems associated with sedentary settlements during the Late Formative period. However, the evidence is primarily based on the presence of materials such as minerals, fossils, and pigments observed at residential sites, or are based on landscape artifact distributions recorded during intensive surveys (that seldom form “sites” for review and treatment considerations). Little is known of the actual logistical procurement or settlement locations in most environmental zones.

Analysis Requirements

- (1) Features, artifact assemblages, or activity loci with good integrity;
- (2) Analysis of associated chipped stone and ground stone tool assemblages;
- (3) Technological data on El Paso brownware ceramics;
- (4) Geochemical characterization of ceramic materials.

Data Requirements / NRHP Eligibility Threshold

- (1) Presence of suitable sample counts of artifacts for technological and compositional analysis in association with a dateable context.

Historic Context: Late Formative Period Logistical Utilization of Mountain Environments

Research Domains: Subsistence / Technology / Settlement Pattern / Social, Ritual, Political Organization

Mountain and foothill landforms have seldom been impacted by military training at Fort Bliss, but the proposed expansion and diversification of training practices suggests that these landforms may be increasingly utilized. Few sites have been recorded in these landforms, but numerous types of logistical sites should be expected. More importantly, it is certain that several rare and unusual site types such as prehistoric mines and other procurement sites, as well as locations for ritual procurement or performance, were present in mountain settings. The ubiquitous presence of fossils and minerals obtained from mountain settings found in Late Formative pit house and pueblo settlements indicates that these upland regions were the subjects of frequent logistical trips.

Limonite and hematite pigment sources are known to exist in the Hueco, Franklin, Organ, and Jarilla mountains (Church et al. 1996), as are lithic procurement sites (Church et al. 1996; Knight and Miller 2003; Lukowski et al. 1999). Although hunting of medium- and large-sized game appears to have been limited during the Late Formative period, deer and other artiodactyl species were occasionally hunted. Logistical hunting camps should be present in mountain foothills and canyons.

The nature of Late Formative period logistical land use of upland zones is very poorly known. This is unfortunate, since settlements in this zone have several implications for understanding Late Formative subsistence practices, the procurement of wood, pigments, minerals, and other materials for both utilitarian and ritual purposes (and exchange of such materials through both local and extra-regional social networks), and perhaps a broader understanding of prehistoric ritual.

Analysis Requirements

- (1) Features, artifact assemblages, or activity loci with good integrity;
- (2) Analysis of associated chipped stone and ground stone tool assemblages;
- (3) Technological data on El Paso brownware ceramics;
- (4) Visual and/or geochemical characterization of pigment and mineral outcrops;
- (5) Description and analysis of prehistoric tools used for mineral extraction, wood procurement, or other activities.

Data Requirements / NRHP Eligibility Threshold

- (1) Presence of suitable sample counts of artifacts for technological and compositional analysis in association with a dateable context; or
- (2) Presence of prehistoric mining or extractive tools (axes, mauls, hammerstones, other battered stones); presence of ritual paraphernalia (ceramics, projectile points, wood items, pigments, fossils); or
- (3) Evidence of prehistoric mining or extraction activities such as adits or pits placed in mineral deposits as well as waste materials and debris.

As set forth in this chapter and Chapter 13, the NRHP eligibility of such sites should not be evaluated on the basis of their rarity or uniqueness. If a site of this type has chronometric data potential, integrity, and has data that can address this historic context, then it may be recommended as eligible for inclusion in the NRHP. If the site cannot be placed in a temporal context, is heavily damaged, or lacks sufficient assemblage data, it should be recommended as

ineligible. If determined eligible for inclusion in the NRHP, subsequent management and preservation decisions can take into account the rarity or special character of such sites.

Historic Context: Economic and Functional Role of Large Thermal Features in Late Formative Period Subsistence and Settlement Systems

Research Domains: Subsistence / Settlement Pattern / Technology

Large burned rock features are a common aspect of Late Formative period sites in alluvial fan environments throughout the Jornada region. Examination of radiocarbon age distributions has determined that these large burned-rock features associated with formally constructed, rock-lined pits or ovens became increasingly common during the Transitional period (A.D. 1000-1300) and continued to be used through the El Paso phase, albeit on a reduced scale. Analysis of flotation samples from fill contents of such features has identified the remains of over 20 plant species (Dering 2001; Miller 1989, 1990; Miller and Stuart 1991).

While leaf succulents have occasionally been identified, the preponderance of plant materials recovered from such features includes various cacti, mesquite, annual and perennial seeds, and even maize. The functional role of such features remains inconclusive; debate continues regarding whether the facilities were specialized ovens for processing succulents such as lechuguilla, sotol, and agave, or served multipurpose roles. In addition, the relationship of these features to nearby residential sites remains in question, given the fact that there is seldom an observed chronological overlap between residential structures and large thermal features at most sites.

Analysis Requirements

- (1) Subsistence analysis of organic and residue samples recovered from thermal features;
- (2) Analysis of feature morphology and rock weight;
- (3) Analysis of burned rock use attributes;
- (4) Analysis of associated tool assemblages;
- (5) Technological data on El Paso brownware ceramics.

Data Requirements / NRHP Eligibility Threshold

- (1) Presence of one or more large burned thermal features with suitable integrity for subsistence analysis; and
- (2) Suitable sample counts of artifacts in dateable contexts for technological and compositional analysis.

HISTORIC CONTEXTS FOR LATE FORMATIVE RESIDENTIAL SITES

The NRHP eligibility of Late Formative period residential sites is seldom the subject of debate or controversy. Such sites typically have excellent preservation of organic deposits and numerous contexts associated with multiple artifact classes, all of which have high sample numbers. Provided that the site has minimal integrity (i.e., it is not severely eroded or damaged), Late Formative period pit house and pueblo settlements have multiple data classes that can address multiple inter-related research domains. Late Doña Ana and El Paso phase villages can be evaluated under the wide range of Historic Contexts provided below.

Historic Context: Late Formative Period Settlement Responses to Environmental Risk - Architectural Form, Site Structure, and Implications for Settlement Pattern, Land Tenure, and Social Organization

Research Domains: Subsistence / Site Formation / Settlement Pattern / Social, Ritual, and Political Organization

Numerous studies of prehistoric population dynamics across the Southwest have observed or posited relationships between climatic variability, various forms of resource stress, and population aggregation, dispersion, or migration. The term *resource stress* includes not only various forms of resource depletion or exhaustion, but also problems of uncertainty, risk, and scheduling associated with resource procurement and agricultural production. Not all are specifically caused by population aggregation; however, all will exacerbate the structural problems associated with population aggregation.

Resource depletion and climatic variability would have been particularly pronounced in marginal environments such as the Jornada Mogollon, a region characterized by temporally and spatially variable, or “patchy”, seasonal rainfall. Spatial and temporal variability in precipitation regimes would have had serious effects on the timing and distribution of water resources available for domestic consumption and agricultural production, such as that available as runoff from alluvial fans or ponded within playas. Periods of decreased annual rainfall, combined with higher temperatures that would increase evaporation rates of ponded water accumulated within playas, would have added further stress to the El Paso phase settlement and subsistence system. Variable rainfall patterns would have also affected the overall biomass within a given location. Moreover, aggregated populations, such as would have been present within El Paso phase pueblos, would soon have exhausted local stores of critical resources such as fuel and construction wood (e.g., Dering 2001), subsistence, economic, and medicinal plants (Miller 1990), and certain fauna (Speth 1991).

The most prominent form of resource stress involves aspects of risk, uncertainty, and scheduling for agricultural production that arise from a particular set of environmental and ecological characteristic of playas and alluvial fan runoff zones. Another prominent form of resource depletion would have involved fuel and construction wood. Fuel wood consumption and exhaustion has been examined in both the context of agricultural groups (e.g., Kohler and Matthews 1988; Kohler et al. 1984; Varien 1999) and hunter-gatherers utilizing burned rock technology (Dering 1999b). When considering the fuel and construction wood requirements of corn boiling and other food preparation tasks, ceramic vessel firing, house construction, and for heating domiciles during the winter months, it becomes apparent that the fuel wood requirements of even a small pueblo population may rapidly exceed the carrying capacity of the local environment. For example, Kohler and others (1984) estimate that a five-person household in the Anasazi region would require over 6,000 kg of fuel wood on an annual basis. Clearly then, in semi-arid regions such as the southern Jornada, intensive use of wood combined with low biomass recovery rates would have resulted in a relatively rapid depletion of fuel sources within the vicinity of aggregated pueblo settlements. In a similar fashion, certain plants of subsistence or economic importance, various fauna, and other critical items would have been rapidly depleted in the vicinity of aggregated settlements.

Causal factors leading to patterns of population aggregation and dispersion, and how such prehistoric populations responded to resource stress, are important archaeological and anthropological topics. The archaeological record of the Late Formative period presents a highly variable assortment of settlement forms, including large, multi-room and plaza-oriented pueblos, numerous smaller pueblos of three to sixteen rooms, groups of surface rooms, and even isolated structures. These settlement forms may be viewed as responses to highly variable resource

distribution where aggregated pueblo populations often dispersed into smaller, more widely disseminated settlements. In addition, distributional studies of projectile points, ceramics, obsidian hydration dates, and radiocarbon dates provide clear evidence of extensive logistical landscape use across most topographic landforms.

The mosaic of Late Formative settlement forms is viewed as an adaptive social and economic response to the risk, uncertainty, and scheduling problems of agricultural production. Settlement strategies must have incorporated a substantial component of residential and logistical mobility to exploit locations where water was temporarily ponded within playas or where floodwaters could be captured along distal alluvial fan piedmonts. Intriguingly, these attributes closely match the characteristics of Late Formative settlements. The majority of agricultural settlements around fan-margin playas consist of small unit pueblos or clusters of non-contiguous surface rooms. Even individual pueblo room blocks show evidence of segmented construction histories that likely reflect intervals of population aggregation and dispersion. The widespread distribution of surface room clusters denotes more residentially mobile form of settlement that can be viewed as a response to the spatial and temporal variability in playa agricultural potential.

It is apparent that the social and cultural ecological aspects of this system were highly fluid, and the nature and timing of the periodic dispersions and aggregations remains open to investigation. Did groups disperse from central pueblo residences on a seasonal basis as suggested by Mauldin (1986), or on the basis of broader and more sporadic climatic patterns of precipitation and temperature? Or, can even longer periods of dispersion be detected where medium-sized and large-sized pueblos were abandoned for periods of years or decades in place of surface room sites and small unit pueblos occupied by “wandering agriculturalists” as described by Nelson and LeBlanc (1986: 250). Finally, at the other end of the spectrum, the possibility that surface rooms represent very short-term occupations as agricultural field houses deserves consideration.

The study of the social, political, and ritual aspects of the human groups who occupied the Jornada Mogollon region merits a renewed focus. Of particular interest, and wider relevance to current archaeological theory, is how social arrangements and political structures facilitated such fluid and dynamic settlement systems. Several aspects of Late Formative residential settlements provide insights into the social and political organization of prehistoric inhabitants. Sites with one or two structures often display an informal arrangement within a site and suggest multiple occupations of a particular location by small groups, or what may be referred to as locational stability and occupational instability (Horne 1993). In other cases, groups of two to five individual structures are formally arranged around an open space that could be considered an informal plaza or courtyard (Dering et al. 2001; Kegley 1980; Lukowski et al. 2006). Similar courtyard layouts in the Hohokam region are considered to represent residential aggregates linked by kinship (Doelle and Wallace 1991; Henderson 1987; Sires 1987; Wilcox et al. 1981). Larger groupings of several such house clusters are thought to represent suprahousehold units (Doelle et al. 1987; Howard 1985; Wilcox 1987).

These variations in architectural form and settlement structure provide interesting contrasts in social organization, particularly when considering the relationship between social and political structures and processes of social aggregation and dispersion. As population aggregation resulted in local resource depletion and stress, responses to compensate for resource stress may have included more wide-ranged logistical settlements at greater distances from primary settlements or dispersion of populations into smaller settlements. Each of these approaches involves differing processes of social and political organization. Moreover, issues of land tenure and territorial rights become increasingly pronounced during periods of greater residential mobility.

Accordingly, the social, political, and ritual dimensions to the study of Late Formative mobility, settlement structure, and resource stress may be examined through three dimensions. First is the

regional dimension involving the political and social structures among populations residing within different geographic areas of the Hueco Bolson and Tularosa Basin. Increasing population growth, combined with the continued need for residential and logistical mobility in times of resource stress, will result in potential tensions over land tenure. These conflicts will, in turn, result in either increasing cooperation or competition and conflict.

Specific social and political mechanisms were required to mediate and negotiate such conflicts and establish and maintain boundaries. Second is the intraregional dimension that involves social arrangements within aggregated pueblos and the maintenance of those ties during periods of population dispersal. Of interest here are the potential ritual or status systems that either encouraged or compelled group cohesion. Finally, the intrasite dimension is of interest. It is at this level that the smallest autonomous social and political units may be identified, whether they consist of extended families, economic household groups (after Netting et al. 1984), or kinship-based corporate groups. By isolating these basic social units, it may be possible to relate the processes by which these groups merged with larger aggregate populations at pueblos.

Analysis Requirements

- (1) Well-designed chronometric analyses to establish occupational histories of sites and contemporaneity of residential structures and activity areas;
- (2) Observations of pit house construction formality as evidence of group composition and settlement duration;
- (3) Comparative analysis of artifact densities as a measure of residential use intensity and duration using accumulations research models;
- (4) Comparative technological and functional data on ceramic and lithic materials;
- (5) Geochemical and petrographic analysis of ceramics and lithic raw material source identification to identify mobility ranges of inhabitants and relationship with other pueblo settlement areas in the region;
- (6) Analysis of tool variability between surface room and pueblo occupations to evaluate how the differing land use, mobility, and social arrangements of these settlements may have conditioned patterns of raw material use, tool form, and tool use intensity;
- (7) Analysis of indicators of resource stress in macrobotanical and faunal samples, as well as analysis of the proportions of different part and age classes representing heartwood, sapwood, and root in collections of mesquite wood fragments;
- (8) Evaluation of architectural forms and features under a coherent model to identify socially- integrative facilities such as communal houses;
- (9) Analysis of ceramic rim orifice diameters or vessel sizes to determine if bimodal distributions are present that may signify the presence of very large jar vessels used for fermentation as part of communal feasting rituals;

Data Requirements / NRHP Eligibility Threshold

- (1) Multiple contexts that can be dated chronometrically; and
- (2) Well-preserved architectural features in association with extramural activity space and other features; and
- (3) Artifact assemblages of sufficient counts and context for analysis of accumulations research models, technological organization, and chemical composition; and
- (4) Well-preserved organic deposits, faunal remains, and large wood charcoal fragments.

Historic Context: Subsistence and Mobility Implications of Isolated Structural Sites in Multiple Landforms

Research Domains: Subsistence / Settlement Pattern

Isolated house structures have been identified at a small yet significant number of sites. The presence of these features establishes several research questions. Some researchers have proposed that such features represent field houses (Batcho et al. 1985; Browning 1991; Browning et al. 1992). Isolated structures are sometimes found near burned rock roasting facilities and may represent logistical land use patterns related to larger residential settlements. It is likely that the large burned rock features mentioned in the preceding historic context may have been used for the bulk processing of plant materials prior to transport to a residential settlement. Another plausible interpretation is that isolated structural sites reflect differential mobility patterns, such as continual, long-term patterns of population dispersal and aggregation in response to fluctuating and 'patchy' precipitation regimes. As implied by these questions, regional knowledge of what these features and sites represent in terms of regional mobility and subsistence economies is limited.

Analysis Requirements

- (1) Analysis of the morphology and features of isolated structures (size, depth, shape, interior features);
- (2) Analysis of associated extramural features and contexts;
- (3) Analysis of associated assemblage data;
- (4) Accumulations research to examine duration of occupation;
- (5) Compositional data for ceramic assemblages to study vessel transport and group mobility.

Data Requirements / NRHP Eligibility Threshold

- (1) Presence of one or two isolated residential structures (hut, pit house, formal pit room) with acceptable integrity; and
- (2) Presence of associated artifacts in suitable sample numbers

Historic Context: Social, Ritual, and Economic Interaction Between Late Formative Period Societies of the Jornada and Adjacent Regions

Research Domains: Social, Ritual, and Political Organization

As noted in Chapter 12, the social, political, and ritual aspects of regional exchange and cultural interaction have been neglected. The nature of regional interaction during the Late Formative period has usually been phrased in terms of interaction spheres and regional systems (Schaafsma and Riley 1999). Opinions range from the Jornada Mogollon populations participating in peer-prestige or peer-polity exchange networks with adjacent regions (Bradley 1996, 1999, 2000) to more extreme views that the rise and fall of the Jornada Mogollon pueblo system was a direct result of the influence of the Casas Grandes regional system (Schaafsma 1979; Wimberly 1979).

The role of Medio period developments at Casas Grandes in the evolution of the El Paso phase pueblo system perhaps has been overstated, while in turn the roles of other regions such as the Chupadera Mesa and Middle Rio Grande Valley, the Western Mogollon, and the La Junta and greater Trans-Pecos, have been understated. For example, it is interesting to note that Chupadero Black-on-white ceramics far outnumber the amount of Chihuahuan Medio period polychromes present at El Paso phase pueblos.

The cultural and social role of the Jornada in Southwestern social and exchange networks has mostly been phrased in unilateral terms. That is, the Jornada has been viewed as a passive recipient of “influences” from Casas Grandes and other regions. A more expansive and realistic perspective would take into account how the Jornada region had a direct and significant contribution of its own on Southwestern social, economic, and ritual developments. Creel (1998) notes that the Jornada region was one of the more profound influences on post-Classic societies in the Mimbres Valley.

The Jornada region has been cited as one of the possible regions where the katchina religion arose during the thirteenth and fourteenth centuries (Adams 1991; Schaafsma 1981, 1992; Schaafsma and Schaafsma 1974). A more parsimonious conception of the inter-regional relationships does not view the Jornada Mogollon as some form of colonial outpost of the more archaeologically visible regions to the west and southwest, but involves a more balanced consideration taking into account regional scale, demographic change, land tenure and territoriality, and the social and ritual dimensions of reciprocal exchange relationships (Bradley 2000; Dering et al. 2001; Miller 2005a).

Several forms of material culture can provide insights into regional exchange relationships. Compositional analysis of obsidian and non-local ceramics, source identification of exotic stone and minerals such as turquoise, minerals, and pigments, and analysis of marine and freshwater shell can provide insights into the direction and magnitude of exchange relationships. Even seemingly mundane items such as avian eggshell may turn out to provide insights into possible aviculture for the production of feathers for exchange. Analysis of residues on the interiors of well-preserved ceramic jars (transport containers) may yield evidence of what organic material was being exchanged.

Several useful models have been proposed that may productively examine the exchange and distribution of status, prestige, and ritual materials across the Jornada, the southern Southwest, and southern Plains. These include peer-polity and prestige exchange systems (Bradley 2000; Whalen and Minnis 2001), ritual economies (Wells and Davis-Salazar 2007), boundary maintenance and identity (Duff 2002; Miller 2005a), social power (Douglas 2000; McGuire 1990); bride exchange and labor (Habicht-Mauche 2002); and economic buffering (Shafer 2003; Spielmann 1982, 1983).

Additionally, the exchange of utilitarian and subsistence goods played a major role in prehistoric economies. The Jornada was strategically positioned between several cultural and biotic regions: the Southwest, the southern Plains, and the La Junta/Rio Grande corridor. Salt, hides, agave, and a myriad of other materials were exchanged within and across the Jornada region. The role of turquoise mining at the Jarilla Mountains source deserves particular attention.

Analysis Requirements

- (1) Geochemical (preferably NAA) data on non-local ceramics and identification of production areas;
- (2) Geochemical analysis of turquoise (preferably Secondary Ion Mass Spectrometry), obsidian (X-ray Fluorescence),
- (3) Identification of species and habitat of marine shell;
- (4) Residue and use-wear analysis of ceramic containers to identify contents;
- (5) Greater attention paid to identification, sourcing, and consideration of miscellaneous exotic or unusual materials (pigments, unusual lithic material, minerals, fossils, freshwater shell, turkey eggshell);
- (6) Incorporation of models and analysis methods to better evaluate and interpret these data.

Data Requirements / NRHP Eligibility Threshold

- (5) Statistically robust samples from secure contexts of non-local ceramics from general culture regions (e.g., Casas Grandes, western Mogollon, Chupadera Mesa); or
- (6) Samples of turquoise (finished items or manufacturing debris); or
- (7) Obsidian artifacts from secure contexts, or
- (8) Statistically robust samples from secure contexts of marine shell; or
- (9) Large sherds from non-local vessels in well-preserved contexts; or
- (10) Unusual, exotic, or rare items of mineral, pigment, stone, fossil, or other items.

**Historic Context: Ritual Performance and Social Organization Among
Late Formative Period Populations**

Research Domains: Social, Ritual, and Political Organization

Aspects of ritual performance and prehistoric ideology and cosmology are poorly known in the Jornada region. This is somewhat perplexing given the widespread evidence for ritual and religious expression throughout the region at such sites as Ceremonial Cave and Feather Cave and the extensive rock art complexes at Hueco Tanks, Three Rivers, Alamo Mountain, and Alamo Canyon/Wilkey Ranch. Additional evidence of ritual is evident in the interior floor features in Room 1 at Hot Well Pueblo that are oriented to align with the vernal equinox (Brook 1979b). Even the near universal 13 to 20 degree east/west offset of Late Doña Ana and El Paso phase houses belies a cosmological basis in site layout.

It is unrealistic to expect that prehistoric ritual and religion can be completely reconstructed on the basis of fragmentary and frequently ambiguous archaeological data. Nevertheless, important insights into generalized religious practice and ideology may be gleaned from several classes of material culture common to the Jornada region. Moreover, the role of ideology and ritual in social production may be examined, including the manner in which religion, ritual, and ideology served to integrate, establish, and maintain particular social structures.

A variety of research questions may be examined in the Jornada region. Does the increasingly elaborate Late Formative period rock art reflect a more complex ideology? Does the appearance of mask (possible katchina) iconography during the twelfth or thirteenth century mirror similar processes in other regions and reflect social responses to demographic and economic upheavals across the greater Southwest? Can the appearance of mask or katchina imagery on rock art or ceramic media be dated with greater accuracy? Can evidence for shamanic specialists and rituals be detected in the archaeological record by identifying certain artifact types or plant remains associated with healing, divination, or ensuring sufficient rainfall? Can evidence for communal and socially-integrative rituals be detected, such as the presence of integrative architecture or artifacts and food remains associated with feasting or corn beer production?

A greater interpretive focus on rock art and ceramic design is required. Additionally, greater attention should be paid to the study of seemingly mundane objects such as fossils, minerals, pigments, stone balls, unusual plant or animal remains, and other unusual artifacts. Grooved quartz crystals are commonly recovered from El Paso phase pueblo settlements. These have occasionally been considered as items of personal adornment, but a closer examination of context finds that many are from ritual contexts and caches. Grooved quartz crystals are widely known for use as “lightning stone” to strike sparks, thus recreating lightning, during kiva ceremonies (Ortiz 1969; Parsons 1939). Fossils and minerals such as selenite (gypsum) and talc are very common at Late Formative period settlements and may have been thought to have medicinal and healing qualities.

Unusual plant remains, particularly of plants with psychotropic properties such as *Ipomoea* sp. (morning glory) and *Datura* sp. (Jimson weed), should be examined. *Datura* pollen and seeds have been recovered from several sites in the Mimbres, western Mogollon, and Anasazi regions, and distinctive “knobby” ceramic vessels thought to represent *Datura* seed pods are common throughout the Southwest and western Mexico (Huckell and VanPool 2006). No *datura* remains have been recognized from the Jornada, but morning glory seeds have been recovered from a Mesilla phase pit house north of Las Cruces (Miller and Stuart 1991).

While the Mesilla phase is earlier than the time period of the current historic context, the finding of these seeds suggests that they were used prehistorically (as well as the fact that ritual use of morning glory may have occurred during the Mesilla phase). Analysis of pollen samples from well-preserved ritual contexts may identify pollen remains of plants commonly used in ritual. Certain artifact types will also provided indirect evidence of ritual plant use. For example, the somewhat common finding of ceramic and stone pipes at Late Formative period settlements (Hunter 1988; Lehmer 1948) provides indirect evidence of tobacco use during this time. Tobacco was widely used in shamanic rituals (VanPool 2003).

Shamanic healing and leadership rituals undoubtedly existed during the Late Formative period. They were surely present during earlier times as well, but aside from rock art the evidence of shamanic practice during Archaic and Early Formative times is much more subtle, dispersed, ambiguous, or missing altogether from the archaeological record. Shamans in Late Formative period Jornada societies were probably low-level specialists in healing, divining, communing with ancestral spirits, and rainfall rituals. However, the potential for utilizing shamanic power as a means of establishing and legitimizing leadership roles (VanPool 2003; VanPool and VanPool 2007) merits further consideration.

The combined and cumulative effects of ritual practice on regional economies, social organization, and landscape use merits closer investigation. Numerous accounts of historic Southwest puebloan groups mention the presence of ritual and sacred hills, springs, caves, mountains, plant gathering locations, and other locations of spiritual or cultural memory (Ferguson 2007; Ortiz 1969; Parsons 1939). Zuni oral histories recount the common use of shrines on mountaintops and springs (Ferguson 2007; Ladd 1983).

Archaeological investigations have verified the presence of such shrines throughout the Mogollon region (Greenwood and White 1970; Morris 1982), some of which continue to be used in the present time (Ferguson 2007). The shrines contain ceramics, beads, sherd disks, effigies, projectile points, and turquoise mosaic items (Morris 1982). Ceremonial Cave and other caves in the vicinity of Fort Bliss have unmistakable evidence of ritual use (Alvarez and Leach 1997; Cosgrove 1947; Creel 1997; Ellis and Hammack 1968). Several caches of small ceramic vessels, fossils, and other ritual items have been recovered from hilltops in the Jornada area (Achim 1984), including the small sand hills just south of Maneuver Area 1 (Hedrick 1997; Moore and Wheat 1951). These types of sites show that specific locations across the landscape were used for ritual performance and religious pilgrimages, and that many such sites do not fit the traditional definition of “site.”

Analysis Requirements

- (1) Identification and detailed analysis (including ethnographic and ethnohistoric research) of minerals, fossils, and pigments;
- (2) Identification and analysis of potential ritual contexts and deposits;
- (3) Analysis of iconographic and ideological aspects of regional artistic traditions (rock art, ceramic, lapidary);

- (4) Analysis of pollen and macrobotanical samples from ritual contexts and deposits with greater attention paid to the potential ritual use of rare or unusual plant and animal remains;
- (5) Analysis of unusual artifacts;
- (6) Analysis of ceramics and midden formation for evidence of feasting or corn beer production;
- (7) Analysis of the contents of caches or deposits of ritual paraphernalia;
- (8) Analysis of ritually and socially-integrative architectural structures;
- (9) Incorporation of models and analysis methods to better evaluate and interpret these data.

Data Requirements / NRHP Eligibility Threshold

- (1) Ritual contexts and deposits (caches, subfloor pits, special areas in rooms or sites); or
- (2) Unusual and rare artifacts such as fossils, minerals, and pigments; or
- (3) Rock art, ceramics, or other media with unequivocal evidence of ritual imagery; or
- (4) Features, architectural forms, or other constructions indicating ritual use; or
- (5) Evidence of shrines and other ritual use of certain landforms such as springs, hill and mountain tops, and rock shelters.

Historic Context: Late Formative Period Subsistence and Subsistence Economies

Research Domains: Subsistence / Technology

As with other temporal periods, the nature of the subsistence base and economy of Late Formative period populations has long been a subject of inquiry. Despite this emphasis, surprisingly few detailed analyses of plant and animal remains have been reported, although this situation is beginning to change with the recent publication of several large-scale macrobotanical and faunal studies. Basic inventories of plant and animal species are useful, but more targeted and question-oriented research should be considered. This involves larger views of subsistence practice, including technologies and other aspects of plant and animal use in prehistoric economies.

First of all, an important aspect of El Paso phase settlement adaptations lies in assessing the degree of reliance on cultivated as opposed to wild or non-domesticated plants. Observed changes in architectural complexity and formality, combined with the location of Late Formative period settlements in relation to topographic zones with nearby water sources, have been cited as evidence of increasing agricultural dependence and reduced settlement mobility during the Late Doña Ana and El Paso phases (Carmichael 1983, 1986a; Lehmer 1948; Whalen 1977, 1978). Miller and Kenmotsu (2004) have summarized the results of a quantitative analysis of over 700 flotation samples from Formative period settlements. A noticeable decrease in cacti and other wild plant species is evident during the El Paso phase. This observation, combined with a drastic reduction in burned rock roasting features, indicates that not only were El Paso phase populations increasingly dependent on agricultural production, but that they also had become increasingly specialized (Miller 2005d). This model is based primarily on data from the basin and alluvial fan landforms of the Hueco Bolson and the Tularosa and Mesilla basins; additional data is needed to determine if similar trends in subsistence and cookstone technology exist in the upland environments of the Sacramento and Guadalupe mountains.

Perhaps the most pressing issue involving the current understanding of Late Formative period subsistence is the lack of information concerning the variety and amount of fauna exploited during these periods. An increasing number of faunal studies have been reported, especially from Early and Late Doña Ana phase occupations (Kenmotsu et al. 2008; Lukowski et al. 2006; Miller 1989, 1990; O'Laughlin 2002). Yet, despite the extensive amount of excavations at El Paso phase pueblos, detailed analyses of faunal assemblages are limited to three pueblos: La Cabrana

(Bradley 1983; Foster et al. 1981), and Hot Well and Sgt. Doyle (O’Laughlin 2005b). Interestingly, faunal remains appear to be relatively rare at El Paso phase surface room components (Browning et al. 1992; Presley and Shaffer 2001), but whether this is due to a decreased emphasis on hunting at this type of settlement or because of poor preservation remains open to question.

Common among all these settlements is the predominance of lagomorph (rabbit) remains (*Lepus californicus* and *Sylvilagus audobonii*), a pattern similar to that of the preceding Mesilla and Early Doña Ana phases. Larger game animals such as deer, antelope, and occasionally bison are present, but occur in relatively small numbers compared to lagomorphs. Yet, a targeted research issue revolves around the relative importance of artiodactyl and other medium-large game animals in Late Formative subsistence economies.

Data from the lowland Jornada should be contrasted against faunal collections from the Sierra Blanca, Capitan, and Pecos Valley regions (Del Bene et al. 1986; Driver 1985; Farwell et al. 1992; Speth and Scott 1985a), with particular attention focused on medium-sized and large-sized mammal remains as indicators of highland versus lowland hunting practices and changing procurement practices involving small and large game animals (Speth and Scott 1985b). Differences in highland and lowland hunting practices may be examined, as well as issues of environmental change, resource exhaustion, and different exploitation patterns of environmental niches such as documented in the Mimbres and Hohokam regions during the Classic and Post-Classic periods (Nelson and Diehl 1999; Sanchez 1996; Shaffer 1991; Szuter and Gillespie 1994).

An issue indirectly related to subsistence practices but having direct and profound implications for resource exploitation and exhaustion involves the procurement and use of fuel wood. Dering (2001) conducted an intriguing study to examine patterns of mesquite fuel wood use and resource stress. During the analysis of wood charcoal samples, he differentiated samples representing heartwood, sapwood, and root. Heartwood is present in older parts of the plant. Therefore, higher proportions of heartwood and root versus sapwood or transitional pieces would indicate procurement of more difficult to collect pieces and, by extension, could be used to infer resource stress involving fuel wood procurement. Dering identified higher proportions of heartwood in samples from El Paso phase contexts in the Loop 375 project area of the Hueco Bolson.

Non-food uses of plants and animals should also be considered. The use of certain plants and animals for medicinal, hallucinogenic, and other ritual or social functions deserves more attention. Unfortunately, the use of plants in ritual activities may not have involved exposure to fire, and often may have taken place in special locations, and thus remains will not be found in the archeological record. *Datura* (*Datura* spp.) seeds have been recovered from several sites in the Southwest (Huckell and VanPool 2006) and indirect evidence of tobacco use is provided by the recovery of ceramic and stone pipes from pueblos in the Jornada region (Lehmer 1948). Ritual or other unusual contexts should receive closer examination. Corn pollen is frequently used in rituals. The possibility of aviculture, particularly the raising of turkeys for production of feathers, should be considered.

Analysis Needs:

- (1) standard macrobotanical, pollen, residue, and faunal analyses
- (2) comparative quantitative analysis of leporid/artiodactyl proportions and attributes of medium and large game remains (e.g., skeletal elements present, butchering marks)
- (3) analysis of fuel wood species and attributes
- (4) analysis of special plant and animal remains, turkey eggshell and bones (if present), pollen analysis of sediments from ritual or unusual contexts
- (5) analysis of residues on the interiors of ceramic vessels

Data Requirements / NRHP Eligibility Threshold

- (1) well-preserved faunal remains in midden contexts; or
- (2) well-preserved wood collections of sufficient size for species and identification of heartwood and sapwood; or
- (3) presence of eggshell, special ritual contexts, or other contexts, items, or organic residues indicating the presence of plant or animal remains that were not used for food.

Historic Context: Late Formative Period Technologies

Research Domains: Technology

Despite the number and extent of excavations conducted at Late Doña Ana phase and El Paso phase residential settlements, the nature of ceramic, chipped stone, and ground stone technologies is very poorly known. Few analyses of chipped stone have been reported. Likewise, few ground stone assemblages have been reviewed beyond basic typological descriptions. The study of indigenous ceramic technologies has fared slightly better through technological analyses of vessel form and manufacturing methods. Some classes of material culture, particularly ground stone, ceramics, and burned rock thermal features, have been used mainly as proxy measures to monitor and infer broad-scale diachronic changes in subsistence practices (e.g., Calamia 1991; Hard et al. 1994; Hard et al. 1996; Miller 2002). Several of these studies propose distinct correlations between technological changes in material culture and changing subsistence economies in terms of increasing agricultural production.

Some aspects of technological adaptations, such as chipped stone, do not appear to indicate a major departure from preceding Formative period phases (Mesilla and Early Doña Ana). Surprisingly, based on the few available studies it does not appear that a major shift in technological organization occurred from preceding phases in terms of raw material procurement and reduction, nor in the range and types of tools produced. Informal core technologies and the production of informal flake tools remain dominant and exploitation of coarse-grained rhyolites, quartzites, and cherts from local valley terrace and alluvial gravel sources continued to provide the majority of raw materials. However, there are too few studies of tools forms to determine whether changes in tool use occurred during these periods.

General long-term trends in ground stone manufacture and use are known as a result of several studies (Calamia 1991; Hard et al. 1996; Mauldin 1995; Mauldin et al. 1998). Large, two-hand manos and trough metates have been reported as the most prevalent ground-stone artifacts of the Late Formative period. As reported in the study by Hard and others (1996), ground-stone manos and metates from El Paso phase settlements continue a trend toward increasing size over earlier periods, a pattern interpreted as reflecting the intensive processing requirements of corn. However, preliminary analysis of the ground-stone assemblage from Madera Quemada Pueblo (Miller and Burt, in prep) has identified a generally low intensity pattern of use among the forms and surfaces of the grinding tools at this site. Contrary to earlier statements regarding the presence of trough metates, the majority of metate forms at Madera Quemada Pueblo were the less intensively utilized and maintained basin forms. While by no means an expediently oriented technology, the ground stone assemblage at this pueblo does not resemble the intensive food processing tools of more intensively occupied Southwestern pueblos. Additionally, there is a combination of greater diversity (richness) of types and multiple uses and recycling patterns. Part of the organization of ground stone technology identified in prehistoric pueblo settlements reflects the broader ritual and political economy, including lapidary industries, production of pigments, and other materials.

The local El Paso brownware ceramic sequence undergoes several changes – some clearly evident and some rather subtle - during the El Paso phase (Perttula et al. 1995; Whalen 1981).

The shift to necked jar forms begun in the preceding Late Doña Ana phase is completed. Neckless jar (*tecomate*) and short-necked jar forms are replaced entirely by necked jars with everted rims. It has been suggested that this shift has to do with greater containment security afforded by necked forms for processing corn (Hard et al. 1994 and Seaman and Mills 1988; each citing Braun 1983), although a combined technical factor of facilitating ease of vessel transport may also be suggested.

Examination of temper quantities and qualities offer additional insights into the changing functions of El Paso brownware vessels. Whalen (1994a) has suggested that increasing densities and sizes of temper grains observed at Late Mesilla versus Early Mesilla components indicates that vessels were being manufactured with greater emphasis on thermal resistance (presumably reflecting a need for increased heat and time required to boil corn). In contrast, Miller and Burt's (2007) analysis of temper and compositional attributes of Mesilla phase brownware assemblages suggest the ceramic vessels were designed to function as portable and durable container and cooking tools. Production decisions and temper selection by Mesilla phase potters were designed to satisfy both the requirements for strong vessels that could be moved from site to site in addition to having moderate resistance to thermal fatigue from cooking and boiling.

Technology is not limited to the three classes of material culture described above. Additional technologies of interest include burned rock thermal features, storage and trash disposal facilities, water and soil control and management technologies, and lapidary and other productions associated with ritual and status.

An often-overlooked aspect in the traditional focus on pueblo habitation sites of this period concerns non-residential sites or short-term residence sites with special processing facilities. Radiocarbon ages from several burned rock features fall within the A.D. 1200-1400 period, indicating that these features offered a contribution to subsistence base even during presumably agricultural periods. Nevertheless, use of the features, and by extension bulk processing of cacti, succulents, or other subsistence practices associated with these features appear to have been substantially reduced during the El Paso phase in comparison to earlier periods (Mauldin et al. 1998; Miller and Kenmotsu 2004).

Extramural excavations at Late Formative period settlements have consistently encountered pits of various dimensions, sizes, and content (Bradley 1983; Lowry 2005; O'Laughlin 2001). It is presumed that the larger and more irregular of such features were adobe borrow pits subsequently used as trash disposal areas (e.g. Carmichael 1983). However, smaller and more symmetrically shaped pits have also been documented, suggesting the presence of storage facilities. Storage is an important consideration for issues of mobility, subsistence, and seasonality (Whalen 1994b). Analysis of storage features should include descriptive information on morphology and volume, as well as potential pollen analysis and other studies that may yield information on the past contents of the facilities. The specific role of such features remains unknown, especially since they were often used as refuse disposal areas.

Another noteworthy technological innovation of the Late Formative period involves the construction and maintenance of water and soil control features. Foremost among such features is the reservoir documented at Hot Well Pueblo (Bentley 1993; Scarborough 1988). The potential for intensive agricultural features should not be ruled out. Additional examples of water control features, as well as terraces, check dams, and other form of water and soil control features undoubtedly exist throughout the region.

Shell, turquoise, minerals, carved stone objects, and crystals are commonly recovered from El Paso phase pueblos, including floor contexts and occasional subfloor caches (Bradley 1983; Lehmer 1948; Lowry 2005; Moore 1947). Palette fragments with mineral residues have been recovered, suggesting the preparation of pigments for ceramic decoration and perhaps personal

adornment. Shell items usually represent trade materials used for jewelry and personal adornment.

An interesting question involves whether turquoise mined from sources in the Jarilla Mountains was manufactured into pendants and *tesserae* (flat square pieces used in mosaics) for export, or if raw turquoise was exported. The latter case seems to hold true, since evidence of large scale turquoise finishing is nonexistent in the northern Jornada region, although recent findings of extensive turquoise workshops near Villa Ahumada (Maxwell and Cruz Antillon 2008) need to be incorporated into any consideration of regional turquoise exchange. This has important implications for the nature or viability of current peer-prestige exchange models between the Jornada and Casas Grandes regions (Bradley 1999, 2000).

Analysis Needs:

- (1) quantitative analysis of technological, morphological, and functional attributes of chipped stone assemblages, including tool form and reduction sequence;
- (2) quantitative analysis of technological, morphological, and functional attributes of ground stone assemblages, including tool form and use intensity;
- (3) quantitative analysis of technological, morphological, and functional attributes of ceramic assemblages, including vessel form and size, temper, manufacturing attributes, and compositional analysis;
- (4) analysis of burned rock earth oven technology;
- (5) analysis of morphology, content, distributions, and use of storage facilities;
- (6) identification and analysis of water and soil control features;
- (7) identification of lapidary industries.

Data Requirements / NRHP Eligibility Threshold

- (1) chipped stone assemblages of sufficient counts and spatial integrity; or
- (2) ceramic assemblages of sufficient counts and spatial integrity; or
- (3) ground stone assemblages of sufficient counts and spatial integrity (including sufficient numbers of whole specimens); or
- (4) presence of well-preserved burned rock earth ovens with associated organic deposits and artifact assemblages; or
- (5) presence of storage facilities; or
- (6) presence of water or soil control features; or
- (7) evidence of lapidary industries (note: evidence of manufacture, not just presence of finished items)

CHAPTER 15. IMPLEMENTING THE SIGNIFICANCE AND RESEARCH STANDARDS AND A PROGRAMMATIC DESIGN OF RESEARCH

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As discussed in Chapter 1, the purpose of this document has been to broadly identify aspects of the Fort Bliss archaeological record that are of scientific interest, and then to detail the types of data necessary to pursue those lines of inquiry during NRHP evaluation programs and data recovery excavations. This document is significantly revised from the original *Significance Standards* published in 1996. The revisions reflect new data that have been revealed in the years since the original document was published, as well as an expanded theoretical perspective that is applicable to the archaeological record at Fort Bliss and elsewhere in the Southwest. The revised *Significance and Research Standards* are intended to balance scientific goals with the practicalities of managing non-renewable cultural resources. At Fort Bliss, such balancing requires resource managers to make difficult decisions about how to allocate limited personnel and budgets so that the primary mission of the post - maintaining military readiness - is not compromised, while simultaneously minimizing adverse impacts to the archaeological record.

It must be emphasized that the research domains in Parts II and III of the revised *Significance and Research Standards* are merely tools used to obtain information pertinent to one or more historic contexts. Alone, they cannot be used as a determinant of NRHP eligibility. For this purpose, the necessary complement to the research design is the historic context. This is to say, while a research design may identify site type X as a data set needed to further scientific understanding of the regional prehistory, it is the historic context that must calibrate the value of a single X site (or hundreds of X sites) in terms of significance and NRHP eligibility.

It is axiomatic that all archaeological sites have some data content, and thus some inherent research value. Whether or not some sites produce a more minimal and threadbare form of “research value” that results in redundantly trivial interpretations is a question archaeologists and cultural resource managers have been debating for many years. We have attempted to develop a more reasoned, forthright, and defensible position on this issue in several of the preceding discussions of Chapters 13 and 14. The new procedures establish a more reasonable conceptual and procedural platform for NRHP eligibility evaluations and CRM management decisions. This is needed because federal laws provide for preservation of archaeological sites only if they meet explicit significance criteria. Any sites that do not meet those criteria are not subject to protection. There are no shades of gray provided by the law; each site is either significant and worthy of protection, or is not significant and is not afforded protection. Typically, the most intensive process in CRM is the initial cycle where a site is identified and evaluated for significance. During this process, each site is assumed to be potentially significant, and is afforded protection, until such time that lack of significance can be demonstrated.

At its core, the research framework has consisted of:

- (1) identification of a set of important regional geoarchaeological, archaeological, and anthropological issues that are currently poorly understood and merit future research;
- (2) identification of currently feasible and appropriate historic contexts to pursue those issues; and

- (3) enumeration of the data requirements necessary to satisfactorily address the historic contexts and evaluate the NRHP eligibility of prehistoric sites at Fort Bliss.

We have designed a research framework that will permit significance evaluations for both known and undiscovered archaeological sites. From a management perspective, two sets of archaeological resources exist at Fort Bliss: (1) sites already on record as a result of previous inventories; and (2) sites not yet discovered. A subset of the first category consists of previously recorded archaeological phenomena that, due to changing methodologies and definitions, were never formally designated as "sites." Depending on which of the many previous inventory projects are used, approximately 40-50 percent of the maneuver and training areas has been archaeologically surveyed, resulting in the identification of about 18,000 prehistoric sites.

In the 1996 *Significance Standards* document, it was noted that the sample of surveyed sites was heavily biased toward the interior basin landform of the Tularosa Basin and Hueco Bolson. This landform continues to contain the majority of prehistoric sites recorded at Fort Bliss, and it is almost certain that this fact will remain unchanged. The combination of geomorphic and cultural factors simply results in a much greater number and density of prehistoric sites in the central basins compared to the alluvial fan, foothill, mountain, and Otero Mesa topographic zones. The central basins were utilized by mobile hunter-gatherer and horticultural groups for over ten millennia, resulting in extensive landscape distributions of thousands of hearth features and artifacts. Instead of being buried, these prehistoric cultural landscapes, or portions of them, are continually being exposed by erosion of eolian sediments throughout the basins.

In recent years, however, the survey focus has shifted to new training areas in the Doña Ana Firing Ranges of the Organ Mountain alluvial fans, the Forward Area Weapons (FAW) corridors in the Hueco Mountains, and several large-scale training facilities and sample surveys across McGregor Range. Forest conservation requirements have also led to surveys of the upland environments of the northernmost reaches of McGregor Range along the Sacramento Mountains escarpment (Knight and Miller 2003). These surveys have provided a much greater amount of survey coverage of the alluvial fans, mountain foothill, and mountain zones of the Sacramento, Organ, and Hueco mountains. As a result of the survey work conducted during the past five years, a site sample that is more - although still not entirely - representative of the variability of prehistoric occupation and land use across Fort Bliss has been obtained.

These surveys have also resulted in a drastic increase in site counts. A simple extrapolation of these data suggests that there may be an as many as 10,000-20,000 additional sites not yet documented among the unsurveyed areas of Fort Bliss. Moreover, the projected construction within Maneuver Area 1 in Texas has required a complete TRU survey of the remaining undisturbed lands between the existing cantonment areas and Loop 375. These surveys, several of which are in progress in 2007, have resulted in the documentation of nearly 200 previously and newly identified sites. It is clear that over the past decade the Fort Bliss Environmental Division has initiated projects that greatly increase the numbers of acres surveyed and the numbers of sites evaluated in an effort to reduce the numbers of unevaluated resources. Therefore, NRHP evaluations of previously recorded and newly discovered archaeological sites will continue for several years.

Yet, as noted in Chapter 1, an important consideration for the current revision and update of the *Significance Standards* is that Fort Bliss is approaching a new phase in the management and treatment of prehistoric cultural resources. The focus of archaeological resource management and research is increasingly turning toward intensive data recovery programs to mitigate the adverse effects of military training activities. Many of the current projects are driven by specific military projects and actions in support of the current expansion of the military mission at Fort

Bliss and proposed transfer of over 20,000 troops to the base as part of recent decisions guided by BRAC.

The revised and updated *Significance and Research Standards* have been tailored to provide a stronger focus on research issues for the design and conduct of mitigation programs. This shift in emphasis toward mitigation prompted the addition of new research dimensions and analysis methods to the current study, as well as a greater appreciation of programmatic and thematic research programs beyond the more site specific research directions driven by eligibility evaluation programs.

THE SIGNIFICANCE AND RESEARCH STANDARDS AS A TOOL FOR ELIGIBILITY EVALUATION AND THE DESIGN OF RESEARCH

This final section of the document outlines the implementation procedures and anticipated problems that may arise for the NRHP evaluation program. In addition, as Fort Bliss increasingly satisfies its Section 110 responsibilities for inventory and evaluation, it will move toward management and treatment of historic properties as part of Section 106 compliance brought about by the increasing number of military undertakings proposed for the coming decade. As a result of this new emphasis, the final summary chapter includes the next stage in the evaluation and treatment of cultural resources – namely, the development of programmatic approaches for the design and implementation of data recovery excavations.

The implementation of the NRHP evaluation procedure is reviewed first. This includes a discussion of several potential training, methodological, and management issues that may be anticipated during its implementation. The effects of geomorphic biases as well as those resulting from the varying intensities of previous surveys are discussed, and the implications these have on observations and assessments of site size and site data content are reviewed. Procedures such as increased subsurface testing designed to reduce the effects of such problems are presented.

The discussion then turns to the future of archaeological data recovery investigations. First and foremost in this regard is the development and implementation of programmatic research designs. It is important to understand that the programmatic research designs are a direct outgrowth of the historic contexts presented in Chapter 14 and are based on the problem statements, analysis requirements, and data needs of individual historic contexts. The guiding philosophical and management vision is that this approach offers a consistent means of unifying the research program at Fort Bliss. This approach will also encourage consistent data collection, analysis, documentation, and reporting procedures so that the results of multiple mitigation projects can be compiled and synthesized. During the following decade, Fort Bliss will increasingly encourage and mandate the design and use of programmatic research designs as part of broad mitigation strategies across the base.

Additional topics covered in the mitigation section include a review of the consensus recommendations for the analysis of material culture developed at the roundtable discussions attended by Fort Bliss CRM managers and contractors. Finally, the issue of sampling strategies for mitigation and analysis of material culture is reviewed.

IMPLEMENTATION OF THE NRHP ELIGIBILITY EVALUATION PROCEDURE: PROSPECTS, PROBLEMS, AND SOLUTIONS

For archaeologists and cultural resource managers to effectively implement the NRHP evaluation procedure, it is essential that the overarching conceptual and philosophical basis of the research program be kept in mind. The NRHP evaluation procedure is, after all, based on the nature of the

archaeological record at Fort Bliss and the greater Jornada Mogollon region and the research themes that may be investigated with that record.

While the research domains and historic contexts are bound within phases and by specific landforms, and are therefore generally synchronic in design and scope, they are truly intended to articulate with broader diachronic research issues at multiple landscape scales. Considerations of site eligibility have been moved beyond the scale of the individual “site” to include broader temporal and geographic scales. Yet the danger persists that, as with numeric ranking systems, the current process can also become formulaic.

CRM archaeology requires a focus on sites as units of management, often without regard for other interesting or scientifically fruitful scales of focus. However, contemporaneous sites do not exist in isolation from one another; rather they co-exist in cultural settlement systems. Arguably, it is the settlement system, of which sites are merely components that should be observed and evaluated. By way of illustration, current thought in the population biology of threatened and endangered species suggests that awareness and protection of ecosystems is as important as is the physical protection of the species itself. Using this analogy, understanding cultural settlement systems is as important as understanding individual sites. This perspective must be kept in mind while using the historic contexts and research domains.

The true design and intent of the current procedure is to consider the implications of a site in relation to an historic context for purposes of NRHP eligibility and within the broader patterns of prehistory across time and space. For example, rather than viewing a terminal Late Archaic assemblage of chipped stone tools and debitage simply in terms of how the materials relate to technological and settlement organization of this period, the broader implications of this single site should also be considered. How does the raw material variation among discarded and refurbished tools and debitage demonstrate practices of “gearing up” for logistically-organized artiodactyl hunting practices? How do differences in the variety and geographic range of raw materials at the site compare to sites of the following early Mesilla phase, and how does this reflect changing hunting practices? How do changing hunting practices reflect changing artiodactyl populations and, in turn, how do these changes reflect the larger environmental, climatic, and demographic changes occurring across the southern Southwest and southern Plains during this period?

A second overarching issue refers to the *more = better* equation that often underlies NRHP eligibility evaluation programs. To assess research potential, and ultimately significance and NRHP eligibility, each prehistoric site at Fort Bliss must be matched against the analysis requirements and data needs of the historic contexts provided in Chapter 14. In general, a site with more data sets has greater overall research potential than another site with fewer data sets. To understand this, one only has to compare the wide variety of subsistence, settlement pattern, technological, and social/ritual research issues that can be investigated with the varied data sets obtained from excavation of an El Paso phase pueblo as opposed to the much more restricted number of research topics that can be addressed with a small collection of chipped stone around a Late Archaic hearth feature.

This does not necessarily mean that the El Paso phase pueblo, nor any single one of its suite of research issues, is inherently more important than the research issue pertaining to the Late Archaic site. The archaeological problem of Late Archaic settlement organization and chipped stone technological organization is of equal status with the research issue of El Paso phase chipped stone technological organization. Accordingly, each site deserves equal consideration for NRHP eligibility. Yet, the fact that the pueblo may address many more research issues is a factor that needs to be considered during consultations on the management and treatment of these two site types. If it comes to a decision on which site to protect and preserve, it is clear that the

pueblo with its much broader relevance to anthropological and archaeological inquiry should be favored.

Nevertheless, there exists a valid concern among regional archaeologists that a simplistic application of the equation *more = better* can introduce a bias against small sites and sparse sites. Indeed, most archaeologists are aware that careful investigation of a well preserved, single occupation site with sparse cultural remains can yield more important archaeological knowledge than a similar investigation of a poorly preserved or vertically collapsed site with hundreds of artifacts.

The current evaluation procedure considerably reduces the effects of this problem. The new program does establish minimal threshold artifact sample sizes. The analysis requirements and data needs of some historic contexts require more substantial artifact counts than the minimum count of 30. Overall, however, the NRHP eligibility of a site depends more upon its integrity, chronological data potential, and ability to address at least one comprehensive historic context than its relative size or the fact that it contains hundreds or even thousands of artifacts. The emphasis is now on what minimal combination of spatially-intact, dateable associations of contexts and material culture will yield information that can address an important historic context. With the revised program, we have changed the equation from *more = better* to *very little = poor*.

Several problems and issues with the implementation of the NRHP eligibility evaluation program may be envisioned, and additional problems will undoubtedly arise during the process of implementing the new program. We have attempted to anticipate several of the more pervasive or troublesome issues and, in the following discussions, have provided guidelines for their resolution.

Assemblage Count Thresholds

The threshold of 30 artifacts is a strongly recommended standard for evaluating the potential of chipped stone assemblages and other material classes to address the research domains and historic contexts. But, it is not an inviolate or eternally absolute standard. As discussed above for unique findings, archaeologists should maintain a certain degree of flexibility and a common sense perspective when it comes to the sample size threshold during the evaluation process. If a discrete Paleo-Indian site consisting of a channel flake and 21 flakes of Alibates Chert is recorded, we shouldn't quibble about the fact that only 22 items are present and the threshold of 30 items has not been met. If, through consultation with Fort Bliss Environmental Division staff, it can be established that the assemblage can contribute to the analysis requirements of the historic context for Paleo-Indian era sites, the site may be recommended as eligible provided that it meets the requirements for geoarchaeological spatial integrity and chronological data potential.

On the other hand, in the majority of cases the quantitative threshold should be maintained. There is real danger in allowing a contractor or principal investigator to reduce the count to 28 or 29 artifacts for a group of sites, which may give incentive for another contractor or PI to suggest that, if a count of 28 or 29 artifacts is acceptable, then just one or two fewer artifacts should also suffice. It doesn't take a clairvoyant to see that a potential end result of this would be a return to the days when sites with four or five chipped-stone items were being recommended as eligible for inclusion in the NRHP.

Unique and Unusual Sites

It must be made explicit that the NRHP evaluation procedure is not intended to cover each and every cultural resource that has been or will be encountered at Fort Bliss. Many unique and unusual sites, features, or objects have been encountered during the three decades of cultural resource surveys across Fort Bliss. The expansion of intensive TRU surveys into previously unsurveyed areas of McGregor Range, Otero Mesa, and other mountain and foothill regions has

resulted in the discovery of several unique sites and items (Figure 15.1) and additional discoveries are certain to occur.



Figure 15.1. Stone effigy found among a light scatter of fire-cracked rock and artifacts during TRU survey of Training Area 12 of McGregor Range, November 2007.

Archaeologists are familiar with the fact that past human behavior was amazingly flexible and adaptable, and likewise considerations of how to interpret and manage the archaeological remains of past human behavior must also be flexible. Rather than explicitly addressing each and every archaeological situation or finding, it is perfectly acceptable to consult with Fort Bliss cultural resource managers and develop a modified or alternate procedure for a unique finding. A situation can be envisioned where a certain type of site will require the development of a new historic context. A noteworthy example is provided by a recent TRU survey on McGregor Range. Analysis of TRU spatial data resulted in the discovery of linear patterns of ceramic potbreaks and discarded sherds denoting prehistoric trails across McGregor Range (Church et al. 2005; Kludt et al. 2007). These “sites” require a broader landscape-scale perspective for the evaluation of their research potential and NRHP eligibility, and as such require the development of a new historic context along with a specific set of analysis requirements and data needs.

Sites such as the prehistoric trails described above and objects such as the example shown in Figure 15.1 may fall outside the range of the specific analysis requirements and data needs for the historic contexts outlined in Chapter 14. In such cases, either a new historic context should be developed or the site should be evaluated through an alternative process. The application of NRHP eligibility criteria other than Criterion D may be considered. It should also be remembered that listing on the NRHP is not restricted to sites, buildings, structures, or districts, but may also include “objects” as defined under 36 CFR 60.3(j). Several such objects, including

the examples of early air defense missiles on display at the Fort Bliss Air Defense Museum, have been listed on the NRHP. It is possible that several of the “objects” recovered from Ceremonial Cave, such as the painted *tablitas* and mask mosaic constructed of marine shell, would meet the requirements for inclusion in the NRHP. From the very short list of eligible and possibly eligible objects mentioned above, it should be evident that the object must be a truly outstanding, important, and unique item. The decision of whether or not to nominate archaeological objects to the NRHP is a management issue for consultation between the Fort Bliss Environmental Division, the Texas or New Mexico SHPO, and the Keeper of the NRHP.

In summary, should unusual and unique sites or objects be encountered, archaeological contractors should discuss the finding with cultural resource managers at the Fort Bliss Environmental Division and determine if an alternative NRHP evaluation process should be utilized.

An example of this process is the recent finding of a possible quarry site for ritual procurement of fossils in the foothills of the Sacramento Mountains (Russell and Landreth 2009). The site cannot be dated using current chronometric or relative methods and it is situated on limestone bedrock and thus lacks geomorphic integrity. However, given the significance of ritual landscapes set forth in Chapter 11, the site was recommended as eligible for inclusion in the NRHP. The site, its contents, and the eligibility recommendation were presented to the Fort Bliss POC, who concurred with the eligibility recommendation.

Data Collecton

Fieldwork for both survey and evaluation projects should be designed to make explicit observations about the nature, frequency, and ubiquity of the key data sets needed to address the intrinsic site attributes outlined in Part II and the cultural research domains defined in Part III. In addition, field recording procedures need to document the information on features, site formation, spatial relationships, and characteristics of assemblage content, variability, and sample size that are required to assess whether a site meets the analysis requirements and data needs of one or more historic contexts.

The use of standardized data forms is indicated to collect meaningful, replicable, and accurate information. The question then becomes “what is standardized?” A management issue Fort Bliss will address is whether all contractors should be required to use a single group of standardized data forms or allow each contractor to develop their own series of standardized forms. The former option is preferred, and the Fort Bliss Environmental Division and its contractors will develop a series of standardized forms that represent a consensus decision on the types and attributes of data to be collected. Acknowledging that achieving a true consensus among archaeologists is about as likely as achieving complete congressional bipartisanship, a compromise solution is offered. Individual contractors may be allowed to add or embellish the forms for their own purposes, as long as the original data collection fields remain intact.

The establishment of data thresholds carries with it an even greater requirement and responsibility for comprehensive and high-quality field documentation. Haphazard or overly hasty field documentation or not properly training and supervising inexperienced crew members may result in artifacts being overlooked. Sites with 35-40 chipped stone artifacts may be reported as having less than 30 and risk being recommended as ineligible for inclusion in the NRHP. The Fort Bliss Environmental Division staff will play an increasing role in ensuring that field documentation standards are maintained among its archaeological contractors.

Field Crew Experience and Training

The experience and training of field crews has long been an issue for CRM archaeology and continues to be a problem for CRM contractors at Fort Bliss. The ability of untrained or

inexperienced crew members to recognize some common artifact types at Fort Bliss has proven especially troublesome. Core reduction debris using coarse materials is often overlooked by crew members who are only minimally trained to identify chipped-stone artifacts or who are familiar only with the nicely formed flakes and tools of bifacial technologies using fine-grained cherts. Many crew members are not familiar with the variations of fire-cracked rock and often mistake large scatters of burned rhyolite, quartzite, and limestone for natural cobble outcrops or rock scatters. Burned caliche may also go unrecognized.

In order to adequately understand geomorphic integrity on a consistent basis, field personnel need to have some level of geomorphic training so they can recognize situations and landforms that have high potential. For example, most, but by no means all, field personnel know that sandsheets are a good indicator of preservation. However, few know the difference between an old sandsheet and a newer sandsheet of blow sand. Likewise, field workers need to be aware of the growing evidence suggesting the likely presence of two or more paleosols occurring sporadically across Fort Bliss.

Training programs have occasionally been conducted by the Fort Bliss Environmental Division and its archaeological contracting firms. LMAS has conducted geomorphology workshops and a workshop on TRU survey methods. The Fort Bliss Environmental Division has sponsored a roundtable discussion of GIS procedures for TRU surveys. GMI has conducted in-house training sessions for the identification of ceramic types and chipped stone technology. However, a more focused and uniform series of training sessions is needed with a greater participation among field and supervisory staff of all contracting firms working at Fort Bliss and the sessions need to be repeated at regular intervals.

Fort Bliss Environmental Division will encourage the development and attendance of workshops for all staff members of contracting firms working at the base. The workshop should minimally be held on a biennial basis, although an annual workshop may be required during years when contractors have experienced significant employee turnover or expansion. Training sessions on geomorphology, lithic materials and reduction sequences, local ceramic technology and identification of non-local wares, ground stone, fire-cracked rock, and perhaps spatial analysis would be of immense benefit to Fort Bliss by bringing some level of consistency to field documentation and NRHP evaluations.

METHODOLOGICAL BIASES WITH THE NRHP ELIGIBILITY EVALUATION PROCEDURE: EXPANDING THE SCOPE OF TESTING PROGRAMS

Mauldin reviews several critical methodological biases in Section 11.2.1 of the final chapter of the 1996 *Significance Standards* (Trierweiler et al. 1996: 250-258). Survey intensity as measured by crew member transect spacing, and geomorphic conditions as measured by the amount of eolian erosion or burial, were seen as the primary factors that determined the boundary definitions and dimensions of archaeological sites recorded during survey. In turn, site size was shown to have a significant effect on observations of feature and assemblage variability, artifact counts, and the number of temporal components observed (see also Mauldin et al. 1999; O'Leary et al. 1997). These observations were based on the results of the Small Sites Project and other large-scale survey and testing projects conducted across the Hueco Bolson and Tularosa Basin between 1992 and 1998 (Burgett and Poche, in prep; Lowry and Bentley 1997; Mauldin et al. 1998).

For sake of continuity in the current document, the original version of this section has been removed and a summary is provided below. However, the discussion continues to be relevant and the 1996 *Significance Standards* should be consulted for a more detailed discussion of these issues. The main points of Mauldin's review are as follows:

- (1) Survey methods and particularly survey intensity (transect spacing) affect the number, size, and content of sites recorded. Survey intensity, as expressed mainly by differences in crew member transect spacing, can determine to a large degree both the number of sites identified and their general size range. As survey intensity increases, more sites are discovered, and these sites tend to be larger in size.
- (2) Site boundary definitions are conditioned by geomorphic conditions and processes. Geomorphic conditions, related chiefly to patterns of deposition and erosion, both open and close "windows" into the archaeological material. Site boundaries are greatly influenced by local conditions of erosion and deposition; patterns of sand deposited in dunes and ridges and interdunal blowouts determine where the boundaries of sites are drawn. Geomorphic processes also impact site assemblage composition by differentially distributing archaeological material on the surface relative to subsurface.
- (3) There is a relationship between site size and data content that can bias assessments of research potential and NRHP eligibility. Larger sites, by virtue of the fact that they encompass more area, contain more artifacts and features relative to small sites. As a function of this larger sample size, these larger sites have a higher probability of containing temporally or functionally diagnostic artifacts and a greater variety of artifact types. That is, the data content of these larger sites is apparently greater than small sites, purely as a function of their larger overall assemblage size.
- (4) Different survey methods, in combination with geomorphic processes, have the potential to influence the apparent data content of a site, and by extension, its overall research potential. Under the mechanics of the Section 106 evaluation process, sites which have higher data content will be assigned a greater research potential. However, if the data content of a site is a function of site size, which is a function of geomorphic history filtered through decisions on site definition and survey intensity, then such an approach would not be appropriate for developing either a description or explanation of past cultural systems.

Some of these problems have been significantly decreased or ameliorated through improvements in field methods and a broader understanding of site structure. The problem of survey intensity is no longer a critical issue. The TRU survey method is one of the most intensive archaeological survey methods used anywhere in North America and provides 100 percent survey coverage. The GIS-defined site definition routines have eliminated much of the personal bias that plagued previous boundary procedures, although issues of geomorphic visibility and the ability of crew members to recognize cultural materials need to be addressed. The issue of site size and content has been addressed by the greater emphasis on site structure and the data potential of intrasite components or subareas within a site, as discussed in Chapter 10. Furthermore, the historic contexts defined in Chapter 14 provide for small, low-density sites to be considered equally for NRHP eligibility provided that they meet certain thresholds of integrity, chronological data potential, and assemblage content. For example, a 50,000 square meter site with 300 widely-scattered, unassociated artifacts may not be eligible for inclusion in the NRHP, while a 50 square meter site with 30 clustered artifacts may be eligible. Judicious and thoughtful implementation of the NRHP evaluation process will reduce the effects of the methodological biases arising from survey methods and site size and boundary definition.

However, one issue that remains unresolved is that of geomorphic bias and its effects on surface-defined artifact content and site boundaries. The problem of site boundaries is especially acute in stabilized dunefields and grassland "mini-mesas." The effects of eolian deposition on site content are particularly vexing for the NRHP evaluation process. For example, how should one evaluate a site if that site has only 20 chipped stone artifacts on the surface, but it is estimated that 60

percent of the site area is buried under 20 cm of eolian deposits with only a few isolated and fire-cracked rocks present on top of the eolian deposit.

The problem of geomorphic effects and biases on surface observations of assemblage content leads to a concern with eligibility recommendations based solely upon those surface observations. Under current Fort Bliss guidelines and contractual requirements set forth in RFPs, NRHP eligibility recommendations must be stated as either eligible or ineligible. The yes/no decision option results in conservative NRHP eligibility evaluations. That is, fearing that a significant site may be overlooked or unprotected, archaeologists tend to error on the side of caution and proceed to recommend unrealistically high proportions of sites as eligible. This in turn increases the costs of mitigation for a proposed undertaking if large numbers of such sites are determined eligible and require mitigation. Such costs may be justified if such sites turn out to have significant data potential. However, most researchers and cultural resource managers would acknowledge that a much more common outcome is that we discover that such sites have little or no research significance. This situation is unacceptable given the modern day costs of archaeological mitigation and the need to judiciously apply funds designated for mitigation towards the multitude of research domains and data gaps identified in these revised *Significance and Research Standards*.

Therefore, for the reasons detailed in Mauldin's discussion in the 1996 *Significance Standards* and the discussion above in these revised *Significance and Research Standards*, it is recommended that surficial examination alone may sometimes be inadequate to make an informed decision on data content and NRHP eligibility of sites in eolian and alluvial landscape settings on Fort Bliss. Two strategies – enhanced testing and phased mitigation – designed to compensate for these potential biases, are discussed below.

Expanded Testing – Frontloading the Field Effort

Many partially buried sites clearly have one or more surface-exposed subareas with integrity, chronological potential, and sufficient artifact content and can be recommended as eligible for inclusion in the NRHP with little debate or dissension. It is the occasional low-density site that is partially buried and/or surrounded by dune deposits that represent a problem for eligibility evaluation based on surface data. These sites typically have ambiguous evidence of whether buried organic deposits are present (integrity and chronological data potential) and whether significant numbers of artifacts remain buried beneath the dune deposits. In such cases, the inventory (TRU) survey and NRHP evaluation programs should be “frontloaded” with more intensive and extensive subsurface evaluations.

From the perspective of cultural resources managers at the Fort Bliss Environmental Division, there is an economic trade-off between investing effort in inventory and testing. A greater effort expended during inventory will certainly require greater up-front funding but may well allow significance evaluation of a greater proportion of all sites. For example, inventories that include subsurface evaluation (geomorphology and/or shovel testing) will evaluate a greater proportion of sites with a higher degree of confidence than similar inventories without subsurface evaluation. Conversely, a lower level of effort expended during the inventory phase may well be cheaper initially, but this option will almost certainly require that more sites will either need costly and labor intensive test excavations at a later point or will have speculative, low-confidence eligibility recommendations that often turn out to be erroneous. In general, it is often more cost-effective in the long run to conduct a higher level of effort during the inventory phase in an attempt to fully evaluate as many sites as possible and reduce the pool of sites that have low-confidence eligibility recommendations.

A related problem is that information available for most sites slated for data recovery is insufficient. Sites thought to have a few stains are found to be pit house villages while other sites

thought to represent large camps are found to be multicomponent palimpsests lacking spatial integrity. This situation makes it difficult to identify the appropriate historic contexts and develop appropriate research designs. In turn, this creates difficulties for scoping the proposed data recovery project and developing realistic cost estimates. Too often, once excavation begins, everything changes.

Consequently, the scope of TRU survey and NRHP evaluation programs will be expanded to more fully characterize the nature and extent of sites. Testing programs need to be of sufficient scope to: (1) estimate the extent of surficial or shallow cultural deposits and the depth and extent of buried cultural deposits; (2) more fully characterize the number of *major* features such as pit houses, middens, large stains, and large burned rock features present at a site; (3) provide more reliable quantitative estimates of artifact counts and the potential for organic samples (radiocarbon, flotation, residue); and (4) generally provide high-confidence documentation on these and other attributes that would assist in the accurate determination of historic contexts, NRHP eligibility recommendations, and the development of research designs and cost estimates for mitigation.

Testing programs should include combinations of backhoe trenching, geomorphic analysis, geophysical survey, manual test excavation units, and auger tests, depending on the geomorphic context and the type of site. Chronometric dating will be expanded to situate sites and their individual occupational components within the appropriate historic context or contexts. Provisions for chronometric dating using established methods (radiocarbon, dendrochronology) and developmental methods (ceramic thermoluminescence, optically stimulated luminescence) will be included in testing programs. Fort Bliss will support enhanced testing routines through stipulations in Statements of Work (Requests for Proposal).

Realistically, under current time and budget limitations, it will sometimes be difficult to achieve these goals. Even in the best of circumstances we should not expect to be able to fully characterize each and every site. With this in mind, cultural resource managers and consultants should keep in mind the concept of “reasonable and good faith effort.” Archaeologists should make a reasonable and good faith effort to identify site content based on surface and subsurface investigation.

It should also be noted that many of the problems described above arise from poor surface documentation during survey and evaluation projects. Artifact and feature counts are consistently underreported, spatial associations and patterning are ignored, and major features are sometimes misidentified or overlooked. Some of these problems will be lessened by the revised NRHP evaluation procedures in this document that require closer attention to assemblage counts, content, and association. Nevertheless, archaeological firms must insist that crew members are trained to recognize the material culture and features typical of the Jornada region and that they are given sufficient time to conduct fieldwork.

Phased Mitigation Programs

Despite (or because of) the increased level of effort devoted to subsurface testing, a small number of sites recommended as eligible for inclusion in the NRHP will unfortunately turn out to have limited research potential. Referring to the example provided above, a site with 60 percent of its area buried under dune deposits has 20 chipped-stone artifacts on exposed surfaces and a small number of fire-cracked rock scattered among the dunes, suggesting that thermal features are present. The majority of subsurface test excavations yield negative results. In one location, however, testing reveals a carbon stain and recovers a Late Archaic projectile point and two chipped stone artifacts. To the project manager these results indicate that the site has chronological potential, geomorphic integrity, and will contain enough features and spatially-

associated artifacts to address the data requirements of one of the Late Archaic period historic contexts, and accordingly the site is recommended as eligible for inclusion in the NRHP.

Unfortunately, a certain proportion of sites that appear on the basis of surface survey and subsurface testing to have research potential will sometimes, during a data recovery program, be found lacking. To continue the hypothetical scenario above, the initial efforts of the data recovery program find that the hearth stain is isolated, no additional artifacts are present around the hearth, and that the other artifacts are generally scattered around the site.

A useful option to deal with groups of sites having marginal or borderline research potential is through the development of “phased mitigation” strategies. This approach uses funding resources to focus the effort on sites with the best potential for recovering significant data. Most mitigation projects include an assortment of sites having different sizes and artifact and feature counts. Some of the sites have limited research potential, but as with the case above were recommended as eligible due to suspected data potential or because of some special characteristic, such as the suspected presence of a rare component or feature.

An initial phase of investigation built into the overall data recovery program will determine whether such sites truly have the potential to address the historic contexts for which they were recommended as eligible. For example, trenches can be placed in the vicinity of the isolated features to assess whether buried cultural surfaces with additional features and sufficient artifacts are present. If no such attributes are evident, it will be recommended that no further work is required at this site. Field days originally slated for data recovery investigations at sites found to have limited research potential can then be reallocated toward more thorough and productive investigations of two or three of the larger and more substantial sites within a given area of potential effect or project area.

THE FUTURE OF MITIGATION AND DATA RECOVERY PROGRAMS: PROGRAMMATIC RESEARCH DESIGNS AND OTHER STRATEGIC APPROACHES FOR MANAGING THE FORT BLISS INVENTORY OF HISTORIC PROPERTIES

Data recovery (mitigation) programs will become increasingly important during the coming years as Fort Bliss’ Section 110 and Section 106 responsibilities for identification and evaluation are completed for large expanses of the Texas and New Mexico maneuver areas. Taking into account the large numbers of undertakings that will result from the unprecedented expansion of housing and training facilities across the post, mitigation of adverse effects to historic properties will gain increasing prominence over the coming decade. The growing number of mitigation projects will require a concerted, communal effort between the Fort Bliss Environmental Division, Texas and New Mexico SHPOs, and Fort Bliss archaeological contractors to ensure that sites are properly studied during these large-scale mitigation projects. The increased number of data recovery programs will entail significant funding issues and Fort Bliss and its archaeological contractors will need to develop means of incorporating basic archaeological research with efficient and cost-effective mitigation.

Prior to discussing strategies for the design and conduct of cost-effective basic research, it is first necessary to define what basic research is and what it is not. We view *basic research* as that which contributes new or corroborative data and insights into specific research domains of the Fort Bliss *Significance and Research Standards*, as well as broader issues of archaeological and anthropological significance. Basic research *is not* the routine performance of technical analyses and boilerplate recitation of well-known interpretations and facts concerning the local archaeological record.

Archaeological survey, testing, and mitigation projects present different opportunities for research. Research is seldom appropriate or particularly informative during NRHP eligibility evaluation projects. Detailed in-field attribute analyses are costly to perform, sample sizes of collected artifacts are generally too small, and accurate chronometric context is usually lacking. Accordingly, most summary analyses of testing data present artifact distributional data by topographic landforms that often simply corroborate existing knowledge (e.g., late ceramic types are more concentrated and prevalent on alluvial fans and around playas). Rarely is a testing project of such magnitude or intensity that enough information can be compiled to allow for some pattern recognition and new interpretations. In contrast, the distributional data provided by TRU surveys offers an entirely new dimension of settlement pattern and landscape analysis that is only beginning to be explored. The local archaeological community fully supports the Fort Bliss Environmental Division in their desire to see the research potential of this survey method fully realized.

Realistically however, when discussing the issue and concept of cost effective research, we are most critically referring to the practice of archaeological mitigation through data recovery excavations. Data recovery excavations present a rather sobering quandary for the design and conduct of cost-effective research. Simply stated - excavations have the most profound ability to expand our knowledge of prehistory and history, but are also by far the most time-consuming and expensive of all archaeological endeavors.

The increasing number of data recovery programs will entail significant levels of funding. They will create opportunities to substantially enhance our ability to address many of the research domains in Parts II and III and to investigate the historic contexts of Chapter 14. To fully take advantage of these opportunities, methods of conducting efficient and cost-effective data recovery programs that will provide new archaeological insights must be developed and refined. Strategic components of this effort include the development of programmatic research designs, consistent requirements for types of data analysis, targeted research programs, and the use of probabilistic sampling designs. These strategies and methods are reviewed in the following section.

Programmatic Research Designs

The primary strategic component of future data recovery programs involves the development of programmatic research designs. The Fort Bliss Environmental Division desires to make progress toward a set of shared research and management goals. One of the primary means of accomplishing a unified and comprehensive research program is through the development of programmatic research designs. With the emphasis on specific, targeted historic contexts and expanded research domains discussed in these *Significance and Research Standards*, this goal is now achievable.

Although certain common site types of certain periods are poorly understood, they continually require mitigation because of their frequency. Archaeological contractors tend to reinvent or recycle research designs, and each contractor has individual preferences for analysis. Moreover, in a competitive bidding environment, it is sometimes disadvantageous to propose a broad suite of analyses for such sites. Research designs must also strike a balance between what is achievable within the confines of the delivery order timeframe and budget and the proposed research goals. It is easy for contractors to propose interesting research, but as timeframes or budgets slip and pressure mounts to meet contractual deadlines, the research ambitions are often scaled back, sometimes to the point of including only *pro forma* data tabulations and generalized interpretive statements. This runs contrary to the definition of basic research provided above.

These situations may be remedied by development of programmatic research designs. Programmatic research designs are not intended to be applied to a single project, but can be applied to similar site types across multiple projects and landforms. Given the poor understanding

of several sites types and time periods, the programmatic approach provides for systematic investigation of such sites.

The historic contexts of the preceding chapters serve as models and guides for the development of unified and comprehensive research programs. An historic context provides data and analysis requirements that effectively constitute the values and characteristics that contribute to the NRHP eligibility of a site evaluated under that context. In procedural terms, collecting these scientific data serves to mitigate the adverse effects of a proposed undertaking on those values and characteristics.

There are numerous benefits to this approach. Review and consultation periods can be streamlined if Fort Bliss (with SHPO concurrence) agrees that a site - or group or class of sites - can be mitigated under an existing programmatic research design. The programmatic approach will coordinate and systematize data collection and reporting procedures, allowing for data from multiple projects to be compiled and analyzed. This approach also unites the series of required technological, morphological, and compositional analyses established later in this section.

Finally, it is conceivable that at some point enough data will be systematically collected to allow for a review of the program. At that point, new directions can be proposed, or it may be found that sufficient data has been collected and no further investigations of this class of site are warranted. As work continues and data is compiled on groups of sites, it will be possible to begin to scale back investigations of certain classes or types of sites (i.e., that are unified through eligibility recommendations under specific historic contexts). In the example of a programmatic research design to be given below, certain small sites representing Formative period logistical procurement are involved. At some point it can be envisioned that enough data on ceramic variability, manufacture, and chemical composition will be gathered from enough sites and landforms that conclusive, synthetic statements can be made regarding the nature of these sites, ceramic production and use, and their roles in logistically-organized settlement of the basin and alluvial fans environmental zones. At this point, this class of site may receive reduced emphasis for mitigation.

Developing Programmatic Research Designs

A programmatic research design is intended to establish a unified and consistent research program for the mitigation of multiple sites determined eligible for inclusion in the NRHP by their ability to address a specific historic context. As noted above, historic contexts provide the foundation for the development of programmatic research designs. An historic context provides data and analysis requirements that must be satisfied in order to effectively mitigate an historic property or group of historic properties. A programmatic research design takes into consideration the data analysis requirements of a historic context, the anticipated site types commonly evaluated under that context, and develops data collection and analysis methods within an appropriate theoretical framework that will provide new or corroborative insights into the historic context.

An example of the development process is as follows. Let us consider one of the historic contexts described in Chapter 14, *Late Formative Period Logistic Exploitation of Basin and Fan Landforms*. This historic context subsumes the Subsistence, Technology, and Settlement Pattern research domains (Chapter s 8, 9, and 11, respectively, of Part III). This is a broad context subsuming a wide range of logistical procurement strategies and resultant site types across two of the major landforms of Fort Bliss. The premise is that there is clear and unequivocal evidence of multiple and extensive logistical procurement systems associated with sedentary settlements during the Late Formative period. Many small sites in the basin and alluvial fan landforms represent the locations of logistically organized extractive and processing tasks for procurement of subsistence, economic, and ritual items and preparation for transport to semi-permanent residential settlements.

The data and analysis requirements for this context include (1) features, artifact assemblages, or activity loci with good integrity; and (2) technological and functional data on El Paso brownware ceramics; and (3) geochemical characterization of El Paso brownware ceramics; and/or (4) technological and functional analysis of associated chipped stone and ground stone tool assemblages. The site types (historic properties) anticipated under this context include demonstrable Formative period components consisting of low-density lithic, ceramic, and ground stone artifact scatters of sufficient spatial integrity to be considered an isolable component.

These data classes, analysis requirements, and site characteristics together form the values that contribute to the NRHP eligibility of the historic property under this historic context. Accordingly, these types of data need to be collected in order to mitigate the proposed or potential adverse effects to the historic property. So, the next point is to develop a unified and comprehensive research program that collects data on these types of material culture, examines and synthesizes the data within the context of current methods and theories, and presents them in a consistent and replicable manner.

In the present example, the research program shall examine the functional, morphological, and technological aspects of El Paso brownware ceramics within a theoretical context of ceramic production, transport, use, and discard under a theoretical model of logistically-organized resource procurement by agricultural populations. Likewise, the functional, morphological, and technological aspects of logistically-organized chipped and ground stone technologies should be modeled. An example of the fully developed programmatic research design for the historic context *Late Formative Period Logistic Exploitation of Basin and Fan Landforms* is included as Appendix A. A second example of a programmatic research design for the historic context *Occupational Histories and Settlement Organizational Responses to Risk during the Late Formative Period* is also included in Appendix A.

A single historic context may have more than one programmatic design. This may reflect different theoretical orientations, such as an examination of settlement pattern and site formation from a behavioral ecological perspective or from the viewpoint of political and ritual organization. In other cases, there may be more than one site “type” that applies to a historic context, thus necessitating the development of more than one research design. For example, the second research design in Appendix A deals specifically with the settlement role of Late Formative period sites having only one or two house structures (e.g., “field houses”). However, this is only one of the possible site types. This historic context *Occupational Histories and Settlement Organizational Responses to Risk during the Late Formative Period* also applies to pit house, surface room, and pueblo settlements, each representing different strategies of population aggregation and dispersion in response to environmental risk and uncertainty.

At any rate, there should seldom be more than two or three programmatic research designs for any given historic context. It is also likely that research designs produced for different components of an historic context will be combined into a single comprehensive research program for all site types under that historic context. The proliferation of multiple research designs must be avoided, for this would simply revert to past times of unstructured and meandering research programs.

Fort Bliss will support the development of programmatic research designs through stipulations in Statements of Work for particular projects. The implementation of this program will have broader implications for long-term mitigation and sampling strategies.

ADDITIONAL CONSIDERATIONS FOR RESEARCH DESIGNS

Targeted Research Programs

One solution for situations involving budget constraints is to focus on a specific research issue or problem and devote the bulk of the analysis and interpretive efforts toward that issue. Other aspects of the excavation may thus receive treatments that are more descriptive. This focused and targeted approach can provide important and useful insights into particular research problems that are lacking in data, are historically understudied, or are otherwise poorly understood.

For example, a rare Middle Archaic site having a large chipped stone debitage and tool assemblage may be the major focus of detailed technological analyses and accompanying study of technological organization, while other small sites of Late Archaic and Formative age investigated during the same project may receive more descriptive treatments. Or, a group of hearth-artifact clusters may receive detailed spatial analysis to examine site structure, occupation history, and group composition, while studies of the associated lithic and ceramic materials would receive analysis that is more descriptive. As a third example, the excavation of a pit house cluster could focus on a detailed and integrated study of the resource procurement, production technology, functional use, and discard of ceramics, leaving issues of subsistence, lithic technology, and settlement organization to future investigators using curated collections from the site.

A potential drawback to this approach is that it may be difficult or improper to attempt to understand one component of human behavior and agency at a site as an isolated phenomenon without considering its relationship to the whole. Archaeological inquiry has long been concerned with understanding the inter-connectedness of material culture patterning and human behavior and adaptation. Parsing out the larger adaptive and organizational aspects of prehistoric settlements often requires an integrated analysis of spatial distributions and site structure, chronometric data, refuse disposal patterns, and production and extractive technologies. Nevertheless, the targeted research approach can provide important middle-range or linking data for such studies.

Targeted research may also be useful when dealing with mitigation programs for undertakings that have limited funding and require the investigation of numerous small, low-density sites within the area of potential effect (APE). In such cases, it is proposed that a sample of the NRHP eligible sites within the APE be selected for detailed and intensive excavation, rather than spreading the limited funding too thinly in an attempt to do a perfunctory level of excavation at every site. It is much better to know two or three sites well than to know ten sites poorly.

Required and Optional Data Analysis and Reporting Methods

A standard series of field and laboratory analyses are required to fulfill the revised standards, research domains, and historic contexts of this document. However, the current Jornada Mogollon analytical “toolbox” has become rather depleted and redundant. Archaeologists tend to continually reinvent things in research designs and the final reports of investigations. How many chipped-stone analyses need to be conducted to rediscover that higher-proportions of fine-grained materials are present at Archaic period sites than at Late Formative period sites? How many more vessel form studies need to be done at low-density basin sites to rediscover that the sample of sherds of suitable size and preservation is too small for meaningful interpretation? How many research designs will continue to propose the analysis of metric size variables among ground stone items, only to rediscover that nearly all the items are fragmentary?

Accordingly, one of the most critical and fundamental questions for the anticipated data recovery programs of the coming decade is: what more can and should be done to interpret prehistoric

material culture, resource procurement, technology, artifact function, and settlement organization? This question was the main point of discussion at the third roundtable meeting attended by representatives of the Fort Bliss Environmental Division and its archaeological consultants. As a result of those discussions, a consensus was reached on a series of analysis methods that should be standard practice during mitigation programs at Fort Bliss. Additional methods of interest were suggested as optional and should be considered when a suitable research situation arises. These analyses are labor intensive or require laboratory fees and thus require dedicated funding and commitment between Fort Bliss and its contractors.

It is critical to understand that the required data analyses essentially reflect the “data needs and analysis requirements” of the historic contexts set forth in Chapter 14. These required analysis and reporting standards are *minimal* research requirements. If they are not included in individual or programmatic research design, that research design must include an explicit rationale and justification for their exclusion. Otherwise, the Fort Bliss Environmental Division and New Mexico or Texas SHPO may reject the research design on the grounds that the document does not meet the requirements for resolution of adverse effects to historic properties set forth under Section 7.4.3.3 of the SOP of the Fort Bliss PA:

If an archaeological site determined to be eligible for inclusion in the National Register of Historic Places, in consultation with the appropriate SHPO, is to be adversely affected by a specific undertaking or as part of the ongoing land management plan, and avoidance is not possible, Fort Bliss will develop an archaeological data recovery plan to mitigate adverse effects to archaeological sites eligible for the significant information they contain.

The plan will be developed in accordance with the ACHP's Recommended Approach for Consultation on Recovery of Significant Information from Archaeological Sites, effective June 1, 1999 and consultations under this PA (*including consultations on the mitigation strategies in the Significance Standards for Prehistoric Archaeological Sites at Fort Bliss once completed*). The results of all such data recovery projects will be submitted to the SHPOs and the ACHP upon completion [emphases added].

Required Components of Research Designs

The following analyses or research considerations are required components of research designs:

Chipped Stone

- Standardized artifact classes, types, and attributes. A standardized series of basic artifact types and attribute states must be recorded and reported for debitage, cores, and tools.
- Tool analysis must be expanded. There is an extensive body of literature available that deals with relationships between settlement structure, mobility, raw material availability, and variation in tool form and use intensity. This body of research will be incorporated into the analysis of chipped stone assemblages at Fort Bliss and a standardized series of artifact types and attribute states must be recorded and reported.
- A comparative collection of major “signature” raw material types will be developed and distributed among contractors. “Signature” raw materials include types that are macroscopically distinctive and have source locations that are known and geographically restricted (e.g., Thunderbird Rhyolite/Ignimbrite, Llanoria Quartzite, Soledad Rhyolite, Organ Mountain Quartz Monzonite). Color-coding of chert varieties will not be required unless a specific color has analytical importance. The collection should be based on existing materials collected during the Lithic Source Project (Church et al. 1996) and housed at the Fort Bliss curation facility.

- The use of 1/8-inch screening for field recovery and identification of bifacial and tool production/maintenance debris will be required. Acknowledging that the use of fine screening can considerably increase the cost and time requirements for excavations, the use of sampling is recommended. Sample units or subunits, excavation blocks, or site areas may be designated for fine screening.

Ceramics

- Analysis of technological and production attributes will be conducted on samples of El Paso brownware. Attributes that can monitor or reveal firing conditions, surface finish details, and secondary use should be consistently monitored. These analyses are optional for assemblages consisting of less than 20 sherds.
- The potential to examine ceramic use wear in the form of attrition, spalling, and etching of interior surfaces will be explored. These analyses are optional for assemblages consisting of less than 20 sherds.
- The feasibility of residue analysis will be explored.
- The analysis of non-local ceramics will include studies that go beyond typological lists. NAA can offer a means of identifying production areas, thereby providing empirical evidence for modeling processes of social exchange and interaction. In situations where 20 or more items of a particular non-local ceramic ware are present, a sample of sherds should be submitted for NAA. These analyses are optional for assemblages consisting of less than 20 sherds.
- In situations where early brownware ceramic production is suspected, NAA will be used in tandem with absolute chronometric methods (radiocarbon, ceramic TL) to determine whether or not the sherds represent locally produced El Paso brownware or early western Mogollon brownware.

Ground Stone

- Raw material type and quality must be recorded and reported. Many ground stone items were manufactured using the consistently identifiable “signature” materials described above. Raw material identification will allow for analysis of resource procurement and tool transport.
- Use intensity and wear patterns must be consistently recorded using standardized attributes developed by Fort Bliss and its contractors.
- Ground stone was recycled for use as cookstones. The presence of recycled ground stone items in thermal features must be consistently documented and reported. This is particularly crucial if the feature has been dated.
- The variation in morphology and use of hammerstones must be documented, including use for tasks other than chipped stone reduction and tool production.

Thermal Features and Other Facilities

- Documentation of fire-cracked rock and/or burned caliche weights within thermal features is a mandatory recording procedure.
- The use and function of thermal features and cookstone will continue to be modeled and explored via ethnographic and experimental studies.

Optional Components of Research Design

The following analyses or research considerations are optional components of research designs:

Chipped Stone

- The analytical utility of the Sullivan and Rozen (1985) classification should be examined and compared against conventional flake attribute analysis and mass debitage analysis.

Ceramics

- Thin section petrography may be used in tandem with NAA to better isolate production areas and prehistoric resource procurement.
- Functional and production attributes based on the analysis of non-plastic inclusions (temper) may be undertaken for assemblages of 20 or more items.

Ground Stone

- Raw material and metric analysis of pestles may be considered. Why are distant raw materials commonplace among pestles?
- Residue analysis of ground stone tools is encouraged.

Thermal Features

- The analysis of fire-cracked rock and/or burned caliche (breakage, firing, discoloration, other measures of use and reuse intensity) may be explored again.
- Residue analysis of cookstone is encouraged.

Prospects and Problems with Probabilistic Sampling Designs

A number of approaches exist for management of large inventories of archaeological sites. One of the most efficient means of reducing costs while maintaining research standards is through the use of well-designed sampling programs during fieldwork and laboratory analysis. Probabilistic sampling is a very effective method of allocating time and labor costs to gain the most scientific information about a site or group of sites. To some extent, the Red Zones on Fort Bliss represent an attempt to manage sites by protecting a representative sample of sites of certain time periods. Other types and scales of probabilistic sampling designs are also feasible for Fort Bliss. The use of sampling as a tool in cultural resource management is permitted under the Section 106 process and related regulations, and is made particularly explicit in the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation*.

Sampling is often an undeservedly misunderstood process and there has been some reluctance among archaeologists and cultural resource managers to use sampling. Concerns are often raised that rare items of importance will be overlooked if only samples of material culture from a region, site, or context are examined. These concerns are generally unfounded. First, it should be emphasized that, with the exception of the improbable case where a perfectly preserved site is 100 percent excavated, all artifact assemblages collected during any archaeological project represent some level of a sample of the entire population of materials once present. In reality, sites are rarely excavated in their entirety, no site in a given region is ever fully investigated, and regions themselves are studied in vastly differing levels of detail.

In a real sense, the sum total of the archaeological record is the only population of interest; that portion of the record that has thus far been examined through archaeological investigation is a

sample of this whole, resulting from the cumulative and conscious decisions about what to investigate made by every archaeologist, and forms the only basis we have for making statements about the past. At an even broader scale, the sum of the extant archaeological record is itself a sample of all the physical detritus produced by people through time, and the vagaries of preservation and archaeological field methods produce “samples” of prehistory regardless of how fully a site is excavated. Second, the concern that rare or unusual items of importance will be overlooked can often be mediated through the use of multi-stage sampling designs. Even with well-designed multi-stage sampling procedures, a certain number of rare or unusual items (“rare event samples”) may remain uncollected, unexcavated, or unexamined. If such a rare item or class of rare item is considered to be particularly important, it can be included as part of a judgmental sample.

Probability sampling, which grew to wide acceptance as a consequence of the “New Archeology” (e.g., Binford 1964, 1965b; Mueller 1975; Vescelius 1960), represents a recognition that sampling, in one form or another, is inherent in archaeology, and that adoption of explicit sampling procedures can allow one to make probability statements about the degree to which the sample reflects the population. The concept of probability sampling is predicated on the idea of data redundancy; that is, that different sites formed through similar behavioral and natural processes should contain similar information. Thus, archaeological research in a given region should experience a phenomenon of diminishing returns; as more and more sites are investigated, the amount of new information per unit of effort should decline. As mentioned above, at some point the excavation of Late Formative period low-density occupations will begin to provide redundant information and mitigation efforts at such sites may be effectively reduced or eliminated.

There are several scales and domains of sampling to be considered: (1) sampling from a population of sites with the intent of selecting a representative sample for mitigation; (2) sampling within a site in order to recover information on morphology, variability, and artifact samples from a representative sample of features and contexts; and (3) sampling from collections of artifacts for increased cost-effectiveness during the analysis of material culture.

Sampling Landscapes and Groups of Sites

The process of sampling groups of sites in order to obtain a subset for mitigation is particularly fraught with problems and uncontrolled sources of potential error. Selecting a probabilistic sample within a group, class, or type of sites is a complex endeavor and should be approached with caution because probabilistic sampling *requires a basic understanding of the population from which samples are to be drawn*. This presents a fundamental problem for probabilistic sampling of groups of sites for mitigation, especially when the variation among site types within temporal periods and landforms is poorly understood.

Site typologies with site classes such as “limited activity site” or “structural site” or “large camp” are based primarily on surface observations of the types of features present. Once excavation commences, it is not uncommon at all to discover a hut structure on the “limited activity site,” to reveal a highly dispersed group of non-contemporaneous features (i.e., limited activity sites) at the “large camp” site, and to find that the structure at the “structural site” is a dispersed stain from two or three hearths. Sampling within groups or classes of sites should be undertaken only under conditions where the sites have been effectively characterized through archaeological testing (refer to discussion on enhanced testing procedures and field documentation standards). It can be justifiably argued that the explicit consideration of the problems surrounding the use of probability sampling make the arguments for site characterization more robust.

From the perspective of long-term management goals, Fort Bliss intends to develop sampling strategies based on classes of sites that are defined according to historic contexts. This is viewed as a productive and systematic means of organizing and classifying sites according to temporal periods, major landforms, and productive research goals. Fort Bliss will enter into consultation with the New Mexico and Texas SHPOs and the local archaeological community on the development of sampling procedures at the site and landscape level.

Another potentially fruitful approach would be sampling by landform parcel if Fort Bliss needs to clear large areas. For example, mitigating all cultural manifestations within a 1 square-kilometer area along a playa would have a good chance of capturing much of the temporal and functional variability among settlements in this area. Again, however, this should be approached carefully. It would be prudent to fully characterize an area and conduct various sampling designs to see which provides the most accurate sample. In addition, a provision for treating rare or unusual sites should be included. If a sampling design resulted in the exclusion of a rare Paleo-Indian site, that site could be included as a judgmental sample.

In these and other cases, the choice of a sampling strategy is a major decision. Although simple random sampling could be used, the best solution is probably one of two basic stratified sampling options. First, some type of stratification by landform, which would consider samples drawn from subpopulations defined by landscape context, is probably the best solution to address the types of scientific concerns that are the focus of this document. This approach is most compatible with an ecological approach to prehistory, because if the strata were carefully selected it would insure that representative sites from all contexts were addressed with equal emphasis. At the same time, the representative sample would allow interpretations of land use, socio-cultural issues such as networking, trade relations, interaction, and other important aspects of prehistoric lifeways.

An alternative strategy would be to stratify the landscape by intensity of military impact (or some other measure of threat to existing resources). This could allow for (1) focusing on retrieval of information from sites most likely to experience future degradation, and/or (2) exclusion of sites in areas where severe erosion or existing military impacts are documented, such that individual sites in the area can be assumed *a priori* to have already experienced serious or fatal damage. While generally less attuned to addressing the range of scientific questions posed in this document, such an approach would be suited to pressing management concerns. Nonetheless, with the expanded military training mission of Fort Bliss that includes a much broader use of the training areas, this strategy may not be much different from the sampling strategy discussed above.

Finally, it is possible that the landscape could be stratified using both of the above criteria, resulting in a two-tier hierarchy of landforms stratified by impact or threat of impact. This approach is one method of partially rectifying the disparity of goals implicit in scientific and management concerns.

Intrasite Sampling

The next scale of sampling is the intra-site level. Sampling designs may be useful for the excavation of pit house fills, midden deposits, and other large, complex, and dense features typically encountered at residential settlements. The present-day costs of archaeological mitigation may prohibit the complete excavation of multiple pit house and midden deposits, particularly since such deposits usually contain dense concentrations of artifacts, burned rock, and faunal bone. Under such circumstances, it will be both necessary and prudent to consider various approaches to sampling the features and refuse deposits.

When it comes to intrasite sampling of complex residential sites, the range of possible sampling strategies and methods is nearly inexhaustible. First, there are multiple options for stratifying the site: by area or household cluster, between groups of pit houses and middens, and hearth features, and within individual pit house and midden fill deposits. Moreover, the investigation of such sites often involves multiple research goals, some of which may have data requirements that can be difficult to satisfy through a single sampling strategy. These factors may require complex approaches to stratifying deposits for sampling. For example, for a site containing 10 pit houses with trash fills and two middens, one could: (1) choose a sample of 40 percent of the houses for complete excavation of fill and floor features; (2) choose a sample of 70 percent of the houses for excavation of floor features, excavating and screening 50 percent of the fill in each structure; or (3) choose to excavate 100 percent of the houses and their floor features but, excavate and screen only 25 percent of the trash fill in each.

A second level of sampling decisions is then required to determine how to sample the fills within the selected house structures and middens. Does one select a simple random sample across all units and levels, a random sample of units stratified by level, or perhaps a systematic stratified sample (e.g., stratigraphic column)? Intrasite sampling of contexts is tied to present and future research directions. If the intent of the study is to only examine architectural variation, there is little need to screen and retain fill deposits. However, the trash fill deposits are often essential to understanding the critical issues of site formation and occupational history at the site.

Sampling designs may also be employed during surface collection and excavation phases of fieldwork. For sites with especially dense surface artifact scatters, random or systematic sample collection grids can provide statistically representative information on assemblage content without the need to collect, process, and curate every surface artifact. Of course, such designs must take into account the research goals of the project. A collection of random grid units across a site will provide a representative sample of material culture for general characterization or comparative analysis but will not be amenable to point pattern spatial analysis.

Sampling Artifact Assemblages

The final and most readily adaptable sampling procedure is the probabilistic sampling of artifact assemblages recovered during mitigation programs. *Sampling is particularly useful for artifact classes that are present in high numbers and have a high degree of attribute redundancy.* The three artifact classes most commonly encountered across Fort Bliss that meet these criteria are El Paso brownware body sherds, chipped stone debitage, and faunal bone. Another artifact type - cookstone (fire-cracked rock and burned caliche) - represents a fourth example of an artifact class that meets these criteria, although cookstone is analyzed less frequently than the other three classes (but see Duncan and Doleman 1991; Tennis et al. 1997). This artifact class may also be sampled, should a particular study require the analysis of cookstone. The use of statistically robust sampling designs for all of these artifact classes is both scientifically sound and highly cost-effective.

To provide a recent example, nearly 8,000 chipped stone artifacts were recovered from a large block excavation at the El Arenal Site in Maneuver Area 2 of the eastern Hueco Bolson (Miller 2007a). A stratified random sampling design was applied that selected a random sample of excavation units stratified by excavation level. This procedure resulted in the selection of a total of 1,056 items for analysis and, since the samples were from all levels in the excavation, provided a sample that was representative of the vertical and horizontal dimensions of the excavation block (thus avoiding assemblage biases resulting from geomorphic processes such as size sorting). The use of this 12.5 percent sample fraction resulted in a corresponding 87.5 percent reduction in the time and cost that would have been required to analyze all 8,000 items. Based on probability theory, it was determined that all summary measurements using these data had a maximum error

rate of ± 3 percent at the 95 percent confidence interval. Thus, the sampling program resulted in a substantial cost and time savings, with very little reduction in data quality and interpretive potential.

Compared to problems involved with sampling groups of sites or intra-site contexts, developing sampling designs for artifact assemblages can be a rather straightforward procedure. Simple random, stratified, and systematic random samples can be applied, depending on the complexity of the deposits and nature of the research issues to be addressed. Multi-stage and proportional sampling procedures offer a means of obtaining different levels of information and are useful for artifact classes that are typically present in smaller numbers. Proportional sampling is the division of the population (e.g., chipped-stone artifacts) into subclasses (flakes, cores, tools) and selection of random samples from each subclass. The use of different sample fractions may be selected for different subclasses to provide sufficient numbers for quantitative analysis. For example, for an assemblage consisting of 20 cores and 2,000 flakes, the use of a universal sample fraction of 10 percent would provide information on only two cores, a statistically meaningless sample size. As an alternative, we would elect to analyze a 100 percent sample fraction of the cores (all 20 items) and 10 percent of the flakes (200 items). This approach would provide sufficient sample numbers for both artifact types. As with any sampling design, the selection of artifact samples for analysis requires a thoughtful approach that considers the inter-related factors of the nature of the population and its archaeological context(s), the need to provide adequate sample sizes of each class and provenience, and the goals of the analysis.

Sampling Designs and Research Goals

Sampling should not be taken lightly. The development of sampling designs requires thoughtful consideration of several aspects of the intended research goals of the project, budget considerations, artifact counts, and the nature of the population (of sites, intrasite contexts, or artifact collections) to be sampled. Sound statistical methodologies have been developed to provide accurate population estimates using samples (e.g., Blalock 1979; Mueller 1975; Nance 1983; Shennan 1988) provided that the measured parameters are simple; however characterization of the range of variation inherent in a population composed of diverse sites representing a range of time periods and cultural traditions is much more difficult. It is also recommended that key personnel involved in decisions regarding sampling designs have a strong background and experience in the development and application of random, systematic, stratified, and multi-stage sampling designs, as well as an understanding of the probabilistic aspects of these approaches.

Poorly conceived sampling designs or designs that do not provide the appropriate types and quantities of data required to address research design questions will prove to be counter-productive to the goal of providing cost-efficient scientific data. It must also be recognized that there are some situations where sampling is either infeasible or inadvisable.

THE SIGNIFICANCE AND RESEARCH STANDARDS: A SUMMARY STATEMENT

One of the paradoxes of cultural resource management is that the state of knowledge is in constant flux, and any research design is by definition a document with a limited life span. At the same time, a research design forms the basis of significance decisions that affect management of that site, which has lasting implications. Although future innovations in archaeological techniques and shifts in basic theoretical paradigms or research strategies have the potential to alter significance criteria and research directions, the law does not allow for site protection unless it meets eligibility requirements for the NRHP. On the other hand, the majority of the research

domains expressed in this document have been a persistent and consistent focus throughout the past quarter-century of archaeological research in the Jornada region; it is likely that research on subsistence, technology, site formation and site structure, settlement pattern, and social organization will continue through the coming decades.

These basic research domains will be improved and refined through the adoption of new perspectives, methods, and technologies. We leave the methods and means of incorporating these new developments to the authors and contributors of the next version of the *Significance and Research Standards*.

Finally, we must realize and acknowledge that archaeologists are not the sole stakeholders in the Section 106 process. The economic implications of Fort Bliss for the El Paso area, the military mission, and the concerns of Native American tribes and interested parties must be considered in the broader decision-making process. These and other real-world considerations must be taken into account during the design and conduct of cultural resource management programs.

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**APPENDIX A. WORKING EXAMPLES OF PROGRAMMATIC RESEARCH
DESIGNS**

Myles R. Miller

**Late Formative Period Agricultural Populations and Logistical Land Use
(Ceramic Models)**

**Formative Period Resource Stress and Limited Activity Structural Sites or
Field House Settlements**

Programmatic Research Design: Late Formative Period Agricultural Populations and Logistical Land Use (Ceramic Models)

The programmatic research design (PRD) is designed to investigate prehistoric archaeological sites determined to be eligible for inclusion in the NRHP by their ability to address the historic context Late Formative period Logistic Exploitation of Basin and Alluvial Fan Landforms. This historic context subsumes the Subsistence, Technology, and Settlement Pattern research domains (Chapters 8, 9, and 11, respectively, of Part III). This is a broad context subsuming a wide range of logistical procurement strategies and resultant site types across two of the major landforms of Fort Bliss. The premise is that there is clear and unequivocal evidence of multiple and extensive logistical procurement systems associated with sedentary settlements during the Late Formative period. Many small sites in the basin and alluvial fan landforms represent the locations of logistically organized extractive and processing tasks for procurement of subsistence, economic, and ritual items and preparation for transport to semi-permanent residential settlements.

The data and analysis requirements for this context include (1) features, artifact assemblages, or activity loci with good integrity; and (2) technological and functional data on El Paso brownware ceramics; and (3) geochemical characterization of El Paso brownware ceramics; and/or (4) technological and functional analysis of associated chipped stone and ground stone tool assemblages.

The research design presented here is focused primarily on models of ceramic use in logistical organized settlement, but can and should be expanded to include other site types and material culture such as ground stone, projectile points, and thermal features.

Research Design

This research domain involves the logistical organization and behavior of Late Doña Ana and El Paso phase populations. Small sites and dispersed, low-density landscape artifact distributions of Late Formative age are present across most landforms at Fort Bliss. For example, Lukowski and Stuart (1996) illustrate the distributions of El Paso brownware sherds across two limited use areas (LUAs) of Maneuver Area 2 in the Hueco Bolson. These parcels were systematically surveyed using the TRU method of documenting all materials along 16 meter-wide transects. The area of these two survey parcels represents approximately 14 square kilometers, and it is noteworthy that not a single $\frac{1}{4}$ km (250 m by 250 m) parcel lacks El Paso brownware sherds. Similar ceramic distributions can be observed in archaeological surveys utilizing landscape field survey and documentation procedures in other areas of the Mesilla Bolson, Tularosa Basin, and across McGregor Range.

These ceramic distributions clearly indicate a substantial amount of ceramic vessel movement across these landscapes during the Formative (or Ceramic) period. Surface-collected El Paso brownware rim sherd assemblages from three such landscape projects have been examined in detail during the Fort Bliss CRCP, and were found to contain relatively even proportions of Mesilla and Early Doña Ana phase El Paso Brown and Bichrome rims and later El Paso Polychrome rims (Miller 2004). The presence of Mesilla phase brownwares is not surprising considering the consensus view that relatively high levels of residential mobility characterized populations of this period. However, the fact that approximately 50 percent of the rim sherds represent post-A.D. 1150 varieties of El Paso Polychrome demonstrates that much of the ceramic patterning is a result of Late Formative period (A.D. 1150-1450) logistical use of the landscape, and hints at a substantial degree of logistical landscape use during a period when most populations were living in relatively stable pueblo and surface room settlements.

Many landscapes and landforms across Fort Bliss contain similar distributions of ceramic artifacts, as well as hearth features and other materials, representing the residues of logistical use of the landscape. Although these low-density distributions of features and dispersed material culture constitute by far the most common type of “site” in the region, archaeologists have not paid sufficient attention to appropriately modeling the role of such sites in regional settlement and subsistence systems. There are several cultural ecological aspects to such studies, but social implications are equally important and intriguing. Are such sites associated with pueblos, surface room clusters, or both settlement types? How were different forms of logistical resource procurement organized among various populations? What types of logistically organized behaviors are reflected in these sites and their material culture? What economic, subsistence, and ritual functions resulted in the formation of these extensive material distributions? Did the hydrological aspects of playas require water transport, often resulting in vessel breakage and thus resulting in the ceramic distributions observed in present times?

Logistical mobility, representing one side of the residential-logistical duality of hunter-gatherer studies of the past several decades, has received much attention in the modeling and interpretation of hunter-gatherer material remains and settlement adaptations worldwide. When it comes to agricultural societies, though, it is interesting to note that logistical mobility is seldom referenced in discussions of either short-term resource procurement or longer-term population movements and patterns of landscape use³. Despite the widespread evidence, both ethnographic and archaeological, of various forms of special use or task specific sites and material distributions representing logistically-organized behavior among agricultural groups, few studies have been undertaken to examine the nature of such sites and the implications for population aggregation, resource procurement, and resource stress.

Furthermore, most models posit test implications of logistical and residential sites solely based on the hunter-gatherer perspective, and make little or no distinction between non-agricultural and agricultural groups. In opposition to this perspective, it is here maintained that the resource structure and nature of the “base” residence of agricultural groups, as well as various forms social organization reflected by aggregated settlements, differ fundamentally from hunter-gatherer groups, and therefore patterns of mobility and sedentism among agrarian societies cannot be understood using the ecological assumptions – nor the temporal and spatial frameworks – underlying hunter-gatherer models.

A general rule among such models is that, as the frequency of residential moves decreases (or, as residential duration and stability increase), the logistical procurement of both primary and critical subsistence resources will be increasingly emphasized. Variations of this model have been used to study hunter-gatherer groups in a multitude of environmental and temporal contexts. The majority of models in the southern Southwest – and particularly within the Jornada region – focus on residential sites of varying duration and intensity and are generally contingent upon a distinctive seasonal component that clearly falls within the hunter-gather cultural ecological paradigm (e.g., Anschuetz et al. 1990; Church and Sale 2003; Dering et al. 2001; Doleman et al. 1992; Ennes 1999; Hard 1983; Mauldin 1986; Mauldin et al. 1998).

³ As a semi-quantitative test case, one can examine the indices of several recent publications dealing with population movement and resource stress in the Southwest for mention of the concept of logistical mobility. For example, in Nelson (1999: 232) the term logistical mobility has a single page reference, while residential mobility is noted or discussed on 19 pages. In Fish and others (1992), logistical mobility is mentioned a single time, despite the fact that a significant segment of the report is devoted to special purpose agave processing sites. Similarly, in Varien (1999: 273-274), mention of logistical mobility is limited to four occurrences, while an entire section of indexed page references is devoted to discussions of residential mobility.

However, the structure of resource procurement differs among agrarian societies. Logistically organized tasks among hunter-gatherer groups serve to collect and transport both primary and auxiliary subsistence, production, and maintenance items to the base residence. In contrast, among agricultural groups it may be presumed that logistical procurement systems were not designed to collect and transport primary subsistence items, those items being the cultigens grown in prepared and maintained agricultural fields.

Moreover, unlike hunter-gatherer groups, the physical and social nature of agricultural settlements and land tenure would have imposed certain restrictions on the range of residential movements. Hunter-gather models are generally environmentally deterministic, where residential and logistical mobility are interpreted by reference to the temporal and spatial distribution of resources (although see Bender 1985; Wiesner 2002 for insights into social dynamics of hunter-gatherer groups). Movement by agricultural groups, occurring under conditions of greater local population densities and restricted territorial ranges from extraregional population growth, would involve problems of land tenure (Adler 1996; Varien 1999) and access to resources. Thus, movement of individual households, small groups, or larger communities in agricultural societies involves a distinctive social component. In addition, the construction of surface rooms and pueblo residences required a significant time and labor investment, thus further constraining the options for residential mobility among agriculturalists.

As noted by several researchers, the introduction and adoption of agriculture is thought to have provided greater control and predictability over the environment (Matson 1991; Minnis 1992; Wills 1988). Interestingly, in opposition to the somewhat greater control over food production, may propose here that the sedentary lifestyle actually entails lesser control over the immediate environment and local catchment areas when it comes to secondary and auxiliary resources such as fauna, fuel and construction wood, wild subsistence and economic plants, sources of stone and clay, minerals, pigments, and other materials required for ritual performance, and other materials due to the depletion of resources resulting from aggregated populations. As agricultural settlements had a much more pronounced effects on local resource availability than mobile hunter-gatherer groups, the range of options to compensate for such affects utilizing strategies of residential mobility would have been more circumscribed. Therefore, it is probable that logistical forays would have involved increasingly wide procurement zones. Upon the initial occupation of a location by a large social group, many subsistence and economic items could be gathered within the general foraging radius of the site. Ongoing residential occupation would quickly reduce or deplete these local resources, requiring logistical procurement from more distant locations, with continued residential occupation resulting in logistical use of increasingly distant landscapes.

Alternative Approaches to the Study of Late Formative Period Logistical Landscape Organization at Fort Bliss

Precedents for this type of study and the expected research results are difficult to find. Studies involving logistical sites at the very low end of the occupational intensity spectrum have been neglected in Southwestern research due to the focus on architectural sites. Special purpose plant processing facilities have occasionally been factored in, most notably in the Hohokam region (Fish et al. 1992), although the Jornada has also seen some emphasis on burned rock midden sites. Elsewhere, Tainter (1991) examines the long-term relationship between seasonal use sites and puebloan communities in north-central New Mexico.

Under the models developed here, logistical organization may be examined under two dimensions of resource stress: resource depletion or exhaustion resulting from population aggregation and the inherent uncertainty and risk in alluvial fan and playa-margin dry farming. In the former case, logistical land use patterns associated with pueblo settlements reflect increasingly distant resource procurement in response to local resource depletion that resulted from population

aggregation. Therefore, one expectation of this model is that logistical sites utilized by a group should not be found in proximity to the primary residential settlement occupied by that group. This component of the model can be tested through compositional sourcing of ceramic items and perhaps via raw material identification of ground stone and certain lithic artifacts. However, a valid critique of this approach is that it is limited to the spatial component of logistical land use. It thus remains rather vague and questions remain as to the specific forms of logistical economies practiced by Late Doña Ana and El Paso phase populations. Additional avenues of study are provided in the following discussion.

A third component of Formative period logistical land use involves the expanded social and ritual relationships within and among social groups inhabiting pueblo and pit house settlements (Plog 1989). These relationships required an extensive procurement system for pigments, fossils, minerals, exotic stone, and turquoise (not to mention extraregional exchange for shell and other materials). Many of these items, including pigments, fossils, and stone, required logistical forays to local mountain foothills and upland environments.

One of the most prominent forms of resource depletion would have involved fuel and construction wood. Fuel wood consumption and exhaustion has been examined in both the context of agricultural groups (e.g., Kohler and Matthews 1988; Kohler et al. 1984; Varien 1999) and hunter-gatherers utilizing burned rock technology (Dering 1999). When considering the fuel and construction wood requirements of corn boiling and other food preparation tasks, ceramic vessel firing, house construction, and for heating domiciles during the winter months, it becomes apparent that the fuel wood requirements of even a small pueblo population may rapidly exceed the carrying capacity of the local environment. For example, Kohler and others (1984) estimate that a five-person household in the Anasazi region would require over 6,000 kg of fuel wood on an annual basis. Clearly then, in semi-arid regions such as the southern Jornada, intensive use of wood combined with low biomass recovery rates would have resulted in a relatively rapid depletion of fuel sources within the vicinity of aggregated pueblo settlements. In a similar fashion, certain plants of subsistence or economic importance, various fauna, and other critical items would have been rapidly depleted in the vicinity of aggregated settlements.

Unfortunately, the behavior associated with logistical wood procurement may not be directly identifiable in the archaeological record (e.g., what technologies beyond hands and feet, and perhaps bundling twine, would be required to harvest and transport wood?) Instead, we may need to develop other middle range proxy studies such as the intriguing one conducted by Dering (2001) to examine patterns of mesquite fuel wood use and resource stress. During the analysis of wood charcoal samples, he differentiated samples representing heartwood, sapwood, and root. Heartwood is present in older parts of the plant. Therefore, higher proportions of heartwood and root versus sapwood or transitional pieces would indicate procurement of more difficult to collect pieces and, by extension, could be used to infer resource stress involving fuel wood procurement.

Other resources would have included various subsistence, economic, and medicinal plants and fauna common around local playa landforms. Presently, it is difficult to detect the procurement and use of many such materials. Rather, it is often necessary to invoke proxy studies that examine the technologies used to procure or process such materials. Three such preliminary research pursuits are proposed for the study of small Formative period logistical sites: analysis of thermal features, chipped and ground stone technologies, and ceramic technological and distributional patterns.

The first research issue to be addressed is whether logistical patterning in a specific project area incorporated the construction and use of small thermal features (or hearths) and to establish if such features date to the Late Doña Ana or El Paso phases. We are considering here the typically small (less than 1 m and often less than 50 cm) ephemeral hearth pits with few or no burned rocks

incorporated into the construction. In one sense, purely logistical settlement organization involving the movement of resources to a primary residence would not appear to involve the use of small thermal features. However, such small hearth features dating to the Late Doña Ana and El Paso phase have occasionally been encountered in the Hueco Bolson and Tularosa Basin. There is, therefore, some evidence that logistical organization during this period did, at times, involve thermal features.

If Late Doña Ana and El Paso phase logistical land use in the project area did involve the construction of small thermal features, such features may have served as more generalized, multipurpose, low intensity, and short-term domestic functions such as providing warmth or food preparation. In other words, thermal features did not provide a specific economic processing function. Interestingly, such an interpretation offers a more parsimonious explanation for the informal construction, small size, and low macrobotanical and faunal recovery rates typical of such features. In addition, the construction of thermal features to provide warmth implies a seasonal aspect to the logistical use, and thus perhaps there is an additional correlation between more extensive logistical resource procurement during the lean winter months and the use of hearths to provide warmth. Perhaps most importantly, however, is that the use of ephemeral heating facilities may also imply a relatively extended occupation span. Such evidence would support the model that Late Formative logistical landscape use involved increasingly greater distances from the primary residence.

Several studies will be undertaken to investigate the potential relationships between hearth construction and logistical procurement. First and foremost, all such features will be dated using the most accurate and reliable chronometric method (in most cases radiocarbon dating). Data on use intensity attributes of small thermal features (burned rock weight, transport distance, quantity, pit size, fill density) will be recorded and compared against thermal features in similar and different landforms and time periods. Additionally, the distributions of hearths and El Paso brownware ceramics will be examined to determine if they are associated, or if they represent two separate but overlapping distributional patterns.

Distributions of lithic and ground stone items constitute the second study domain. Unfortunately, this domain is often hindered by the lack of chronometric control for the majority of these materials. With the exception of projectile points, it is extremely difficult to place scattered lithic and ground stone artifacts within a temporal context unless a particular lithic or ground stone item can be conclusively dated through unambiguous association with a hearth feature. Ground stone artifacts occasionally may be datable due to the common occurrence of recycled ground stone artifacts as hearthstones. An interesting issue for understanding changing patterns of logistical landscape use involves whether the recycling of ground stone items as hearth stones shows distinct temporal patterns. In other words, would the use of small thermal features for domestic purposes, and not on-site processing, be reflected by the fact that ground stone was considered more important for use as hearth or boiling stones rather than processing implements?

The third component of Late Doña Ana and El Paso phase logistical land use involved the use of ceramics. The widespread distribution of El Paso Polychrome ceramics across the landscape offers the most conclusive evidence for extensive logistical land use by puebloan populations. Additionally, aside from radiocarbon dating of hearth features, ceramics offer the most chronologically secure and consistent means of examining Late Formative period logistical strategies.

Modeling Late Formative Period Logistical Mobility and Ceramic Distributions

The extensive distributions of El Paso brownware ceramic sherds across the intermountain basin landforms is one of the more intriguing aspects of landscape artifact distributions and their relationship to logistical resource procurement and mobility. Clearly, long-term patterns of

ceramic vessel use that frequently resulted in breakage occurred across the central basins, although the use and discard of ceramic sherds as tools is also a distinct possibility. Several uses of ceramic vessels may account for the patterns observed in the vicinity of playas, and in an attempt to understand the causal factors underlying these distributions we propose several research directions based on the concept of resource stress and playa hydrology. These uses include water transport for domestic consumption and food processing, water transport for supplemental pot irrigation, collecting and transporting foodstuffs or status items such as fermented beverages, transport and caching of ritual or status items, and as tools. Of course, any number of combinations of these uses is both possible and likely.

Ceramics offer perhaps the most productive means of investigating broad pattern of logistic behavior across different landscapes. Several alternative models and test expectations are proposed. The models of ceramic distributions are based on the two categories of resource stress: (1) responses to local resource depletion or exhaustion resulting from population aggregation; and (2) practices of water transport resulting from spatial and temporal variability in playa resource structure and playa margin agricultural potential.

Water Transport

The previous review of the hydrological characteristics and agricultural potential of playas establishes several implications for prehistoric water consumption and transport. Given the transient, variable, and overall uncertain nature of water resources available in playas, it is proposed that widespread water transport may have provided an important and fundamental means of partially overcoming the shortcomings of playa agriculture needed to support both aggregated and dispersed settlements. The use of vessels for supplemental irrigation of dry farming locales may have been an important strategy to reduce agricultural risk. At this point, water either would have had to be procured from the closest playa or bajo containing freshly ponded water or from springs, wells, or temporary runoff catchments. In addition to drinking water, other domestic uses for water would have included consumption for boiling corn and other plant foodstuffs and occasionally the use of water for manufacture of adobe and caliche plaster during construction of residences. The manufacture of El Paso brownware ceramics also required water during the preparation of the clay and surface treatments involving self-slips.

Logistical patterns of water procurement and transport thus may account for the extensive distributions of ceramics around playas and across portions of the central basin. The fundamental question of water transport involves the relative labor requirements and risk avoidance strategies involved in logistical versus residential mobility among agricultural populations inhabiting playa margin environments. In other words, at what point would it be more economically prudent and labor efficient to use logistical water transport to bring water to an existing settlement as opposed to dispersing populations and constructing new settlements? Likewise, at what point would the labor requirements of supplemental pot irrigation of one or more agricultural fields offset the costs of moving a settlement or risking agricultural failure? Given the variability in timing and duration of water in playas, it often may have been easier to transport water to settlements than to move settlements to water sources.

We therefore envision four alternative practices involving prehistoric water transport and resource stress:

- local transport of water to playa-margin settlements for human consumption and domestic uses
- transport of water from playas with ponded water to settlements near dry or drying playas
- water transport to local dry farming fields for supplemental irrigation
- transport of supplemental irrigation water to multiple field locations as a buffering strategy to reduce agricultural risk

If water transport were a common practice, ceramic vessels would have served as primary means of transporting water to settlements or fields. While use of bladders, skin containers, pitch-coated baskets, and other organic forms of water transport vessels is well-documented ethnographically, the manufacture of these items would have required certain ancillary resources and technologies that may have been rare, difficult to procure, or of excessive cost for Jornada populations. For example, large and medium game animals are a generally rare among the faunal records of Late Formative agricultural settlements through the region (Bartlema 2003; Bradley 1983; Browning et al. 1992; Duncan et al. 2002; Foster et al. 1981; Hanson 1990; Lowry 2005; Miller 1989; Presley and Shaffer 2001; Shaffer 1999). Based upon the MNI calculations from these studies, it is unlikely that a sufficient number of medium and large mammal species would have been available to furnish the material needed to manufacture more than a small number of bladder or skin containers. Moreover, tree species yielding pitch or sap are uncommon except at high elevations in local mountain chains. The use of gourds as “canteens” is documented ethnographically for several groups across the southern Southwest and northern Mexico (Fontana 1983; Pennington 1962: 215-216; 1969: 212-213; 1980: 311) and may have provided a local exception. The most common species used for water canteens is the Bottle gourd (*Lagenaria siceraria*), which has been identified in flotation samples from a small number of pueblo sites in the Jornada (Foster et al. 1981; Lowry 2005). These gourds seldom exceed 20 cm in size, and thus the volume of water that can be stored or transported is rather limited. Therefore, it is presumed that the environment placed some limitations on the range of water transport technologies that could be adopted by agricultural groups in the Jornada, and accordingly the utilization of ceramic vessels for water transport would have served as an efficient and necessary alternative.

Unlike procurement of fuel and construction wood, the logistical procurement of water would have left some evidence in the archaeological record in the form of broken ceramic vessels. Breakage and loss of ceramic vessels during transport is a common occurrence among ethnographically and archaeologically documented contexts. Data on vessel use among the Kalinga note that 88.6 percent of breakage events outside household use contexts occurred either while cleaning pots or during transport to and from water sources (Tani 1994: 60-61), and similar breakage patterns have been detected among the Shipibo-Conibo tribes of Peru (DeBoer and Lathrap 1979). Windes (1991: 124) observes that utilitarian jar forms represent the majority of vessel forms recovered along short road segments near Chacoan settlements such as Pueblo Alto. Noting that water would have been a major resource need for the inhabitants of highly aggregated settlements, he concludes that these patterns reflect water transport to the pueblos. Studies of ceramic breakage patterns may therefore offer a productive means of modeling and interpreting ceramic distributions and logistical behavior in the Jornada region.

Additional archaeological correlates of water transport may be monitored among ceramic assemblages. For example, general vessel form and ceramic type should reflect utilitarian focus on water transport. Jar forms should predominate in vessel assemblages used for water transport. The proportion of jar forms should significantly exceed the typical 80 percent to 20 percent jar-to-bowl proportions common among El Paso brownware assemblages observed at residential sites throughout the region. In a similar fashion, extra-regional ceramic types should be rarely represented among water transport assemblages. As Windes (1991) noted for the Chaco road collections, most water transport vessels were locally produced utilitarian wares. Church and others (2001) suggest that Chupadero Black-on-white jars would have served as useful water containers. We agree that Chupadero jars could have served as a useful and preferred household water storage and serving containers. However, non-local ceramics such as Chupadero Black-on-white and Chihuahuan Medio period polychromes, and White Mountain Redware, are present in much fewer numbers than local brownwares in logistical contexts, indicating that local wares were preferred for utilitarian water transport.

Additional technical attributes should reflect vessels used for water transport. Howard (1981) lists a series of predicted vessel attributes for various functional uses. Under his model, water transport vessels should lack sooting, have generally uniform dimensions and shapes, have a low degree of surface attention with slips or glazes to reduce permeability, be lightweight, have restricted orifices, and should show an emphasis on strength in construction. Some researchers in the area have proposed that necked vessels offer greater containment security for boiling corn, and thus the incorporation of necked jar forms in regional El Paso brownware ceramic assemblages reflects the increasing processing requirements for maize (Hard et al. 1994; Seaman and Mills 1988; each citing Braun 1983). An equally plausible explanation is that necked vessels facilitate lifting, handling, and harnessing, reduce spillage, and allow for efficient sealing, and thus are more efficient for the transport of water and other materials (D. Arnold 1985; P. Arnold 1999; Smith 1985) although studies by Henrickson and MacDonald (1983) and Reid (1990) suggest that this may not always be the case. In a study of El Paso brownware jar rim forms from several pit house, surface room, and pueblo occupations in the region, Miller (1997) found that El Paso Polychrome collections from surface room occupations tend to have more highly everted rims and thinner vessel walls. These technical aspects are interpreted as a means of facilitating transport of the vessels to and from the less residentially-stable surface room settlements. Striated vessel exteriors may facilitate movement and transport, as smoothed or polished vessel surfaces may be slippery, especially for water transport vessels (Reid 1989; P. Rice 1987). Conversely, the application of slips to vessel surfaces helps reduce permeability, a desired characteristic for water transport and storage vessels and cooking pots (Schiffer 1990a, 1990b).

Collecting and Transporting Foodstuffs, Medicinal Plants, and Other Plant Materials

Ceramic vessels may have been used for gathering and collecting certain subsistence plant materials (seeds, fruits, leaves), medicinal plants, or other materials such as agave shoots for fibers. It is also possible that ceramic vessels were used to transport processed cacti and succulents from logistical burned rock sites along the alluvial fans. Again, accidental vessel breakage and loss during multiple collection events would have resulted in the deposition of sherds across the landscape. Despite the obvious weight factor involved, ceramics may have been more efficient than gourds, netting, or basketry for the collection of certain types of small plant parts, seeds, and seed stalks or pods (Eerkens 2003). Chenopodium stalks and seeds and other plants with small seeds may have been among the more common subsistence items gathered in playa and playa margin settings. Despite this occasional preference, however, it is thought that fiber cordage and basketry would have served as a lighter and more efficient means of bulk collecting for most plant materials. Numerous examples of fiber baskets and cordage net containers have been recovered from excavations in well-preserved dry cave deposits throughout the region (Alves 1930; Cosgrove 1947; Creel 1997; Hamilton 2001; Lambert and Ambler 1961; O'Laughlin 1977).

The technical aspects of ceramic vessels used for plant collection would differ from water transport and storage. The need for continual access to the interior would require relatively wide orifice diameters, as opposed to the need for restricted orifices on water transport vessels to prevent spillage (D. Arnold 1985; Hally 1986; P. Rice 1987). It is possible that vessel volumes, dimensions, and wall thickness would also covary as the weight and volume requirements of water transport and plant collection would differ substantially (Howard 1981). Interior surface treatments could also reflect differences, as smoothed and striated interiors offer differing evaporation and storage capabilities (Schiffer 1990a). For purposes of modeling logistical collections resulting from resource depletion around a primary residence, it would be expected that the chemical profile of sherds used in long-distance collection should differ from those of local residential occupations.

Transporting Fermented Beverages for Ritual or Communal Feasting

Over the past several years the issue of communal and ritual feasting among prehistoric societies has received increasing attention (e.g., Dietler and Hayden 2001; Mills 2004; Potter 2000). Ethnographically and ethnohistorically documented feasting and alcoholic beverage consumption is widespread throughout the American Southwest and northern Mexico (Waddell 1980), including the consumption of tesguino, a fermented corn beverage, among the Tarahumara of Chihuahua (Kennedy 1963; Merrill 1978).

A consideration of the highly fluid and dynamic nature of Late Formative period settlement in the Jornada region begs the question of how prehistoric groups maintained exchange and information networks, mediated land tenure disputes among groups with high levels of residential mobility, and otherwise maintained social and political connections in the context of continually shifting primary residences. Communal ritual, including feasting, provides an efficient and popular means of compelling social interaction among isolated groups. Given the historical and ethnohistorical continuity of fermented beverage consumption in the Southwest, it would not be unreasonable to propose that prehistoric Jornada populations participated in such activities.

If beverage transport did contribute to the ceramic distributions in the area, it may be possible to identify vessels used in such activities. Several relatively distinctive technical and use-alteration attributes indicate the use of vessels for fermentation, storage, and serving of fermented beverages. First, extensive pitting of vessel interior surfaces should be evident, having resulted from the acidic nature of the liquids (Arthur 2002; Hally 1983; Skibo et al. 1997). In one of the most detailed ethnoarchaeological studies of ceramic use and feasting, Arthur (2002) reports that surface attrition on ceramic vessels (both interior pitting and exterior wear from movement) occurs primarily due to fermentation of high-status foods, and thus suggests a potential relationship between ceramic use-alteration and household economic status. Vessels used for boiling may have had rough surface treatments to increase thermal shock resistance (Schiffer et al. 1994). In addition, and perhaps most importantly, fermentation vessels tend to be among the largest vessels within the household inventories of many ethnographically documented groups (see examples of tesguino ollas in Fontana 1979; Merrill 1978; Pennington 1963). Therefore, significantly larger vessels should be detected among the rim sherd collections of ceramic inventories used for fermentation and transport (for Blinman 1989; Blitz 1993; Potter 2000 for archaeological examples of this pattern). A fundamental flaw with the beverage transport model is that such large vessels were commonly left at primary residence sites as site furniture. The large size and combined weight of ceramic vessel and beverage contents may have been rather prohibitive for anything except very short trips. Of course, it is possible that fermented beverages could have been decanted from large ollas to smaller jars for transport. These vessels should have similar use-alteration attributes as the large fermentation vessels.

Secondary Use of Ceramic Sherds as Tools

The secondary use of ceramic sherds as tools also could have contributed to the extensive distributional patterns observed in the region. An important distinction between this use of ceramics and those reviewed above is that it was sherds, rather than vessels, being transported across the landscape. The observed ceramic distributions across regional basins, or at least a component of such distributions, would have resulted from discarded and broken sherd tools rather than broken vessels, and thus should exhibit different forms of distributional patterning and specific attributes. Most notably, of course, will be the presence of ground, chipped, or abraded edges on sherds.

Data on worked or edge-modified sherds is available from several habitation sites in the region (see discussions in Hard 1983; Miller 1989, 1990; Sale 2003) but is lacking from assemblages representing low-intensity occupations or logistical landscapes. Several forms of utilized sherds

and edge modifications have been identified, but the most majority either have rough, uneven and heavily worn edges suggesting their use as scoops or digging tools, smooth edges with polish and striations suggesting possible pottery production tools, and smooth, rounded edges from finely-shaped disks and palettes. Sherd scoops and digging tools are more common among logistical plant processing sites on alluvial fans and were likely used during the construction and emptying of roasting facilities. Similar forms of sherd tools have been recovered from Hohokam agave processing sites (Van Buren et al. 1992). Vessel fragments with smoothed edges have also been recovered from the floors of habitation structures, rock-lined pits, and other thermal features at some habitation sites, including items that are sooted, contain traces of pigments, or are otherwise unmodified. Possible uses for these items range from grills for parching seeds, plates for serving food, and palettes for pigment preparation.

The uses for such items often can be inferred on contextual and other evidence at the habitation sites (e.g., Oppelt 1984). Most ethnographically-documented practices of secondary use of sherds involve domestic production and subsistence tasks such as scoops, palettes, pot holders, temper, lids, pottery tools, kiln wasters (see summary in P. Rice 1987:294). In the present case, however, it is difficult to posit exactly what these tools would have been used for in logistical contexts around playas and within the central basins.

One potentially interesting aspect is that circular sherds with smoothly ground edges often have holes drilled in the center. These have often, based on relatively meager evidence, been interpreted as spindle whorls or gaming pieces. An alternative explanation is that they were used to seal the orifices of ceramic vessels.

If the use and discard of sherd tools created a significant component of the ceramic distributions within a given area, then likewise a significant proportion of edge-modified sherds should be present in the assemblages. Sherds from the project area will be examined for evidence of secondary use in the form of ground, striated, or abraded edges. The type of abrasion will be monitored. In addition, the diameters of any sherd disks or disk fragments will be estimated and compared to the distributions of vessel orifice diameters recorded among logistical and residential sites in the vicinity.

Transporting and Caching Ritual or Status Items

Ceramic vessels, being much more secure and resilient than organic containers, would have been the preferred means of transporting ritual and status items, and appear to have definitely been the preferred technology for caching such items. Isolated caches of jewelry or minerals in the region have usually been found within ceramic containers (Achim 1984; Kelly 1977; Wooldridge 1979). Ceramics used for caching can easily and unambiguously be identified by the simple fact of their association with cached ritual or prestige items. However, compared to the multitude of common domestic and ritual uses of ceramic vessels, caching is exceptionally rare and is often involves unique locations such as niches in limestone hills or mountain slopes and escarpments (e.g., Achim 1984; Moore and Wheat 1951; Wooldridge 1979) or within floors or pits at residential sites (e.g., Hill 1971; Phelps 1967) and it is highly unlikely that this behavior contributed in any significant manner to the logistical ceramic distributions under study.

Summary: Alternative Hypotheses and Test Implications for Logistical Ceramic Distributions:

Ceramic studies offer the greatest temporal control and variety of approaches for studying logistical mobility. However, the problem of equifinality must be considered when modeling the relationships between ceramic distributions and the various forms of logistical landscape use. One or more logistical patterns could conceivably result in similar ceramic attributes and distributional patterns. Some studies will require larger distributional data to track vessels across broad areas. We hope to monitor these results of this and other ongoing mitigation programs to compile

distributional ceramic data across the Hueco Bolson and Tularosa Basin at larger spatial and temporal scales. In the interim, and for purposes of modeling, the following discussion establishes a series of test expectations involving various ceramic attributes and geochemical distributional patterns for the alternative models of logistical ceramic distributions/

We envision three alternative patterns of ceramic use and logistical organization involving prehistoric resource stress:

- (1) logistical collection and transport of subsistence and economic items to the primary residence, with increasing transport distances resulting from local resource depletion
- (2) the use of sherds as tools for logistical procurement tasks around playa margins
- (3) water transport

In addition, a fourth alternative may be considered that involves a special type of transport:

- (4) transport of fermented beverages for communal feasting or other socially integrative functions

Four patterns of logistical water transport have been proposed based on the boundary conditions established in the discussion of playa hydrology and agricultural potential:

- (1) local transport of water to playa-margin settlements for human consumption and domestic use
- (2) transport of water from playas with ponded water, or from other sources, to settlements near dry or drying playas
- (3) water transport to local dry farming fields for supplemental irrigation
- (4) transport of supplemental irrigation water to multiple field locations as a buffering strategy to reduce agricultural risk

Table 1 summarizes the various technological, performance, and use-alteration attributes expected for patterns of ceramic utilization presented throughout the previous discussion. Distance from source expectations for chemical provenience signatures of El Paso brownware ceramics are also provided in this table. These expectations are based on the premise that, if the ceramic distributions arose from logistical forays at increasing distances from a primary pueblo residence, it would be expected that the chemical profile of sherds broken and discarded during long-distance collection events should differ from those of local residential occupations. Upon obtaining a sufficient sample number of sites and assemblages, it is hoped that one or more of these attribute clusters will become consistently manifested, ultimately leading to empirically-based insights into Late Formative period logistical use of the playa margin landscape.

Table A.1.
Alternative Models for Logistical Ceramic Use and Technological, Performance, and Use-Alteration Expectations

Alternative	Ceramic Type	Vessel Form	Rim Form	Orifice	Wall Thickness	Surface Finish	Edge Modification
Subsistence Collection and Transport	EP brownware (utilitarian)	variable	direct, everted	wide restricted, unrestricted	unknown	striated, variable	absent
Sherd Tools	Local and Non-Local	typical bowl, jar ratios for type	very few rims	n/a	variable	variable	present
Water Transport	EP brownware (utilitarian)	>95% jar	highly everted	narrow restricted	thin	smoothed, self-slip, slight polish, no sooting	absent
Fermented Beverage Transport	EP brownware (utilitarian, elaborate polychrome?)	>95% jar, large size	everted, large size	wide or narrow? restricted	thin	smoothed or striated, interior pitting	absent

Distance model for chemical compositional groups

Alternative	Chemical signature of ceramics from logistic locales	Geographic Distributions
Subsistence Collection and Transport	Non-local	Widespread, playa and non-playa
Sherd Tools	Variable	Widespread, playa and non-playa
Fermented Beverage Transport	Non-local	Widespread, playa and non-playa
Water Transport		
Local transport for domestic use	Local	playa margins
Distant transport for domestic use	Non-local	playa margins, between playas, highly patterned
Local supplemental irrigation	Local	playa margins
Distant supplemental irrigation	Non-local	playa margins, between playas, highly patterned

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Programmatic Research Design: Formative Period Resource Stress and Limited Activity Structural Sites or Field House Settlements

The programmatic research design (PRD) is designed to investigate a subset of prehistoric archaeological sites determined to be eligible for inclusion in the NRHP by their ability to address the historic context Occupational Histories and Settlement Organizational Responses to Risk During the Late Formative Period. This historic context subsumes the Subsistence, Site Formation, Settlement Pattern, and Social, Ritual, and Political Organization research domains (Chapters 8, 10, 11, and 12 respectively, of Part III). This context examines the relationships between resource structure characteristic of the desert lowlands of Fort Bliss (high spatial and temporal variability in rainfall, temperature, and biomass) and settlement strategies and resultant site types.

The data needs and analysis requirements for this historic context include (1) analysis of the form, formality, and permanence of architectural and storage features; and (2) application of accumulations research models; and (3) analysis of assemblage diversity, technology, and portability; and (4) geochemical sourcing to examine procurement and catchment ranges; and/or (5) analysis of site formation and site structure; and/or (6) analysis of resource stress and depletion.

The premise of the PRD is that a broader range of functional interpretations and settlement models should be explored for sites with single structures that have often been interpreted as “field houses.” The typical historic property (site type) will involve Late Formative period residential settlements consisting of a single house structure (occasionally two structures) associated with low-to-moderate density of material culture. The sites will have Formative period components that can be verified through chronometric dating. The research design presented here is focused primarily on site types characterized by a single house structure. It may be expanded to examine different strategies of population aggregation and dispersion in response to environmental risk and uncertainty as reflected in pithouse, surface room, and pueblo settlements.

Research Design

Isolated Doña Ana phase and El Paso phase structures have been reported at FB 10411 (Mauldin et al. 1998), FB 12432 (Lowry and Bentley 1997), and LA 72859 [MOTR site] (Browning et al. 1992) in the Hueco Bolson of Fort Bliss Maneuver Areas 1 and 2. Elsewhere, similar structures have been documented at the Vista del Sol Site (Miller et al. 1993), Keystone Dam 37 (Carmichael 1985), possibly at the Gobernadora Site (Miller 1989), the Doña Ana County Airport (DACA) Pithouse Site (Batcho et al. 1985), and at numerous sites in the San Andres Mountains (Browning 1991).

Some researchers have explicitly interpreted these and other such settlements as field house occupations (Batcho et al. 1985; Browning 1991; Browning et al. 1992; Duran and Batcho 1983), although Carmichael (1985) interprets the structural remains (and burned rock middens) at Keystone Dam Site 37 as representing mobile hunter-gatherer groups that co-existed with sedentary agriculturalists – an example of “adaptive diversity.” Aside from this lone alternative view, the field house interpretation has maintained primacy in the literature and continues to be cited in various publications (e.g., Abbott et al. 1996; Church et al. 2002; Dering et al. 2001; Mauldin et al. 1998; Miller and Kenmotsu 2004; Railey 2002).

However, regarding the archaeological study of field house settlements, as early as 1978 McAllister and Plog observed:

The interpretation of sites with small and crude architectural units represents an important challenge to Southwestern archaeologists. For many years, such sites have been ignored because they were missed by surveyors employing overly extensive techniques, or were judged not worth excavating. Alternatively, when noted, *such sites have been casually interpreted as “field houses” with little or no systematic testing of the interpretive hypothesis* [McAllister and Plog 1978:17; emphasis added].

It is the issue of presumptuous interpretation expressed in the passage above that establishes the foundation of the current research design. It may very well be that these settlement types in the Jornada do represent field houses using Woodbury's (1961) original definition as such. However, substantial variation exists among small architectural settlements across the Southwest, and not all such settlements may have functioned solely as field maintenance settlements (Kohler 1992; Ward 1978). Ebert and Kohler (1988:114) observe that, “Among Pueblo agriculturalists, both living and prehistoric, special-purpose sites have often been lumped under the rubric of “field houses,” although they may have had many functions.” Perhaps unsurprisingly, this variation is also manifested in the small sample of “field house” settlements documented in the Jornada region, and thus a more rigorous analytical approach to identifying such settlements is clearly warranted. It may also be more appropriate at this point in time to adopt a less value-laden term, such as “limited activity structural site,” rather than “field house.”

First and foremost, agricultural field houses are, by nature and definition, generally positioned in close proximity to the agricultural fields the inhabitants were maintaining (Ciolek-Torrello et al. 1998; Lightfoot 1993a; Preucel 1988; Sullivan 1994; Woodbury 1961; see also numerous examples in Ward 1978). That is, structural remains of settlements with one or two houses have often been documented in proximity to evidence for the construction, maintenance, and supervision of intensive agricultural field and hydraulic systems, such as check dams, terraces, mulched fields, rock piles, bordered fields, as well as combinations of these features. In such cases, a relatively clear association exists between the habitation structures thought to represent field houses and the specific agricultural fields and hydraulic systems being maintained by the inhabitants of the structures (Lightfoot 1993a, 1993b).

In many cases in the Jornada Mogollon region, no distinctive evidence of intensive agricultural and hydraulic landscape modifications has been observed (contra Hubbard 1987) with the exception of the possible reservoir at Hot Well Pueblo. Of course, this does not mean that some forms of low intensity agricultural landscape modifications were not undertaken. Agricultural practices along alluvial flood plains and runoff channels probably consisted of simple stick and pole diversions, small and shallow earthen check or diversion dams, and other ephemeral water diversion and capture methods similar to those documented among the historic Pima, Papago, Tohoho Oodham, and Hopi (Castetter and Bell 1942, 1951; Hack 1942; Nabham 1985, 1986; Nabham and Sheridan 1977). Such practices would have left little trace or have long since been eroded, although it is possible that at least some of these artificial hydraulic features would have been buried and preserved under alluvial flood sediments. Yet, subsurface geomorphic investigations along a 200 meter-long segment of the Franklin Mountains alluvial fan piedmont found no evidence of buried diversion channels or dams (Miller and Ponczynski 1989; Dockall 1999). Accordingly, the linkage between agricultural field house settlements and relatively intensive field and hydraulic systems is rather tenuous in the Jornada. However, it is also probable that many agricultural fields were simple ak chin runoff fields situated along distal alluvial fan piedmonts or dry farmed fields along playa margins. Due to the unpredictability and risk involved with farming these areas, it is possible that ak chin or dry farmed fields were often maintained at a distance from the primary residence and may have involved temporary settlements.

Second, and of near equal importance, a review of the Southwestern literature finds that sites and occupations assigned as field house settlements display a surprising range of variability in terms of architecture, size, site layout, and artifact content and diversity (Kohler 2004; Orcutt 1993; Pilles 1978; Powell 1983). The functional role of fieldhouses clearly incorporates a seasonal component, but also several economic and functional roles beyond mere field maintenance. In an intriguing study of field house occupations on the densely inhabited Pajarito Plateau, Orcutt (1993) observed significantly higher proportions of faunal remains and obsidian tools (procured from obsidian sources located at some distance from the canyon floors) at field house settlements than at local pueblo settlements, indicating that additional subsistence and economic roles beyond mere field maintenance were performed by the inhabitants of field houses. In addition to subsistence and economic roles, field house settlements may have played important roles in establishing and maintaining land tenure (Kohler 1992).

A similar range of variation is present among the sample of Jornada Mogollon sites having one or two structures. The range of variation is surprising in light of the fact that the sample of excavated sites is very small (n=7). Table A.2 provides basic information on this sample of sites. We are here concerned primarily with Late Doña Ana phase and El Paso phase isolated structural sites, as these periods are demonstrably agricultural (Whalen 1994; Miller and Kenmotsu 2004). Numerous incidences of isolated Mesilla and Archaic structures have been documented, but it is much more likely that these represent mobile settlement systems rather than field houses associated with sedentary agriculturalists.

As illustrated in Table A.2, substantial variation exists among the architectural forms, assemblage content, and extramural features documented in this small sample of habitation sites. Small architectural sites in the San Andres alluvial fans and arroyo-margin terraces typically have surface-visible architecture consisting of stone foundations, or cimientos (Browning 1991). Sites in the central basins include a variety of structural forms ranging from ephemeral round and shallow pit structures to deeper, rectangular structures and formally constructed surface rooms. Taking into account the relationship between the construction formality of architectural structures at a habitation site and settlement duration or intensity, it is evident that the limited activity structural sites in the area represent a wide range of settlement histories.

The considerable variation among assemblage size and diversity among the sample of sites provides further evidence that settlement histories were highly variable. The DACA Pithouse Site contained over 4,100 sherds (Miller 2001:147), compared to less than 100 at FB 10411 (Mauldin et al. 1996) and 50 recovered from around the Vista del Sol Site structure (Miller et al. 1993). Lithic and ground stone counts had similar ranges of variation. Equally intriguing is the variation among subsistence items. While this factor is partially conditioned by preservation factors, it still remains interesting that faunal and plant remains suggesting a fully domestic occupation were recovered from the Gobernadora, MOTR, and DACA sites. In contrast, faunal bone and charred food items were rare or absent at the remaining sample of limited activity structural sites.

Of critical interest is the variation among the sample of sites in the presence or absence of extramural features and particularly storage pits. It appears that most sites having some degree of extramural excavations, such as FB 10411, MOTR, Gobernadora, Vista del Sol, and Keystone 37, apparently lacked extramural pits. In marked contrast, one of the hallmark attributes of the Doña Ana Airport Pithouse Site was the presence of numerous large and deep extramural pits positioned within a 20 m distance of the two structures (Batcho et al. 1985). These pits contained dense deposits of charred plant remains (primarily corn, beans, and mesquite) and artifact refuse, and suggest that long-term storage was a prominent aspect of the settlement.

Table A.2.
 Characteristics of Some Possible Late Formative Period Field House Settlements in the Jornada Region

Site Number (Name)	Structure Type	Extramural Features	Relative Assemblage Density	Content Diversity	Ritual or Status Items	Other
FB 10411	round, shallow, and ephemeral	Hearth, no pits	moderate	low	None	
FB 12432	subrectangular, deep	Unknown	moderate	low	None	
41EP321 (Gobernadora)	subrectangular, deep	Formal roasting pits? No hearths or pits	high	moderate	Shell beads? (in fill)	
LA 72859 (MOTR)	surface room with plastered floor	Hearth? No pits	high	high	Turquoise, shell, bone, pigment	
41EP2970 (Vista del Sol)	subrectangular, shallow with interior pit	Hearth, no pits	low	low	None	
41EP492 (Keystone 37)	subrectangular, deep	Hearth, no pits	Moderate	low	None	
LA 26788 (DACA site)	1 surface room with formal floor and 1 round, shallow structure	Multiple deep storage and trash pits	high	high	None	Wide variety of non-local ceramics, large quantity and variety of subsistence items from pits
San Andres Mountains (several sites)	cimiento construction, floor and subfloor unknown	unknown	moderate?	unknown	Unknown	

Aside from storage pits, the Gobernadora site is intriguing because of the potential association of an isolated structure and several rock-lined pit roasting facilities (Miller 1989), suggesting that bulk processing of cacti and succulents during the Late Doña Ana phase and early part of the El Paso phase along the Franklin Mountain alluvial fan piedmont may occasionally been of such magnitude and duration that temporary habitations were required.

Finally, the presence or absence of ritual or status items is noteworthy. A somewhat surprising number and variety of status or ritual objects were recovered from the MOTR Site, including turquoise, shell, and bone jewelry items, and several mineral and pigment items (Browning et al. 1992). With the exception of a small number of shell beads recovered from a questionable context (trash fill in a pit house) at Gobernadora, ritual or status items are notable by their absence among limited activity structural sites in the region. Although no such items were recovered from the DACA Pithouse Site, it is important to note that a wide range of Chihuahuan ceramics were present. These findings add another aspect of variation to the small sample of Jornada sites and again suggest that perhaps such sites had several functional roles.

Alternative Models of Limited Activity Structural Sites

From the preceding discussion it is evident that limited activity habitation sites in the Jornada region exhibit a substantial range of variation, and it is likely that a wider range of functional and social roles may be posited for such occupations. Based on this variation, four models may be proposed for the study of limited activity structural sites on Fort Bliss.

(1) Small structural settlements with one or two structures served as agricultural field houses. Two corollary functions are subsumed under this model. First, such settlements served as temporary residences during the construction and maintenance of agricultural fields and perhaps associated water diversion and capture (hydraulic) facilities. Second, such settlements may have served to establish and maintain land tenure as posited by Kohler (1992). A combination of both models is also plausible and likely. However, when considering analytical approaches or expectations for these two corollary functions, it should be cautioned that

..no completely satisfactory distinction can be made between the expectations of models that view field houses as the result of attempts to minimize the cost of having to maintain fields at some remove from habitations, and models that view field houses as attempts by some corporate groups to restrict access to resources [Kohler 1992: 632; see also Orcutt 1993].

(2) Small structural settlements functioned as extended seasonal procurement or hunting camps. The possible association of isolated structures and roasting facilities at the Gobernadora site suggests that bulk processing of cacti and succulents may occasionally been of such magnitude and duration that temporary habitations were required. The occupation of small structural sites during extended hunting trips may also be considered.

(3) Small structural settlements represent episodes of pronounced population dispersion during periods of extreme resource and/or social stress. During periods of extreme resource stress (and accompanying stresses on social networks, particularly at aggregated settlements) would have resulted in the widespread dispersion of small social groups across the landscape in a fashion similar to previous cultural phases in the region. Such a settlement system would resemble earlier periods characterized by small, low-intensity occupations across multiple environmental zones.

A corollary to this model is that some small structural settlements could represent the final dissolution of the El Paso phase puebloan settlement system, a position that is similar to that above except that settlements would be restricted to a narrow time range of perhaps 10-20 years at the end of the El Paso phase at circa A.D. 1450.

(4) Small structural settlements represent a variety of functional and social roles, including as yet unspecified functions. While not actually representing an alternative model, the fourth alternative explanation is that such settlements represent other as yet unknown or unspecified functions.

The final alternative is mentioned because of the wide variation among the sample of limited activity structural sites in the area, and the numerous questions that arise from the preceding review and discussion. What social and settlement factors led to the deposition of ritual and status objects at the MOTR site, and what factors led to the transport of such a wide variety of Chihuahuan ceramics at the DACA Pithouse Site? What functional role in the larger El Paso phase settlement system did the single, isolated, and ephemeral structure at FB 10411 in the central Hueco Bolson have played?

Specific Research Questions and Analyses

Research Question 1. In a comparative sense, what is the duration and function of the residential components consisting of single isolated structures? How do these occupations relate to the larger settlement system?

Evaluating, in a relative sense, the timing, length, and intensity of the occupations at the residential components of these sites is important for determining the length of time that the resident social group(s) remained separated from primary residences. The presence or absence of storage facilities and the volume of such features may indicate whether storage of agricultural produce took place. Data from the sites investigated during the project can be compared to that documented for the seven limited activity structural sites listed in Table 1.

Data Needs and Analyses:

Data needs	Analyses
a) Record of pit house construction formality	a) Comparative analysis of architectural construction formality
b) Record of artifact assemblage attributes and proveniences.	b) Comparative analysis of data as a measure of residential use intensity and duration using accumulations research models.
a) Presence and nature of extramural pit features.	c) Evaluate presence and types of pits, comparative analysis of storage volume.
b) Record of technological and functional attributes of ceramic and lithic assemblage.	d) Compare technological and functional data on ceramic and lithic materials with other Late Formative period residential sites in the area.
c) Ceramic and raw material from the project area and other Late Formative period residential sites in the area	e) Geochemical and petrographic analysis of ceramics and raw material source identification to identify mobility ranges of inhabitants and relationship with pueblo occupation areas in the vicinity.
d) Assemblage content and diversity	f) Comparison of assemblage content and diversity with other limited activity structural sites.

Research Question 2. Which of the competing alternative models of limited activity structural sites reviewed above can be applied to the occupations at sites with isolated structures in the project area?

Expectations for Field Houses: Under this model, occupations at these sites functioned specifically as field houses for the establishment and maintenance of agricultural fields, as well as to maintain tenure to certain field areas. It is expected that analysis of architecture and storage capacity would determine that these were seasonal, yet relatively long-term, settlements with the full range of residential functions. It is also expected that such sites will be situated in close proximity to agriculturally productive landscapes. It is also expected that such occupations will have comparatively diverse artifact inventories.

Expectations for Seasonal Procurement or Hunting Settlements: Under this model, occupations at these sites functioned specifically as seasonal base locations for bulk procurement or processing of plant and/or animal foods. It is expected that analysis of architecture and storage capacity would determine that these were relatively short-term, seasonal settlements with a limited range of residential functions. It is also expected that such sites will be situated in close proximity to productive resource areas, such as alluvial fan piedmonts, canyons, foothills, and river terraces. It is also expected that such occupations will have comparatively limited artifact inventories of low diversity.

Expectations for Population Dispersion: This model proposes specific social and cultural-ecological relationships and requires a broad, regional scale of analysis. A basic premise is that resource depletion and stress played a major role in structuring Doña Ana phase and El Paso phase settlement adaptations. Aggregated populations occupying El Paso phase pueblos would soon have exhausted local stores of critical resources such as fuel and construction wood, subsistence and medicinal plants, and fauna. Periods of decreased annual rainfall, combined with higher temperatures that would increase evaporation rates of runoff water contained within playas, would have added further stress to the El Paso phase agricultural subsistence system. Uncertainty and risk factors symptomatic of playa and floodwater agricultural practices in the arid Jornada region would result in the frequent need for aggregated populations to disperse. Population dispersion may have occurred on a seasonal basis or resulted from climatic and demographic pressures. In some cases, severe resource stress may have resulted in pronounced levels of population dispersion, such as limited activity habitation sites. It is also possible that some of the small structural settlements could represent the final dissolution of the El Paso phase puebloan settlement system, a position that is similar to that above except that settlements would be restricted to a narrow time range of perhaps 10-20 years at the end of the El Paso phase at circa A.D. 1450.

Such settlements may be difficult to differentiate from short-term resource procurement settlements. However, it is probable that such occupations would more closely resemble Mesilla phase, and perhaps even Archaic period, mobile hunter-gatherer settlements than pueblo or pit house village occupations. We would also propose that ritual and status items should be rare or absent, reflecting the dissolution of social and political structures present at aggregated pueblo settlements. In addition, analysis of subsistence economies, fuel wood, and other economic indicators should show evidence of resource stress. Finally, if dating methods of sufficient resolution and precision are available, we will attempt to determine if the settlements date to the terminal years of the El Paso phase.

Data Needs and Analyses: At the present time, the evidence for any or all of these models is equivocal. Several lines of evidence will be brought to bear on these issues during the analysis of various classes of data from the project area.

Data needs	Analyses
a) Refined chronometric dating. b) Artifact counts, densities, and diversity c) Record of type, number, and provenience of ritual and status objects d) Architectural formality and storage capacity e) Identification of heartwood, sapwood, and root specimens among wood charcoal samples; identification of faunal species indicative of local environmental stress; identification of greater proportions of non-domesticated plants indicating possible agricultural stress	a) Refined chronometric design and interpretation: multiple chronometric datasets will be examined to establish whether terminal El Paso phase occupations are present b) Comparative analysis of assemblage content c) Comparative study of social and political organization among limited activity structural settlements d) Comparative analysis of architecture and storage to evaluate whether sites functioned as relatively long-term field house settlements e) Analysis of subsistence economies to evaluate evidence of resource stress and depletion.

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APPENDIX B. ACRONYMS

ACRONYMS

ACHP	Advisory Council on Historic Preservation
ADA	Air Defense Artillery
Amsl	Above mean sea level
APE	Area of potential effect
AR	Army Regulation
AMS	Accelerator mass spectrometer
ANOVA	Analysis of variance
ANPP	Aboveground net primary productivity
BRAC	Base Realignment and Closure Act
BLM	Bureau of Land Management
Cheno-Am	<i>Chenopodium/Amaranthus</i>
CIEP	Crossover immunological electrophoresis
CLT	Central Limit Theorem
CRM	Cultural resource management
CRCP	Chronometric and Relative Chronology Project
CRMP	Cultural Resources Management Plan
DEM	Digital elevation models
EPAS	El Paso Archeological Society
ESR	Electron spin resonance
ET	Effective temperature
FAW	Forward Area Weapons
GBFEL-TIE	Ground-based Free Electron Laser Technology Integration Experiment
GIS	Geographic information systems
GPS	Global positioning system
GMI	Geo-Marine, Inc.
HBE	Human behavioral ecology
HSR	Human Systems Research, Inc.
ICRMP	Integrated Cultural Resource Management Plan
IRSL	Infrared stimulated luminescence
Jornada LTER	Jornada Long-Term Ecological Research
LMAS	Lone Mountain Archaeological Services, Inc.

MNI	Minimum number of individuals
MOA	Memorandum of Agreement
NAA	Neutron activation analysis
NAGPRA	Native American Graves Protection and Repatriation Act of 1990
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NISP	Number of identifiable specimens
NRHP	National Register of Historic Places
OCA	Office of Contract Archeology
OCR	Oxidizable carbon ratio
OSL	Optically-stimulated luminescence
PA	Programmatic Agreement
PALM	Potential archaeological liability maps
PDA	Personal digital assistant
PP	Primary productivity
ppm	Parts per million
ppt	Parts per thousand
RFP	Request for Proposal
RSI	Rim Sherd Index
SADIE	Spatial analysis by distance indices
SCS	Soil Conservation Service (renamed the Natural Resources Conservation Service – NRCS)
SIMS	Secondary ion mass spectrometry
SHPO	State Historic Preservation Officer
SOP	Standard Operating Procedure
TL	thermoluminescence
TRADOC	United States Army Training and Doctrine Command
TRC	TRC Environmental, Inc.
TRU	Transect recording unit
USGS	United States Geological Service
VGP	Virtual geomagnetic pole
VLCS-	Very long chain (C20, C22, and C24) saturated fatty acids
VLCU -	Very long chain (C20, C22, and C24) unsaturated fatty acids
XRF	X-ray fluorescence

APPENDIX C. AGENCY REVIEW LETTERS



TEXAS
HISTORICAL
COMMISSION

The State Agency for Historic Preservation

RICK PERRY, GOVERNOR

JOHN L. NAU, III, CHAIRMAN

F. LAWRENCE OAKS, EXECUTIVE DIRECTOR

December 18, 2008

Brian Knight
Senior Archeologist
Department of the Army
Headquarters, US Army Garrison Command
Environmental division, Conservation Branch
IMWE-BLS-PWE
Fort Bliss, Texas 79916-6816

RE: Project review under Section 106 of the National Historic Preservation Act of 1966, Draft *Significance and Research Standards for Prehistoric Archaeological Sites at Fort Bliss (Revised 2008): A Design for the Evaluation, Management and Treatment of Cultural Resources*, Fort Bliss Project 0516, El Paso County, Texas (Army-Fort Bliss)

Dear Mr. Knight:

This letter serves as comment on the proposed federal undertaking from the State Historic Preservation Officer, the Executive Director of the Texas Historical Commission.

The review staff, led by Debra L. Beene, has completed its review. Thank you for a well written and comprehensive significance standards document; we highly applaud this new approach in studying and evaluating the extensive and significant prehistoric occupations in this portion of the Jornada region. It provides a programmatic approach to the evaluation, management and data recovery of prehistoric cultural resources within Fort Bliss and this cultural region of Texas and New Mexico. We support the two tier ranking system in determining National Register of Historic Places (NRHP) eligibility; only when a site has demonstrable spatial integrity and chronological potential, will it be further evaluated through the research domains that are specifically tailored to the nature of the prehistoric archeological record of Fort Bliss and the greater Jornada region.

This document should be used as the guide for focusing all future research at Fort Bliss; all contracting cultural resource firms should be required to incorporate the programmatic approaches for evaluation, management and data recovery by focusing on the characteristics that make a property eligible. These guidelines should result in the type of investigative reports we wish to see on a regular basis and clearly demonstrate the potential of Jornada Mogollon research to address issues of archeological and anthropological significance.

We look forward to further consultation with your office and hope to maintain a partnership that will foster effective historic preservation. Thank you for your assistance in this federal review process, and for your efforts to preserve the irreplaceable heritage of Texas. **If you have any questions concerning our review or if we can be of further assistance, please contact Debra L. Beene at 512/463-5865.**

Sincerely,

F. Lawrence Oaks, Executive Director

cc: Sue Sitton, Archeologist, Fort Bliss
Myles Miller, Archeologist, Geo-Marine, Inc.

FLO/dlb

Sackett, Russell H Mr CIV USA IMCOM

From: Jimmy Arterberry [jimmya@cne-mail.com]
Sent: Thursday, November 13, 2008 10:12 AM
To: Sackett, Russell H Mr CIV USA IMCOM
Subject: DSS

Good morning Russ!

I finally got through the Draft Significant Standards document. Although it is quite interesting, our concerns relate to the potential loss of sites that are determined to be ineligible for the NRHP. The research design is remiss of the indigenous perspective, which is that "all of these sites, whether small or large have the potential to yield significant data and are better serving to the future of this country's history by being left undisturbed". But more importantly, these sites represent our ancient histories and are the physical evidence of our existence here in the Americas. The DSS addresses the limitations and bias of individuals, such as; funding restrictions, personnel qualifications, training/time constraints, BRAC requirements, as well as numerous others, but the real question for us is whether the eligibility determination is being made in consideration to the impact on Native American history. As the heirs and descendants of such cultural magnificence, evidenced by archeological features/sites, it is imperative that a recognition for the continual protection of such resources be addressed by those responsible for their maintenance. If one hearth represents a source of procuring sustenance and another as spiritual realization, then how is the sacredness of each defined in the significance standards data collection process and taken into consideration as being NRHP eligible? If both are viewed in relation to each other and as separate, yet equal, then it is obvious that each is significant in its own right and worthy of protection, as evidenced by purpose and in consideration of unknown but relevant data potential.

The DSS summary statement provides a well thought out message which states "...a research design forms the basis of significance decisions that affect management...which has lasting implications" and although..."the law does not allow for site protection unless it meets eligibility requirements for the NRHP"...it is the responsibility of cultural resource managers and others involved in the evaluation process of sites to acknowledge a responsibility towards the future as well as past. Please consider these comments as words of insight, when making a reasonable and good faith effort to identify site significance in the broader decision making process. Jimmy

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BILL RICHARDSON
Governor

STATE OF NEW MEXICO
DEPARTMENT OF CULTURAL AFFAIRS
HISTORIC PRESERVATION DIVISION

BATAAN MEMORIAL BUILDING
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March 3, 2009

Brian Knight
Senior Archaeologist
Department of the Army
Headquarters, US Army Garrison Comment
Environmental Division, Conservation Branch
IMWE-BLS-PWE
Fort Bliss, Texas 79916-6816

Re: Proposed *Significance and Research Standards for Prehistoric Archaeological Sites at Fort Bliss: A Design for the Evaluation, Management and Treatment of Cultural Properties* (revised 2008)


Dear Mr. Knight:

I wanted to thank you for your patience and I am, by this letter, providing the official comments on the draft significance standards on behalf of the New Mexico State Historic Preservation Officer (NMSHPO). I first want to recognize the commitment Fort Bliss has made, particularly over the past decade, to support and develop its cultural resources management program. The revised significance and research standards are another step in the maturation of the program that will not only streamline consultation but also should continue to enhance the quality the cultural resources studies at Fort Bliss and increase their impact and contribution to archaeology in New Mexico and Texas.

The draft document provides a comprehensive review of previous research at Fort Bliss and well-developed rationale for new priorities and approaches. The topics are well written and clearly demonstrate Fort Bliss' continued leadership role in advancing knowledge of the prehistoric occupation in the Jornada Mogollon region. The New Mexico SHPO strongly endorses the intent to move forward research and emphasize topics and approaches that have broad anthropological and archaeological relevance.

As you and I discussed, I do have some reservations about the evaluation criteria and the potential bias that could be introduced by eliminating sites that are difficult to date or assign to an occupation period from future protection. These sites, collectively, may be critical in the future and many may be lost for future study. At the same time, I am in overall agreement with the research priorities advanced in the document and recognize the more limited potential of these sites to address the questions of current importance.

Brian Knight
March 3, 2009
page 2

Rather than asking Fort Bliss to revise the document at this time, the NMSHPO supports its implementation for a period of five years and requests that Fort Bliss agree to prepare a document that assesses the effectiveness of the program at that time. If necessary, the document could recommend that the program be amended or revised and final decisions would be made in consultation with the New Mexico and Texas SHPOs. During this same period, NMSHPO will be reviewing the preliminary results of another new approach and research program in southeast New Mexico (BLM Permian Basin MOA) that could, in conjunction with the work at Fort Bliss, lead to better management of the cultural resources in southern New Mexico.

Thank you again for extending our comment period. We look forward our continued work together.

Sincerely,



Jan V. Biella
Deputy State Historic Preservation Officer



United States
Department of
Agriculture

Forest
Service

Lincoln National Forest

3463 Las Palomas Rd.
Alamogordo, NM 88310
(575) 434-7200

File Code: 2360

Date: November 6, 2008

Brian Knight
Senior Archeologist
Department of the Army, Headquarters, U.S. Army
Garrison Command
Environmental Division, Conservation Branch
IMWE-BLS-PWE
Fort Bliss, TX 79916-6816

Dear Mr. Knight:

Thank you for the opportunity to review the document *Significance and Research Standards for Prehistoric Archeological Sites at Fort Bliss (Revised 2008): A Design for the Evaluation, Management, and Treatment of Cultural Resources*. The document has a great deal of information and data. The Heritage Resource staff at the Lincoln National Forest has a few comments focusing on eligibility determinations for the National Register of Historic Places.

According to the document, National Register eligibility determinations are based on present regional research issues. Research issues and needs may change as new methods for dating and analysis develop, flexibility in site management should be practiced especially for smaller site with integrity.

A not eligible determination for a site with less than 30 lithics and a dateable feature is flawed. These small sites could be grouped by date, increasing the statistical sample size of the artifacts. The document states "...contemporaneous sites do not exist in isolation from one another; rather they co-exist in cultural settlement systems" pg 15-4. If pot breaks were viewed individually in a similar fashion, the prehistoric trails found on Fort Bliss would have been over looked.

The document relies on National Register evaluation criterion D for determining eligibility, when Tribes may have other applicable criteria especially for site types like pueblos and rock art.

The document does not address the management of sites on the Lincoln National Forest, located in training area 33. The cultural resources and artifacts there in are the property of the USDA Forest Service. The Department of Defense has been designated the lead agency for National Environmental Policy Act compliance (Master Agreement Between Department of Defense and Department of Agriculture 1988). There is no specific reference in the agreement as to the procedure for National Historic Preservation Act management and review. Nor does it cover the



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procedure for compliance with the host of additional federal laws like the Native American Graves Protection and Repatriation Act. The forest would like the opportunity to review and comment on documents concerning cultural resources in training area 33 and receive a copy of final documents, survey maps and site records. ...

Sincerely,

A handwritten signature in cursive script that reads "Diane White".

DIANE WHITE
Heritage Program Manager



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