A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West

Final Report

Volume I:
Introduction and
Physical Environment

June 1981

Prepared by:
Science Applications, Inc.
1710 Goodridge Drive
McLean, Virginia 22102

A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West

FINAL REPORT

June 30, 1981

Volume 1 | **Introduction**
Physical Environment

Contract Number AA551-CT8-40

Submitted to:

Bureau of Land Management
Hale Boggs Federal Building
500 Camp Street
New Orleans, Louisiana 70130

Submitted by:

Science Applications, Inc.
1710 Goodridge Drive
McLean, Virginia 22102

TABLE OF CONTENTS - VOLUME I

LIST OF FIGURES

LIST OF TABLES - VOLUME I

1.0 EXECUTIVE SUMMARY

A survey and evaluation of the cultural resources on the Continental Shelf of the southeastern United States was conducted to assess the research needed to support the cultural resource management plan. The results and conclusions of this survey will serve as a framework for the management of those cultural resources.

Discovery of reliable evidence of human prehistoric occupation on the Southeastern United States Continental Shelf has never been reported. Therefore, the population distribution of prehistoric man on the shelf, if he ever lived there, is unknown. In contrast, the location of many shipwrecks throughout the study area is known, but the location of many more is unknown. The study design for addressing these two unknowns was to develop models to predict the location of these cultural resources.

Both predictive models are based on the controlling physical environmental parameters. The prehistoric model uses Coastal Plain settlement patterns of early populations in the Atlantic Coastal Plain and adjacent areas as an analog to a shelf settlement pattern. The shipwreck model uses socioeconomic and political conditions during various time periods in addition to environmental parameters to predict shipwreck population distribution.

The approach to the model development was to conduct a comprehensive survey and review of existing data related to the past and present physical environment, prehistoric archeology, and shipping of the southeastern United States. An extensive bibliography of published and unpublished literature has been assembled and reviewed. The sources included university, public, and private libraries, computerized bibliographies, libraries of state and Federal agencies, private company reports, and museum libraries. Archeological and paleontological data in museum and private collections was examined.

Interviews were conducted with researchers, museum curators, state and Federal officials, and salvage operators, as well as avocational archeologists and divers.

The physical environmental parameters that came together to form habitats attractive to Paleoindian through Late Archaic populations are the same parameters that can preserve or destroy the record of his presence. Similarly, geography, geomorphology, and climate, at least in part, control the distribution of shipwrecks. Geological processes can also destroy or preserve the physical integrity of wreck sites, depending on the nature and intensity of the processes involved.

The modern Continental Shelf, south of Cape Hatteras, is relatively shallow before the slope increase marks the edge of the Continental Shelf. This slope break varies from less than 60 metres south of Cape Hatteras to less than 10 metres south of Palm Beach, Florida. In contrast the shelf break off New York exceeds 140 metres.

The significance of this relatively shallow shelf is that sediment transport and deposition on the whole is quite active. In some areas of the shelf, bedrock is exposed with little or no sediment to protect historic or prehistoric artifacts from destruction by wave energy or currents. In both areas, the surface of the shelf is not the same surface that was exposed during lower sea levels. The subaerial surface has either been destroyed or buried, although locally it might periodically be exposed.

There are only certain environments where prehistoric sites could have survived the high energy beach zones as sea level rose. These environments are where post-habitation sediment deposition was greater than the erosion that has occurred at the sites since habitation. The erosion that occurred could have been on the shoreface during sea level rise or modern submarine scour. The flood plain or delta of a river and a back-barrier lagoon beach all have a potential for high rates of sedimentation.

The preservation potential for shipwrecks is highest in areas of low energy and/or high rates of sedimentation. Such environments would be found in a river or harbor, or near an inlet margin, where scouring activity is minimal.

Geological factors that were critical to earliest prehistoric populations were rivers and outcrops of rock suitable for the manufacture of stone tools. Rivers were an obvious source of freshwater, but also attracted game, and depending on origin and course might contain gravel and cobbles for toolmaking. Evidence for ancient river channels on the shelf is sparse, but what could be interpreted from the data as continuous rivers were plotted on maps.

Outcrops of cryptocrystalline rock such as chert, jasper, or flint occur most commonly in the Piedmont, far from the Continental Shelf. Some chert outcrops, however, do occur in the inner Coastal Plain of South Carolina but cryptocrystalline rock has not been reported on the shelf.

It is proposed in this study that a new sea-level curve be adopted for the shelf south of Cape Hatteras. The proposed curve is based on a reassessment of old data combined with new data. According to this curve, sea level in this area had a maximum low level of 60 metres below present level. Because the shelf is shallow, the area exposed is nearly the same for both curves, but the duration of potential habitation is shorter for the new curve.

The shelf off the Georgia and South Carolina coast appears to have the greatest potential for supporting human habitation. This area of the shelf also has the greatest potential for site preservation based on environmental parameters. The river channels that once flowed on this portion of the shelf could have provided all of the required environmental conditions for habitation. Preservation of these sites is probable since a relatively thick sedimentary sequence has been deposited since shelf exposure.

Pollen records and climatological models have been used by others to reconstruct the climatic zones of the southeastern United States. These zones indicate that large game animals were contemporary with Paleoindians. These animals include mammoth, mastodon, bison, sloths, camels, and deer. These animals were a potential food source, but whether they were actually exploited as such in the southeast has not been unequivocally proven.

This study has demonstrated that the availability of certain types of lithic materials was a critical element in the adaptive system of Paleoindians. The population density therefore decreased as the distance from the source of suitable rock increased. Terrestrial archeological data indicate that through time, population concentrations approached the present day shoreline from the Piedmont. This does not rule out occupation on the shelf at any time, but it does suggest that whatever the availability of faunal resources, the lack or limited distribution of other variables critical to the adaptation of early populations discouraged intensive occupations in this area. By the time the modern Coastal Plain became inhabited to any great extent, sea level was within several metres of the present level. Therefore, those submerged environments that had the greatest number of critical necessities near the present shoreline seem to have the greatest potential for containing archeological data (assuming preservation at those sites).

Based on patterns of hurricane landfall and geomorphic promontories, the areas that should contain the greatest shipwreck population density are Cape Hatteras and southern Florida. This is supported by existing records of ship losses. The distribution of shipwrecks throughout the study area is highest within the 20-metre isobath. Shipwreck data throughout the study area varies in completeness. Records of ship losses is strongly dependent on, among others, the type of ship, the coastal population, the time period, cause of sinking, and the care given to preserving records.

Within the study area, the North Carolina coast has the greatest density of known shipwreck sites. Wreck sites of all periods are clustered along the shoals of Cape Hatteras, Cape Lookout, and Cape Fear. The second highest density is along the beaches between Tubbs Inlet and Carolina Beach, along Bogue Banks and between Cape Lookout and Cape Hatteras.

In South Carolina, the most archeologically sensitive area is Charleston Harbor and the shoals at the entrance to the harbor. Other highly sensitive shipwreck areas include Port Royal Sound, Beaufort Anchorage, Cape Romain and Georgetown Anchorage. Relatively few sites are reported beyond the 20-metre isobath.

In the past, relatively little attention has been directed toward determining the extent of the shipwreck population along the Georgia coast. During a recent literature search conducted by the Savannah District U.S. Army Corps of Engineers, an inventory of over 100 ships was compiled for the Savannah River and Brunswick area. Most of the sites appear to date from the late 19th to early 20th century. There is little reliable data on ships lost during the 16th and 17th centuries despite extensive Spanish colonial activity. The shipwreck predictive model suggests the likelihood of a number of shipwrecks dating from the late 16th to mid 18th century which have gone unrecorded along the coastal waterway in vicinities such as Cumberland Island, Brunswick, and St. Simons Island.

The record of ships lost along the east Florida coast is more complete. Shipwreck clusters were identified off St. Augustine, Cape Canaveral Shoals, St. Lucie Inlet to Sebastian Inlet, and Biscayne Bay. The shipwreck distribution model predicted that most of these wrecks would date between the 17th and 18th century in these areas. It was also predicted that 19th and 20th century wrecks would occur in other areas, such as the St. Johns River, Amelia Island, Cape Canaveral, and the Palm Beach-Jupiter coast. This has been largely confirmed by the plotted site distribution.

The clustering of early sites along the Florida Keys is not as apparent as it is off the east coast. The reason is that numerous citations on 16th and 17th century wrecks simply state that a ship was lost "off the Florida Keys." Another reason for lack of wreck clusters is that there were no ports in the Keys during the 16th and 17th century where the loss of ships might have been reported. From 1821, shipwrecks began to be reported along the outer reef tract and shoal, areas which are hazardous to navigation throughout the Keys, from Biscayne Bay to Key West.

Key West Harbor is another area of high shipwreck concentration for all periods. Although infilling and dredging of various areas of the harbor has destroyed many wrecks, several known sites exist which should be protected from further adverse impact.

The technical limitations of various remote-sensing systems for detecting cultural resources have been evaluated. Prehistoric artifacts for the most part cannot be detected using existing systems. These sites are probably small and are often hard to detect even on land. If a submerged shell midden existed it could be imaged by a side-scan sonar system, sub-bottom profiler, and possibly by a magnetometer. The fact that interpretive keys have not been developed for these systems means that the anomalies created by the midden or other archeological features could resemble many other physical environmental features.

Video and fixed-frame camera systems can be used to document a site discovered by other means but are not practicable for reconnaissance because of high cost and slow tow required. Shipwrecks in general are easier to detect using existing systems. Magnetometers can be used to detect ferrous objects, and side-scan sonar and depth recorders can record wrecks projecting from the bottom. The most cost-effective system would be an array of instruments, such as a magnetometer, side-scan sonar and a video system. A multiple-sensor system with real time data display provides the advantages of each system with the option to verify anomalies as they appear.

It is clear from the data analyzed during this study that there are many deficiences in the physical environmental, prehistoric archeological, and shipwreck archeological data bases. Well-planned studies are needed to address the deficiencies before refinements to the cultural resource management plan can be made. For example, site specific studies at shipwrecks should be conducted to determine what variables affect the distribution of artifacts and the physical integrity of hull structures in various depositional environments; the interrelationship between underwater cultural resources and the surrounding natural environment; and the present physical integrity and archeological potential of selected wreck sites. The objective of this reasearch should be to provide data for the refinement of the predictive model outlined in this study.

Additional research should be directed towards studying the remnants of terrestrial and fluvial environments on the near-shore shelf. A specific area such as the Savannah River would be a prime area to conduct detailed stratigraphic and sedimentological surveys. This river drains areas that would have been a primary source of lithic raw materials. The gravel in the submerged stream-bed should contain some of these rocks.

This study had several objectives but the most important was to provide a framework for the development, and recommendations for the implementation, of a cultural resource management plan. The framework prepared in this study is based on the predictive models for prehistoric and shipwreck archeology. The maps that have been prepared for this study display most of the data upon which the models are based.

The recommended approach for management of cultural resources on the shelf is to consider the total resource base rather than isolated sites. Within this approach the three goals outlined in Executive Order No. 11593 for the management of cultural resources can be accomplished. These goals include the identification, protection, and enhancement of resources. The prehistoric archeology model is based on the distribution of environmental variables, the correlations of those distributions with archeological resources during the various prehistoric archeologic periods, and the information available within the appropriate areas of each state. The interrelationship of these factors was the basis for three archeological sensitivity zones. Within the limits of the data, Sensitivity Zone 1 corresponds to Management Zone I, since submerged prehistoric resources have the highest probability of occurrence within this zone. Active surveys should be required in this zone before development of any type is permitted. It is expected that prehistoric cultural resources within Zones 2 and 3 do not exist or cannot effectively be identified or preserved. Therefore, these two zones comprise Management Zone II where no surveys should be required.

Three management zones have been identified for historic shipwrecks. Each zone represents varying levels of archeological sensitivity and has a different recommended survey procedure. The recommended survey intensity is commensurate with the archeological sensitivity of the known and/or predicted sites within the respective zones.

The management of prehistoric archeological resources on the South Atlantic Continental Shelf is based on a limited data base and the formulation of predictive models. It should be recognized that resource management is a continuous process, and that management plans and procedures should be responsive to newly developed information. This is particularly true in any area about which so little is known. The conclusions developed here should be regarded as only the first step in developing a comprehensive archeological resources management plan for the South Atlantic Continental Shelf.

2.0 STATEMENT OF PURPOSE

The purpose of this study was to determine the origin and recoverability of cultural resources that could be impacted by oil and gas operations on the Continental Shelf of the southeastern United States, and to provide a basis for developing an effective cultural resource management plan.

The cultural resources are considered an integral part of the total resources of the Outer Continental Shelf. The congressional mandate exists for the protection and management of the cultural resources on the Outer Continental Shelf. This mandate is set forth in the National Environmental Policy Act of 1969 (83 Stat. 853: 42 U.S.C. 4321), Executive Order 11593 of 1971, and The Archeological and Historic Preservation Act of 1974.

While many activities associated with the exploitation of oil and gas resources on the Outer Continental Shelf could impact cultural resources, the probability of destroying prehistoric archeological sites or historic shipwrecks is not well known for any given area because few, if any, systematic studies have been conducted to determine the distribution of archeological sites.

It is a well documented fact that sea level 16,000 years ago was significantly below present levels, and that within the study area as much as 380,000 square kilometres of the Continental Shelf were exposed at one time. However, this study, along with work from other studies, has recently prompted a reassessment of the United States Atlantic Coast sea-level curve that has served as a standard reference for the past 11 years. In plotting new data (from other studies) and replotting old data, a new sea-level curve has been prepared that is as much as 75 metres above the old curve. This means that sea level was much higher 16,000 years ago than previously thought. This new curve, if adopted, will apply only to the Southeast Atlantic Coast. In terms of cultural resource sites, the effect is that approximately the same area of the Continental Shelf was exposed, but for a much shorter period of time.

There is evidence from archeological field studies that prehistoric man inhabited southeastern North America during glacial and postglacial times. It is possible that these people may have also lived on what are now the submerged lands of the Continental Shelf. If this is true, then these early inhabitants undoubtedly left evidence of their activity on the shelf. The question is whether that evidence could survive the destructive force of waves during sea level rise and shoreline transgression. Recovery of some adequately preserved megafaunal elements from the shelf may justify cautious optimism about the recovery of human artifacts.

Another aspect of the environment is the source of food resources for early inhabitants of the Continental Shelf. These food resources were dominated by Pleistocene megafauna such as mammoth, mastodon, white-tailed deer, walrus, and ground sloths. Archeological evidence supports the assumption, though not unequivocably, that prehistoric man in the southeastern United States did hunt these large mammals for food. Camp sites have been discovered where bones of these mammals bear the markings of stone tools.

Since evidence of prehistoric man in the Coastal Plain of the southeastern United States is fairly well documented, it is important that this evidence is factored into the Outer Continental Shelf predictive model. It was assumed that cultural behavior, including settlement patterns, 10,000 to 15,000 years ago in the area of the modern Coastal Plain, is the analogue for humans who lived on the Continental Shelf before it became submerged.

Settlement patterns have been defined based on the location and distribution of sites in the modern Coastal Plain. These settlement patterns are dictated largely by the parameters of the physical environment. These physical parameters were assumed to be operative in former times and thus dictated the settlement pattern of human populations on the shelf. Based on this assumption, the Continental Shelf has been segregated into zones exhibiting varying degrees of probability of containing prehistoric cultural resources.

A similar methodology was applied to predicting the location of historic cultural resources. Shipwrecks occur throughout the study from Cape Hatteras to Key West, although concentrated in the areas at the two extremes of the study region. Many of these wrecks have never been charted, and only a few have been assessed in terms of their archeological significance. The maritime history of the southeastern United States was studied to determine the significance of ports and ship routes during various time periods and how these factors affect wreck distribution. It was assumed that the greater the density of ship traffic along a given route, or in the approach to a particular harbor, the greater the probability of shipwrecks occurring in those areas. The archival information retrieved during the study has supported this assumption.

Once the zones of highest probability of discovering prehistoric and historic cultural resources were identified, recommendations for verifying the significance of these zones are made. The capability of various remote-sensing systems for identifying cultural resources is evaluated and specific procedures and sensor arrays are recommended for use in conducting future field surveys on the Continental Shelf.

The overall application of the results of this study will be in the formulation of a cultural resource management plan. The Bureau of Land Management intends to implement its cultural resource management plan, as leases are sold and oil and gas operations on the shelf intensify. If oil and gas exploration is to be conducted in a specific lease block that has been designated as a zone which may contain cultural resources, various surveys will be required prior to exploration to further characterize the potential for the occurrence of archeological resources. If they do occur, efforts will be made to either study, recover, or protect them.

3.0 APPROACH

3.1 DATA COLLECTION

Although there was a substantial degree of variation in emphasis by the complement of scientists used for the study, the following three basic sources of information were utilized throughout:

- Literature surveys - directed toward a more complete understanding of the state of knowledge regarding a particular topic of interest within the study area.
- Personal communication and interviews - particularly important to soliciting ideas and information from individuals with a reported, or demonstrated, knowledge of the Outer Continental Shelf, paleontology, prehistoric archeology, and shipwreck archeology.
- Museum surveys and visits - this source is important as it represents the single most reliable source of artifacts which bear some relation to past or current activities and processes on the Continental Shelf.

Available published literature concerning the physical and cultural environment of the study area was reviewed and evaluated. Extensive use was made of computerized bibliographic retrieval systems, government and university library holdings both in the Washington, D.C. area and in those locations with geographic or topical relation to the study area. In addition, many of the universities maintain extensive collections of artifacts and other data regarding the South Atlantic Shelf. Many published sources of information and data were utilized during the course of the study. In many cases, access to unpublished data proved to be extremely valuable to the overall study effort.

Personal interviews with leading experts in the field, as well as local enthusiasts such as sport divers, were of considerable aid in verifying and supplementing information gleaned from published and unpublished sources, and in suggesting previously unrecognized sources for additional data.

3.2 MAP PREPARATION

The discussion that follows describes the salient features of the cartographic process utilized in the compilation and production of the map segment of this document. Conceptually the process consists of the following four steps:

Step 1. Data Collection
Step 2. Data Processing
Step 3. Information Display
Step 4. Image Processing

Implicit in such an organizational structure is the idea that Steps 1 and 2 represent the role of the technical staff members who possess a need for thematic maps, and Steps 3 and 4 are fulfilled primarily by the cartographer. While feedback occurred at each step, it was most prevalent between Steps 2 and 3 when members of the technical staff (paleontologists, geomorphologists and shipwreck archeologists) worked with the cartographers to establish the most effective graphic means of data communication. The final step was concerned mainly with determining the specific means of map production (diazo, offset printing, xerox). This dynamic systems approach proved to be an extremely effective means of producing maps which specifically address the need for an aid in managing the resources of the Outer Continental Shelf.

A series of 36 charts at a scale of 1:500,000 accompanies this document and is divided along the following topical lines:

Plate 1. Paleoshorelines, Prehistoric Management/Sensitivity Zones

		Period
Plate 2.	Historic Cultural Resources	1500-1700
Plate 3.	Historic Cultural Resources	1701-1820
Plate 4.	Historic Cultural Resources	1821-1865, 1866-1916
Plate 5.	Historic Cultural Resources	1917-1945, 1946-1979
Plate 6.	Historic Cultural Resources	Management Zones

In order that each map retains a manageable size, the study area was arbitrarily divided into 6 sub-regions; thus requiring a total of 36 maps to obtain complete thematic and spatial coverage of the South Atlantic Coast.

4.0 DISCUSSION

4.1 PHYSICAL ENVIRONMENT

4.1.1 Geology

This section is intended as an overview of the past and present geomorphic setting of the study area and the processes that shape it. The physical environmental parameters that came together to form the habitats attractive to early human populations are the same parameters that can preserve and destroy the record of their presence. The same holds true for historic data. Geography and geomorphology in part control the distribution of shipwrecks while the processes that can destroy, can also preserve them.

If the hypothesis that man inhabited some portion of the Continental Shelf when it was exposed during the last glacial cycle is to be tested, it is first necessary to describe the environment in which he lived. The following discussion presents a description of the modern Continental Shelf geomorphology and sediments, and an assessment of their age and how much they have changed since man might have lived near them. The discussion of the evolution of shelf and coastal geomorphic features gives insight into the preservation and destruction potential of prehistoric and historic artifacts.

The major source of freshwater on the shelf for man and game would have been rivers and streams. The origin and course of modern rivers are discussed in terms of the information that they contribute to the location of relict channels on the shelf. Rivers also represented an important secondary source of transported rock, needed by prehistoric man for stone tool manufacture. The most significant outcrops cut by this drainage system are addressed.

The limits of the exposed shelf are identified for 2,000-year time intervals. The paleoshorelines at these intervals are defined with the help of a new sea-level curve proposed for the first time in this report. The preservation potential of prehistoric sites during the coastal response to rising sea level is also addressed.

4.1.1.1 Modern Continental Shelf

Geomorphology The modern shelf south of Cape Hatteras is characterized by a relatively shallow shelf-slope break, ranging from less than 60 metres south of Cape Hatteras to less than 10 metres south of Palm Beach. In contrast, the shelf break off New York, for example, exceeds 140 metres. Shelf width throughout the study area varies greatly: 25 kilometres off Cape Hatteras, 130 kilometres off central Georgia, and 5 kilometres south of Palm Beach. Much of the near-shore is characterized by barrier islands, with a shoreface that is relatively abrupt, dropping to a depth of about 10 metres. Shoreface gradients often exceed 2 percent. In contrast, slopes on the shelf are closer to 0.05 percent.

The inner shelf contains many well-oriented linear sand bodies with relief of 1 to 5 metres, and wave lengths of hundreds to thousands of metres. Roughly half of these linear sand-body fields are oriented at an oblique angle to the shoreline. Considerable debate has arisen concerning the origin and age of these sand bodies (see Emery and Uchupi, 1972), but the greatest agreement is with the theory that they are modern, often active only during major storms.

The age and activity of this sand is significant in terms of the preservation potential for archeological artifacts. If these sand bodies are recent and periodically active, the subaerial surface available to prehistoric man may be buried or destroyed. If the surface was destroyed, projectile points may still survive occasional movement and by their own properties, if not their location or associations, could contribute information to the archeological record. For shipwrecks, repeated burial, and exposure by wave and current activity can diminish the archeological value by also moving artifacts or damaging the structure of the wreck.

Based on wave climate, tidal range and fluvial sediment input, the Continental Shelf can be divided into a number of depositional and geomorphic provinces. The geographical provinces from north to south are: 1) the Carolina salient - Cape Hatteras to Cape Romain; 2) the Georgia Bight - Cape Romain to St. Marys River; 3) the northern-central Florida Shelf - St. Johns River to Palm Beach; and 4) the southern Florida Shelf - Palm Beach to Key West (Figure 4.1.1).

The Carolina salient is dominated by cape retreat massifs or cape-associated shoals. These are the large sandy shoals that extend seaward, from the cuspate forelands almost to the shelf edge. These sand bodies are the thickest Holocene sediment accumulations (up to 14 metres) within this zone (Meisburger, 1978) (Figure 4.1.2). Numerous smaller sand ridges and sand waves are superimposed on them, indicative of active sand transport and substrate response to the modern shelf hydraulic regime. Between these sand bodies, particularly in the inner shelf and nearshore zone, are shoreface-connected and shoreface-detached linear shoals that can extend up to 10 kilometres in length and form a 15-55° angle with the shoreline trend (Duane et al., 1972). These features are fairly common in Raleigh Bay between Cape Lookout and Cape Hatteras, and in Long Bay between Cape Fear and Cape Romain. Linear shoals of this type are nearly absent on the inner shelf in Onslow Bay between Cape Lookout and Cape Fear. Because the Quaternary sediment cover is thin in many places, Tertiary sedimentary rocks are exposed (Mixon and Pilkey, 1976). Without sediment cover, artifacts would be exposed to a greater degree of abrasion against a rocky bottom, plus more frequent movement by waves.

The Georgia Bight shoreline is dominated by numerous large tidal inlets and ebb-tidal deltas. As sea level rose and the shoreline retreated, these extensive shoals were left on the shelf as relict deposits, and partially modified by the open-shelf hydraulic regime. Since the wave climate is low and extratropical storms uncommon, these inlet or estuarine-associated shoals remained roughly intact as topographic features, termed estuarine retreat "blankets" (Swift and Sears, 1974).

These estuarine retreat "blankets", coupled with the large suspended sediment load introduced to the Georgia Bight (Meade, 1969),

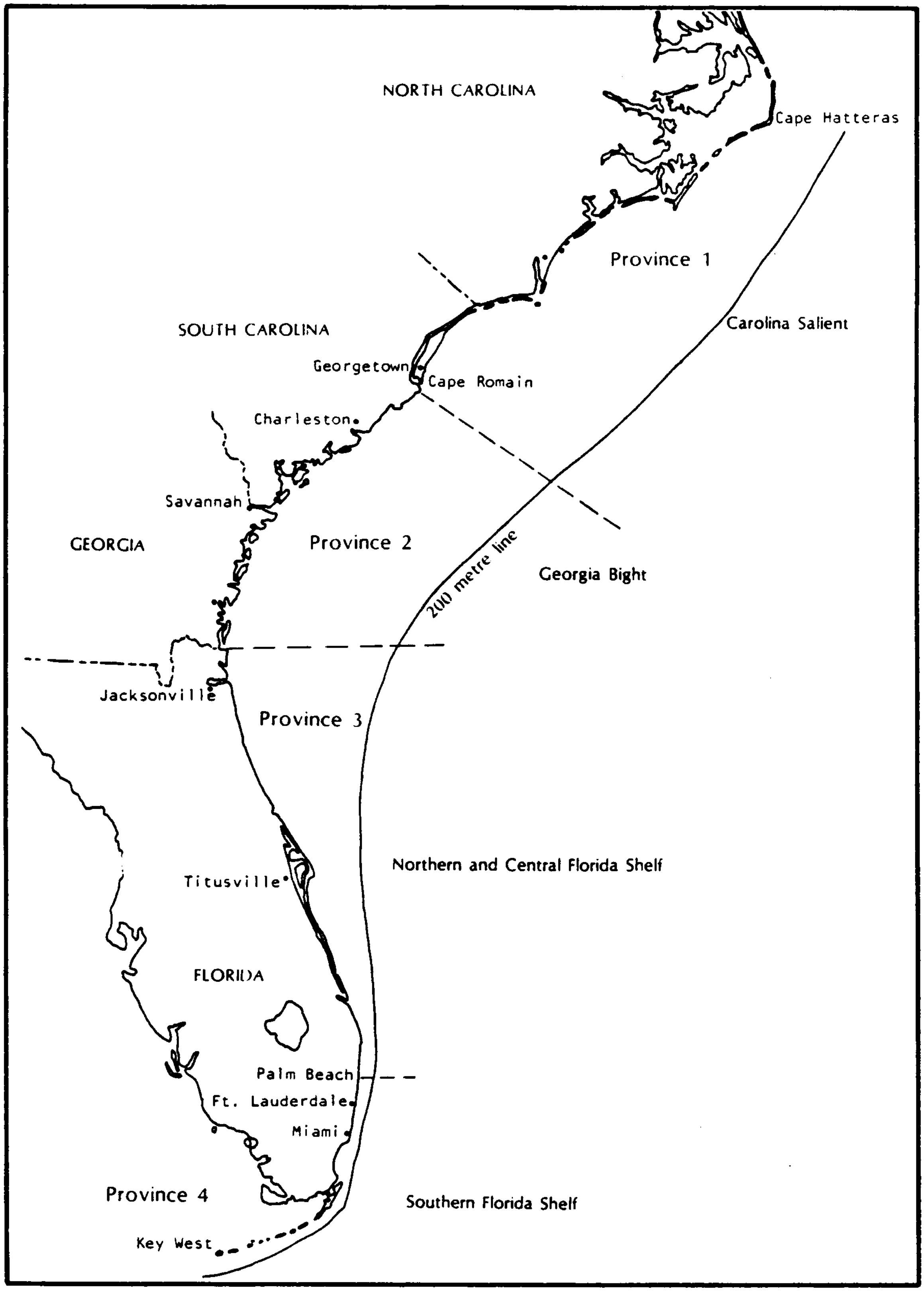


Figure 4.1.1 Coastal Sediment Discharge and Wave Climate of the Middle Atlantic Bight and Resulting Depositional Provinces

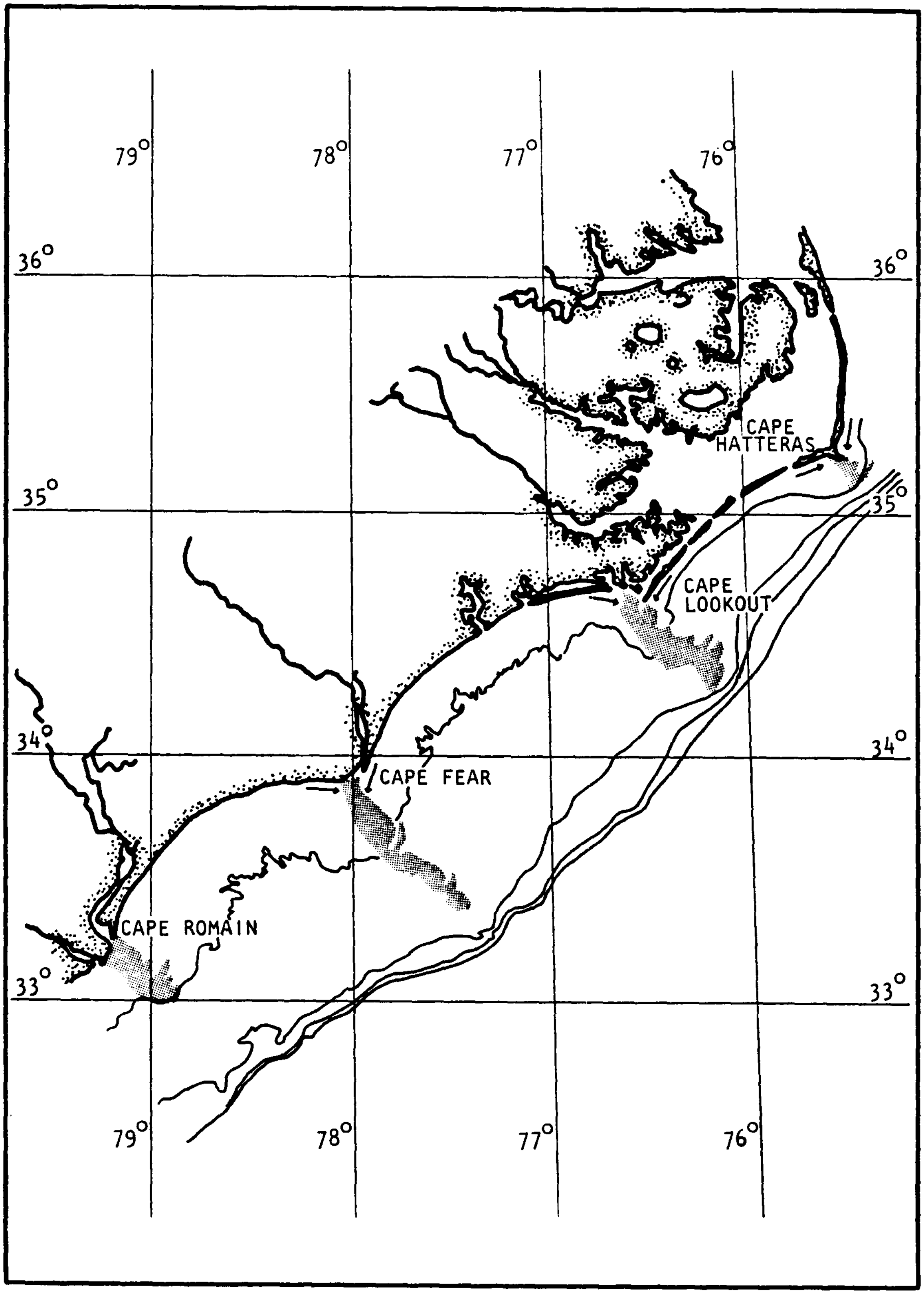


Figure 4.1.2 Cuspate Coast of the Carolinas

result in the thickest and most extensive Late Quaternary stratigraphic section in the entire study area (up to 20 metres thick) (Henry and Harding, 1978). This suggests that the highest preservation potential of the coastal environments within the study area is in the Georgia Bight. However, exposed rock surfaces, reefs, and hardgrounds with a relief of 1 to 2 metres do occur where the Quaternary section is missing (Hunt, 1974; Henry and Giles, 1978), which locally decreases the preservation potential. Reefs and hardgrounds can occur from the nearshore to the shelf edge, and their distribution is presently unpredictable (Henry and Giles, 1978; Woolsey, 1977). Recently, broad mapping programs for these hardgrounds have been conducted by the United States Geological Survey in conjunction with the Bureau of Land Management. Most hardgrounds and reefs mapped to date occur within the mid to outer shelf area. Samples of the strata indicate a variety of ages including Miocene, Pleistocene, and Recent (Dr. Pete Popenoe, personal communication, March 1979). Composition includes phosphorite, carbonate and quartz sandstone (Luternauer and Pilkey, 1967).

The north and central Florida shelf represents a transition from the estuarine retreat blanket of the Georgia Bight and the mixed carbonate/clastic depositional regime to the south. The shelf narrows significantly from 115 kilometres wide off Jacksonville to only 5 kilometres off Palm Beach. Holocene cover is generally thin to absent; rarely is the Quaternary section thicker than 5 metres, except underneath the linear or cape-associated shoals such as Cape Canaveral. No important sources of fluvial sediment exist south of the St. Johns River. Consequently, all terrigenous sands (quartz, feldspar, heavy minerals, etc.) are derived from the Georgia Bight by southerly longshore transport. As a result, reworking of Tertiary rocks is probably an important sediment source during sea level fluctuations, as is production of biogenic sands, particularly in the south.

Hubbard et al. (1974), and Meisburger and Duane (1971) show a series of rocky platforms or terraces of low relief (1 to 3 metres) south of Cape Canaveral. Quasi-active, isolated linear shoals lie on these rocky surfaces. Also, reef-like structures (1 to 3 metres in relief) are attached to these rocky substrates, particularly near a slight slope break.

Within the center of this shelf province lies the Cape Canaveral cuspate foreland and its inner-shelf linear, and cape-associated shoals (Field and Duane, 1976). The reasons for the development of a cuspate foreland at this location are not understood. An ancestral Pleistocene cape structure lies shoreward of the modern Holocene feature. The seaward shoals represent the thickest Quaternary stratigraphic section within this shelf province (up to 18 metres thick). More importantly, peats obtained by vibracoring strongly suggest that back-barrier environments are preserved within the shelf stratigraphic section in this area. The radiocarbon dates from peats show Holocene and late Pleistocene ages which would be contemporaneous with early human populations if they existed here (Field and Duane, 1976). Field (1974) suggests that these peats may be strand-line deposits which were buried within the cape-associated shoal formed during the mid-Wisconsin regression (25,000 years B.P.). The potential for preservation of prehistoric artifacts in this environment is expected to be high.

The <u>southern Florida shelf north of the Keys</u> is narrow, dominated by reef structures and, with the exception of the northern portion, is almost entirely a carbonate depositional environment (Duane and Meisburger, 1969; Enos and Perkins, 1977). The seaward limit of the shallow shelf is a relict Holocene reef line that lies in approximately 15 to 25 metres of water. Seaward of this outer shelf-edge reef the upper continental slope is characterized by ridges and reefs in 50-100 metres of water. Duane and Meisburger (1969) show that four reef lines occur in the Hallandale, Florida area. In this area, reef tracts become more discontinuous to the north and south. Lighty (1977), and MacIntyre and Milliman (1970), have shown that these reefs are early Holocene and at least 10 metres thick. However, for reasons not well understood, they were not able to keep pace with sea level rise and are now inactive, supporting little or no coral growth. <u>In situ</u>

carbonate skeletal sands have accumulated up to 5 metres in the topographic lows between the reefs. These areas presumably would have high preservation potential for cultural resources. The reef lines would, however, contribute significantly to the destruction of shipwrecks that may be periodically moved against them by waves.

In this nearshore area, the Pleistocene Anastasia and Miami Limestone outcrops occur frequently. Small sabellariid worm reefs are commonly established on these rocky surfaces (Multer and Mulliman, 1967; Kirtley, 1966). Duane and Meisburger (1969) have shown that very little sediment exchange occurs between the mixed terrigenous/carbonate sands of the beach zone and the offshore carbonate sands.

The shallow shelf seaward of the Florida Keys can be considered a subprovince, being a modern, windward, shallow carbonate margin facing an open seaway (Hine et al., in press). The outer shelf consists of intermittent flourishing reefs, barren rubble flats and mounds, and belts of thin, mobile sand bodies (Multer, 1977). The slope, seaward of the shelf-edge reef tract, drops off steeply into the deepwaters of the Florida Straits. Holocene sediment cover can be as much as 15 metres thick. Underlying rock topography is irregular, and includes both buried reefs and solution structures. The relief of the active reefs along the outer Keys may be entirely due to Holocene growth. The inner shelf contains thinner (5 metres maximum thickness) and muddier sediments. Small patch reefs, tidal deltas, mud mounds, grass beds, and rocky floor highs represent the main environments (Enos and Perkins, 1977).

The preservation potential of archeological sites on this subaerially-exposed pre-Holocene surface would be high. The mode of shoreline transgression and environmental development is totally different in a carbonate regime than in a terrigenous regime. As the seaward reefs build up, the back reef areas become flooded by low-energy lagoonal waters. Carbonate producing organisms generate sediment which would slowly bury man-made artifacts or sites. Since most wave energy is expended on the shelf-edge reef, it would be unlikely that the lagoonal sedimentary sequence would be disturbed to any significant depth by high-energy events.

Freshwater ponds in this area were probably nonexistent due to the well developed secondary rock permeability caused by solution. In short, the southern Florida exposed shelf was probably an inhospitable environment for human populations.

Sediments Analysis of sediment characteristics such as grain-size, composition, thickness, distribution, and origin can be helpful in identifying the subaerial shelf-environmental parameters important to man, such as the origin of lithics, fluvial regimes, and estuaries.

In general terms, the Continental Shelf south of Cape Hatteras is viewed as being covered with medium-to-coarse sand representing a relatively high-energy environment. Finer-grained material (fine sands and muds) occur only within a relatively narrow band on the innermost shelf (Pilkey and Frankenberg, 1964), as well as in several North Carolina rivers. Nearshore sands (on the inner and middle shelf) tend to be low in calcium carbonate and composed mainly of quartz and feldspar. This trend changes to the north with the sand becoming more quartzitic and containing lower amounts of calcium carbonate. South of Cape Canaveral, shelf sands become primarily carbonate due to a lack of terrigenous influx.

The more feldspar-rich sands reflect both derivation from the Piedmont province (also the most likely source of lithic raw material) and rigorous chemical weathering, whereas the quartzite sands in the south indicate derivation from Coastal Plain rivers and (in the extreme south) more severe chemical weathering. Other sedimentary components undoubtedly represent residual material derived from underwater outcrops. Phosphorite pellets in Onslow Bay and Frying Pan Shoals, glauconite grains on the outermost shelf, and carbonate lithoclasts along much of the entire shelf suggest a wide distribution of such outcrops.

The age of shelf sediments appears to be relict, that is, present-day rivers are not delivering large amounts of sediment to the shelf environment (Meade, 1969). This fact, plus the occurrence of shallow-water indicators (ooids, algae, beachrock, and oysters) indicate that most of the sediments were deposited during the last low stand of sea level, or during the subsequent transgression. Modern sediment input is primarily into the extreme nearshore zone. In fact, it may be that modern carbonate deposition exceeds fluvial influx (Milliman et al., 1972).

While the shelf sediments may be primarily relict in age and composition, they probably do not show all of the parameters reflective of shallow-water deposition. For instance, no surface sediments show the fine-grained nature one would expect for relict soil zones, estuarine muds, or lagoonal sediments, although undoubtedly such environments were present during the transgression. Swift et al. (1972) have termed such sediments "palimpsest", that is, relict in age and composition, but at least partly modern (sub-relict) in terms of textural character. This "palimpsest" character is very important for consideration here, since it, together with the smoothed topography on the shelf, strongly indicate the reworked nature of the shelf sands. Thus there is little chance that human relics would survive in context. They may, however, be scattered out of context.

4.1.1.2 Modern Physical Processes on the Continental Shelf

<u>Wave Climate</u> Deepwater wave-energy flux diagrams and continental shelf wave-height frequency histograms (Nummedal et al., 1977) indicate a distinct trend of decreasing wave height and energy from Cape Hatteras, North Carolina to Jacksonville, Florida. Wave-energy values then increase slightly down the east coast of Florida to Miami. The basic cause for this trend is the regional change in

shelf width and slope. North Carolina Capes and the south Florida coast are situated close to the edge of the Continental Shelf. As a result, the shelf surface is narrow and relatively steep. This allows a significant portion of the wave-energy associated with the large, deepwater, oceanic waves to reach the coast. Consequently, these coasts are high-energy wave-dominated.

The shelf is only 25 kilometres wide at Cape Hatteras, and 2 kilometres wide at Miami. The wave climate, however, has lower energy at Miami than at Cape Hatteras due to the sheltering effect of the Bahama Banks, and the lower frequency of extratropical storms. Much of the energy of deepwater waves is lost over the broad and shallow central portion of the Georgia Bight through frictional effects as these waves cross this wide shelf. The coastline from southern South Carolina to northern Florida is a low wave-energy zone.

Although it does not necessarily follow that the higher wave-energy coasts erode faster than the low wave-energy zones, the increased surf zone intensity does suggest that archeological artifacts were more likely to be destroyed during Holocene sea level rise. Even today, surf zone intensities along the relatively low wave-energy coasts are still sufficiently vigorous to destroy man-made structures such as seawalls, groins, and jetties.

<u>Tidal Range</u> The large embayment composing the Georgia Bight causes an amplification of the ocean's tidal wave as it crosses the shelf, resulting in increased tidal range at the central coastal portion of the embayment (Silvester, 1974; Nummedal et al., 1977). Spring tidal range is greatest (2.8 metres) in the Savannah, Georgia area, and decreases both in a northerly and southerly direction (Figure 4.1.3).

This coastwide trend of changing tidal range has had significant effects on the modern coastal geomorphology and distribution of depositional environments. The large tidal range at the central portion of the embayment causes strong tidal currents in and out of numerous large tidal inlets and sounds. As a result, much of the inner shelf and

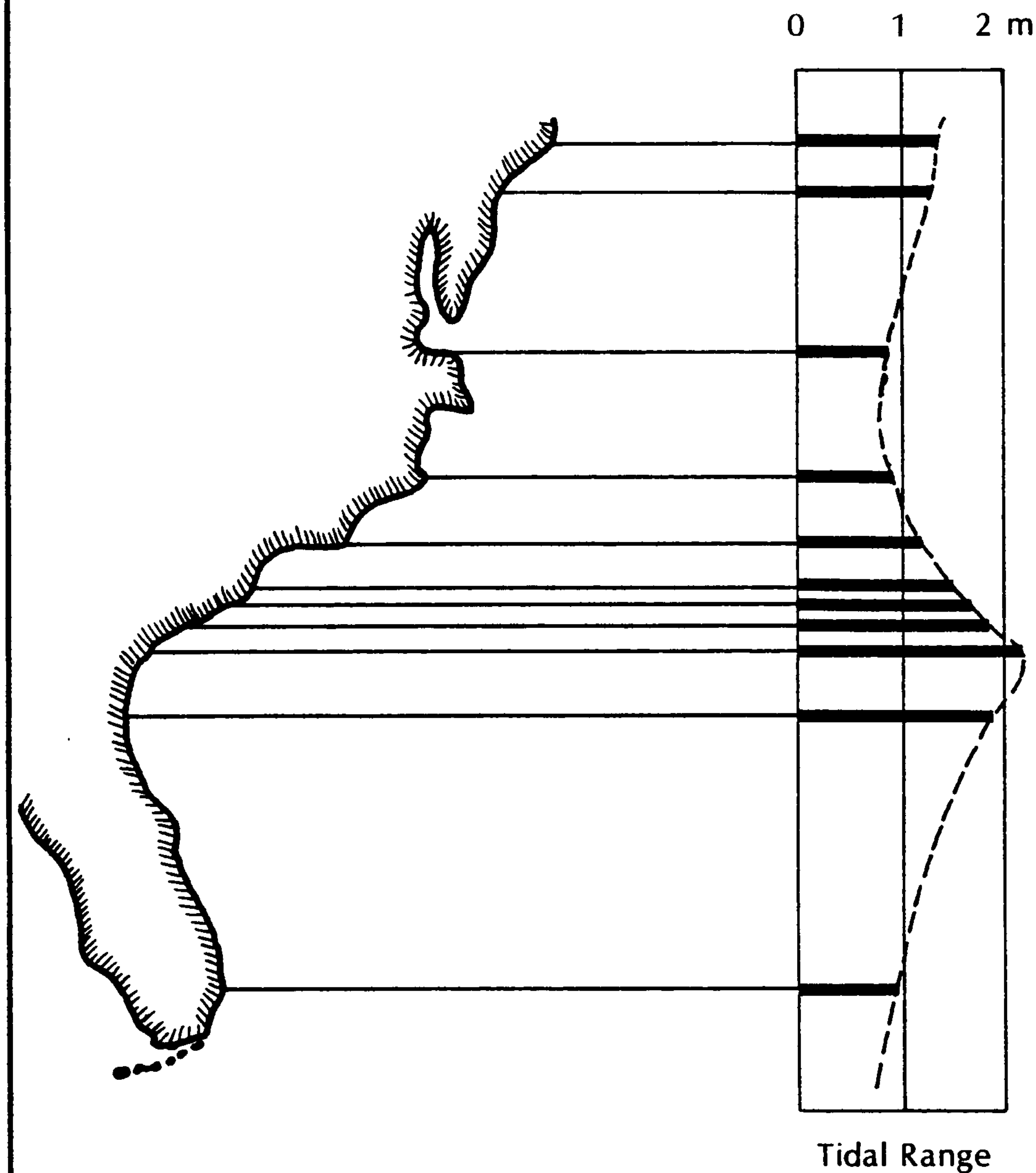


Figure 4.1.3 Tidal Range Variation Along the Southeast Coast of the United States

nearshore sediment, particularly near the inlets, is actively reworked by tidal currents. Ebb-tidal deltas associated with inlets are active as much as 12 kilometres seaward of the shoreline, and have migrating channels up to 15 metres deep within them. Earlier coastal environments, and consequently possible archeological sites, would be subject to destruction or dispersal by vigorous tidal current activity in this coastal sector even if those sites survived coastal submergence during sea level rise.

Storm Frequency Tropical storms, including hurricanes, influence important geologic processes that pose a great threat to archeological data and present-day man-made structures in the coastal zone. The large storm waves, and more importantly the storm surge associated with large tropical storms, can cause long-term significant alteration of coastal environments.

Early-season hurricanes generally move out of the Caribbean and western Atlantic and into the Gulf of Mexico, skirting southern Florida. Later in the hurricane season, storms tend to recurve eastward after formation in the south-central Atlantic, and move north and northeast along the southeast Atlantic coast.

The two promontories - the Florida peninsula and Cape Hatteras, are the first likely landfalls to be encountered in the respective portions of the hurricane season. Thus, as expected, these two geographical regions harbor the greater number of shipwrecks, with the intervening coastline having a relatively lower density of wrecks. This presumption is in fact supported by the data.

Major storms are capable of completely submerging low, frequently overwashed barrier islands (Hayes and Kana, 1976; Godfrey and Godfrey, 1973). Since tropical storm frequency in these areas ranges from 5 to 8 every 10 years (Cry, 1965; Cry and DeAngelis, 1965), coastal drownings would make life hazardous for man on the coast, and also would be quite destructive to any archeological sites. On the other hand, hurricanes can redeposit up to a half-metre of sediment in shoal water areas (Ball, 1967; Perkins and Enos, 1968), possibly enhancing preservation of archeological sites.

Extratropical storms, known as northeasters, are low pressure centers passing west-to-east, most frequently during the winter. These cyclones may have a more significant impact on both man and the geologic environment than tropical storms because of their size and high frequency. These storms can be up to 1,400 kilometres in diameter, and have peak winds over 130 kilometres per hour (Fair and Feit, 1978). Most engineers point to the Ash Wednesday storm of 1962 (an extratropical cyclone) as being the most devastating storm ever to strike the United States East Coast. Geological oceanographers are now beginning to realize that these storms also may erode and transport more shelf sands than do hurricanes (D.J.P. Swift, personal communication, 1978). Hurricanes are smaller in diameter (commonly 160-320 kilometres) than extratropical storms, but move faster. Although the largest hurricanes can develop winds of 280-320 kilometres per hour, most never have peak winds over 210 kilometres per hour.

Within the study area, the North Carolina coast, with its relatively high-frequency of both tropical and extratropical storms, is the most storm-dominated coastal sector.

Oceanic Currents The influence of the Gulf Stream on shelf processes and sedimentation is only recently being addressed. Geologists have noted large, erosional features on the Portales and Miami Terraces and the Blake Plateau (Mullins and Neumann, 1979). However, these features are deeper than 400 metres, and would have been submerged even during the last major glaciation. There are erosional surfaces on the shelf edge off North Carolina (Cape Fear Terrace and an unnamed terrace off Cape Lookout) in shallow water (60-100 metres). These rocky zones may have been eroded by the Gulf Stream during higher-than-present sea-level stands when meanders of the current could have moved onto the shelf. But sea levels high enough to cause this erosion did not occur within the last 20,000 years. Present data indicates that the Gulf Stream, in a direct sense, is not significant to the probability of the occurrence of archeological sites.

4.1.1.3 Coastal Geomorphology

Barrier Islands. Davies (1964), Hayes (1975), and Hayes and Kana (1976) have classified depositional coastlines on the basis of tidal range. Even though wave-energy plays a significant role in coastal sedimentation, emphasis has been placed on tidal range because "the effectiveness of wave action diminishes and tidal current activity increases as the vertical tidal range increases" (Hayes and Kana, 1976). Davies (1964) recognizes three classes of coasts:

Table 4.1.1 Classifications of Coasts Based on Tidal Ranges

Class	Tidal Range (Spring)
Microtidal coasts	0-2 m
Mesotidal coasts	2-4 m
Macrotidal coasts	4 m

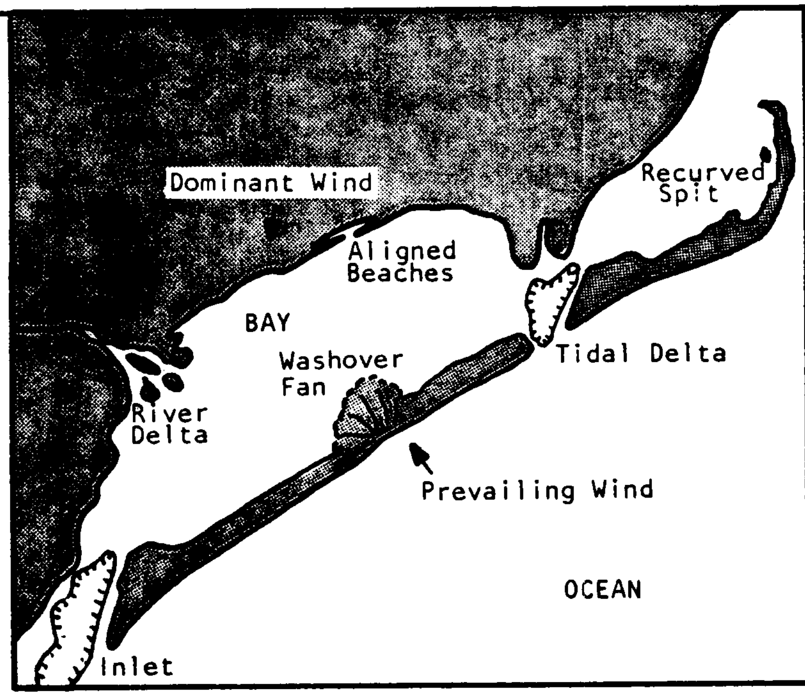
Hayes and Kana (1976) and Hine and Boothroyd (1978) have restricted microtidal coasts to tidal ranges less than 1 metre. Following this revision, the north-central North Carolina coast (Cape Hatteras to approximately Cape Fear) and the central - south Florida east coast (Daytona to Key West) can be considered microtidal. The southern South Carolina - Georgia coasts are mesotidal, with transitions between the microtidal and mesotidal areas. No macrotidal coasts are present in the study area.

Hayes (1975) has shown that tidal range controls the occurrence of certain types of coastal features and environments. Nummedal et al. (1977) also shows general trends of occurrence of coastal features within the study area.

Table 4.1.2 and Figure 4.1.4 illustrate the different shapes and sizes of barrier islands and their associated inlets and tidal

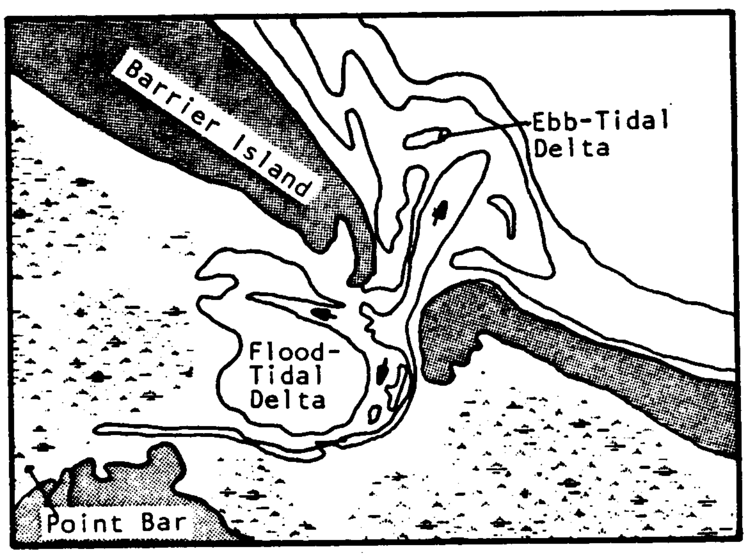
Table 4.1.2 Some General Geomorphological Differences Between Microtidal and Mesotidal Barrier Islands (Hayes and Kana, 1976)

Barrier Type	Length	Shape	Washover Features	Tidal Inlets	Flood-Tidal Deltas	Ebb-Tidal Deltas
Microtidal	long (30-100 km)	elongated	abundant; washover terraces and wash-over fans numerous	infrequent	large; commonly coupled with washovers	small to absent
Mesotidal	stunted (3-20 km)	drumstick	minor; beach ridges or washover fans rare	numerous	moderate size to absent	large with strong wave refraction effects



MICROTIDAL ESTUARY MODEL

Sand bodies in this type of estuary are mostly storm- or river-generated (e.g., washover fans; river deltas) or wave-generated (e.g., aligned beaches; recurved spits). Tidal deltas are usually small. Most of the estuaries of the Gulf of Mexico are of this type.



MESOTIDAL ESTUARY MODEL

Tidal deltas and point-bar deposits are the principal sand bodies occurring in this type of estuary. Examples of this type include most of the estuaries on the shoreline of New England and those of the Wadden Sea, The Netherlands.

Figure 4.1.4 Estuary Models

deltas. Microtidal barrier island coasts are long, linear, generally topographically low, and are dominated by storm washover features. Inlets are not common on microtidal barrier islands, therefore the possibility of washover frequency during rising storm surges is increased (Hayes and Kana, 1976). Most of the remaining microtidal and microtidal/ mesotidal transition barrier island types that have been frequently inundated by storm surge, would not support a maritime forest, and would not have freshwater available. As a result, these coasts probably could not support human habitation for long periods of time. Even if major archeological sites had been established, washover activity and erosional retreat would have destroyed them and dispersed individual artifacts. As exceptions, Hatteras Island, Shackleford and Bogue Banks in North Carolina, and portions of Cape Canaveral, Florida, are all microtidal islands that have received a high supply of sand during the late Holocene, and have prograded seaward. They support large maritime forests; some have freshwater lakes and might have provided a stable, safe habitation site for early human populations.

Mesotidal barrier islands consisting of the "sea islands" (Zeigler, 1959) along the southern South Carolina and Georgia coasts are generally beach-ridge dominated (both Pleistocene and Holocene), and support well-developed maritime forests. Numerous wide, ebb-dominated tidal inlets are common along this coast. These inlets produce large ebb-tidal deltas which extend up to 12 kilometres seaward. These shoals refract waves, thereby significantly affecting accretion/ erosion on the barrier beach up to several kilometres away from the inlet. A small lateral movement of an inlet can affect a significant portion of the beach. As suggested by Fitzgerald (1976), Morton and Donaldson (1973), and Oertel (1975), deeper inlets may not migrate significant distance laterally because the channel walls are flanked by compact, erosion-resistant Pleistocene muds and clays. However, these inlets do migrate short distances, making that portion of the adjacent barriers closest to the inlet most unstable (Fitzgerald, 1976). Episodic rapid accretion and erosion is common. If man had settled along these shores, then the central portions of these islands (stable forested beach ridges separated by linear freshwater ponds/lakes) would have been the most attractive area. To date, numerous archeological sites have been found along these areas (DePratter and Howard, 1977).

Mainland Beaches. Some sections of the coast between Cape Hatteras and Miami Beach do not contain barrier islands. Instead, a mainland beach is exposed to the open ocean. These mainland beach zones probably occur where the earlier Holocene barrier island system joined the Pleistocene mainland through landward migration and lagoon contraction. Only a narrow, thin Holocene sandy veneer presently covers these Pleistocene sandy strandline deposits. These zones are Fort Fisher, North Carolina; a 40-kilometre section of northern South Carolina near Myrtle Beach; a 25-kilometre section south of Jacksonville, Florida; a 10-kilometre section south of Jupiter Inlet, Florida; and much of the 70-kilometre section from Boynton Beach to North Miami Beach, Florida.

The Pleistocene mainland in most cases represents a slightly higher, well-vegetated, former barrier shoreline dominated by wide sequences of beach ridges. The exact age of the Pleistocene mainland is difficult to ascertain, but these older barrier systems probably represent higher sea-level stands of Silver Bluff, Princess Anne, or Pamlico age (Hoyt and Hails, 1974). Because these sections were formed under conditions of higher sea level, the Pleistocene barrier systems are topographically higher than the adjacent Holocene barriers. This higher ground may have provided stable and secure sites for human populations.

Rocky Islands. The Florida Keys south of Miami consist of Pleistocene lithified back reef (Key Largo limestone). An oolite sand shoal facies (Miami limestone) extends 170 kilometres to the southwest (Hoffmeister et al., 1976; Multer, 1971). The islands are stable since most shoreface retreat is by local bioerosion. However, these islands are low lying (highest elevation only 6 metres above mean sea level), and have little soil and generally scrubby vegetation. These mostly small islands are separated from each other by as much as 12 kilometres of open water. Historically, tropical storm frequency is about eight storms per 10 years (Cry, 1965; Hine, 1977), possibly causing partial or total submergence of many of the islands. In short, it would appear that the Florida Keys would not be very attractive to substantial numbers of early inhabitants.

Cuspate Forelands and River Deltas. The cuspate forelands or capes are significant coastal geomorphological forms, as five of these features (Hatteras, Lookout, Fear, Romain, and Canaveral) occur within the study area. Their origin is not well understood. They probably formed during initial sea level rise (16,000 B.P.), and were developed as the coastal zone retreated westward across the shelf. Converging longshore transport systems deposited sand in permanent sinks at their apices. As the cuspate foreland retreated, these sand bodies were left on the shelf as cape retreat massifs or cape-associated shoals (Swift et al., 1972). These large, shelf sand bodies are the best evidence that capes formed early in the sea level rise and are not simply a late Holocene development. Hoyt and Henry (1971), suggest that the capes are drowned river deltas. Two of the modern capes which are presently associated with modern rivers are modified deltas (Cape Fear - Cape Fear River; Cape Romain - Santee River). Furthermore, it is possible that the paleo-Albemarle delta generated Cape Hatteras and the paleo-Neuse delta formed Cape Lookout. There is no obvious river that can be associated with Cape Canaveral.

Rivers, rather than delta plateaus, were probably more important to early inhabitants, since streams provided relatively easy access to and from the interior portion of the Coastal Plain and piedmont. If this is true, then the other streams originating in the piedmont such as the Altamaha and Savannah may have been important for transportation. During the Holocene transgression, when most shorelines were retreating (except around river deltas), these deltas might have attracted inhabitants not only due to the freshwater/transportation advantages, but because of the stability of the coastal environment.

Marshes and Estuarine Systems. Variation in tidal range strongly controls the development of marshes, meandering tidal creeks, tidal flats, and main estuarine channels. Marsh systems and associated tidal flats and meandering tidal creeks become more abundant with increasing tidal range. Consequently, the most completely developed marsh systems lie within the mesotidal coastal zone. Generally, with increased tidal range, the area of the intertidal zone increases. This periodic subaerial exposure allows marsh plants to extend themselves laterally, mostly by rhizome development. As marsh grasses colonize exposed tidal flats, they trap muds which accumulate vertically and help to build up the marsh surface. Since the microtidal coasts do not have extensive intertidal zones, marshes are generally small as they cannot extend out into open water. Consequently, the topographically lower areas behind microtidal barrier islands never infill with marsh, but rather develop into open water lagoons capable of generating relatively high wave-energy which can erode interior shorelines. Marshes in this environment are restricted to low-energy narrow fringes along the lagoon-estuarine shoreline, and also relict flood-tidal deltas. In areas where the microtidal barrier system is near the Pleistocene mainland and the back-barrier zone is narrow, marshes extend nearly continuously across the lagoon.

Marshes are one of the most biologically productive environments. The annual standing crop of marsh grasses produces a high biomass which, when broken down by bacteria and fungi, becomes a major contributor to the marine food chain. More important, however, to prehistoric man, were the intertidal flats and meandering marsh creeks inhabited by shellfish -- an obvious and easily obtainable food source. The mesotidal coastal zone, with its relatively stable barrier island system (except in immediate vicinity of inlets), and the prolific back-barrier marsh system, would have been an attractive area for man.

The estuarine system of North Carolina is perhaps the largest in the study area, even though the back-barrier marshes are small. The regionally low gradient behind the Outer Banks has resulted in extensive flooding of eastern North Carolina. Where flood plains such as those of the Neuse, Tar, Roanoke, and Chowan Rivers once existed, large linear estuaries with associated drowned lateral streams are now present. As the coastal rivers and streams initially were submerged by rising sea level, marshes developed and grew rapidly. However, as the sea continued to rise, the marshes became exposed to the more open water, and began to erode with increased wave energy. As a result, the leading edge of the marine or estuarine transgression in North Carolina became an active marsh fringe which is now rapidly growing into and succeeding forested highlands on its leading edge, but is eroding just as rapidly on its trailing edge.

Assuming that human communities were established along interior estuarine systems far from the migrating barrier island system, preservation of these sites by burial should be high. Most likely the sites would have initially been covered by the encroaching marsh system. Even if most of the marsh had been eroded away during later submergence, the basal peats and underlying preexisting surface would probably survive the migration of the estuarine beach zone. Once covered by estuarine water, accumulations of muds would further bury such sites. By the time the barrier system had migrated into these areas, the original sites would have been covered by a thick (3- to 6-metre) sequence of estuarine muds, flood-tidal delta sands, and back-barrier overwash sands. If shoreface incision were not great, the archeological sites and the protective estuarine muds could lie buried beneath active Holocene sands on the shelf with continued sea level rise and landward barrier island movement. Recovery of peat during coring on the shelf could be the mark of a zone of potential preservation of cultural resources.

The same could be true for archeological sites originally developed along the mesotidal (South Carolina and Georgia) marsh systems far behind the active barriers earlier in late Pleistocene/Holocene. However, in Florida, large back-barrier estuarine systems similar to those in North Carolina probably did not exist due to the steeper shelf slope.

4.1.1.4 Drainage System

Significance. The fluvial drainage system within the study area is important for several reasons: it provided a means for transporting gravels or exposing rocks composed of cryptocrystalline siliceous minerals that could be used for making tools; it provided access across the Coastal Plain and into the piedmont from the coast; near the coast it formed large estuarine systems which were rich in seafood; and it provided a reliable freshwater source.

Modern Drainage Systems. The rivers can be divided into two types: (1) those originating in the crystalline piedmont; and (2) those originating in the Coastal Plain. Piedmont streams generally have larger discharge peaks, and are more turbid than the Coastal Plain streams (Table 4.1.3). High discharge values relate directly to sediment transport capability of these streams. With the piedmont rivers generally having both wider channel floors and higher discharge, it follows that during lower sea level most sediment (including gravel) was introduced to the lower Coastal Plain and the shelf. Seismic profiles run in the Cape Fear River (Hine et al., in preparation,a) show that large sand waves (2 metres high, spacings of 50 metres) are ubiquitous, and indicate extensive bedload sand transport during flood stages. However, it is possible for Coastal Plain streams to excavate older and deeper fluvial deposits locally and to initiate coarse sediment transport from these zones. Data by Hine et al. (in preparation,a) shows that the White Oak River, a Coastal Plain stream, has cut vertically 22 metres into the Late Tertiary rocks and sediments. While this process of downcutting could provide an additional source of crystalline rocks, predictions of locations where such vertical downcutting and cryptocrystalline gravel exhumation by Coastal Plain streams is difficult. Generally, the piedmont streams would be expected to provide the larger volume of potential toolmaking gravels for prehistoric man than Coastal Plain streams.

TABLE 4.1.3 Known Major River Systems of the U.S.
East Coast South of Cape Hatteras

Piedmont Origin	Extreme Historical Discharge	Coastal Plain Origin	Extreme Historical Discharge
Tar (N.C.)	1050 m^3/sec	Neuse (N.C.)	1704 m^3/sec
Cape Fear (N.C.)	2796 m^3/sec	N.E. Cape Fear (N.C.)*	
Pee Dee (N.C.-S.C.)	8074 m^3/sec	South Cape Fear (N.C.)*	
Santee (S.C.)	3728 m^3/sec	White Oak (N.C.)*	
Savannah (S.C.-GA)	7650 m^3/sec	Little River (N.C.)*	
Altamaha (GA)	8500 m^3/sec	Waccamaw (N.C.-S.C.)*	
		Little Pee Dee (S.C.)	782 m^3/sec
		Salkehatchie River (S.C.)	66 m^3/sec
		Broad River (S.C.)*	
		Black (S.C.)	354 m^3/sec
		Edisto (S.C.)	694 m^3/sec
		Congaree (S.C)*	
		Ogeechee (Ga.,)	850 m^3/sec
		Canoochie (Ga.)*	
		Satilla (Ga.)	3120 m^3/sec
		St. Marys (Ga.-Fla)	796 m^3/sec
		St. Johns (Fla.)*	

*Separate Discharge Rates are unavailable

Table 4.1.3 and Plate 1 (Volume V) show that the majority of the piedmont streams discharge into the Georgia Bight. This is perhaps the main reason that this coastal and shelf section has the thickest terrigenous Quaternary stratigraphic section. Recent vibracoring on the shelf in the northern sector (50 kilometres north of Cape Romain) of the Georgia Bight shows that gravel sized sediments (2-75 mm) do occur (Ayers et al., 1979). These gravels lie on top of preserved back-barrier sediments and at the base of modern shelf sediments, suggesting that this concentration is a basal lag which may have been concentrated and buried at the base of the shoreface during transgression. Consequently, this coarse deposit cannot be considered an *in situ* fluvial deposit; however, it does indicate that coarse sediments did exist within the pre-Holocene sedimentary cover, and that they may have been accessible to man. It is doubtful that cryptocrystalline gravels have accumulated to any significant (geologically) degree in the North Carolina or Florida Coastal Plain or shelf. However, local, small accumulations, which may be insignificant geologically may have great importance archeologically.

Coastal Plain streams, although they may not be important sources of cryptocrystalline gravels, do form important, large estuarine systems on flat inner shelves. The Roanoke, Chowan, Tar, Neuse, North and New Rivers in North Carolina are all essentially Coastal Plain streams that flow into very large estuarine systems. With abundant food from the estuaries, high ground (high banks occur along portions of these estuaries (Bellis et al., 1975), protective forests and abundant freshwater, these drowned river valleys are likely to have been attractive areas for early habitation.

It should be pointed out that no streams originating in the piedmont terminate along the Florida coast (Meisburger and Field, 1975). The Coastal Plain streams that do occur have very low discharge rates. The terrigenous sediments that exist on the shelf along the Florida coast have been carried from the north by longshore transport, and the calcareous sediments have been generated *in situ*.

Sources of Toolmaking Cryptocrystalline Rocks. Interviews with a number of Coastal Plain stratigraphers (D. Heron, Duke University; W. Wheeler, UNC Chapel Hill; D. Colquhoun, University of South Carolina; H. Cramer, Emory University; E. Meisburger, CERC Corps of Engineers; and S. Wise, Florida State University) have revealed the following points concerning the distribution of potential toolmaking gravel-sized sediment on rock outcrops:

1. Morrow Mountain, Moore County, North Carolina within Pee Dee River Basin. This is an excellent source area for cryptocrystalline siliceous minerals. Many Paleoindian artifacts have been made from rocks in this area. However, the river gravels from the modern Pee Dee contain none of this material. These river gravels are mostly vein quartz, a variety of quartz not suitable for toolmaking. Within the Pee Dee flood plain sediments, many "points" and artifacts made from Lower Paleozoic meta-siltstones and cryptocrystalline quartz are found, but no source rocks or gravels are found.

2. In the Fayetteville, North Carolina area a basal conglomerate consisting of hard slates, volcanics, and petrified wood are found at the bottom of the Pleistocene section, all of which would be useful for toolmaking. The Cape Fear River runs through this area, and could have incorporated some of this material into its bedload.

3. In Jasper and Beaufort County, South Carolina, the Coosawhatschie Clay, which overlies the Miocene Hawthorn Formation, contains high quality chert and other very hard cryptocrystalline material.

4. In Sumter County, South Carolina, at Tavern Creek, the Black Mingo Formation (Paleocene-Eocene) crops out and contains some hard crystocrystalline material. This creek is a tributary to the Santee River system.

5. Near Savannah, Georgia, at Shell Bluff, the Eocene McBean Formation is a well known area where prehistoric man obtained white chert which he used as a raw material for making tools. Presumably, gravel-sized sediments of this type could have been transported onto the shelf by the Savannah River.

6. The Suwanee Limestone, Oligocene, located in the central Georgia Coastal Plain (Houston County, Georgia) has abundant cryptocrystalline material in outcrops. This material is a product of weathering alteration, and does not occur in the

subsurface. The Altamaha River drains the outcrop area and could have carried this suitable toolmaking material onto the shelf.

7. Thin beds of marine cherts are found throughout the Eocene rocks in the Georgia Coastal Plain. These beds are not extensive, less than 30 centimetres thick, but consist of diatomites and spicularites, which were suitable for tools.

8. Of the 1400 vibracores taken by the Coastal Engineering Research Center (CERC, U.S. Army Corps of Engineers) for their Inner Continental Shelf Sediment and Structure Program (ICONS), none contained any archeological object or material suitable to make stone tools. This program has concentrated on the Florida coast and the Cape Fear area, North Carolina. There have been no CERC-ICONS projects off all of South Carolina and Georgia.

Buried Channels on the Continental Shelf. Bathymetric data show little evidence of relict river channels crossing the seafloor. Since rivers undoubtedly flowed across the southeastern shelf during lower stands of sea level, it could be concluded that the channels have been extensively buried during, or subsequent to, the Holocene transgression.

The locations of some of these larger river channels buried on the Continental Shelf are listed in Table 4.1.4. Since the high resolution seismic survey data analyzed during this study (Field and Duane, 1974; Duane and Meisburger, 1969; Meisburger and Duane, 1971; Meisburger and Field, 1975; Meisburger, 1978; Woolsey, 1977; Henry and Harding, 1978; Hunt, 1974; Henry and Giles, 1978; Hubbard et al., 1974; Ayers et al., 1979; Hine et al., in preparation,a) was not originally intended to address the problem of locating and identifying buried fluvial channels on the shelf, only limited mapping of these structures is possible using this data. Because most of the data are concentrated within the inner shelf zone, it was not possible to accurately plot the course of these fluvial systems to the distal margin of the shelf.

Table 4.1.4 Locations of Buried Shelf River Channels

North Carolina

- Bogue Banks - Various tidal inlet channels which are not Pleistocene rivers. The one exception is the White Oak River, a buried Coastal Plain stream 22 metres deep running underneath Bogue Island (high resolution seismics).

- Channels of the Cape Fear River - A number of large buried channels, up to 30 metres deep near Cape Fear, suggest that the Cape Fear River has taken several paths in the past on the now submerged shelf. Some smaller channels can be seen to the Southeast of Cape Fear, these may be tributaries, small Coastal Plain streams or even old, buried tidal inlets (high resolution seismics).

South Carolina

- Santee River channel and delta - the paleo-delta of the piedmont-originating Santee River system has been tentatively identified due east of the Bull Bay segment of the South Carolina coast (Swift et al., 1972). It is an extension of the present day Santee delta which appears on the shelf as a buried channel. There is no seismic or vibracore evidence, however.

- Waccamaw Shelf Valley - Located off Murrels Inlet north of Georgetown, South Carolina. Could be surface geomorphological manifestation of Waccamaw, Black, and Pee Dee River channels on the shelf floor. No seismic profile data.

Georgia

- Seismic profile data along the inner Georgia shelf identify buried channels possibly incised by the Savannah and Altamah Rivers on the shelf (Woolsey, 1977). The latter crosses the profile line so that its exact position is uncertain, but they do resemble extensions of present day river systems.

- Various other channels, probably estuarine retreat paths not associated with freshwater systems.

Florida

- No major streams flow off the Florida peninsula except at the northern border with Georgia. Much of this shelf is rock or relict reef features - particularly in the south. Some Coastal Engineering Research Center (CERC) publications do suggest tidal inlet scars off the Fort Pierce area. There is a large channel structure off Jacksonville which is considered to be the ancestral St. Johns River valley.

4.1.1.5 Paleoshorelines and Sea Level Determination

Because of the lack of detailed sub-bottom data, paleoshorelines on the Continental Shelf south of Cape Hatteras are assumed to parallel present-day shelf bathymetric contours. In order to determine the exact position of sea level at any time during the past 20,000 years, an accurate sea-level curve was needed, one that was specific to the area south of Cape Hatteras.

Determining the sea-level curve during the past 20,000 years is a difficult task for any area. Several major problems are particularly important in this discussion. First, proper sea-level indicators must be selected. The best ones are saltwater peat, intertidal oysters (Crassostrea virginica) and aragonitic ooids (a calcium carbonate concretion known to form in water depths less than 3 metres). Other so-called indicators, such as "beachrock", corals, calcareous algae and many species of mollusk shells often present more problems than they solve, since these forms can live (or lithify) within a much greater depth range. For example, reef corals can grow anywhere within the upper 50 metres of the water column. Thus, these "indicators" in fact only indicate that sea level was at that depth or shallower. Conversely, freshwater peat, often found in shallow borings on the Continental Shelf, only indicates that sea level was lower than that point at the time when the peat was formed.

A second problem concerns the tendency of indicators to be transported. If, for example, an oyster shell is moved several kilometres by currents or waves, the depth at which it ultimately is found may be different than where it lived. Basing a relict sea level on such false "indicators", therefore, could yield inaccurate results. Several authors (MacIntyre et al., 1976; Blackwelder et al., 1979) emphasize using only "in place" shoreline indicators, that is, those which have been sampled in locations coincident with where they formed. This means obtaining samples, mainly peats, oyster shells and "lagoonal deposits" by shallow borings. The determination of saltwater versus freshwater peats is made on the basis of plant species identification.

As will be seen, however, most "movable" indicators correspond closely to a curve formed by "in place" indicators, although understandably, the scatter of points is greater.

A third problem in determining sea level is the reliability of dating techniques, particularly carbon-14. The half-life of carbon-14 is approximately 5,700 years, which means that after 28,500 years, the fossil retains only 2^{-5}, or 3 percent of its original radiocarbon. As this amount of original carbon becomes smaller, the impact of contamination by modern carbon increases and as a result there is an apparent age decrease. For instance, contamination of a "dead" (that is, older than 50,000 years) fossil with 3 percent modern carbon, which is quite possible if boring algae are active, could give this "dead" fossil an apparent age of 28,500 years. In fact, many fossils dated at between 25- and 40-thousand years, when dated by other radiometric means, have been found to be more than 100,000 years old. Thus, most workers discount carbon-14 age determinations on materials older than 30,000 years, and recognize potential problems in dates older than 15,000 years.

Fourth, while shallow-water indicators for the past 6,000 years are relatively abundant, reported dates for older indicators are relatively few, particularly those older than about 12,000 years B.P. This in part reflects the paucity of reliable indicators and the fact that older indicators may be covered by subsequent sedimentation. This problem has been helped by extensive vibracore data collected along the coast of North and South Carolina (Field et al., 1979; Blackwelder et al., 1979). Still, to obtain sufficient older dates to construct a "reliable" curve, previous workers have had to use data from very large areas (and assume that these areas are tectonically uniform). The error in this assumption is discussed below.

The fifth and perhaps greatest problem is that the sparse number of reliable indicators does not allow for inferences about the various stillstands or short-term reversals in the Wisconsin regression or Holocene transgression. It is known from the occurrence of shelf terraces and historical data that such short-term fluctuations in climate and sea level must have occurred, and that these fluctuations must have resulted in a rather irregular sea-level curve. However, the few available dates only permit the construction of a smooth curve. This problem, although clearly recognized, may be impossible to solve using present-day techniques.

Figure 4.1.5 illustrates the most widely accepted sea-level curve for the eastern United States developed by Milliman and Emery (1968), and was based mostly upon dates from shoreline indicators taken from north of Cape Hatteras (Emery and Garrison, 1967). Three major changes in this curve have led to a reconsideration of its value to the area south of Cape Hatteras. First, Dillon and Odale (1978) have shown a definite downwarping of the shelf north of central New Jersey (approximately 40°N), indicating that a considerable number of the sea-level indicators used by Milliman and Emery in construction of their curve (particularly those from greater depths) came from a subsiding shelf. Since these indicators defined the deepest part of the curve, a recorrected curve (Dillon and Odale, 1978) shows the lowest depression of sea level to be about 90 metres, or about 40 metres less than that proposed by Milliman and Emery.

Second, many of the points that delineated a deep stand of sea level on the southeastern shelf (such as "beachrock", and algal rock) probably should be eliminated since they are not reliable shallow-water indicators (MacIntyre et al., 1975).

Third, and most important, several workers (MacIntyre et al., 1977; Blackwelder et al., 1979) have pointed out that shells found lying on the seafloor are subject to transport by currents. Thus, without better control, it is impossible to ascertain whether these potentially "moveable" indicators are in place. MacIntyre et al. (1977) pointed out that of the 44 carbon-14 dates of oyster shells taken from the North Carolina Shelf surficial sediments, nearly all occurred at far shallower depths than predicted by the Milliman and Emery curve. This non-correlation led MacIntyre et al. into a circular argument:

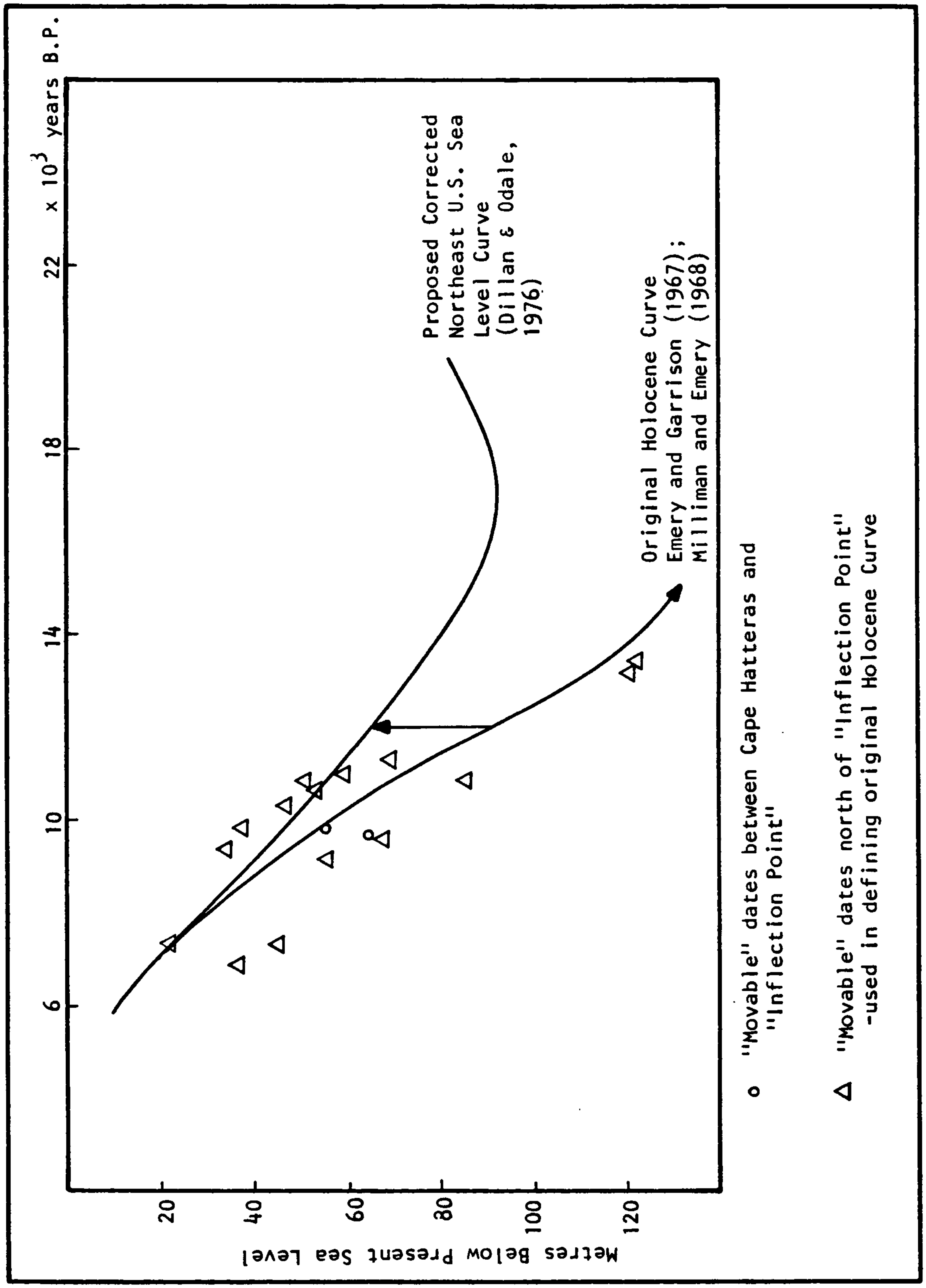


Figure 4.1.5 Sea-Level Curves

the dates disagreed with the curve; therefore they must have been moved, and therefore were not reliable sea-level indicators; thus the Milliman and Emery curve must be in error. MacIntyre added that curves constructed on the basis of such movable objects were subject to considerable error. Until recently, all curves had been constructed on "movable" indicators.

More reliable sea-level indicators are those found below the seafloor, in deposits that are intertidal, and that clearly have not been transported since deposition. Marine peats or oyster shells within lagoonal sediments are perhaps the best examples of such "in-place" indicators. Blackwelder et al. (1979), have gathered dates from a number of such in-place indicators sampled by vibracoring on the shelf south of Cape Hatteras and have proposed a sea-level curve much shallower than even the corrected curve of Dillon and Odale. Other in-place indicators from the south (Field et al., 1979) agree closely with this new curve. Interestingly, most of the "movable" dates supplied by MacIntyre et al. (1977) and Milliman and Emery (1968) (for those indicators south of Cape Hatteras) also cluster around this new curve.

The argument comes full circle; MacIntyre et al. dates did not agree with the Milliman and Emery curve because the latter curve does not apply to the shelf south of Cape Hatteras, rather than that the indicators themselves were moved.

As seen in Figure 4.1.6, the sea-level curve for the Continental Shelf south of Cape Hatteras is thus determined to be distinctly shallower than the curve for the shelf north of the "inflection point" delineated by Dillon and Odale. The shelf between these two zones, that is to say, the shelf from central New Jersey to Cape Hatteras, has few dated sea-level indicators. However, the few available dates, particularly "in-place" indicators from coastal Delaware (Kraft, 1977; Belknap and Kraft, 1977) indicate paleoshorelines roughly between those indicated by the northern and southern curves. If in fact the New Jersey-Cape Hatteras shelf does represent a continuum between the

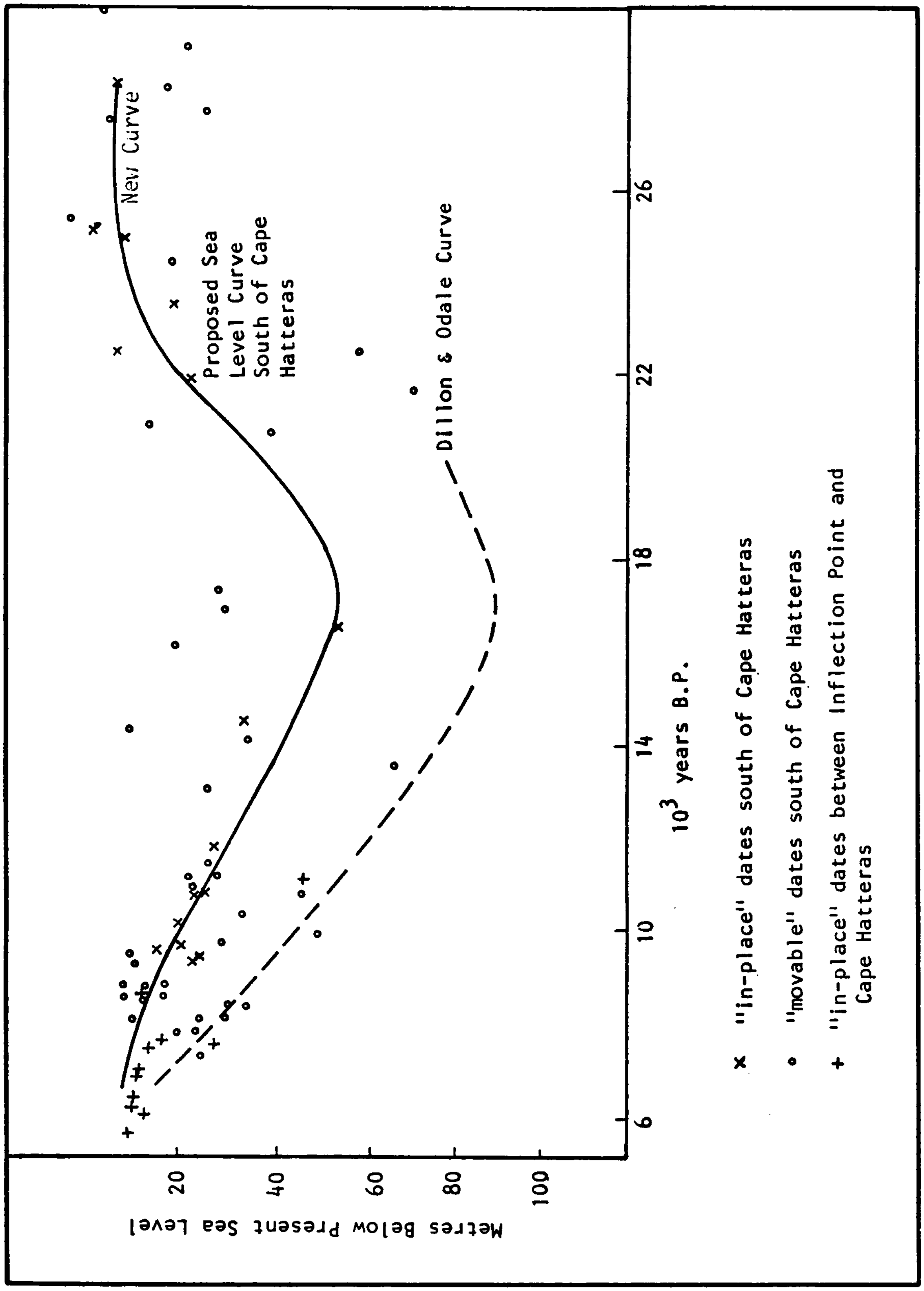


Figure 4.1.6 Proposed Sea-Level Curve for the Continental Shelf South of Cape Hatteras

northern and southern curves, it may suggest a broad transition between these two zones rather than a sharply demarcated hinge line. However, whether the northern zone represents primarily subsidence, or whether the southern zone represents uplift, is not firmly known. One can suspect that the northern area may have subsided more than Dillon and Odale calculated, or the change in the shape of the geoid (K.O. Emery, personal communication, 1979) may also account for this difference between north and south. Clearly, this question requires further study.

A final point should be made: with the available data, the date or depth of maximum low stand of sea level cannot be specified. The oldest in-place data is 16,500 years. If the data of maximum low stand agrees with other areas (of which curves have been constructed) and with the maximum glacial advance, it should be expected that this period must have occurred about 17,000 to 18,000 years B.P. The new curve reaches a depth of about 60 metres (which is near the shelf break) at this date. Most obvious wave cut terraces south of Cape Hatteras appear to fall within 5 metres of this depth (P. Popenoe, USGS, personal communication, May 1979), supporting the hypothesis of maximum regression.

The new curve means that the rate of sea level rise was less. With the previous Milliman and Emery curve, sea level would have transgressed nearly 100 metres (vertically) between 15,000 and 8,000 years B.P.; in this same time interval, sea level would have only transgressed 45 metres using the proposed southeastern United States curve (Table 4.1.5). Thus advancing sea level may not have had quite the same effect in the south that one could envision using the older Milliman and Emery curve.

Table 4.1.5 Sea-Level Stands for Various Times During the Past 20,000 Years

Years Before Present	Metres Below Present Sea Level
6,000	10
8,000	12
10,000	23
12,000	35
14,000	44
16,000	56
18,000	57
20,000	44

Implications of the new sea-level curve for the shelf south of Cape Hatteras are important. Because the southern shelf lies in depths mostly shallower than the maximum regression showed by the new curve, the actual area available to prehistoric man is only slightly smaller than that calculated using the previous curves; however, the duration of potential habitation of the shelf was shorter (Table 4.1.6). For example, using the Milliman and Emery curve, it can be calculated that the length of time that prehistoric man could have lived at or near the shelf edge (assumed to be 55 metres south of Cape Hatteras) would be about 11,000 years (between 10,000 and 21,000 years B.P.). Using the Dillon and Odale curve, this time interval is reduced to 10,000 years. But with the new curve, the time interval is only about 3,000 years (15,500 to 18,500 years B.P.).

Finally, mention must be made of the comparison between this sea-level curve and those proposed for other shelf areas in the world. The term "eustatic" sea-level curve, although proposed by many authors (Curray, 1965; Milliman and Emery, 1968; Morner, 1976) appears to be a wish rather than a reality. This is clearly seen by the stark difference between curves proposed for the shelf north and south of Cape Hatteras. Curray's curve for the Gulf Coast diverges from both,

Table 4.1.6 Duration of Continental Shelf Exposure

Metres Below Present Sea Level	Time Interval at or Above Sea Level Thousands of Years B.P.	Duration of Time Thousands of Years	% of Time Exposed During Last 20,000 Years
10	6-20	14	70
20	9.5-20	10.5	52
30	11-20	9	45
40	13-20	7	35
50	14.8-19.3	4.5	22
60	0	0	0

Interval and duration of time during the past 20,000 years in which various depths on the present shelf were at or above sea level. The proposed sea-level curve has been used for this calculation.

while Kowsman and Costa's curve (1979) (based on in-place indicators from south Brazil) corresponds closely with the original Milliman and Emery curve. The problem, clearly, is one of local tectonic activity, coupled with changes in the geoid. We therefore can make no claim as to the applicability of the curve for the shelf south of Cape Hatteras to a more extended area, except to say that it probably cannot be applied to most other shelves, or conversely, that other curves derived from other parts of the world can be applied to the shelf south of Cape Hatteras.

4.1.1.6 Coastal Response to Sea Level Change

Primary Variables/Development of Shelf Stratigraphic Models

Numerous investigators have shown that the Holocene sea level rise has played a key role in the origin and development of the Inner Continental Shelf and modern barrier island system (Hoyt, 1967; Pierce and Colquhoun, 1970; Otvos, 1970; Dillon, 1970; Swift, 1975; Field and Duane, 1976). Because some of the inner shelf is underlain with Holocene lagoonal sediments (Stahl et al., 1974; Shideler et al., 1972; Sheridan et al., 1974) the retreating coast must have been dominated by barrier island systems. Consequently, the "roots" of these former barrier islands should be preserved in varying degrees within the geologic formations of the Inner Continental Shelf.

Investigations using high resolution seismic profiling, vibracoring, and C^{14} dating have shown that the true nature of the Quaternary section on the inner shelf is highly complex and varies significantly from one province to another (Uchupi, 1970; Swift, 1970; Meisburger and Duane, 1971; Shideler and Swift, 1972; Shideler et al., 1972; Field, 1974; Sheridan et al., 1974; Stahl et al., 1974; Field and Duane, 1976; Twitchell et al., 1977). Field and Duane (1976), Duane et al. (1972), and Swift et al. (1972) have shown that the Inner Continental Shelf off the eastern United States coast can be subdivided into geomorphic zones based upon dominant topographic features. It should follow that these different shelf zones may have distinct stratigraphic sections as well.

Swift (1975), recognizing these different shelf provinces and a wide degree of variability within each one, has suggested a framework of six basic modes of shoreline translation (Figure 4.1.7). Each mode demonstrates differing degrees of stratigraphic preservation or destruction based upon the direction of profile, equilibrium movement, and changes in profile curvature. Further variations of each of these modes are possible as well.

Using the modes of shoreface movement shown in Figure 4.1.8, one can illustrate the resulting shelf stratigraphy during varying rates of sea-level fluctuation. For example, in an area undergoing rapid sea level rise, which has a low regional gradient, high wave-energy, and low sediment supply, one would expect an "erosional transgression" (Figure 4.1.8A) with little or none of the coastal environments preserved on the shelf. An example of a region with these characteristics would be the Inner Continental Shelf off Bogue Banks, North Carolina. At 9,000 years B.P., sea level was rising at the rapid rate of 0.6 metres/100 years. Since the shelf gradient in this area is extremely low (40 cm/km), the time-averaged rate of coastal retreat was 1.5 km/100 years or nearly 30 cm/week. Such flooding would not allow any significant coastal stratigraphic sections to develop. Any sediments accumulating on or behind such a rapidly retreating coast were probably stripped off by the shoreface translation.

However, in another area at another time, when the regional gradient is steeper, sediment supply is higher, wave climate lower, and sea level rise not as rapid, one would expect a "depositional transgression" (Figure 4.1.8B). In this case, much of the lagoon-marsh-back-barrier depositional environments would be preserved on the shelf. However, it seems doubtful that any subaerial environment of the barrier island would be preserved on the shelf. In order for this to occur, such environments would have to pass through the surf zone without being destroyed. This is difficult to imagine since most coastal subaerial environments are composed of easily erodable sediments. In carbonate environments, where coastal beaches and dunes can become well lithified

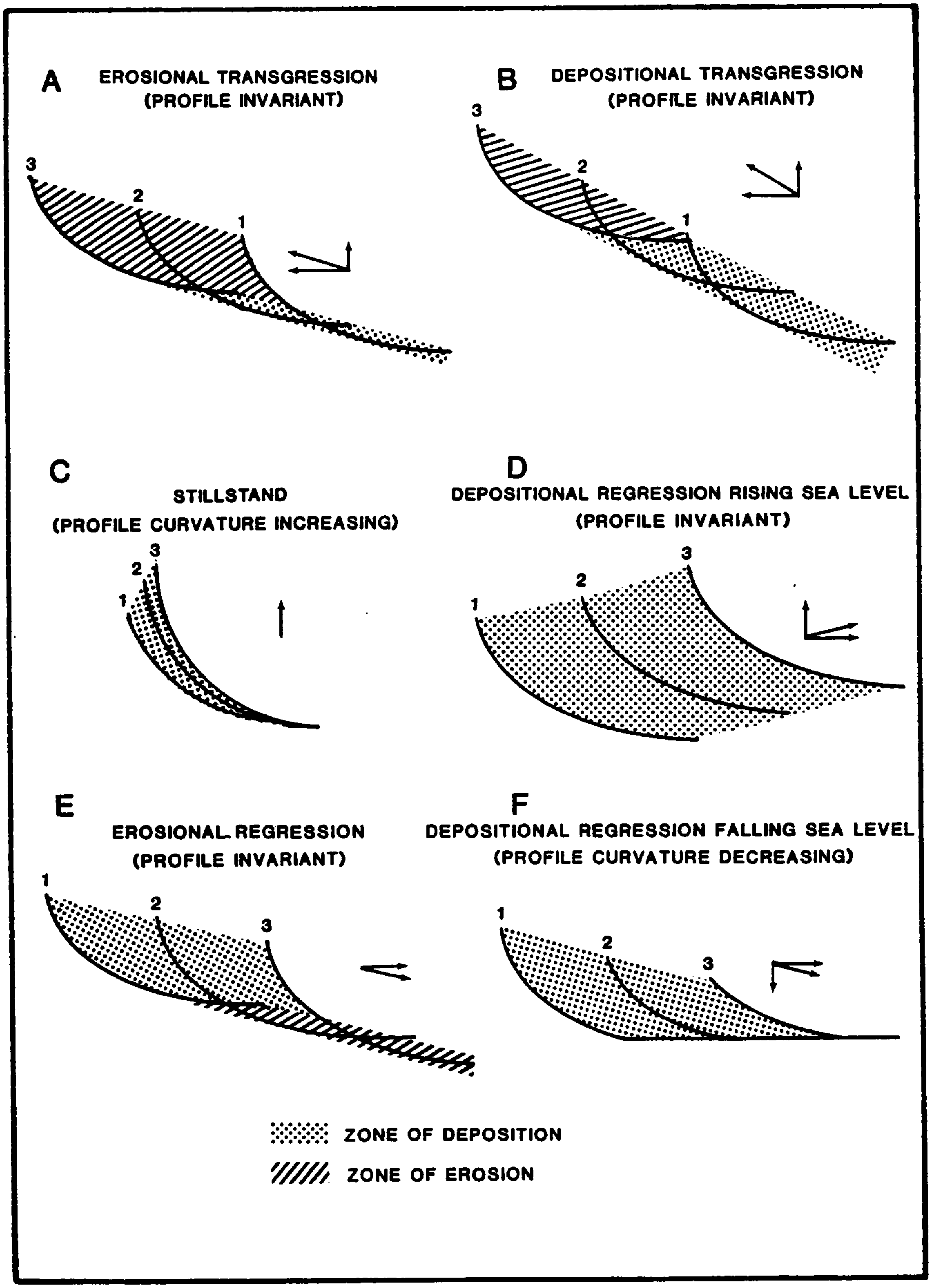


Figure 4.1.7 Modes of Shoreface Translation

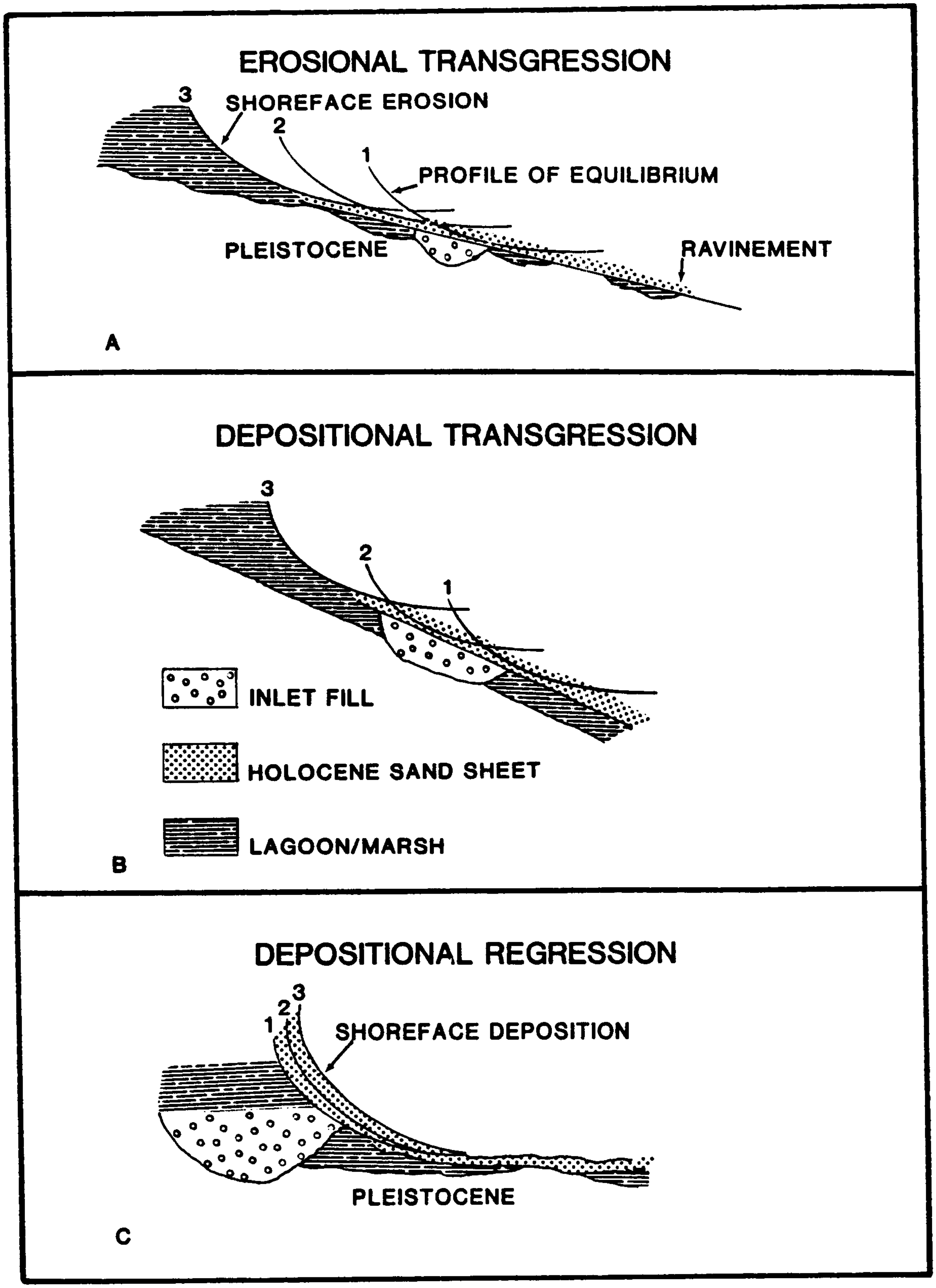


Figure 4.1.8 Shelf Stratigraphy as a Result of Transgression/Regression

(beachrock, eolianite) prior to inundation, these environments can and do pass through the surf zone relatively unscathed and persist as topographic features on the shelf.

During sea-level stillstands or periods of slow rise, it is possible for the barrier shoreline to prograde seaward -- a "depositional regression" shown in Figure 4.1.8C. During this time, the accumulating sediments form a wide, topographically high coastal environment. When sea level rise accelerates to its earlier more rapid rate, the shoreface profile (profile of equilibrium) begins to erode into this sediment accumulation. With the rapid flooding of this coastal area, the shoreface profile rises vertically and quickly translates horizontally landward so that a large portion of the barrier/back-barrier stratigraphic section remains on the shelf as a broad topographic high or a sudden/localized increase in the shelf gradient representing a sea-level stillstand. Only the superstructure (including the subaerial surface) of the wide barrier/lagoon complex is eroded. If man established sites on the mainland side of such a stalled, mid-shelf barrier island/lagoon-estuarine complex, it would be possible for such sites to become buried by marsh-lagoon-back-barrier sediments. If the renewed sea level rise was then rapid, these sites could well have been buried deep enough so that the landward migrating shoreface would not reach the depth of the artifacts. As a result, they would be preserved on the shelf. By locating submerged paleoshorelines which developed on the shelf during a stable sea level, a zone of high preservation potential for possible archeological sites could be inferred landward of these shorelines.

If much more high resolution seismic profiling and vibracore data were available, it would be possible to make maps of the Continental Shelf depicting zones of erosional transgression, depositional transgression, and depositional regression. With such maps, the preservation potential of subaerial environments and the likelihood of occurrence of archelogical sites could be assessed.

Those sections of the shelf dominated by an erosional transgression would have the lowest preservation potential. In this case, the landward moving shoreface profile would have cut down and removed or reworked most if not all of the recent coastal environments and also would have destroyed the Pleistocene subaerial surface as well. Most of the North Carolina and Florida terrigenous Continental Shelf probably experienced this type of transgression judging by the lack of Quaternary sedimentary cover and the widespread exposure of rock surfaces. The cape-associated shoals are obvious exceptions.

Those sections of the shelf dominated by a depositional transgression would have a high preservation potential for sites that had been established on the mainland sides of lagoons and along the banks of estuaries. Those sites established on a retreating barrier were probably destroyed since the "subaerial surface" of these features are generally eroded even though much of the underlying coastal stratigraphic section is preserved. Most of the middle and inner Continental Shelf off South Carolina and Georgia was probably influenced by this type of shoreface translation. The outer shelf off these states is rocky and probably experienced an erosional transgression.

The carbonate-dominated shelf off southern Florida behaved differently than the northern terrigenous shelves. This shelf probably has the highest preservation potential of the underlying Pleistocene substrate due to its indurated character and reef development resulting in a low wave-energy environment. Perhaps the best preserved areas would be the relics of karst topography such as sinkholes. Recent studies (Clausen et al., 1979) have reported preserved relicts in present-day Gulf Coast terrestrial sinkholes. Sinkholes present on the Atlantic Coast Shelf may prove to be sites with high preservation potential. While available bathymetric charts do not always indicate such sinkholes, fishermen have known of them for years.

Coastal/Nearshore Depositional Features and Processes. Along the wave-dominated coastal sectors (North Carolina and Florida primarily), vigorous and frequent sand transport occurs from the surf zone out to depths as much as 20 metres. Indeed, during major storms, sand and even gravel-sized sediment may be in transport (Gadd et al., 1978; Swift and Freeland, 1978). Therefore any prehistoric site or shipwreck located in water shallower than 20 metres and within the wave-dominated, microtidal coastal/inner shelf sector has been and will be influenced by frequent (10-50 times per year), long duration (3 hours to 3 days) flows of at least 50 cm/second. These values are estimates based upon the presence of large sand-wave fields on the inner shelf recorded by Swift and Freeland (1978) and Hunt et al. (1977), and known velocities needed to generate such bedforms (Boothroyd and Hubbard, 1975).

The surf zone and shallow nearshore (0-5 metre depth) are the highest wave-energy environments. Flow fields and resulting topography established by shoaling and breaking waves are intense and complex. The literature concerning the dynamics and sedimentation within this zone is very large and certainly beyond review for this report. Komar (1976) and the United States Army Corps of Engineers' Shore Protection Manual (1973) are key references. Offshore bars are common features along wave-dominated coasts and represent temporary seaward storage of beach sands during high wave-energy conditions. These features can change shape and size rapidly, but are probably never more than a few metres in height. They can be commonly cut by rip current channels. Longshore currents within the surf zone can exceed 150 cm sec^{-1} (3 knots). Rip currents, although less vigorous in nature, can transport large quantities of sand away from the beach and can extend hundreds of metres from shore.

Because most wave-dominated coastlines are undergoing erosion and because the substrate within the surf and shallow nearshore zone is so highly mobile, the potential for permanent preservation of prehistoric sites or shipwrecks by burial is low. In this high energy zone, artifacts are constantly being scattered and unless they are highly resistant to large wave and current forces as well as biological and chemical destruction, most man-made features are quickly destroyed. Since some sediment is advected or diffused seaward of this zone into deeper water, sediment accumulations in the zone between 5-20 metres are not always great enough to bury shipwrecks as well.

Along the modern, wave-dominated nearshore zone, there are two zones of sedimentation that could preserve structures by burial. They are on or along the large cape-associated shoals off the present-day capes or cuspate forelands, and also on or along the linear shoals presently forming in the nearshore along straight coastal sections. The cape-associated shoals have received their sediment supply from converging longshore transport systems terminating at the cape apex. As sea level has risen, the cape morphology is maintained and a long, shelf-transverse, sand body representing a depositional sink is left on the shelf to be reworked by the deepening and changing shelf hydraulic regime. These sand bodies are intermittently active, because sand waves which are as high as 7 metres occur on them (Hunt et al., 1977). With such large-scale depositional features migrating on the surface of these sand bodies, it is entirely possible for wrecks to become buried and remain buried for long periods of time. The shoals themselves have historically been hazards to navigation and numerous wrecks have been associated with them.

The linear shoals (Duane et al., 1972) forming in the nearshore zone are smaller sand bodies than the cape-associated shoals. They commonly occur on top of the cape-associated shoals as secondary features even through they can be tens of kilometres long and up to 12 metres in relief. Along the Continental Shelf, these features extend away from the coastline generally at a 15-55° angle and occur bimodally in water depths of 8 to 9 metres and 14 to 16 metres (Field and Duane, 1976). As the shoreline retreats due to rising sea level, these topographic features remain on the shelf and are modified by the more open shelf hydraulic regime. These features are much more important north of Cape Hatteras but do occur within this study area along the following zones:

1. A 10-kilometre section from Cape Lookout north of Core Banks, N.C.;
2. A 10-kilometre section north from Cape Fear;
3. Off St. Simons Island, Georgia;
4. Chester Shoal, 10 kilometres north of Cape Canaveral;
5. Section between Vero Beach and St. Lucie Inlet, Florida;
6. A number of small linear shoals associated with the large ebb-tidal delta systems in the tide-dominated zone of the Georgia Bight.

Shipwrecks could be located along these shoals. During high wave-energy periods, storm waves could break on the shoal crests posing a hazard to ships in the vicinity. Should wrecks lie on the flanks of these shoals, they could become buried by the active sand movement and hence preserved.

Along the tide-dominated coast of the Georgia Bight (southern South Carolina to northern Florida), the nearshore zone is dominated by the large ebb-tidal deltas associated with the numerous tidal inlets. These large sand bodies extend seaward from 10 to 14 kilometres and are commonly covered with active swash bars (Hubbard et al., in press). Since these large shoals guard the entrances of harbors and seaports, they become significant hazards to navigation. Commonly, the seaward termination of the main ebb channel within these sand bodies occurs in shallow water and, where no dredging has occurred, can only be crossed by ships at high water. During storms, passage into the harbor over this outer bar is hazardous and undoubtedly many ships have been lost in the past. The actively migrating channels and swash bars on these ebb-tidal delta shoals provide the mechanism for burial and preservation. Also, because wave-energy is generally lower along this coastal sector than the wave-dominated zones to the north and south, shipwrecks are not as adversely affected by frequent, high-energy events. Ships wrecked on the margins of ebb-tidal deltas in microtidal, wave-dominated zones are probably destroyed since the margins of these deltas received the highest wave-energy along this coastal type.

Along the nearshore and on the inner shelf between the ebb-tidal deltas the regional wave-energy is low due to the sheltering and refraction effects of the large, seaward-extending sand bodies. Little bedload sediment transport probably occurs in this zone. As a result, shipwrecks on the seafloor in this area have a higher chance of remaining intact than in higher wave-energy environments and possibly are partially covered with sediment.

4.1.2. Late Pleistocene Climatology

The view of climate as an "almost-intransitive variable" (Lorenz, 1967) implies that climatic change behaves as a random phenomenon with large changes often resulting from small alterations in conditions. The temporary southward extension of the limits of snowfall by unusually cloudy winter conditions can result in a positive feedback process, such as higher albedo, cooling of the ground and lower atmosphere, more persistent snowcover, and eventual extension of the snowfield.

4.1.2.1 Evolution of Climatic Zones

Other than such geologic factors as topography, the determination of site environmental components is highly dependent on site climatology and meteorology. Indeed, one can argue that the large-scale climate of the region throughout the timeframe covered by the study is more significant in determining original site location than is small-scale site meteorology. For example, mixed pine and deciduous growth in the late Quaternary southeast is found in a climatic belt whose boundaries are determined more by large-scale factors than by the local vagaries of topography and wind.

By setting a framework of the paleoclimatology of not only the area of study, but the entire mesoscale climate pattern, a firm foundation can be set for the more site-specific, climate-dependent factors: sea level changes, vegetation types, megafauna, and food sources. The hierarchy of determining factors leading to the present location and condition of cultural resources can thus be summarized: large-scale physical factors, especially climate, determine the smaller-scale biologic setting (vegetation, megafauna, invertebrate food sources) which favor or oppose human settlement there. Once the site has been impacted by human or faunal remains, physical changes (for example, rate of sea level rise) will determine its state of preservation and its recoverability (for instance, its impact by rate of river sediment discharge).

The world-wide cycle of pre-Pleistocene and Pleistocene Glaciation, although well-marked by physical evidence, remains unexplained as a feature of global climate. Although there have been fluctuations about world-wide mean temperatures since the melting of the Wisconsin icecap, the fact that reestablishment of continental glaciation has not taken place indicates the possible occurrence of a positive feedback event in the direction of warming at the end of the Wisconsin Glacial maximum.

The climatic zones established in the study region at the time of glacial maximum, and their subsequent alteration, were determined by the location of the Laurentide ice mass, the proximity of the Atlantic Ocean's ameliorating influence, and the relatively low relief of the region. The essential determining factor was the meridional temperature gradient between the boreal periglacial boundary of the region and the temperate southern extremity in Florida. Hence, as an initial assumption, climatic zone boundaries can be assumed to lie approximately parallel to the receding front of the ice sheet, that is, more or less east-west within the study area.

Further, except for the extreme southern region, the generally non-arid present-day climate of the region appears to have held since the Wisconsin maximum (although northern portions were somewhat dryer under the influence of glacial adiabatic winds). These conditions, favorable to large numbers of species of flora, led to more indistinct zonations by species than would occur in communities bounded as well by relief or sharp precipitation boundaries. The patterns of moisture and aridity, in turn, were determined primarily by large-scale global climatology.

Inferences about large-scale and mesoscale climatology from the end of the Wisconsin Glaciation to the present are based primarily on indirect evidence, from paleobotany and paleozoology. The period from the end of the Wisconsin Glacial maximum (about 18,000 B.P.) until approximately 9,000 B.P. was marked by a general warming trend and melting of the continental glaciers that had prevailed earlier over North America and Europe. Following the end of this Preboreal period in North America (Lamb et al., 1966) the climate cooled somewhat. The Preboreal in North America came 1,000-2,000 years later than it did in Europe, primarily because the North American continental ice sheet was a large continuous mass some 1 to 3 kilometres deep, rather than the small multicenter glaciations that occurred in Europe. Hence, melting of the continental glaciers in North America, because of the continental climate in central Canada, took longer than in Europe (Lamb et al., 1966).

Primary evidence for oceanic temperature boundaries in the Quaternary comes from the stratigraphy of calcium carbonate layers in deep ocean sediments (Mctyre et al., 1976). The present foraminifera and coccolith boundaries are marked by very strong differences in speciation as a function of surface temperature and salinity. By assuming that such temperature-specific varieties of fauna were also present in the Paleoatlantic, it is possible to infer surface isotherms from the demarcation lines between the different species in the cores taken in the Atlantic. From such boundaries numerous workers (see Mctyre et al., 1975) note that at 18,000 B.P., the last glacial maximum, the waters north of 45 degrees north were primarily polar waters with little mixing between the Gulf Stream (which was then somewhat south of its present position), and subpolar water to the north of the Gulf Stream. The present surface temperatures in the region of study, that is from Cape Hatteras south, in August range between 26°C and

28^oC, while in August 18,000 B.P. they were 2 to 4 degrees cooler (that is 22^oC to 26^oC). At the time of the pre-Boreal maximum in North America, about 9,000 B.P., the Atlantic subpolar gyre was some 3 degrees south and somewhat east of its present position. This marked the point at which the North Atlantic circulation diverged from its eastward course to carry warmer waters along the west coast of Europe. Since the present study area is south of the 42 degree parallel, its oceanographic properties have essentially been stable since the Wisconsin maximum. The primary difference has been the movement northward of the 26^oC surface isotherm (Hecht, 1973; Climap, 1976).

Lamb (1971), used this oceanographic evidence as well as indirect evidence of the type of melting taking place in the North American continental ice sheet (Clark et al., 1978) to develop isopach maps. The isopach data, ranging from surface pressure to 500 mbar, is used to determine atmospheric circulation from the time of the Wisconsin maximum to the present. These isopach maps can be supported by surface conditions, such as surface temperature and precipitation conditions inferred from paleobotanical evidence. Generally, the picture that emerges of North America at 8,500 B.P. is of a deep cold trough remaining over the Midwest. This feature continued to draw arctic and polar air down into Middle America, due to the remaining residual ice caps over northern Canada. The ice caps had not yet melted because of the great thickness of the Wisconsin Glaciers. As the geography of the ice boundaries and the ice depth changed, there were changes in circulation at around 4,000 to 6,000 B.P. The trough weakened, moved northward, and generally more mild conditions ensued. From this and other evidence, Lamb et al. (1966) derived presumed circulation patterns for the atmosphere and hence concluded that at about 8,500 B.P. very strong, dry winds prevailed in the wintertime over North America. Since then, circulation has become weaker, trending more east-west and less north-south in orientation. This brings milder conditions to North America because of the lessening of circulation of colder arctic air into the continent.

Ruddiman and Glover (1975) used the previously noted ice remnants as well as faunal evidence to derive presumed circulations at 9,300 B.P. (Figure 4.1.9). Generally, the polar jet was fixed a few degrees south of the maximum ice sheet. Air circulated southeastward from the Yukon to the Great Lakes region, and thence directly eastward across the North Atlantic, bringing cold polar air over the Atlantic and Europe.

4.1.2.2 Environmental Zones

Several studies have revealed the limits of biotic zones in the eastern United States at the time of full-glaciation. Hare (1976) notes the boundaries between full-glacial biomes based on July mean daily temperatures. The area under study falls primarily within two communities, the Boreal forest which prevailed from Cape Hatteras south of approximately Onslow Bay, and south of that, deciduous communities. Hence, the southern boundary of the Boreal forest at full-glacial times fell approximately half way down the East Coast from the northern to southern boundary of the study area.

Whitehead (1965), notes findings of Buell and Frey from Carolina Bay sediments of alternating organic and inorganic zones. An upper organic horizon at about 10,224 B.P. shows pine pollen and other nonthermophilic species from dominantly cold conditions. Singletary Lake, however, showed thermophilic types of about the same age, indicating a biotic boundary in that region. There is, however, controverted evidence of a deciduous "reserve" in the southeast or Gulf Coast area during the Wisconsin maximum (Whitehead, 1973). This area, even during the greatest extent of glaciation, may have formed a region east or south of the Appalachian barrier from which deciduous species migrated north during the Atlantic period.

Generally, as noted by Whitehead (1973), there were significant differences between late Pleistocene and Holocene communities in the east. Boreal communities extended at least 600 kilometres south of the edge of the glaciation and over 1,000 kilometres south of the present

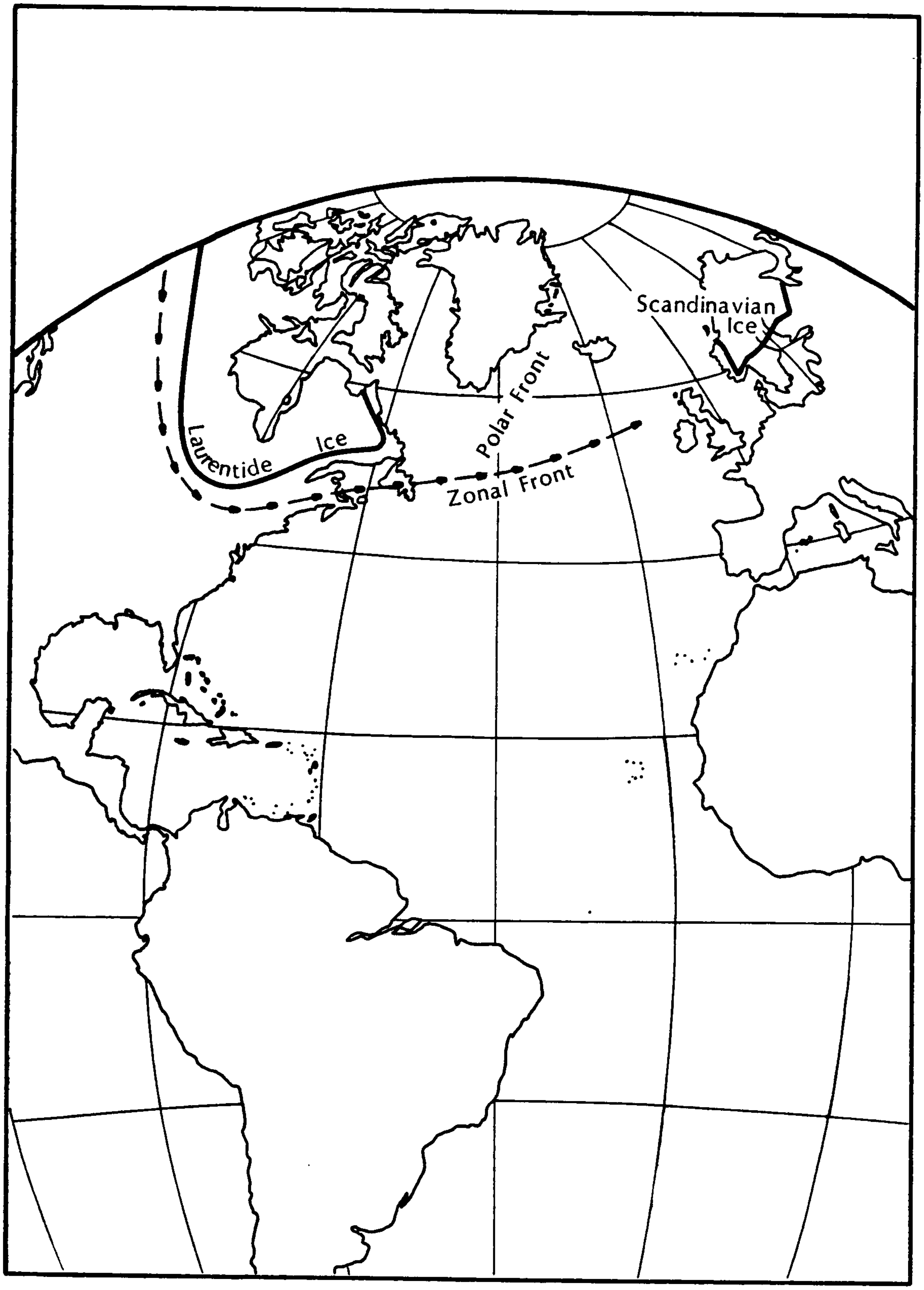


Figure 4.1.9 Calculated Trajectory of the Polar Jet at 9300 B.P.

Boreal forest. Tundra vegetation and boreal communities appear to have displaced temperate vegetation from the edge of the continental glaciation south to Georgia.

The picture that emerges of late Pleistocene climate in the region is of sub-Boreal conditions in the north, through temperate conditions in the south. Delcourt and Delcourt (in press) note the uncertainty in dating the maximum displacement of the eastern deciduous forest, 22,000 to 16,500 B.P., due to the uncertainty in the time of the maximum Laurentide glaciation. However, during the glacial maximum they note a xeric (or sub-humid) oak-hickory woodland in southern Georgia and passing northward, pine-spruce forests are first encountered in the Carolinas. Delcourt and Delcourt believe a scrub vegetation regime existed on a sandy base for the Southern Florida peninsula at the time of full-glaciation. The type of vegetation in the transition regions is still speculative, because of the inherent uncertainties in the provenance of pollen remains and their recovery location. As noted below however, two key sampling sites are known on the continental rise.

4.1.2.3 Pollen Records on the Coastal Plain

The most direct records of the environments inhabited by Prehistoric Man in the southeastern United States come from fossil plant remains. These paleobotanical records include some vegetative parts such as leaves or needles, but the vast majority of the relevant data comes in the form of pollen grains. In most instances these pollen samples are taken from lake cores.

In the past decade the study of late Pleistocene and Holocene pollen records (palynology) has attained a considerably expanded data base and a moderately sophisticated level of interpretation. Pollen-rich cores with multiple carbon dates often tell the history of vegetational change on the Coastal Plain during the last 30,000 years or more. Palynological evidence from the present study area and adjacent regions provides an excellent indication of the vegetation and climate confronting the first human inhabitants of the southeastern United States.

At present, these pollen data must be interpreted with some caution for several reasons. The most obvious reason is that the number of sites sampled in the southeastern Coastal Plain is very limited. A second concern is the fact that pollen, most of which is wind-borne, presents a broadly integrated sample of the vegetation in a given region. It does not sample only local plants, nor does it sample all plants equally. Pine pollen, for example, is notoriously abundant and can carry for long distances. The occurrance of robust samples of pollen on the continental rise attests to the remarkable portability of pollen by wind and water currents (Balsam and Heusser, 1976). One method of adjusting for transportation bias has been to determine absolute accumulation rates of pollen grains, instead of bulk percentages, but no such studies have been completed in the southeast (Davis, 1966). Thus, the results cited below, while of fundamental importance to this survey, must be interpreted as broadly as possible, pending further refinements.

The palynological results as reviewed here are divided chronologically into late Pleistocene records and early Holocene records. This division is useful for two reasons. First, there is very strong evidence of rapid and fundamental climatic and vegetational change at this boundary, approximately 10,000-11,000 B.P. Secondly, this boundary represents the great shift in human cultural traditions from the Paleoindian Period to the Archaic Period. It is probably no coincidence that the boundaries between major environmental modes and cultural modes are approximately contemporaneous.

Late Pleistocene Palynology

The assumption that vegetation south of the glaciers in North America was essentially unaffected by Pleistocene climatic changes was strongly challenged by Deevey (1949). However, Braun (1955) upheld this viewpoint in extensive studies of modern floristics, and the continued prevalence of this assumption probably deterred serious investigation of pollen studies well south of the glacial margins. Only in the last decade has it become obvious that some biomes shifted 1,000 kilometres to the south during full-glacial conditions. This knowledge has encouraged the recent upsurge of more refined pollen studies in the unglaciated eastern states.

To the north and west of the present study region, tundra forest dominated all terrains. Maxwell and Davis (1973) studied Buckle's Bog at an elevation of 800 metres in the Allegheny Plateau of Maryland and found evidence of an arctic-like tundra across the whole plateau. The predominant full-glacial vegetation consisted of Cyperaceae (sedges), Graminae (grasses), *Artemisia* (wormwood), and aquatics such as *Typha* (cattail). Arboreal pollen of *Picea* (spruce) and small-grained *Pinus* (probably jack pine) were about 20 percent each, and hence came from some distance. Comparisons with modern pollen grains at various distances from Boreal coniferous forests suggest that spruce forests lay about 25 kilometres away, presumably at lower elevations in coastal Maryland and Virginia. These results are confirmed by tundra samples from the Marsh Site, Round Glade and New Paris Sink (Guilday et al., 1964), all in Pennsylvania.

Maxwell and Davis (1973) conclude that the

> "magnitude of [southward] displacement is greater than biogeographers had imagined. New evidence presented here and in other recent papers shows a broad tundra belt in the eastern United States extending from the edge of the ice sheet at least 300 kilometres southward at higher elevations along the Appalacian mountain chain."

At lower elevations toward the Atlantic coast, spruce forests predominated. These are well documented in the Shenandoah Valley sites studied by Craig (1970) and Dismal Swamp sediments studied by Whitehead (1972). Well developed spruce forests have also been indicated at the present mouth of Chesapeake Bay by Terasmae's analysis of buried peat pollen samples (Harrison, 1965).

Spruce forests extended southward at least into northeastern North Carolina during the last glacial epoch. Whitehead (1973) reports an excellent pollen core with numerous radiocarbon dates from Rockyhock Bay in Chowan County, North Carolina. In the slow but apparently continuous accumulation of silts between about 30,000 and 10,000 years B.P., the predominant pollen types are two kinds of Picea (black and red spruce) and a small Pinus (red and/or jack pine). The third most abundant tree pollen belongs to Abies (fir). Sedges and grasses are abundant along with northern shrubs such as Lycopodium species. Thus, spruce forests, with a unique mixture of northern species, extended south along the coastal lowlands of North Carolina.

Two important marine records of late Pleistocene pollen come from two cores on the continental rise between Cape Hatteras and Chesapeake Bay. Sediments between 15,000 and 10,000 years B.P. are dominated by pine pollen but also include high spruce and for counts (Balsam and Heusser 1976). These records suggest that the Boreal Forest best known from the coastal lowlands of North Carolina extended eastward onto the Continental Shelf.

In southern North Carolina, the Carolina "Bays" of Bladen County provide excellent pollen records through the late Pleistocene and Holocene. These bays range along the Coastal Plain from southeastern North Carolina into northern Florida and consist of clusters of cuspate dunes now usually enclosing silt-filled lakes. The "silt zone," representing slow deposition of low organic sediments, recurs in the late Pleistocene part of each bay core studied (Frey 1951, 1953, 1955; Whitehead 1963, 1964, 1965, 1967), and it produces an abundance of small Pinus pollen (probably jack pine) and some spruce. The absence of other arboreal pollen types is notable. Aquatic floral elements, mainly Isoetes microspores, indicate very cool lakes of low productivity. In addition, a number of non-arboreal "heliophytes" were sampled, including compositae such as Ambrosia and Ericaceae (heaths) and Graminae (grasses). "The best match among published modern pollen assemblages derives from areas of jack pine forest in Manitoba" (Whitehead, 1973).

To the southwest, Watts (1970, 1980) has described full-glacial pollen assemblages from two small ponds in Bartow County, Georgia. Although these sites are in the Appalachian Mountains, they compare very closely with the pollen samples of the Carolina Bays. They provide macrofossil evidence (needles) that the dominant small pine pollen was jack pine. Presumably the belt of Boreal pine (and spruce) forest that extended from northwestern Georgia through southeastern North Carolina continued to the full-glacial coastline now approximately 100 kilometres to the east of the present Carolina coast.

Full-glacial pollen samples from coastal South Carolina and Georgia have not been discovered to date. Professor W.A. Watts of the University of Dublin (Ireland), however, continues his studies in Georgia in an attempt to fill this major gap. He has encountered a consistent problem in that most small lakes on the Coastal Plain were drained by lowered water tables during full-glacial epochs. Thus, several cores pass through very late glacial and Holocene samples abruptly into interglacial samples which are beyond the range of reliable radiocarbon dating. The full-glacial interval is represented only by a nonconformity (Watts, 1969, 1971).

The full-glacial vegetation of south-central Florida is well represented by Watts' (1975, 1980) sample from Lake Annie at an elevation of about 40 metres in Highlands County. It records a nearly continuous rain of pollen from 37,000 to 13,000 years B.P. The principal pollen contributors were Ceratiola (rosemary) and Polygonella (sandhill polygonella) both xerophytic shrubs now living on dry dune ridges in Florida. At present they are accompanied (except locally in exceedingly well-drained sites) by scrub oaks and sand pine. But, in the long full-glacial part of the Lake Annie core, the contribution of pine was exceedingly small; therefore, they are assumed to have been transported for a good distance). Even the scrub oak pollen is sparse enough to suggest that the oaks occurred in scattered stands in a very open scrub vegetation. Graminae (grasses) and compositae, especially Ambrosia (ragweed), were relatively more abundant than now. The plant associations in Florida were remarkably arid-adapted and the climate was evidently drier than it is today.

Strong implications of more arid climates in the southeastern Coastal Plain are not restricted to the Lake Annie pollen sample. The fact that most lake cores record a nonconformity due to total drying up must be taken as a serious piece of evidence. In the Pee Dee River area of northeastern South Carolina, Thom (1967) has shown that the extensive build-up and movement of dune fields was largely a full-glacial phenomenon. Thom (1967) and Whitehead (1973) have proposed the same explanation for the aeolian features of the Carolina Bays.

Whitehead (1973) has pointed out the curious absence of any evidence of extensive full-glacial deciduous forests in the Coastal Plain of eastern North America. This is puzzling in view of the dominant role of deciduous forests over nearly the whole region today. Possibly the deciduous forests predominated over much of the Georgia and Florida lowlands. The record as presently known in these states is so limited that it may well be misleading. As Whitehead's (1973) map suggests, deciduous forests ought to have occupied considerable parts of Georgia and Florida. This view gains some support from the occurrence of mixed mesophytic forest pollen in full-glacial deposits in Mississippi and Louisiana (Delcourt and Delcourt, 1977) and in northern Florida (Watts, 1980).

In summary, an increasing number of pollen cores are beginning to paint a coherent picture of late Pleistocene floristics. The vegetation zones appear as a series of latitudinal bands well south of their modern counterparts. Hare (1976) has interpreted the temperature implications of these bands of tundra, spruce woodland, jack pine woodland, and probable deciduous forest during the full-glacial interval. Assuming present-day macroclimatic correlations of the predominant tree types, he has estimated the mean July daytime temperatures of the ecotones. Thus, the July daily temperature at the northern margin of the spruce woodland in northern Virginia was probably 14°C to 15°C, and that at the southern boundary of the jack pine woodland (probably in South Carolina) was probably 21°C. These summer temperatures of the full-glacial were 7°C to 10°C below those of the present. As Hare (1976) further notes, the winter temperatures of the late Pleistocene then deviated much less from the summer temperatures than they do now, due to the stabilizing affects of the continuous massive ice front. Whitehead (1973) in his review of North Carolina pollen samples estimated that winter temperatures were as much as 15°C below present and summer temperatures about 9°C colder than now. As Hare (1976), Whitehead (1973) and others have repeatedly noted, the floristic communities of full-glacial times had species compositions quite distinct from any modern analogues. Therefore, these estimates of temperatures regimes may be crude, and appropriate transfer functions will require more detailed quantitative analysis (Watts, 1980).

4.1.2.4 Late Pleistocene Vertebrates as Climatic Indicators

The fossil vertebrate record is for several reasons an ideal complement to the pollen record as an index of former climatic conditions of the southeastern United States. First, the conditions favoring deposition are typically quite different; vertebrate bones more often survive in coarse or well-oxidized sediments. Second, bones are more easily preserved. Third, bones are more readily discovered. Therefore, investigated vertebrate fossil sites are more numerous and more widely distributed than investigated pollen sites. A vertebrate site rather specifically samples a local area, whereas a typical pollen profile represents a much broader regional source area. Most pollen samples are swamped by abundant windblown species such as pine, even if the source is tens or even hundreds of miles away. Vertebrates, on the other hand, usually can be assumed to accumulate within their natural home ranges. As Webb and Clark (1977) observed, the climatic models based on pollen types need verification and supplementation by climatic values from such independent sources as terrestrial faunal remains.

The main disadvantage of vertebrates as climatic indicators is that often they have a less direct relationship to ambient climatic factors than plants or invertebrates. Under many conditions the critical factors for a particular vertebrate species are vegetational or edaphic rather than climatic *per se*. Some important exceptions occur among cold-blooded vertebrates where their physiological well-being demands that their lower temperature limits must not be exceeded for long. Land tortoises are a good example of coldblooded vertebrates that have significance in the late Pleistocene of the southeastern United States.

Even for thermally tolerant large mammals, however, knowledge of preferred vegetational requirements may clearly indicate the distribution of former habitats. In this way megafaunal data may be broadly comparable to palynological data in their climatic significance.

A second disadvantage of vertebrate fossil data for Pleistocene climatic reconstructions is the fact that many of the species are extinct. Obviously no direct physiological studies can be carried out. In practice, however, this problem can be largely overcome by circumstantial evidence. For example, the tundra food preferences of the woolly mammoth are evident from its frozen stomach contents, or from the surviving species that occurred with it, and its temperature range is broadly indicated by its long thick fur coat. Similarly, ground sloth habitats and climates have been outlined on the basis of analyses of their skins and dung samples. Many other fossil groups have close living relatives which usually (but not always) may be taken to indicate approximately the same environmental preferences.

The inadequacies of any single vertebrate species as an indicator of climate or habitat tend to be overcome when two or more indicator species are considered in concert. This faunal approach is followed in the following review. On the basis of two or three corroborative vertebrate species, three broad latitudinal zones are recognized in the southeastern Coastal Plain (Figure 4.1.10).

From north to south the three broad faunal regions from the late Pleistocene of the southeastern Coastal Plain are defined as follows on the basis of their faunal remains:

1. Boreal Faunal Region
2. Temperate Faunal Region
3. Subtropical Faunal Region

These vertebrate data complement the pollen data. For vertebrate evidence, as for pollen evidence, the late Pleistocene climatic zones lay remarkably far south of Holocene climatic zones, and imply many habitats quite unlike any now in the southeast.

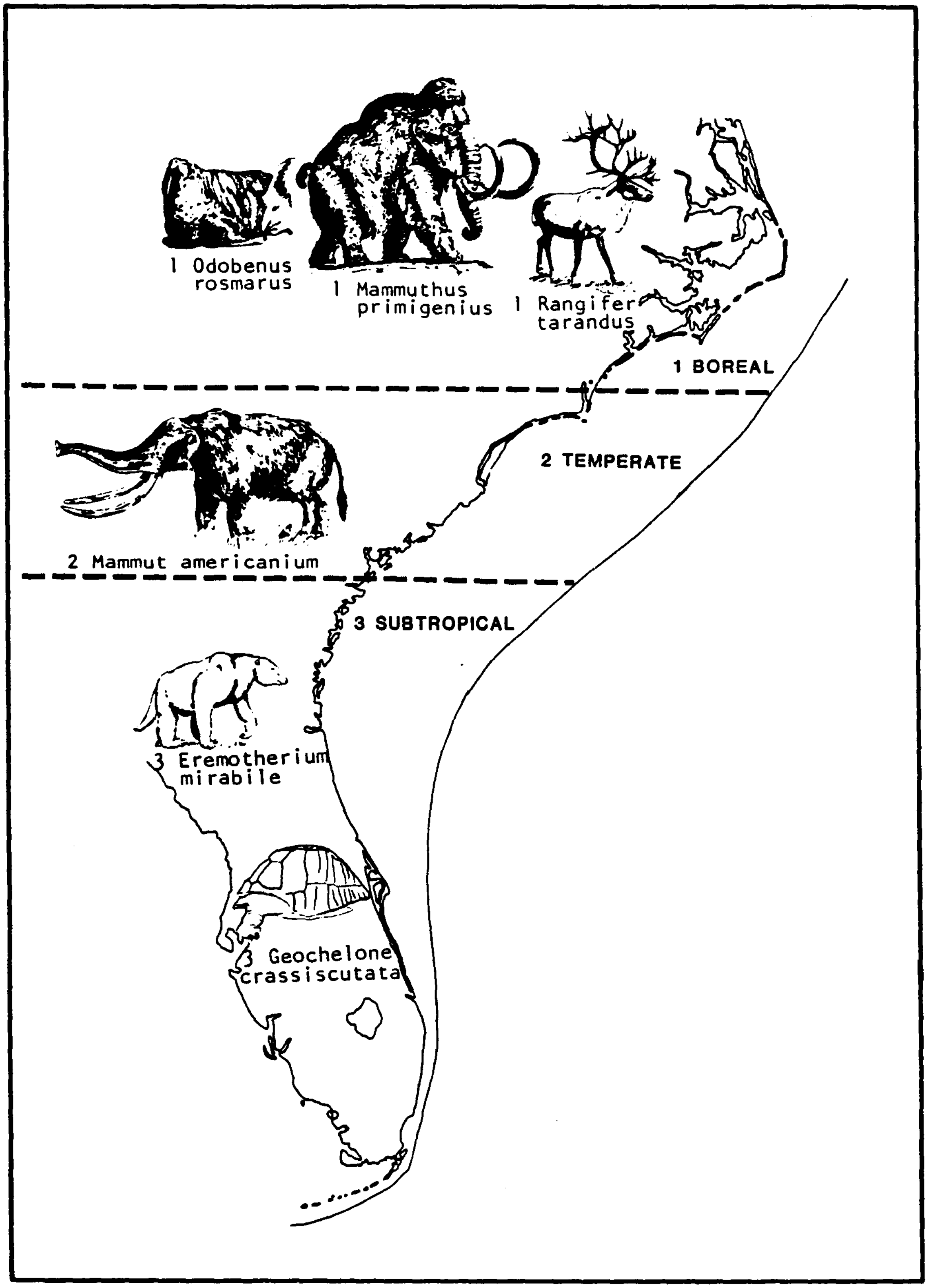


Figure 4.1.10 Representative Megafauna of Late Pleistocene Bioclimatic Zones

1. Boreal Faunal Region

As shown in Figure 4.1.10 the Boreal Faunal Region extended from the north, southward along the Coastal Plain of North Carolina. The vertebrate evidence corresponds well with palynological evidence: together they mark the extension of the tundra biome far south of its present range. Boreal vertebrates also extended southward along the coast of North Carolina. It also extended onto the shelf at least 10 kilometres off the present coast. Whitmore et al. (1967) described eleven specimans from the Outer Continental Shelf off the Chesapeake Bay area. In the present study area three specimans of Mammuthus primigenius, the woolly mammoth, also occurs with Rangifer tarandus, the caribou, at a fossil vertebrate site east-southeast of Currituck Beach, North Carolina. This site clearly records the occurrence of these two tundra-grazing species together on the shelf (see discussion of shelf sites Volume I 94-101). Based on pollen from frozen mammoth stomach contents, their diet was about 97 percent grasses (Tikhomirov, 1958). Woolly mammoth remains occur as far south as Charleston, South Carolina. There, however, they are less abundant than Columbian mammoths, and while they surely imply extensive grazing conditions, they may have been seasonal inhabitants of cool temperate grasslands rather than boreal tundra. The presence of other grazers, principally Equus and Bison in coastal North Carolina, further supports the interpretation of this era as predominantly tundra habitat. Evidence of active dune fields and extensive aeolian sand deposits in coastal North Carolina reinforces the view that vegetation was sparse, and the landscape unforested (Whitehead, 1973).

The Carolina Coastal Plain and shelf yield a large number of Odobenus rosmarus (walrus) specimens. An early occurrence is noted by Hay (1923) near Kitty Hawk, North Carolina, and others are cited herein. Fossil walruses are particularly liable to be preserved because of their dense durable bones, and they are sufficiently distinctive to arouse curiosity, and to be identified with relative ease.

Walruses are predominantly molluscivorous, and gather their food at depths up to 80 metres, but usually 20 to 30 metres. Their remains, therefore, may be expected to be found widely over the near Continental Shelf off the Carolinas. The climatic requirements of O. rosmarus have been studied in some detail by Ray and Fay (1968), and by Fay and Ray (1968). Walruses occupy boreal waters, and rarely extend far from the coast. At present their Atlantic Range does not extend south of the Gulf of St. Lawrence. As Ray and Fay (1968) observe, "only a few vagrants occur south of the 10° isotherm." Since walruses are highly gregarious, such occasional vagrants are relatively unimportant. Walruses spend much of their time on land, where basking is an important part of their physiological and behavioral pattern. However, at ambient temperatures above 19°C, walruses become thermally stressed. Thus, the southern limits of their range can be related both to sea surface temperatures and to daytime land temperatures.

The presence of walruses in marine deposits of the late Pleistocene, as with the evidence of Rangifer and M. primigenius from terrestrial sources, indicates that boreal climatic conditions extended southward along the Atlantic coast well into North Carolina. Their formerly much greater southward range (about 20 degrees of latitude south of their present range) clearly indicates the southward extension of climatic and, therefore, also of biotic zones along the Atlantic seaboard during the late Pleistocene. The southern limit of late Pleistocene Odobenus on the coast roughly coincides with the southern limits of tundra vertebrates on the land.

The southern limits of these Boreal vertebrates extend more or less laterally into the Appalachians. If anything, the southern limits might grade slightly to the north, presumably due to higher levels of precipitation and snowfall. In the Ridge and Valley Province, at elevations around 400 metres, Guilday (1978) describes a "faunal gradient" from taxa indicating tundra and open spruce woodland in the periglacial zone in Pennsylvania to denser woodland of northern conifers at Clark's Cave, Virginia. Ray, Cooper and Benninghoff (1967) described M. primigenius and Ovibos (muskox) with abundant spruce pollen at Saltville, Virginia. The interpreted habitats of these Boreal vertebrate faunas agree well with those based on pollen spectra from the same sites (Guilday et al., 1964).

2. Temperate Faunal Region

The zone of temperate forests and grasslands was markedly compressed in a north-south direction along the Coastal Plain. In the late Pleistocene it extended from about Cape Fear, North Carolina, to about Charleston, South Carolina. The vertebrate samples from this region are diverse, and include complex megafaunal samples of both browsers and grazers. The most striking distinction from the northern fauna is the regular presence of sizeable percentages of browsers, especially Mammut americanum, the American mastodon. As in the Great Lakes region M. americanum may be most abundantly associated with spruce forests (Dreimanis, 1968). On the other hand, it also occurs widely in other parts of the country in mixed mesophytic situations, the only difference being that it tends to share the browsing role with other species. Where such other browsers as Odocoileus virginianus (white-tailed deer), Alces alces (Elk), or Megalonyx jeffersoni (Jefferson's ground sloth) occur, the vegetation is probably mixed mesophytic woodland.

Grazers remain prominent in this temperate faunal zone. The characteristic mammoth is Mammuthus columbi, although, as noted above, M. primigenius seems to have ranged south of strictly tundra terrain, possibly on a seasonal basis. Even so, the specific distinction between the two mammoths remained clear, implying that they maintained some form of ecological separation. Bison and Equus continue in these temperate assemblages, although Bison tends to become more frequent than in the tundra biome, presumably because it was particularly successful in ecotonal areas, where it could assume the role of a browser or a grazer.

Other grazers ranged from the south into the temperate faunal zone: fossil camelids such as Camelops and Hemiauchenia, and the capybaras (great amphibious rodents). Hydrochoerus and Neochoerus are the most frequent examples. Presumably they required the broad range of temperate vegetation and the year-round productivity that were available in temperate grasslands and woodland ecotones.

Within this compressed temperate zone, there was surely a number of different habitats in a complex mosaic. Woodland habitats included northern conifer forests, northern hardwood forests, oak-hickory and oak-pine forests, among others that have been relatively well-differentiated in some sites on the basis of local pollen samples. Open country habitats included extensive coastal grasslands and marshlands, as well as more local, often edaphically controlled, scrub habitats. Vertebrate sites generally do not distinguish clearly between the various forest habitats. However, they may provide a ready clue as to the relative importance of open habitats versus woodland habitats. A particularly useful ratio is simply the mastodon-mammoth ratio. Since both groups are large proboscideans, they may be assumed to have had similar population parameters, similar biomass, and similar likelihoods of preservation and collection. If molar teeth are used, it is necessary to divide the number for mastodon by two, since Mammut americanum had twice as many fully molariform teeth as Mammuthus columbi or M. primigenius. The mastodon/mammoth ratio gives a general indication of the proportion of woodland to grassland in the vicinity of a vertebrate site (Slaughter, 1962; Guthrie, 1968). To date, this ratio has not been applied in vertebrate studies on the southeastern Coastal Plain. In general, however, Coastal Plain sites have more mammoth remains in relation to mastodons than do inland or especially upland sites. More detailed data are available and their analysis would be extremely useful in reconstructing detailed environmental mosaics in the late Pleistocene of the Coastal Plain.

The temperate vertebrate zone extends westward onto the Piedmont and, with a cooler aspect, into the Appalachians. In east-central Georgia, Voorhes (1971) described the Little Kettle Creek local fauna with Mammut americanum, Odocoileus virginianus, and Bison species. The presence also of a single Mammuthus tooth in this small sample gives evidence of a grazing habitat as well as a woodland habitat, and this is further supported by the presence of bog lemmings and red-backed voles in the same site. The fauna from Baker Bluff Cave in the Appalachians of Tennessee, 500 kilometres south of the periglacial zone, reflect mixed northern hardwoods, conifer stands, and patchy meadows and grasslands (Guilday, 1978).

3. Subtropical Faunal Region

The subtropical vertebrate fauna reached northward along the Coastal Plain as far as Charleston, South Carolina, it extended southward through most of Florida, and from there westward around the Gulf of Mexico. During the last glacial interval, when the coastal lowlands expanded widely to the east, especially off of north Florida, the subtropical fauna attained an extraordinarily broad range. Only small patches of that vast area are now exposed along the present coast. The best known and earliest discovered example is the site from Skidaway Island, Georgia, where over a century ago Leidy (1874) and others described a distinctive sample of subtropical late Pleistocene vertebrates. Recently two similar sites have been discovered from below sea level, one from the shelf off of Brunswick, Georgia (Frank Whitmore, personal communication, U.S. National Museum, May 1979), and the other from 11 metres below sea level on the Gulf Coast of Florida, discovered during excavation for the Crystal River Nuclear Power Plant. The latter provides a particularly rich sample of subtropical savannah vertebrates (Webb, 1978).

The characteristic large mammals of the subtropical vertebrate fauna are the giant ground sloth, Eremotherium mirabile, and the gomphotheriid proboscidean, Cuvieronius obscurus. Both genera range from the Charleston area through Georgia southward, around the Gulf of Mexico and throughout the American tropics. The former was a browser and the latter primarily a grazer. Both occur ubiquitously throughout their ranges, suggesting that as herbivores their tastes were cosmopolitan. They presumably required large amounts of browse and graze on a year-round basis.

Another large herbivore characteristic of the subtropical vertebrate fauna is Geochelone crassiscutata, a giant tortoise closely related to the present Galapagos Tortoise. It ranged from Charleston southward along the coasts of Georgia throughout Florida and widely in the American tropics. These tortoises were grazers, though not specifically arid-adapted as are many modern tortoises. The modern relatives of this tortoise cannot survive in freezing winter temperatures, and like it are too large to burrow and hibernate. In frosty climates their massive digestive systems cease to function and they also fall easy prey to pneumonia. It is almost certain that the northern limits of the range of Geochelone crassiscutata falls below the line of winter frosts during the late Pleistocene (Hibbard et al., 1965; Auffenberg and Milstead, 1965). Thus giant tortoises indicate persuasively that mild (nonfreezing) winters, similar to southern Florida today, occurred from Charleston southward during the late Pleistocene.

Other subtropical vertebrates also occur regularly with these conspicuous indicator species. The long-nosed peccary, Mylohyus nasutus, the spectacled bear, Tremarctos floridanus, the southern llama, Palaeolama mirifica, the extinct armadillo, Dasypus bellus, and the giant armadillo, Pampatherium septentrionale are other common examples. Also many temperate species range south along with the specifically subtropical species. Thus, these are typically the richest and most diverse vertebrate samples of the late Pleistocene (Webb, 1974).

Along the coasts and in the river mouths the characteristic subtropical vertebrate is the manatee, Trichechus trichechus. Its range in the late Pleistocene extended along central Georgia and possibly to Charleston, South Carolina. This species does not survive today in freezing winter temperatures, except where warm springs sustain it, and therefore except for non-winter vagrants, it is confined to central and southern Florida today.

The range of these subtropical vertebrates as far north as Charleston, South Carolina indicates that, in the late Pleistocene, freezing winters did not extend as far south as they do now. Thus the temperate zone was remarkably compressed both by the southward extension of the Boreal zone, and by the northward extension of the sub-tropical zone as is often indicated by shallow marine records in the Caribbean and southwestern Atlantic seas (Hecht, 1973; CLIMAP, 1976; see Figure 4.1.10).

4.1.3 Late Pleistocene Paleontology

4.1.3.1 Limitations of Paleontological Data

Records of late Pleistocene fossil vertebrates in the southeastern United States are very extensive. Indeed, almost every county of the Coastal Plain boasts at least a mastodon tooth or two. Bones and teeth of horses and mammoths are very common as well. Some sites produce hundreds of excellent species that lived here together some ten to fifteen thousand years ago. The Melbourne Bone Bed in Florida produced fossils of more species of large land animals than live in all of North America today (Ray, 1958).

Clearly such a wealth of paleontological data can be used to reconstruct former environments and potential human food resource zones in this region. Presumably such information can help indicate where human cultures might have been most successfully established. However, before such a chain of reasoning can be constructed, it is necessary to consider a number of problems that beset interpretation of the fossil record. Principal among these problems are those of inexact field data, uncertain stratigraphy, uncertain determinations of age, and accumulation of death assemblages rather than life assemblages.

The first and most serious limitation on the usefulness of many fossil vertebrate collections is uncertainty as to their exact source. Most fossils are discovered by accident. In such cases it is easy for the discoverer to overlook the importance of recording precise data before the fossils are collected. It is often difficult to recall or reconstruct the original provenance after the fact. Other specimens are remotely or blindly removed from their original position, for example during dredging, excavating or mining, so that back-tracking to the true source is difficult or impossible. In such cases the stratigraphy, age and faunal or cultural associations cannot be determined with any degree of certainty.

A second problem with many fossil collections is the lack of a precise stratigraphic context. Often adequate local information permits the stratigraphy to be reconstructed, but in more complex sites this is not possible. Fossils that have washed onto a beach or fallen into a stream have no stratigraphic context. In such cases an educated guess may be preferable to total ignorance.

In the Coastal Plain, stratigraphic sections may be complex, involving subtle but repetitive sedimentary sequences. Often, the original collector's view of the stratigraphy was much too coarse. For example, at the Vero Site in Florida, the association of human skulls and other bones with mammoths and other late Pleistocene megafaunal remains were accepted as contemporaneous by many early investigators but have been seriously questioned by more recent investigators. Exact stratigraphy is crucial to resolve such an important debate.

In order to relate any given site to others in the region, an accurate system of age correlations is necessary. This is especially important during the Pleistocene when changes proceeded on a large scale and at a rapid rate. During the Paleoindian period, it is helpful to know the ages of the various fossil occurrences within the nearest thousand years or less. Unfortunately such ages are still a rarity for fossil vertebrate sites.

Two methods of considerably different precision have been used to determine the ages of Pleistocene vertebrates in the southeast. The first is radiocarbon dating. Bone collagen usually provides reliable dates, either to cross-check other organic dates or, in their absence, by itself. Unfortunately no such dates have been obtained from the known occurrences of shelf vertebrates. Recent advances in the technology of dating small samples now assure that such dates can be obtained. The materials should be tested at the earliest possible opportunity to prevent contamination.

The second method, which is much less refined, utilizes biostratigraphic data. The time ranges of vertebrate species empirically determined from other dated occurrences are assumed to have about the same time range in undated sites. Some species that evolved rapidly or had short duration due to the times of their immigration or extinction are especially useful as time indicators.

The most useful biostratigraphic indicators in the present context are the species of _Bison_ and of _Mammuthus_ (wooly mammoth). _Mammuthus primigenius_ did not enter temperate North America until the latest Pleistocene and _Mammuthus floridanus_ does not appear to have evolved until that time, thus both are temporally restricted. Similarly, _Bison bison antiquus_ evolves rapidly into _Bison bison bison_ during the latest Pleistocene and early Holocene, thus making it a very sensitive but continuous indicator of time. Thus mammoths and bisons can provide very useful indications of the time period during which they lived.

Prior to 1951 when radiocarbon dating began to be applied, biostratigraphic schemes for Pleistocene vertebrates could not be effectively checked. They were therefore liable to serious error. A very influential but inaccurate scheme of Pleistocene biostratigraphy was extensively promulgated by Dr. O.P. Hay (1923). His data is still sometimes cited by researchers unaware of its inaccuracy. It is necessary to reconsider virtually all of Hay's Pleistocene correlations in the light of modern biostratigraphic controls, paleomagnetic, potassium/argon dates, and paleomagnetic sequences in the late Pleistocene radiocarbon evidence.

A final set of problems concerns interpretations of the biological and cultural associations that may be found in fossil vertebrate sites. As noted above a great deal depends on detailed stratigraphic control. But even when specimens are precisely collected and their occurrences carefully recorded in the same stratum, the question is not fully resolved. It is still not proven that the species or artifacts were really associated in life or at exactly the same time. There is an important difference between preserving an association in life (biocenosis) and preserving an association in death (thanatocenosis). For example, Suwannee (Clovis-like) points and late Pleistocene mammoth bones occur in the same thin fluvial stratum in Silver Springs Run in Marion County, Florida. This does not constitute, as was first claimed, proof of a hunter and game relationship. Proof of that relationship requires a more thorough analysis of a number of factors, such as texture and fabric of the sediments, their probable rate of deposition and the rate of stream flow. The nature and associations of the mammoth bones and other vertebrate fossils would also be important clues to the ecological context of the fossil site. Such data are required in order to sustain a reasoned judgment as to the communities associated in a fossil site.

4.1.3.2 Late Pleistocene Megafauna as Food Resources

Large vertebrates of the late Pleistocene were presumably the principal food resources of Paleoindians. In cooler glacial climates they were also presumably the principal source of covering and clothing material. The large-game hunting peoples either arrived in North America, or underwent a "population explosion," or both, between 11,000 and 12,000 years ago; for their culture is recognized "on the basis of many sites and thousands of single Clovis points found from the Atlantic Coast to the Pacific, and from central Canada to central Mexico." "It is the...most widespread cultural complex known in the New World, and it represents our first technological revolution" (Haynes, 1970).

The purpose of this section is twofold:

1. to review the most important and most abundant large vertebrate species that occurred on the southeastern Coastal Plain during the late Pleistocene; and
2. to indicate which of these species of megafauna may have been the most useful sources of food and other resources for man on the Continental Shelf.

Since 1932 when Clovis fluted points were discovered in association with mammoth remains, there has been no serious doubt that Paleoindians in North America were primarily large-game hunters

(Wormington, 1957). Nevertheless there has been legitimate debate on the question of the degree to which other resources may have supplemented large mammals. On a Clovis, living "floor" at Murray Springs, Arizona, Haynes and Hemming (1968) found little evidence of other food resources besides large mammal (mainly mammoth) bones, scattered, frequently broken, and occasionally stacked artificially. On the other hand, in the Pacific Northwest, Borden (1979) ascribes a more diversified economy to the people of the "Protowestern Tradition:" "In their food quest, these groups concentrated on large game when available, but they also hunted smaller species. Next to hunting, the gathering of plant foods and small animals, including mollusks, provided major sources of sustenance, whereas fowling and fishing were of negligible significance." In either event, there is still broad agreement on the fundamental place of large game hunting in the economy of North American Paleoindians.

A fundamental assumption here is that the more extensive western records of large game hunting may be translated to the eastern seaboard whenever the magafaunal species is the same and when it is abundantly represented in late Pleistocene paleontological sites. Although evidence from the southeastern Coastal Plain is scanty, here are some data to support the presumption that the large game hunting traditions prevailed there as well. For one thing the lithic traditions were not greatly altered. Had the Paleoindian economy undergone any marked shift, the basic toolkit composition ought to have reflected it. Secondly there are some documented occurrences of butchered or worked large mammal bones. For example a vertebral spine of Mammuthus floridanus from the late Pleistocene of the Sante Fe River in Florida bears two sets of fresh butchering cuts (Bullen et al., 1970). An Equus tibia from the nearby Waccasassa River had the distal end bevelled and the marrow cavity enlarged to form a special tool (Auffenberg, 1965). The figure of a woolly mammoth incised on a whelk shell from the Coastal Plain of Delaware, if authentic, represents broad continuity in both artistic and hunting traditions from Eurasia through western North America to the Middle Atlantic seaboard (Kraft, 1977). Thus, there are several clues to confirm, and no data to deny, that Paleoindians extended their big-game hunting traditions onto the southeastern Coastal Plain and probably onto the shelf.

The following paragraphs characterize the principal large game species available in the southeast and their preferred habitats, and estimates their probable roles as Paleoindian food resources.

Mammuthus The most common megafaunal remains at well documented fluted-point sites represent some species of *Mammuthus* (Haynes, 1970). At least three, and possibly five mammoth species are involved in North America. In Beringia (on both the Siberian and the Alaskan sides) late Pleistocene hunting peoples relied very heavily on the woolly mammoth, *M. primigenius* (Irving and Harington, 1973). On the other hand, the classic Clovis tools of the Llano Complex of Texas and New Mexico (Sellards, 1952) were employed in hunting and butchering *Mammuthus columbi*. The major differences characterizing this latter species were its thinner coat and its larger size (about 3.6 metres to the shoulder compared with 2.8 metres in the wooly mammoth). Presumably these differences were relatively unimportant to hunters as compared to differences in climate, terrain and other environmental conditions.

On the Coastal Plain and shelf of the southeastern United States these same two mammoths were probably primary hunting targets. *Mammuthus primigenius* ranged south through North Carolina and in at least one instance to Charleston, South Carolina, and occurred quite commonly on the shelf from New England into the Carolinas. In South Carolina and Georgia *Mammuthus columbi* becomes the common mammoth in many coastal sites, and it is found in North Carolina along the coast and on the shelf.

A third mammoth species, *M. floridanus*, is recognized in Florida. Characterized mainly by its still larger size, it may well be only a subspecies of *M. columbi*. The Florida Mammoth has been implicated as Paleoindian prey in at least three Florida sites, namely Vero, Silver Springs, and the Sante Fe River (Bullen et al., 1970).

The fourth and largest species of mammoth in the southeast is the Imperial Mammoth, *M. imperator*. It ranges widely through the southeast, generally south of the range of *M. primigenius*, but often sympatric with M. columbi. Skeletons may attain heights of over 4.0 metres. They have been found in association with fluted points in some sites in western North America (Martin and Guilday, 1967).

Mammoths of all species are primarily grazing species. Their high-plated molars are well equipped for chopping coarse siliceous fodder, principally grasses. The Beringian samples of M. primigenius are associated with tundra vegetation and other grazing mammals (Guthrie, 1968), and several frozen specimens have had tundra grasses and shrubs (e.g., Ranunculus) preserved in their stomachs. The more southern species were also primarily grazers, and were presumably found in or near grasslands, prairies, marshlands and savannas.

Mammut The American Mastodon, Mammut americanum, was a heavily built proboscidean with shorter limbs than any of the mammoths. Its shoulder height was 2 to 3 metres. Its molars, consisting of only three or four low transverse crests, functioned primarily in browsing rather than grazing. In glacial margin areas of eastern North America mastodons are very commonly associated with spruce forests and peat bogs, and there is no doubt, from the stomach contents of several, that spruce was their normal diet (Dreimanis 1968). On the other hand, mastodons also occur extensively southward on the Coastal Plain into southern Florida. In regions south of the Carolinas they appear to be associated both with deciduous forests and with non-Boreal coniferous forests. In Florida, mastodons are more common in inland stream and spring sites than in coastal wetlands; presumably this reflects their preference for wooded settings rather than open prairies, marshlands or grasslands.

The importance of mastodons as a Paleoindian food source has been controversial. The abundance of Mammut in forested regions of eastern United States naturally implicates it as a large game species. Williams and Stoltman (1965) hypothesized "that during the Paleoindian era fluted-point makers roved the countryside in pursuit of big game, primarily the mastodon." They further observe "an overall pattern correspondence between the distribution of fluted points and mastodons in the Southeast."

On the other hand, until very recently there has been no direct evidence to indicate butchering or artificial bone breakage. Martin and Guilday (1967) observe that if mastodons were hunted "it must have been mainly ... in upland areas where bones were not preserved." Indeed, in the eastern United States, where spruce and other forests are extensive, that explanation (i.e., poor preservation in uplands) seems plausible. In the semiarid west spruce and other forest habitats appropriate for mastodons are quite limited, thus seemingly explaining why butchered mammoth remains there far exceed butchered mastodon remains.

In the east, American Mastodon is abundant and ubiquitous and ought therefore to have been at least as extensively hunted as were mammoths. That presumption, most extensively advocated by Williams and Stoltman (1965) has recently received some confirmation. In a very early site in the northern Yukon, Irving and Harington (1973) found *Mammut americanum* in the same site and the same stratum with worked mammoth and caribou specimens. And Haynes (1975) found *Mammut* at the Lehner Site, a Clovis site in Arizona with extensive mammoth butchering activity. Most recently, Palmer and Stoltman (1976) reported *Mammut americanum* in an archeological context in southwest Wisconsin. Thus, the view that at least some Paleoindian bands hunted *Mammut* seems highly probable.

Bison Across North America the second (after Mammoth) most common group of large mammals associated with Paleoindian hunting camps and kill sites are *Bison*. For example, *Bison* is well represented at the Clovis Site itself, and is present on the living "floor" at Murray Springs (Haynes, 1970). A number of western sites feature massive slaughter of large buffalo herds in box canyons, buffalo jumps and dune traps (e.g., Frison, 1974).

The Bison in question is usually recognized as the large species, *B. antiquus*. There is, however, continuous diminution in size in American Buffalo throughout the late Pleistocene, Holocene, and Recent; thus the distinction between *B. antiquus* and *B. bison* is somewhat arbitrary. Most recent students of the problem acknowledge that it is arbitrary, but find that the distinction is nonetheless useful. Because of the very rapid change in late Pleistocene and Holocene Bison it still serves as a rather precise chronological indicator.

The wide distribution of Bison in eastern North America is often unappreciated, perhaps because the great herds of buffalo in historic times were confined to the Great Plains. Bison in eastern North America are virtually indistinguishable from those in the west and midwest, and this continuity extends throughout the late Pleistocene and into historic times. The continuous presence of Bison has been well documented in Florida by numerous records reviewed by Robertson (1974), and by several early historic records noted by Roslund (1960). The late Pleistocene sites with B. antiquus include both inland stream sites such as Ichetucknee River and coastal marsh sites such as West Palm Beach with a bone-carbon date of about 21,000 B.P. (Converse, 1975). Thus Bison would be expected to be an important grazing animal in wet prairies, savannah grasslands and coastal marshlands.

To date no direct evidence is known of Bison kills from Paleoindian sites in the southeastern Coastal Plain. This may reflect the relatively small number of sites in the area, or it may reflect the relatively low density of Bison herds in the area, or a combination of both. The presence of Bison at sites such as Vero and the Ichetucknee River where Paleoindian crania and tools are present underlines the possibility that hunting utilization of Bison will eventually be established in the Southeast.

Equus The horse is the third group of large mammals most frequently associated with Paleoindian hunting cultures in western North America (Haynes, 1970). Equus is also a very abundant element in late Pleistocene sites on the Coastal Plain in the southeastern United States. One elaborately worked fossil tibia from the late Pleistocene of the Waccasassa River in Florida gives credence to the view that horses were potentially important Paleoindian game.

There are at least three species of Equus among the late Pleistocene fauna of the Southeast, E. fraternus, E. leidyi and E. complicatus being the most common. As with most of the large game animals (except Mammut and the sloths) Equus is a grazing herd animal. An abundance of the animals indicates grasslands or savanna woodlands.

Hemiauchenia Fossil camels occur at many sites in the southeastern United States. Although some specimens have been referred to the large genus Camelops, these have been found in error, and where determinate, belong to the genus Hemiauchenia (formerly Tanupolama). Such animals are primarily open country grazers, and may occur in moderately large bands. Thus, at some Florida sites these large fossil llamas are quite abundant.

In the western states camelids were definitely hunted and butchered by Clovis type Paleoindians. At Gypsum Cave in Arizona, charred and broken Hemiauchenia remains were found 2 metres from fluted points. Likewise Frison et al. (1978) have described parts of a young Camelops in a typical Bison kill site. With this background in mind, late Pleistocene Hemiauchenia in the southeastern Coastal Plain must be considered a potential food source for Paleoindians.

Rangifer The caribou extends southward into North Carolina where it occurs on the shelf with Mammuthus primigenius. Typically Rangifer tarandus form large migratory herds which feed mainly on tundra lichen and generally graze in open country.

In the late Pleistocene of Europe, reindeer (Rangifer) were important sources of food and raw materials, and they appear in bone and antler carvings and in cave art. In the New World such associations are limited; Irving and Harington (1973) report butchered Rangifer material in a very old site in the northern Yukon along with worked woolly mammoth bones. There is no documentation to date of caribou hunting in eastern North America. Nonetheless in tundra environments on the shelf, that might be expected.

Odocoileus Odocoileus virginianus, the white-tailed deer, is widely represented in late Pleistocene sites in the Southeast. On the other hand, deer seldom attain very great abundance in these late Pleistocene sites. At present, and presumably in the past, Odocoileus were primarily forest browsers, also venturing into open meadows and marshes on forest edges. It would not be surprising if Odocoileus had been hunted by Paleoindians, but there is no present evidence. As will be noted below, white-tailed deer became very important to post-Pleistocene Indians in the southeast after most of the other megafauna had become extinct.

Eremotherium This species, the greatest of all ground sloths, ranged into the southeastern coastal lowlands from the American tropics. It is common in the late Pleistocene from the Florida and Georgia coasts, as well as the Georgia shelf. (The northernmost record from New Jersey is probably an interglacial age.)

The extinction of Eremotherium and other ground sloths is usually attributed to hunting by early American Indians (Martin, 1967). It is indeed easy to suppose that elephant-hunters would switch to this slower but equally magnificent game.

Odobenus Jaws and teeth of Odobenus rosmarus (walrus) occur rather commonly in coastal sites and on the Continental Shelf as far south as central North Carolina. Records of fossil walruses from even farther south (e.g., Ashley River, South Carolina, recorded by Hay, 1923) cannot be accepted because their taxonomic identity is uncertain and their age may be Tertiary (C. E. Ray, personal communication, 1979).

Clearly these large gregarious animals would provide a valuable source of food, hide, and ivory to Paleoindians in north coastal parts of the Southeast. In Beringia Odobenus rosmarus played an important role as a late Pleistocene prey species, and still does so for Eskimos and Aleuts (Laughlin, 1967). As yet, there is no evidence of such coastal hunting in the middle Atlantic states.

Geochelone The giant tortoise, Geochelone crassiscutata, is the only non-mammalian large vertebrate that was probably utilized by Paleoindians in the Southeast. These great lumbering creatures, weighing 500 kilograms were grazing animals that ranged widely through grass and scrublands. By the late Pleistocene their range had retreated in the face of cooler climates to lowland Georgia and Florida (Clausen et al., 1979; Auffenberg and Milstead, 1965).

It has long been evident that these great tortoises would have been easy and valuable prey to Paleoindians. The early hunters have often been indicted as the cause of the extinction of Geochelone throughout the New World except in the Galapagos Islands. Recently the first direct evidence of such hunting has been discovered at Warm Mineral Springs in Florida, where a large Geochelone has been discovered in an archeological context with a stake driven into the shell. Thus, the giant tortoise may be included with the several kinds of large mammals as megafauna utilized by Paleoindians in the Coastal Plain of the Southeast.

4.1.3.3 Key Paleontological Sites

A few of the most important megafaunal sites are reviewed in the following paragraphs. Many other sites are represented on Plate 1 (Volume V) and form the basis of the broader discussions of environments and food resources above. Special attention has been directed to those rare occurrences of megafaunal elements on the present Continental Shelf, as they provide the most direct evidence of human food resources and its subsequent preservation in the coastal area of the present study. Secondly, major coastal megafaunal sites in close proximity to high sensitivity areas, and therefore with a strong possibility of utilization by Paleoindian cultures, are considered in some detail.

The sources of data regarding these megafaunal sites are diverse. About half of them have been published in the literature. Many of the older published sources, notably Hay (1923), had to be critically reviewed with respect to age and taxonomic groups. Unpublished sources account for nearly as many megafaunal sites. For the most part these unpublished site records are represented by collections in permanent public institutions, primarily museums, but also university departments and research institutions. A few important sites documented only on the basis of private collections are mentioned, but it should be noted that the enduring character of such collections is never certain.

4.1.3.4 Megafaunal Occurrences on the Shelf

The few dozen records of large Pleistocene land animals from the western Atlantic Continental Shelf are especially important because they provide direct clues to conditions on the shelf when it was exposed (Figure 4.1.11). First, they reinforce evidence from other sources that the shelf was extensively exposed as dry land (transport of these specimens into deep marine waters is shown below to be most unlikely). Secondly they provide direct evidence of the terrestrial environments that existed on the shelf during the late Pleistocene. Finally they affirm the habitability and preservability of some of the late Pleistocene inhabitants of that region.

It is probable that these large land animals lived on the Continental Shelf near where they have been recovered. This is particularly evident when remains of several individuals of more than one species are found in one deposit. A posterior mammoth molar is dense and weighs between 4 and 20 kilograms, decreasing the possibility of transportation by water. Further, none of these specimens shows any sign of water abrasion. The fresh preservation of many of the tooth roots suggests that they recently were broken out of their respective jaws or skulls. Presumably the more fragile jaws and the limb bones are broken, scattered, or discarded. Short-distance stream transport of a carcass is a possibility. Even so, it is highly probable that provenances of recovered specimens closely reflect the true home ranges of the large mammals to which they belong.

The fact that large land mammals lived on parts of the Continental Shelf implies the possibility that Paleoindians could also have occupied the same general areas. This implication is particularly

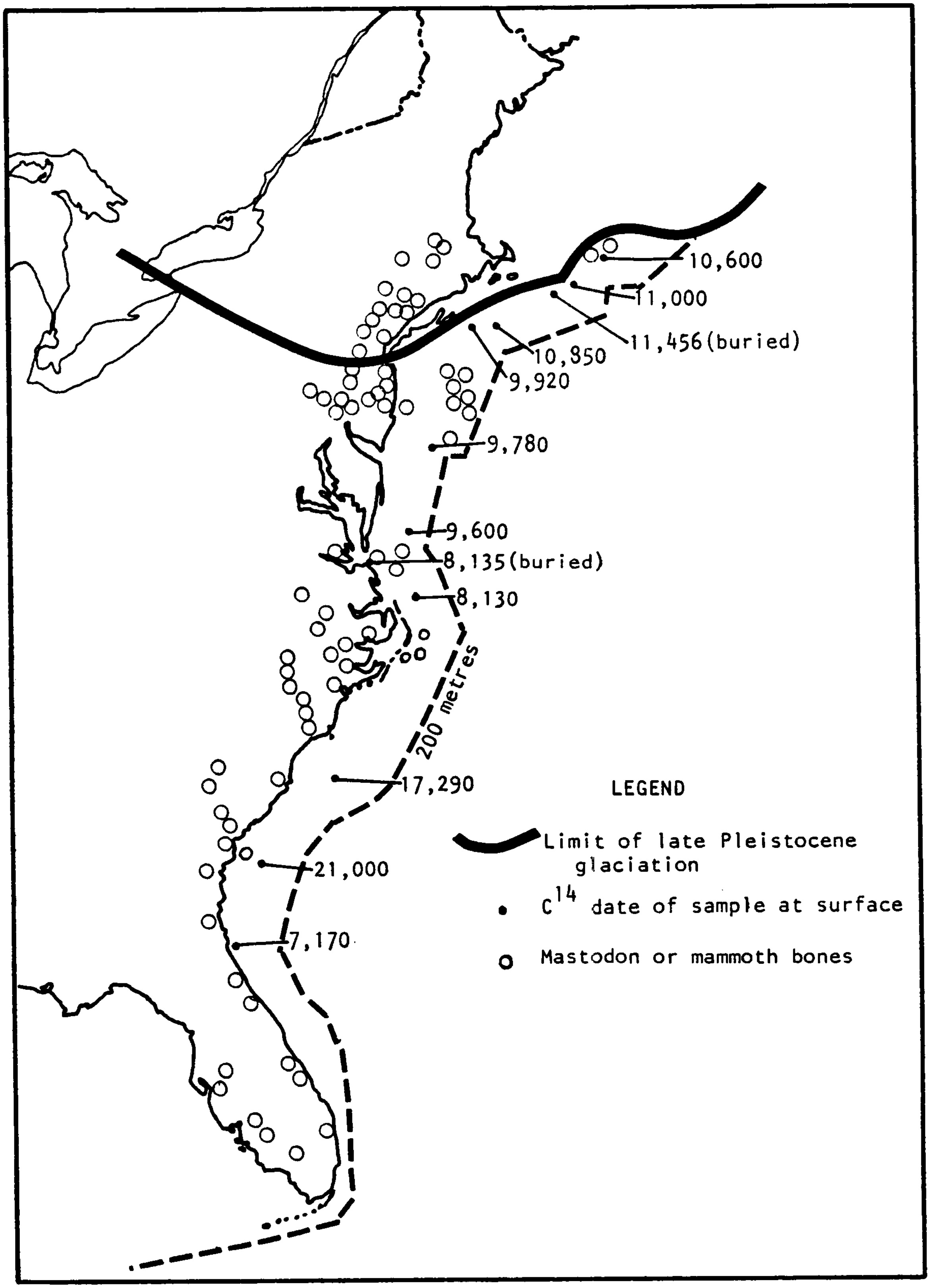


Figure 4.1.11 Atlantic Coast Megafaunal Sites

by C-14 dates (Figure 4.1.11). The history of these terrestrial and freshwater fossils shouls not be confused with marine fossil remains also encountered on the same parts of the Continental Shelf (Figure 4.1.12).

The fact that large land mammals lived on parts of the Continental Shelf implies the possibility that Paleoindians could also have occupied the same general areas. This implication is particularly cogent in the case of shelf occurrences of woolly mammoths and reindeer, for, as discussed before, these were prime game species of early hunters in northern North America and Asia. This view is reinforced by the probability that these fossil mammals were wholly contemporary with Paleoindians in eastern North America. The chronology of sea level changes discussed above (Section 4.1.1.5), largely limits the period when land animals and early man inhabited the shelf to the interval between 18,000 years B.P. and 5,000 years B.P. Further support for this timeframe comes from the animal species themselves; for they are full Boreal types which would be unlikely to reach latitudes south of Canada except during a full-glacial interval. Thus, megafaunal species and Paleoindians probably occured together on the shelf. To date no bone-carbon dates have been obtained from the fossil vertebrates dredged from the shelf. This is an unfortunate oversight, which urgently needs to be corrected. Such carbon dates are needed to confirm the predicted late Pleistocene age of the shelf vertebrates.

Eight large land-mammal specimens have been traced to the Continental Shelf south of Cape Hatteras (Table 4.1.7). Four came from a single clam-dredge "site" southeast of Currituck Beach in North Carolina. Another came from off the mouth of Albemarle Sound, also in North Carolina. The remaining three specimens recorded to date were dredged 1 1/2 miles off the Brunswick Bar in Georgia.

Table 4.1.7 Large Mammals on the Shelf South of Cape Hatteras

Site 1	Shelf vertebrates off Currituck Beach, 13 miles ESE of Loran A Station 1750, North Carolina. In clam-dredge <u>Mammuthus primigenius</u> (three molars) and <u>Rangifer tarandus</u> (one antler).

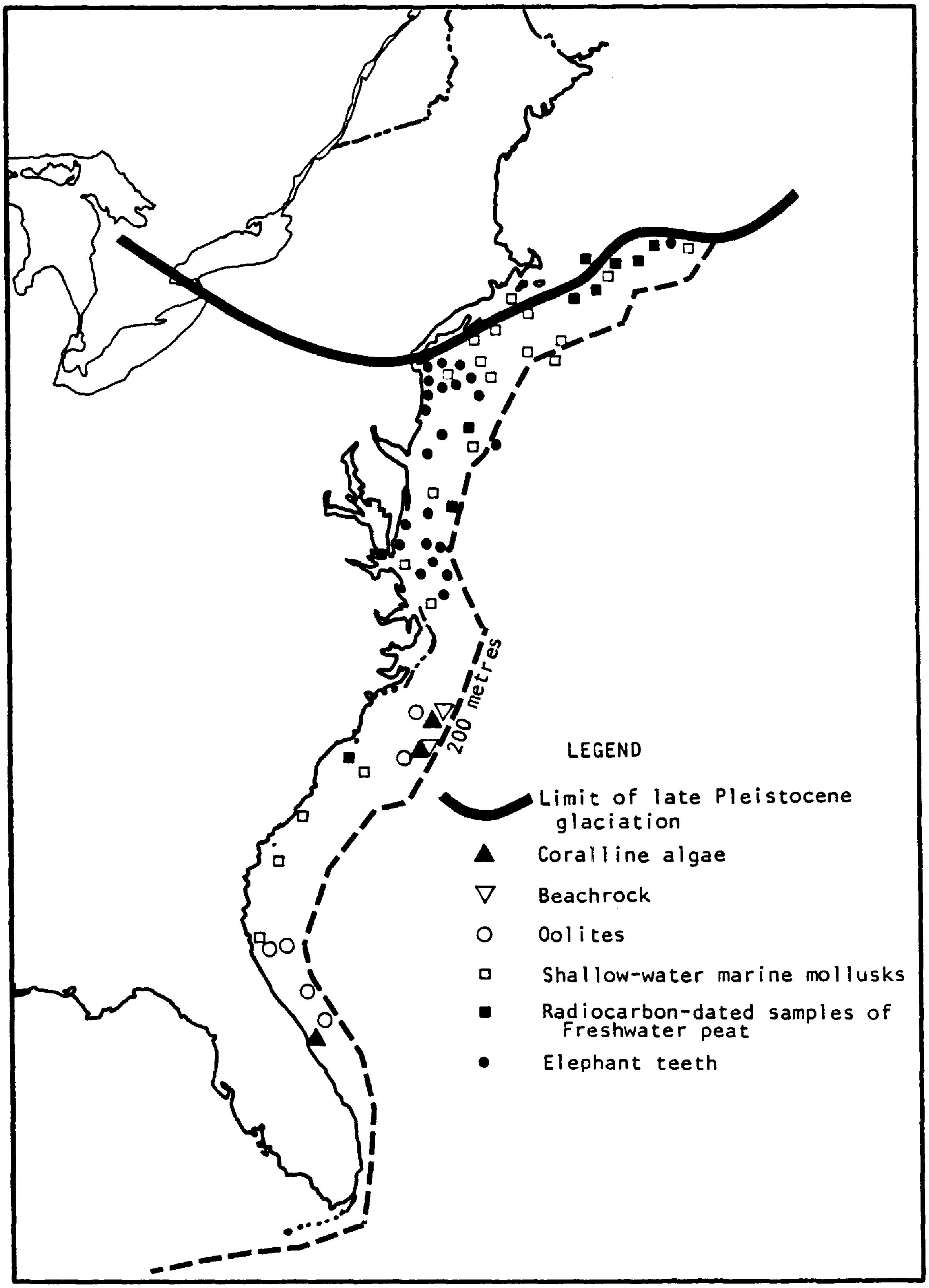


Figure 4.1.12 Distribution of Algae, Beachrock, Oolites, Mollusks, Freshwater Peat, and Elephant Teeth

Site 2 Off mouth of Albemarle Sound, about 10 miles southeast of North Carolina. In clam-dredge. Mammuthus, species indefinite (one molar).

Site 3 Exact location unknown about 3 miles southeast off Ocracoke inlet, North Carolina near 35°N latitude, 76° W longitude (Whitmore et al., 1967).

Site 4 One and one-half miles off Brunswick, from 32 feet depth. In channel dredging hopper. Cuvieronius obscurus (one molar) and Eremotherium mirabile (two tooth plates).

This sparse and curiously spotty record of shelf occurrences of large land animals requires explanation. North of this study area the occurrences of "probosidian teeth" are much more common (Whitmore et al., 1967), as remarked by Edwards and Merrill (1977). The reason for this difference is related to the present distribution of commercial clam-dredging grounds. The southernmost areas reached are one day's cruise from Chesapeake Bay and harbors to the north. Thus northern North Carolina is the southern limit of frequent records. South of that point commercial clam-dredging is not practicable. The exceptional Georgia records of fossil land animals occurred in relatively deep channel-dredging off of a barrier island area. If a search were made, the remains of many more large fossil vertebrates might be expected on the shelf.

Because of their direct implications for shelf environments and their possible role as Paleoindian food resources, the few shelf occurrences of land vertebrates are discussed here in more detail. Each of these specimens is preserved in the U.S. National Museum, Department of Fossil Vertebrates. Other occurrences, once known in private collections, cannot now be located, and are therefore omitted.

The richest single dredge site is that 13 miles ESE of Loran A Station 1750 off Currituck Beach, North Carolina. There, three molars of Mammuthus primigenius (the woolly mammoth) and an antler of Rangifer tarandus (the caribou) were collected from one clam-dredge locality.

The teeth do not appear to represent a single individual. This relatively large sample of fossils suggests a fossil deposit of some kind, presumably a local basin of freshwater sedimentation. No indication of sediment types encountered there is available from the clam-dredgers who recovered the fossils (Eshelmann, personal communication). The range of both species is confined to tundra or open Boreal woodland conditions, indicating therefore, the presence at one time of these environments on the shelf off of northern North Carolina.

The isolated occurrence of one mammoth tooth off of Albemarle Sound has less clear environmental implications. The single tooth does not represent *Mammuthus primigenius*, the woolly mammoth, but is more nearly comparable to *M. columbi*, the Columbian Mammoth. This species is elsewhere associated with transitional conditions to mixed deciduous woodlands rather than a fully Boreal regime.

The shelf specimens from off southern Georgia represent a very different setting. They include a third lower molar of *Cuvieronius obscurus* (a sub-tropical or Gulf Coastal *gomphothere*), and two cheek tooth plates of *Eremotherium mirabile* (a giant ground sloth). These specimens belong to a characteristic subtropical savanna fauna commonly found in Florida and around the Gulf of Mexico in lowland areas. They indicate a warm and equable climate with a relatively diverse deciduous woodland interspersed with grassy meadows. This may be the most direct piece of evidence supporting the statement of Edwards and Merrill (1977) that during the late Pleistocene the region from Florida to the Carolinas "approached optimal conditions for the earliest Americans." Evidently the climate on the southern Coastal Plain was relatively warm and moist and supported a sub-tropical savanna.

A few dozen additional land mammal specimens have been taken from the Continental Shelf north of Cape Hatteras. Because they further clarify the significance of shelf specimens, they are included in the following analysis.

Figure 4.1.13 summarizes the water depths of all adequately located mammoth and mastodon fossils from the Atlantic Continental Shelf. These data include unpublished records as well as the published studies of Whitmore et al. (1967) and Edwards and Merrill (1977). Among these records is a smaller, wide ranging sloth, of the genus Megalonyx, not of the larger subtropical genus Eremotherium. A higher frequency of shelf fossil recovery is evident in the bathymetric ranges 20 to 29, 40 to 49, and 80 to 89 metres. The concentration of teeth in the 40 to 49 metre interval has a probability of less than 0.05 of being a random distribution. There are several explanations advanced for this evident pattern. These depths may be the most frequently dredged by commercial clam-fishermen, but this has been denied. Another possible explanation is that these depths occupy much larger shelf areas on the fisheries grounds, but this does not seem to be true. And finally it is possible that the former coastlines at these depths were particularly favorable for the existence of land vertebrates or that they were occupied for longer periods of time.

Since the apparent clustering of megafaunal records at certain depths on the Continental Shelf may provide the best available clues as to probable places of Paleoindian associations if indeed they exist on the shelf. It is of great significance if such clusterings represent real prehistoric environmental signals. Late Pleistocene megafaunal sites exposed today along the Coastal Plain are most frequently and most abundantly sampled in peaty and/or lagoonal sediments developed inland from Barrier Islands near the littoral zone. It seems possible therefore that Proboscidian teeth on the shelf may have concentrated in similar environments. As noted above they are generally well preserved since they were apparently not transported. Thus the most likely conclusion is that Proboscidians were fossilized in particular abundance in the 40-49 metre interval on the Continental Shelf when this was near the littoral zone. According to the sea-level curve proposed in this report (Figure 4.1.6) the seaway near this interval for several thousand years at about 20,000 years and again at about 14,000 years B.P. was quite stable. This long stillstand of the sea indicated by the proposed

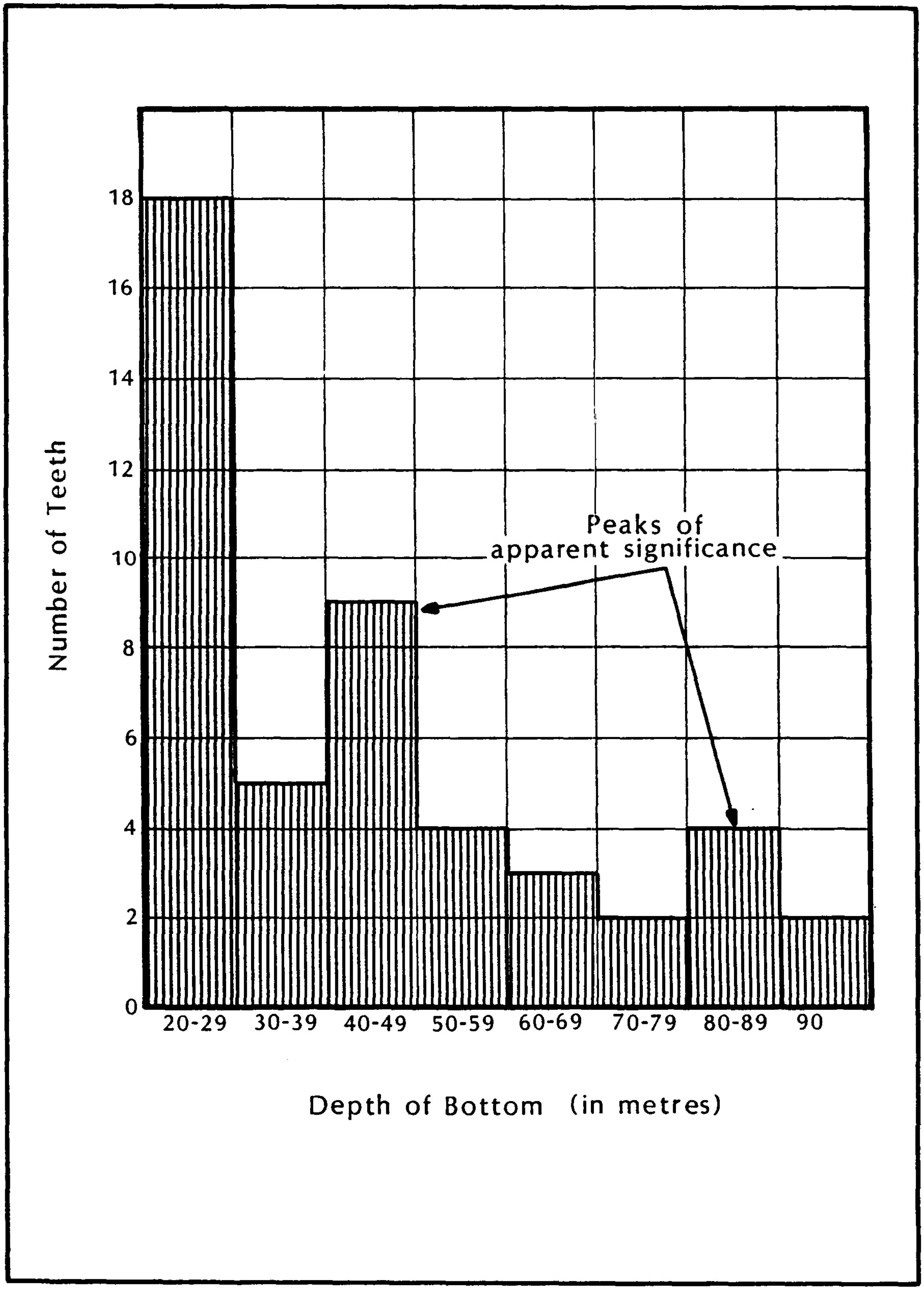


Figure 4.1.13 Depths of Terrestrial Fossil Vertebrate Teeth on the Atlantic Shelf

sea-level curve and the concentrations of Proboscidian teeth in the near littoral zone strongly support one another.

4.1.3.5 Megafaunal Occurrences on the Coastal Plain

The few fortuitous records of late Pleistocene fossil vertebrates from the Continental Shelf sample only one or two specimens each and therefore provide a limited view of the shelf environment. To provide a fuller view, the next step is to carefully examine the best-known sites producing a rich sample of late Pleistocene megafauna from along the present coast. Presumably they had broad continuity with and differed unimportantly from the fauna then extant on the exposed shelf.

The two most important areas, according to current information, are the Charleston area in South Carolina and the Vero-Melbourne area in Florida. Although these two site complexes by no means exhaust the subject, they provide the best gauge of a complex and in many instances poorly documented subject. For example, a third very important area is between Brunswick and the Sea Islands of Georgia, but no field paleontologist has yet succeeded in collecting more than an isolated tooth or two in place within that area. Most information comes from channel dredging, and therefore lacks adequate stratigraphic control or carbon-datable samples. As will be seen, the Charleston and Vero areas have much in common and thus may be taken as broadly representative samples of coastal and shelf megafauna.

These coastal megafaunal sites share three features important to the purposes of this study:

1) each site produces a large sample of late Pleistocene vertebrates from one or more precise localities;

2) each site occurs just above or just below present sea level; and

3) each site accumulated freshwater clastic sediments when the sea must have stood well below the present level.

Thus each of these sites appears to have sampled the late Pleistocene megafauna when its environment was continuous with that on the exposed shelf.

Charleston Area Sites Study of these sites began late in the 19th century when phosphate mining began along the Ashley River and others in the area such as the Stono, Edisto, Cooper and Coosaw Rivers. The fossils that appeared extensively seemed to be associated with the phosphate beds as well as with sediments nearer the surface. With minor exceptions, the fauna was badly mixed without enough careful collecting to provide a stratigraphic control.

Nevertheless the fauna was of intense interest to many, and was carefully analyzed by F.S. Holmes and Joseph Leidy in their 1860 study of "Post-Pliocene Fossils of South Carolina" and again by Leidy (1877). A controversial aspect of these early studies, taken up especially by Professor Agassiz at Harvard, was whether Suidae (pigs) and Hominidae were associated in the Charleston area with the extinct megafauna. This question was never resolved.

Until recently nothing of major significance was added to the early studies. In 1965 Dr. Clayton Ray of the U.S. National Museum (1965) recorded a partial cranuim of *Glypototherium* from just below sea level at Edisto Island, which constituted the northernmost record of these extinct armadillo-like creatures. And still more recently three teams have begun carefully to excavate key localities in the Charleston area: Janet Roth and Joshua Laerm (University of Georgia, Natural History Museum) at Edisto Island (Roth and Laerm, 1980); Albert E. Sanders (Charleston Museum) at Charleston; and Robert Weems (U.S. Geological Survey, Reston, Va.) in several sites. Together these current studies promise a much fuller view of the complex vertebrate history in the area.

Summarizing preliminary reports from these study teams (Robert E. Weems, Joshua Laerm, and Albert Sanders, personal communication), at least three vertebrate-bearing horizons have been documented in the area (Table 4.1.8). Mixing of faunal elements from these different levels has led to past confusion. Only the uppermost of these units is of interest here, for it is the one that produces Wisconsinan terrestrial megafauna from at or below present sea level. Presumably this is the same unit from which Holmes and Leidy (1860) obtained fossil vertebrates in "blue mud only a few feet above tide level...about ten miles above Charleston."

The most complete faunal sample from a single late Pleistocene site is that from just below tide level (and washing up on the beach) on Edisto Island about 21 miles SW. of Charleston. They occur in fine clastic sediments of the Silver Bluff Formation as recognized by Colquohoun (1969). The extinct species from the very extensive vertebrate fauna are listed in Table 4.1.9 (Janet Roth, M.S. Thesis, 1979, University of Georgia; Roth and Laerm, 1980). No carbon samples have been dated yet, but the fauna, in particular _Bison antiquus_ and _Mammuthus columbi_, indicate that a Wisconsinan age is probable.

Sites now being studied by Dr. Robert E. Weems of the U.S. Geological Survey include some late Pleistocene samples. They generally lie near present sea level, but they are lithologically difficult to distinguish from older (Sangamonian) sediments of the upper Ladson Formation, which range up to elevations of 22 feet, are more generally marine (although they, too, produce _Eremotherium_) and have an age of about 80,000 years based on a uranium date from coral.

The ecological implications of the Edisto Island and presumably other late Pleistocene vertebrate samples from the Charleston area are of special interest here, because similar conditions may have extended eastward onto the exposed shelf. The predominant vertebrate fossils are large grazers, most of which were herd ungulates. These include horses, camels, mammoths and bison. Giant tortoises, glyptodonts and most of the ground sloths also fall in this broad category. Browsing vertebrates were also present, notably mastodons, tapirs and peccaries. Large freshwater mammals, notably giant beavers, giant capybaras and abundant muskrats, not to mention fishes, turtles and alligators,

Table 4.1.8 Charleston Area Stratigraphy (modified from Robert Weems, personal communication, 1979)

Age (magnetic epoch)	Formation	Relative Position of Sea Level	Lithology	Vertebrate Fossils	Environment
Wisconsinan and Sangamonian (normal)	Silver Bluff Formation	Below present level	Sands and clays; often grade into soils	Major megafauna (see Edisto Island faunal list)	Cool, dry, mixed temperate woodland and coastal savanna 5% spruce pollen
Sangamonian (?) (Normal)	Ladson Formation	From nearly 30m above to about present level	Phosphatic sands and gravels at base; sands and clays above	*Eremotherium*, *Bison*, *Equus* and marine vertebrates	Comparable to present (inter-glacial)
Late Pliocene (Reversed)	"Waccamaw Formation"	At least 3m above present level	Thin beds of shelly sand and shell marl	*Hipparion*, *Gavialo-suchus*, marine invertebrates	warm, humid

Table 4.1.9 Extinct Species from Edisto Beach, South Carolina (Roth and Laerm, 1980)

Extinct Land Tortoise	Geochelone crassiscutatta
Giant Armadillo	Dasypus bellus
Glyptodont	Glyptotherium floridanus
Jefferson's Ground Sloth	Megalonyx jeffersoni
Giant Ground Sloth	Eremotherium mirabile
Harlan's Ground Sloth	Glossotherium harlani
Giant Beaver	Castoroides ohioensis
Giant Capybara	Neochoerus pinckneyi
Extinct Wolf	Canis dirus
Extinct Jaguar	Panthera onca augusta
Extinct Spectacled Bear	Tremarctos floridana
Mastodon	Mammut americanum
Mammoth	Mammuthus columbi
Extinct Tapir	Tapirus haysii
Extinct Horse	Equus fraternus
Extinct Peccary	Mylohyus fossilis
Extinct Camel	Palaeolama mirifica
Extinct Bison	Bison antiquus

indicate the proximity of a major river system. The aquatic and terrestrial vertebrate fauna suggests a mosaic of deciduous woodland and grassland savanna, crossed by major meandering streams. Such a productive ecosystem presumably extended eastward following a gentle gradient.

Vero Area Sites The Atlantic coast of Florida produces a number of very rich late Pleistocene vertebrate sites. They include a string of remarkably similar sites from at least as far north as Ormond Beach to at least as far south as Palm Beach. The best known of these is the Vero Site, widely heralded for the discovery there of Vero Man by Sellards (1916). Sellards' report was the first claim of an association between the remains of man and extinct animals in the New World. The report stirred considerable controversy, and several aspects of that controversy have not yet been wholly resolved.

As with many of the Florida Atlantic sites, the Vero deposits accumulated geographically between the Silver Bluff terrace sands on the seaward side and the Pamlico terrace sands on the inland side. The classic Vero site (Vero 1), where Vero Man was found, was exposed by east-west canal diggings that intersected a large lenticular body of fossiliferous stream deposits. Two major problems beset the first studies at Vero:

1) Many of the best specimens came from spoil banks produced artificially by digging and dredging operations;
2) Nature had also produced stratigraphic mixing; Van Valkenburg Creek had cut and redeposited some of the fossiliferous deposits at the original site. Vero Man, although collected in place, may or may not have come from the reworked part of the Vero 1 section.

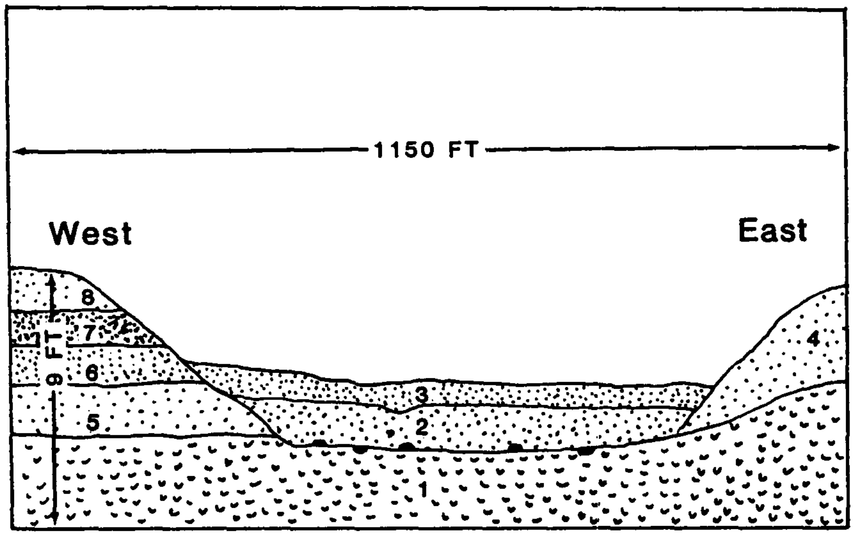
Because of these stratigraphic problems, many students have wholly written off any and all possible associations inferred from work in the Vero area.

Despite these problems (or perhaps because of them), a number of capable workers have described and confirmed a coherent stratigraphy in other sections at Vero. They have also supported their conclusions with some appropriate carbon dates from their sections. The early studies were by Sellards himself (1917) and by Chamberlain (1917), and subsequent detailed studies were made by Rouse (1951) and by Weigel (1962). Figure 4.1.14 is a diagrammatic section modified from Weigel's detailed studies. The old stream system (away from the canal and Van Valkenburg Creek) consists of two easily distinguishable units, separated by an erosional unconformity. These were designated by Sellards (1916) and all subsequent workers as Bed 2 (below) and Bed 3 (above). Bed 2 lies on the Anastasia Formation (Sellards' Bed 1), which is a widely distributed shell marl ("coquina") of Sangamonian (last interglacial) age or possibly of mid-Wisconsinan (interstadial) age. Bed 2 consists of light and dark, medium to coarse, cross-bedded sands with heavy mineral banding. Bed 3 is composed of loose white sands and mucky clay containing decayed plant remains.

Bed 3 contains abundant human skeletal material. It also produces pottery (St. Johns plain and St. Johns check-stamped), bone implements (mainly of white-tailed deer), and fragments of chert projectile points. All of the vertebrate remains from this unit pertain to extant forms (contrary to Hay, 1917). The rich organic remains belong to hydrophytic plants, indicating a marshy setting. In most places Bed 3 grades insensibly into present soil profiles.

The most important unit in the Vero area is Bed 2. The stream deposits of this unit range from less than half a metre up to about one metre in thickness. At several sites the sands are highly fossiliferous. Weigel's quarry 3A produced the extinct species listed in Table 4.1.10 along with a much larger number of extant species. The vertebrate fauna is characteristic of the very late Pleistocene.

In conjunction with Weigel's study, the Florida Geological Survey submitted four carbonaceous samples from various levels in Bed 2 to the Geochemical Lab of Humble Oil Co. for radiocarbon dating. Three



Bed 1 of Sellards is marine Anastasia Formation of probable Sangamonian age. Bed 2 of Sellards is principle fossiliferous unit, of cross-bedded sands, with dates between just over 8,000 B.P. and 3,550 B.P. Bed 3 consists of loose sands and organic muck. To the west is the Pamlico dune section; to the east is the Silver Bluff dune section. (After Weigel, 1962).

Figure 4.1.14 East-West Stratigraphic Section at Vero Area

Table 4.1.10 Extinct Species from Vero, Site 3A in Florida (after Weigel, 1962)

Extinct land tortoise	*Geochelone sellardsi*
Extinct stork	*Ciconia maltha*
Passenger pigeon	*Ectopistes megratorius*
Harlan's ground sloth	*Glossotherium harlani*
Jefferson's ground sloth	*Megalonyx jeffersonii*
Extinct armadillo	*Dasypus bellus*
Extinct armadillo	*Holmesina septentrionalis*
Extinct bog lemming	*Synaptomys australis*
Extinct capybara	*Hydrochoerus aesopi*
Extinct wolf	*Canis ayersi*
Extinct fox	*Vulpes palmaria*
Extinct jaguar	*Panthera onca augusta*
Saber-tooth cat	*Smilodon* sp.
Mastodon	*Mammut americanum*
Mammoth	*Mammuthus columbi*
Extinct peccary	*Mylohyus fossilis*
Extinct tapir	*Tapirus veroensis*
Extinct horse	*Equus fraternus*
Extinct camel	*Palaeolama mirifica*
Extinct bison	*Bison antiquus**

*See Robertson (1974)

uncharred samples from the base of Bed 2 gave one date of 8,200 ± 960 radiocarbon years B.P., another date of 2,500 ± 110, and one date beyond the range of then-available techniques. An uncharred piece of wood from the upper part of Bed 2 yielded a date of 3,550 ± 120 radio-carbon years B.P. Weigel (1962) interpreted these data rather literally, concluding that Bed 2 was continuously deposited from more than 30,000 years until 3,550 B.P. It seems more probable that the one maximum date had absorbed carbonate from the underlying marl and that the age of just over 8,000 radio-carbon years was an appropriate lower limit. The known ranges of extinct megafauna suggest strongly that this date would then be a little younger than it ought to be, but still not more than one or two thousand years off. Weigel's detailed collecting (by 6-inch intervals) shows an upward diminution of the percentage of extinct species within Bed 2, thus tending to confirm its deposition at about the end of the Pleistocene.

The question of human association with the extinct megafauna in Bed 2 remains controversial. In his detailed excavations in apparently undisturbed stream deposits, Weigel (1962) claims to have found "several flint spawls" in association with extinct species in the upper part of Bed 2. The skull of Vero Man, originally collected in place by Sellards was interpreted by T.D. Stewart of the U.S. National Museum as a Paleoindian skull. Sellards had also collected several human limb bones and a thin sharp-edged chert fragment with extinct vertebrates at Vero site 1. The early Holocene dates of Bed 2 suggest, at the very least, that the deposition occurred during the time of overlap between extinct animals and man in North America.

Some additional evidence bearing on this matter come from the Melbourne Bone Bed, north of Vero but remarkably similar in most features. From the Golf Course Locality on the west side of Melbourne a rich late Pleistocene vertebrate fauna has been described (Gazin, 1950; Ray, 1958). Four notable features of the fauna and its occurrence bear on the possible influence there of Paleoindian culture:

1) The late Pleistocene mammalian fauna includes a maxillary bone identified as <u>Canis familiaris</u>, and that bone appears to have been cut while still "green" (Ray, 1958);

2) chert fragments occur in the same stratigraphic unit;

3) human limb bones occur in the same unit; and

4) Heizer and Cook (1952) found closely similar fluorine levels (therefore presumably similar antiquity) for human bones and _Equus_ and _Mammuthus_ bones from the same depositional unit.

Thus, there is evidence of a late Pleistocene and possibly early Holocene association of megafauna and man in the Vero area of Florida.

An ecological interpretation of the Vero sites has much relevance to the search for comparable late Pleistocene faunas (with possible human associations) on the then-exposed shelf. The site of Bed 2 deposition represents a freshwater stream, possibly influenced by spring tides. The coarse sands were shed mainly from coastal dunes seaward of the freshwater deposits; but finer sediments may have also come from poorly drained pine flatwoods and marshes on the landward side. The seaward sources probably supported spruce pine, scrub oak and other scrubby herbaceous plants as do beach ridges in the area today. The extensive samples of grazing ungulates and sloths indicate more grassland than now appears in coastal Florida. Freshwater taxa are well-represented, though not as abundantly as at Edisto beach near Charleston. Overall, the Florida setting was somewhat warmer and drier than the South Caroling setting, but the major features of the predominant megafauna were comparable. Both settings provided abundant large game herds and freshwater fishing.

4.1.4 Holocene Climatology

4.1.4.1 Postglacial Evolution of Climatic Zones

The large extent of the North American Laurentide ice mass, centered in mid-continent far from either Atlantic or Pacific, meant that recession of the ice occurred somewhat later than the melting of the marine-influenced European glaciers. The Pleistocene/Holocene time boundary in North America was thus displaced to a later time from the world-wide average.

The replacement of a spruce-dominant speciation by a pine-dominant one marked the beginning of the Holocene in the Southeast at about 9,500 B.P. (Leopold, 1967). Previous to this, however, migration of biome boundaries had occurred as the glacial icemass receded northward and westward.

Hare (1976) notes the boundaries between full-glacial biomes based on July mean daily temperatures. The area under study falls primarily within two communities, the Boreal forest which prevailed from Cape Hatteras south to approximately Onslow Bay, and south of that, decidous communities. Hence, the southern boundary of the Boreal forest at full-glacial times fell approximately half way down the East Coast from the northern to southern boundary of the study.

Moran (1972) based further evidence of boreal boundaries on radioisotope dating and found that the coastal end of the demarcation line progressed northward with time. At 16,000 B.P. it was in northern Georgia, at 15,000 B.P. in southern South Carolina, at 14,000 B.P. in northern South Carolina, and by 13,000 B.P. the boreal forest boundary had reached Cape Hatteras. Moran also notes that surface temperatures computed from inferred circulations off the Wisconsin Glacial sheet were in fact warmer than what was expected due to adiabatic heating as winds moved down the glaciers. At a latitude of 40° north during January, mean temperatures in the midwestern and eastern United States are computed to have been some $2^{\circ}C$ warmer than today because of the heating of the downslope winds. In fact the gradient of temperature was much sharper in July near the glaciers because of the very large cold mass and stationary cold air fixed over the glacier at the time.

In the transition from the full-glacial late Pleistocene into the postglacial Holocene, rapid northward migration of the latitudinal belts of vegetation began. At the same time, different species spread (and crossed former community groupings) at different rates under different local circumstances. Most of the details of this complex and rapid migration and forest community reorganization are poorly understood.

At Buckle's Bog in Maryland (Maxwell and Davis, 1972) open spruce woodland appeared at about 12,700 B.P., giving way to a mixed pine and deciduous forest by about 10,500 B.P. In the Shenandoah Valley, spruce forests were replaced by Quercus (oak), Tsuga (hemlock) and other hardwoods during the early Holocene (Craig 1970). In northeastern North Carolina at Rockyhock Bay the full-glacial boreal forest was succeeded at about 11,000 B.P. by northern hardwoods including Betula (birch), Fagus (beech), Acer (maple) and Tsuga (hemlock). And then, by 10,000 B.P. it was replaced by a more typical deciduous forest dominated by Quercus (oak) and Carya (hickory). At the same time the swamps accumulated more peaty sediments more rapidly than during glacial conditions.

On the continental slope off Cape Hatteras cores V24-1 and V26-176 provide pollen diagrams spanning the Pleistocene-Holocene (Balsam and Heusser, 1976). In both cores glacial pollen assemblages dominated by pine and also characterized spruce and fur, are supplanted by a pine-oak assemblage which includes substantial frequencies of birch and hemlock. This temporate floral assemblage supplants the late Pleistocene Boreal assemblage at about 10,000 years B.P. and persists with little change until 3500 years B.P. Presumably these early Holocene pollen assemblages were transported by water from adjacent coastal lowlands including the then exposed upper shelf.

Watts' (1969, 1971, 1980) studies of early Holocene pollen-bearing sediments in southern Georgia and north-central Florida produce evidence of predominantly scrub oak and sand pine. This tends to support his older record from Lake Annie in its implication of great aridity for Florida during the glacial. By 8,000 B.P., these pollen samples began to include more mesic deciduous trees as well as extensive Taxodium (swamp cypress). At Lake Annie itself pine-oak dominance had been established over purely dune shrubs by 13,000 B.P., and by 4,700 B.P. Myrica (wax myrtle), Taxodium (swamp grass), Serenoa (saw palmetto) and other mesic trees had entered the area, as they do today. As Watts (1975) observes "it is not easy to see why a dry Pleistocene climate produced sand-dune vegetation whereas a dry Holocene climate yielded oak scrub prairie."

bands reflect the climatic shifts attending the withdrawal of the Laurentide glacier fronts. The changes were very dramatic beginning about 11,000 B.P. Oak-dominated deciduous forests had reached their present positions by 7,000 B.P. at the latest (Bernado and Webb 1976). Thereafter many indications suggest that the climate became wetter, but no further warming seems to have occurred. Greater extremes of summer and winter temperatures, such as we now experience, were established by 7,000 B.P., as the melting of the Laurentide ice sheet was completed.

Some evidence of climatic zonation, and climatic evolution in the Holocene, can be inferred from extinction patterns of Pleistocene flora and fauna after the onset of post-Pleistocene conditions. Such evidence, however, depends on sharp climatic zonation occurring over large areas. Conditions in the humid southeastern United States were less adverse for most species than, say, those in the more arid southwest, where relatively small changes in temperature and weather patterns might result in large relative differences in rainfull and food vegetation patterns. For example, the replacement of spruce-dominant forest by pine-dominant species at about 9,500-9,000 B.P. appears to have been very rapid (about a thousand years or less) in the southeast (Leopold, 1967), at a time when other evidence (Delcourt and Delcourt, in press) indicates a sandy base/scrub cover in the area, i.e., relatively arid compared to present conditions.

The climatic and vegetational changes to modern conditions on the Coastal Plain of the non-glaciated states preceded by a few thousand years the rapid postglacial rise of sea level. Therefore, the early Holocene enrichment of forest types had a definite impact on human cultures on the Continental Shelf and coastal lowlands. Presumably, the greater variety of flowering plants and deciduous trees and the longer growing season provided a much greater array of food and river resources to the Archaic period population of the region. The data to prove such an assertion are not presently known from the Continental Shelf. On the other hand, the rich variety of such resources used by Late Archaic cultures along the present coast lends some support to this supposition. After about 6,500 B.P., however, the area of coastal wetlands was greatly reduced by rapidly rising sea level. Presumably, Early and Middle Archaic cultures had at least as much reason to rely on coastal resources as did Late Archaic cultures. This view, however, must remain in the realm of supposition for the present.

4.1.4.2 Holocene Food Resources

The relatively sudden extinction of most of the megafauna at the end of the Pleistocene must have had a severe impact on the Paleo-indian hunting cultures that relied heavily upon them for food and clothing. The fact that there was some cultural continuity between Paleoindian and Archaic ways of life shows that there was a transition during which Amerindians discovered alternative sources of protein and in all other respects learned to survive without the megafauna. There is no clear consensus as to what alternative food resources resolved this "protein crisis." Possibly several of the proposed answers are true.

There is wide agreement that one of the safest places to survive during times of protein scarcity is along a productive coast. As Laughlin (1967) observes, "People who inhabit a coastal area can command a large portion of the rich marine resources of the ocean in addition to those of the land, without leaving the shore." There is no reason to doubt that Paleoindian bands had made use of such resources. There may even have been specialized marine mammal hunters, as suggested above. But as the most familiar species of big game on which they had relied began to disappear, the richness and reliability of coastal resources must have become even more important.

During this difficult transitional period, as the megafauna were disappearing along with the traditional Paleoindian economy, the essential coastal resources which may have saved the Amerindians in the southeast lay along the shallow shelf between 15 and 25 metres below present sea level. Quite possibly this is why so few bits of evidence from transitional and Early Archaic cultures are known.

During the early Holocene, inland hunting was not wholly destroyed. Odocoileus virginianus, the white-tailed deer, became very abundant and ranged throughout virtually all terrestrial habitats. Presumably Odocoileus' success was a response to the expanded opportunities left by the great megafaunal extinctions; the deer broadened its niche to partly exploit those vacated by horse, camel, sloths, mastodon, and mammoth. A complementary relationship appears to exist especially between the Camelidae and the deer during the latest Pleistocene and early Holocene. At inland sites, in addition to white-tailed deer there were a great array of small vertebrates, invertebrates and, presumably, plants. Whole biotic communities were broadly utilized by most Archaic cultures.

The principal biotic communities that were important to Archaic cultures in the southeastern Coastal Plain include the following broad groupings:

1. Upland communities
2. Fluvial settings
3. Saltmarshes and estuaries
4. Coastal marine sites

As this list suggests, Archaic economies appear far more varied from place to place than known Paleoindian economies. It does not seem likely that any of these broadly defined communities originated as wholly new entities in the quaternary, but it is certainly clear that the terrestrial communities were extensively reorganized at the end of the Pleistocene. To exploit each Holocene community a rather detailed knowledge of the local ecology and life history of many plant and animal species was required. Whether a given band of Archaic Indians exploited one or more than one locale is an important, unresolved question. Quite possibly they changed environments seasonally, but it seems unlikely that they were broadly nomadic.

The early Holocene record of human resource utilization in this region is further complicated by the very rapid environmental changes that accompanied deglaciation in northern temperate latitudes.

Beginning about 11,000 B.P. the boreal climatic zone of the late Pleistocene retreated rapidly northward as deglaciation accelerated (Bloom, 1975). However, not every zone shifted in the same way. Curiously, the subtropical zone shifted southward, and all along the Coastal Plain the climate seems to have become wetter (Watts, 1970; Whitehead, 1972). As detailed above, the sea rose rather rapidly, shifting coastal zones landward. Most temperature-sensitive marine organisms also shifted their ranges northward in response to warming surface and coastal waters.

The following discussion deals broadly with the major food resources that Archaic cultures found on the Coastal Plain of the southeastern United States. The simplest approach is to review the resources generally used by Archaic Indians in each of the principal communities. Such ecological subdivisions seem to persist, broadly speaking, through the temporal subdivisions of the Archaic and through any other geographic zonations along the Coastal Plain.

There is a legitimate question as to the relative importance of animal versus plant species as sources of food and fiber. The practical point is that plant remains are seldom adequately represented; whereas animal hard-parts are usually very well sampled and in modern quantitive excavations can give reasonable estimates of diet, minimum numbers of individuals harvested, and even approximate intake of protein and calories (Wing and Brown, 1979). With plants, ordinarily only a few durable nutshells or seeds are left to represent them. Therefore, it is the animal record that should be relied upon for a meaningful record. This argument becomes mooted once agriculture is established, but that does not become an important feature in the Southeast until one or two thousand B.P. (Goggin and Sturtevant, 1964).

<u>Upland Habitats</u> During the Holocene the most important terrestrial food resource in the southeast was <u>Odocoileus virginianus</u>, the white-tailed deer. Its bones are usually the most common animal remains in inland sites. The hunting traditions of Archaic cultures must have been focused clearly on this species. One deer provided not

only a large quantity of high-protein food, but also excellent hides, sinews, bones and antlers. A high level of craftsmanship developed utilizing deer bones and antlers, often with fine engraving or polishing for rough or smooth surfaces. Antler tips made light curved implements; the compact edges of cannon bones made dense straight tools. While the uses of meat and hides are not usually recorded by preserved materials, their presumed uses continued in the southeast through Woodland cultures and into historic times. During the early 18th century the annual export of deer hides from Charleston reached nearly a quarter of a million. Usage in pre-Columbian peak years may have reached similar levels, but that is difficult to estimate. In any event, *Odocoileus virginianus* was the primary game animal during the Holocene.

It is important to determine more specifically which upland habitats were utilized by deer and presumably searched out by Archaic Indians. In the Cooper River valley of South Carolina, Brooks et al. (personal communication) regarded most Archaic sites as "small, upland deer-hunting and oak-hickory nut extraction camps situated on small, dispersed patches of relatively well-drained soils." During times of lower sea levels such sites may have been more extensive in inland regions. Such habitats account for less than 40 percent of the area of South Carolina today. In Florida the preferred deer habitat and the one in which they are most readily hunted is likewise well-drained pine-oak uplands. Such habitats comprise about 35 percent of Florida's land area today and may support up to one deer for every 54 hectares (Harlow and Jones, 1959). Deer range into many other habitats, including swampy settings, but their prime habitat is pine-oak open woodland.

Bison might be supposed to have been a major source of food for Archaic Indians, but that is not the case in the southeast. Its continuity from the late Pleistocene into the Holocene and its previous role as a major target species of Paleoindian cultures would seem to mark it as a crucial line of survival during the Holocene, at least in the plains and east into the prairies. But in the southeast the particular ecological niche of *Bison bison* removed it from the list of important food resources for Archaic Indians. In the southeast, with the generally wetter climates of the Holocene, _Bison_ existed in small patchy plains and ecotonal (forest edge) ranges among woodlands and savannas. Due to these marginal conditions they apparently formed only small herds of which the movements were extensive but not readily obvious. They were a sparse and unreliable food resource. This was still their condition when observed by the first Europeans in the southeast (Roslund, 1960).

Smaller terrestrial vertebrates of a considerable variety played an important part in the nutrition of inland Archaic Indians. Among the common small game may be mentioned _Didelphis marsupialis_ (possums), _Procyon lotor_ (raccoons), _Meleagris gallapavo_ (turkeys), _Gopherus polyphemus_ (gopher tortoises), and _Terrapene carolina_ (box turtles). The importance of turkeys as an abundant food resource of Amerindians was well-documented by the first Europeans who early began to export them. Acorns and hickory nuts were surely very important fall crops, and berries and roots were gathered also. The key habitats for such a rich array of resources were well drained uplands and forest edges.

Fluvial Sites. Archaic sites along riverbanks and especially at the confluences of tributaries and major streams produced a wide range of food resources. Such sites permitted exploitation of the terrestrial resources above as well as the freshwater resources discussed here. For the most part, the seasonal resources were only available during a small portion of the year, whereas the fluvial products could be obtained throughout the year. Especially important were slow-swimming fishes including _Amia calva_ (bowfin), _Lepisosteus_ spp. (garfishes), _Ictalurus_ spp. (freshwater catfishes), and various turtles which could be caught on the bank, including _Trionyx_ spp. (softshell turtles), _Chelydra serpentina_ (snapping turtles) and _Chrysemys_ spp. (sliders and cooters). _Alligator mississipiensis_ were often taken and presumably were prized for their excellent meat and hides.

Saltmarshes and Estuaries. Farther downstream a different, even more productive set of aquatic resoures was available. During low tides many reliable animal resources became readily and predictably accessible. The most obvious example is Crassostrea virginica, the oysters. Mercenaria mercenaria (quahog clams) were also widely used. Great shell mounds of their discarded shells occur along the inland margins of the Georgia sea islands and up such rivers at the St. Johns in Florida, and attest to their economic significance. Oyster shells were often dumped in an orderly manner to form rings, causeways and dikes; thus oysters became important structural materials after the animal had been extracted.

Other notable food sources among the littoral invertebrates were Uca spp. (fiddler crabs), Littorina and Neritina (marsh snails), and Paleomonetes (grass shrimps). Aquatic birds such as ducks, geese and herons, as well as their eggs in the spring, were available in saltmarsh and estuarine areas. Some of the abundant brackish-water fishes that could be added to those encountered upstream were Mugil (mullet), Bagre and Arius (sea catfishes) and Cynoscion nebulosus (sea trout).

It is a common mistake to assume that vertebrate and arthropod food resources were less important than the mollusks at shell mound sites. This conclusion seems obvious where oyster shells are so much in evidence (DePratter and Howard, 1977). However, quantitative analyses of edible parts and their nutritional values point clearly to the opposite conclusion (Marrinan, 1976). Much of the oyster is just shell, and the edible meat has higher water content and lower protein content (by one-third or even one-half) than anadromous fish or other vertebrate meat.

The great importance of coastal, especially estuarine, sites in the southeastern Coastal Plain during the Late Archaic and Woodland periods has a definite environmental basis. As emphasized by Larson (1970) in his study of subsistence on the Coastal Plain, in no setting other than an estuary can so many rich resources be tapped within such a short distance. A special issue of Oceanus (1976) provides a concise review of the extraordinarily high productivity of estuarine settings around the world. The more difficult question is whether these resources were tapped early in the Archaic while they were exposed on the Continental Shelf or whether they became important only late in that cultural period.

In view of their importance as sites for human economy it may seem strange that coastal cultures are poorly known or unknown in the southeast until the Late Archaic. In Brazil, likewise, they are not known until about 7,000 B.P. Presumably this is because older coastal sites lie some 25 metres below the present sea level on the inner shelf. On the St. Johns River in Florida some large shell middens (up to 20 feet high and 200 feet long) consist mainly of freshwater species, notably Viviparus and large Pomacea (apple snails). The upper portion of one such midden had a C-14 date of 5,300 B.P., so that the base must be older (Bullen and Slight, 1959). Other St. Johns middens accumulated at least 5 to 6 feet below the present river bed, possibly as long ago as 6,000 to 7,000 years B.P. (Bullen, 1975). Possibly such ancient freshwater shell middens represent the poorer inland fringes of richer coastal culture that lies buried on the shelf.

Coastal Marine Sites Still another rich set of resources are supplied on a year-round basis by coastal beach or bay sites. Shallow marine resources include an incredible variety of mollusks and fishes as well as other marine invertebrates and vertebrates. Late Archaic shell middens at fully marine situations often include considerable numbers of Donax variabilis (coquina clams), Busycon caricum (knobbed whelk), Tagelus plebeius (razor clams), Modiolus demissus (ribbed mussels), Anadara ovalis (blood arks), Oliva (olive shells), Mellita (sand dollars) and Astropecten (starfish). Near St. Augustine, Florida, many middens consist largely of coquina shells. Often crabs such as Persephone and Hepatus are included, as are lobster such as Panulirus, the tiny lobster of south Florida.

Important onshore marine fishes included Archosargus probatocephalus (sheephead), Pogonias chromis (black drum), Brevoortia tyrannus (menhaden), Caranx hippos (jack), and sharks, especially Ginglymostoma, but including even Galeocerdo (tiger sharks) and Carcharodon (great white sharks). As Gilmore (1977) shows, the variety of inshore fishes increases dramatically near the boundary between the temperate Carolinian province and the tropical Caribbean province, which today lies in north Florida.

Many of the molluscan shells were used in a variety of ways. For example, Mytilus edulis (the edible clams) were an important source of Royal Purple dye. Oliva shells and Marginella shells were useful as ornaments. From the thick shell of Busycon (whelks) and Strombus (conchs) many implements were fashioned, including hammers, scrapers, chisels, and a supposed hoe using the columella as its strong axis, as well as pendants, coins and probable net weights. In short, the margins of the sea provided an immense storehouse of food and material resources for the Archaic Amerindians of the southeast. Since the early record of their utilization of this immense resource is sparse, it seems likely that it lies on the shelf.

4.1.5 Acknowledgements

The authors of Volume I are herein acknowledged. The Executive Summary and Sections 2.0 and 3.0 were written by Mr. Dennis T. Stanczuk of Science Applications, Inc., with a contribution in Section 3.0 by Mr. Roderick G. Hansen, also of Science Applications, Inc. Dr. Albert C. Hine from the University of South Florida wrote Section 4.1.1, Geology, with the exception of Subsection 4.1.1.5, Paleoshorelines and Sea Level Determination, which was written by Dr. John D. Milliman who is from Woods Hole Oceanographic Institute. Sections 4.1.2, 4.1.3, and 4.1.4, dealing with Pleistocene climatology and paleontology and Holocene climatology, were authored by Dr. S. David Webb, assisted by Mary Ellen Ahearn and John Baskin, all of the Florida State Museum. Mr. Stanczuk was responsible for overall technical editing.

The copy editing and overall document production was the responsibility of Ms. Jane Hill. Her dedication to the project is most gratefully appreciated. The work of the word processing specialists, Ms. Maryle Yager, Ms. Rejane Goldfrank, Ms. Mary Jane Drake, is acknowledged. Graphics were prepared by Mr. Bob Kliner, and cartography was done by Mr. Roderick G. Hansen, Mr. Dennis T. Stanczuk, Mr. Gene Pucknat, and Mr. Spencer Dean.

Appreciation is expressed to the following individuals for their valuable comments and contributions regarding the geology of the study area. Dr. D. J. P. Swift of the National Oceanic and Atmospheric Administration - Atlantic Ocean Marine Laboratory, Miami, provided valuable information on the physical processes of the Continental Shelf and research projects which have studied those processes. Dr. V. J. Henry of Skideway Institute of Oceanography, is gratefully acknowledged for his contribution of data and reports on hardgrounds and reefs in the Georgia Bight. Special thanks are expressed to the following individuals for the information they provided on the sources of cryptocrystalline rock in the South Atlantic Coastal Plain: Dr. Sherwood Wise, Florida State University; Dr. H. Carmer, Emory University; Dr. Walter Whaler, University of North Carolina; and Dr. Duncan Heron, Duke University.

Appreciation is expressed to Dr. Edward Meisburger of the Coastal Engineering Research Center, U.S. Army Corps of Engineers for advice and data in aiding the cultural resource evaluation.

Special thanks go to Dr. Mahlon M. Ball, of the United States Geological Survey for providing preliminary reports on high resolution seismic profiling and side-scan sonar on the South Florida Shelf, and Dr. Orrin H. Pilkey from Duke University for providing preliminary vibracore data on the Georgia, South Carolina Shelf.

It is appropriate here to acknowledge the outstanding cooperation provided by many persons and institutions without which such a full compilation of paleontological information would have been unthinkable. Above all, the full cooperation of Dr. Frank Whitmore of the U.S. Geological Survey and Dr. Clayton Ray and Robert Purdy of the U.S. National Museum were crucial. They freely offered access to their excellent records and extensive collections, including their own unpublished investigations.

Individuals who generously made collections available and unpublished data in their care are the following:

Dr. Don Baird
Museum of Paleontology
Princeton University
Princeton, New Jersey

Dr. Gerald Baum
Department of Geology
College of Charleston
Charleston, South Carolina

Dr. Don Colquohon
Department of Geology
University of South Carolina

Mr. Howard Converse, Jr.
Department of Natural Sciences
Florida State Museum
Gainesville, Florida

Dr. Ralph Eshelman
Calvert Marine Museum
P.O. Box 97
Solomons, Maryland

Dr. Charles H. Fairbanks
Department of Anthropology
University of Florida
Gainesville, Florida

Mr. Michael Frazier
Mississippi State Museum
Jackson, Mississippi

Dr. John Griffin
Division of Archives and History
Tallahassee, Florida

Dr. John Guilday
Carnegie Mellon Museum
Pittsburgh, Pennsylvania

Mr. Pete Harmatuk
P.O. Box 9
Bridgeton, North Carolina

Dr. Clifford Jeremiah
6749 Fincannon Road
Jacksonville, Florida 32211

Dr. Joshua Laerin
Department of Zoology
University of Georgia
Athens, Georgia

Dr. David Lee
North Carolina State Museum
P.O. Box 27647
Raleigh, North Carolina 27611

Dr. Jerry Milanich
Department of Social Sciences
Florida State Museum
Gainesville, Florida 32611

Dr. James McWhorter
Department of Biology
Miami-Dade Jr. College
Miami, Florida

Dr. Lewis D. Ober
Department of Biology
Miami-Dade Jr. College
Miami, Florida

Paul W. Parmalee
Department of Anthropology
University of Tennessee
Knoxville, Tennessee

Dr. Les Picker
Director of Marine Resources Center
Manteo, North Carolina

Dr. Robert Purdy
Department of Fossil Vertebrates
U.S. National Museum
Washington, D.C.

Dr. Clayton E. Ray
Department of Fossil Vertebrates
U.S. National Museum
Washington, D.C.

Dr. Horace G. Richards
Academy of Natural Sciences
Philadelphia, Pennsylvania

Dr. Albert Sanders
Charleston Museum
Charlestown, South Carolina

Dr. Bill Watts
University of Dublin
Dublin, Ireland

Dr. Walt Wheeler
University of North Carolina
Chapel Hill, North Carolina

Dr. Donald Whitehead
Department of Botany
University of Indiana
Bloomington, Indiana

Dr. Frank C. Whitmore, Jr.
Vertebrate Paleontologist
U.S. Geological Survey
Washington, D.C.

Dr. Elizabeth Wing
University of Florida
Gainesville, Florida

These collections, both large and small, provide valuable data and permanently retain the specimens and their records that sustain scientific knowledge. Among those supplying crucial information to the present study were the following:

Florida Geologic Survey, Tallahassee, Florida

Florida State Museum Collections (Zooarcheology, Archeology, Vertebrate)

Daytona Beach Museum of Arts and Sciences Museum, Daytona Beach, Florida

West Palm Beach Museum of Natural History, West Palm Beach, Florida

Marine Resources Center, Manteo, North Carolina

North Carolina State Museum, Raleigh, North Carolina

Calvert Marine Museum, Calvert, Maryland

Princeton University Museum, Princeton, New Jersey

Carnegie Museum of Natural History, Pittsburgh, Pennsylvania

Charleston Museum, Charleston, South Carolina

U.S. National Museum of Natural History, Washington, D.C.

U.S.G.S. Collections, Reston, Virginia

American Museum of Natural History, New York, New York

Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania

Maryland Geological Survey Collection, Johns Hopkins University, Baltimore, Maryland

Museum of Science and Technology, Washington, D.C.

4.1.6 Bibliography and References Cited

Auffenberg, W.; Milstead, W. W. Reptiles in the Quaternary of North America. Frey, D. editor.; 1965.

Ayers, M.; Blackwelder, B. W.; Howard, J. D.; Kee, F.; Kabel, H.; Pilkey, O. H. Georgia Embayment Staff: Vibracore Investigations: Final Report, Duke University. U.S. Geological Survey on Georgia Embayment Shelf Studies. Bordon, D. E. Peopling to Early Cultures of the Pacific NW. Science 203:963-971; 1979.

Bagnold, R. A. The flow of cohesionless grains in fluids. Phil. Trans. Rol. Soc. London. 249:234-297; 1956.

Bagnold, R. A. Mechanics of marine sedimentation: Hill, M. N., ed. The Sea. Interscience Pub.:507-582; 1963.

Baker, S. Storms, people, and property in coastal North Carolina. UNC Sea Grant Publication. UNC-SG-78-15:82. Raleigh, NC: North Carolina State University; 1978.

Ball, M. M. Carbonate sand bodies of Florida and the Bahamas: Jour. Sed. Petrology 37(2):556-591; 1967.

Balsam, W. L.; Heusser, L.E. Directo Correlation of Sea Surface Paleo-temperatures, Deep Circulation, and Terrestrial paleoclimates: Foraminiferal and Palynological Evidence from Two Cores off Chesapeake Bay. Marine Geology 21:121-147; 1976.

Beardsley, R. C.; Putnam, P. Circulation on the New England Continental Shelf: Response to Strong Winter Storms. Geological Reesearch Lett. 1:181-184; 1974.

Belknap, D. F.; Kraft, J. C. Holocene relative sea-level changes and coastal stratigraphic units on the northwest flank of the Baltimore Canyon Trough geosyncline. Journal of Sedimentary Petrology 47:610-629; 1977.

Bellis, V.; O'Connor, W. P.; Riggs, S. R. Estuarine Shoreline Erosion in the Albemarle-Pamlico Region of North Carolina. UNC-SG-75-29 (UNC Sea Grant Publ.); 1975.

Bernado, J. C.; Webb III, T. Changing patterns in the Holocene pollen record of northeastern North America: a mapped summary. Quat. Res. 6:64-98; 1976.

Blanton, J. O.; Bailey, L. L.; Hayes, D. W.; Dicks, A. S. Data Report No. 1, Oceanographic and Meteorological Data 15 Km off the coast of Georgia: Technical Report No. 78-b:49. Georgia Marine Science Center, Skidaway Island, GA; 1978.

Blackwelder, D. W.; Pilkey, O. H.; Howard, J. D. Late Wisconian Sea Level Curve for the Southeastern United States Continental Shelf. 204:618-620; 1979.

Bloom, A. Glacial and Pleistocene Geology. Flint, Richard Foster. Published Wiley, N.Y., 1957. 553 pages.

Boothroyd, J. C.; Hubbard, D. K. Genesis of bedforms in meso-tiday estuaries: in Cronin, L. E., ed. Estuarine Research II:217-234. Geology and Engineering. New York: Academic Press; 1975.

Borden, C. E. Peopling and Early Cultures of the Pacific Northwest. Refers to early inhabitants in Nevada, Washington and Oregon. Science 203:963-971; 1979.

Braun, E. L. The phytogeography of unglaciated eastern United States and its interpretation. Botany Review 21:297-375; 1955.

Braun, P. Sea level rise as a cause of shore erosion. Proceedings ASCE, Journal Waterways and Harbors Div. 88:117-130; 1962.

Bullen, R. P.; Waller, B. I.; Webb, S. D. A marked mammoth bone from Fla. American Antiquity 35:203-205; 1970.

Bullen, R. P. A Guide to the Identification of Florida Projectile Points. Revised Edition. Kendall Books, Gainesville, FL; 1975.

Bullen, R. P.; Slight, F. W. Archeological Investigations of Green Mound, Florida. Wm. L. Bryant Foundation of American Studies Report Number Two; 1959.

Chamberlain, R. T. Interpretation of the formations containing human bones at Vero, Florida. Jour. Geology 25:25-39; 1917.

Clark, J. A.; Farrell, W. E.; Peltier, W. R. Quaternary Research 9:265-287; 1978.

Clausen, C. J., et al. Little Salt Spring, Fla: A Unique Underwater Site. Science 203:609-624; 1979.

Clausen, C. J.; Cohen, A. D.; Emiliani, C.; Holman, J. A.; Stipp, J. J. A Unique Underwater Site. Little Salt Spring, Florida. Science 203:4381; 1979.

CLIMAP Project Members the Surface of the Ice-Age Earth. Science 191:1131-37; 1966.

Colquohoun, D. J. Geomorphology of the Lower Coastal Plain of South Carolina. South Carolina State Develop. Board, Div. Geol., MS 15:1-36; 1969.

Converse, Howard, Jr. A Pleistocene Vertebrate Fauna from Palm Beach County, Florida. The Plasterjacket, 21:1-15; 1975.

Craig, A. J. Vegetational history of the Shenandoah Valley, Virginia. Geol. Soc. Amer., Spec. Pap. 123:283-296; 1970.

Crutcher, H. C.; Quayle, R. G. Mariners Worldwide climate guide to tropical storms at sea: U.S. Naval Weather Service Command. p. 426; 1974.

Cry, G. W. Tropical cyclones of the North Atlantic Ocean: tracks and frequencies of hurricanes and tropical storms. 1861-1963. U.S. Weather Bur. Tech. Paper 55:148; 1965.

Cry, G. W.; DeAngelis, R. M. North Atlantic cyclones. U.S. Dept. of Commerce, Weather Bureau Climatological Data, National Summary 16(13); 1965.

Curray, J. R. Late Quaternary history, continental shelves of the United States. Princeton Univ. Press. 723-735; 1965.

Davies, J. L. A morphogenic approach to world shorelines. Zeits. Fur Geomorph. 8:127-142; 1964.

Deevey, E. S. Biography of the Pleistocene. Geol. Soc. Amer. Bull. 60:1315-1416; 1949.

Delcourt, P. A.; Delcourt, H. R. The Tunica Hills, Louisiana-Mississippi: late glacial locality for spruce and deciduous forest species. Quat. Res. 7:218-237; 1977.

Delcourt, P. A.; Delcourt, H. R. Late Pleistocene and Holocene Distributional History of the Deciduous Forest in the Southeastern United States. (Contribution No. 12, Center for Quaternary Studies of the Southeastern United States). Veroffentl. Des. Geobotanischen Inst. Der ETH, Stift. Rubel (Zurich). In press.

DePratter, C. B.; Howard, J. D. History of Shoreline Changes determined by archeological dating: Georgia Coast, U.S.A.: Ellison, S.P., ed. Trans. - Gulf Coast Association of Geol. Soc. 27:251-258; 1977.

Dillon, W. P. Submergence effects on a Rhode Island barrier and lagoon and inference on migration of barrier. Jour. Geology 78:94-106; 1970.

Dillon, W. P.; Oldale, R. N. Late Quaternary sea-level curve: Reinterpretation based on glaciotectonic influence. Geology 6:56-60; 1978.

Dreimanis, A. Extinction of mastodons in eastern North America: testing a new climatic environmental hypothesis. Ohio J. Sci. 68:267-272; 1968.

Duane, D. B.; Field, M. E; Meisburger, P. E.; Swift, D. J. P.; Williamns, S. J. Linear shoals on the Atlantic Inner Continenal Shelf, Florida to Long Island: Swift, D. J. P.; Duane, D. B.; Pilkey, O. H. eds. Shell Sediment Transport: Process and Pattern 447-499. Stroudsburg, PA: Dowden, Hutchinson and Ross; 1972.

Duane, D. B.; Meisburger, E. P. Geomorphology and sediments of the nearshore continental shelf from Miami to Palm Beach, Florida. U.S. Coastal Engineering Research Center, Tech. Memo 29:47; 1969.

Edsall, D. W. Southeast Georgia Embayment High Resolution Seismic Reflection Profile Survey: First Report to Bureau of Land Management, USGS, Office of Marine Geology, Woods Hole, MA, Open File Report 78-80; 1979.

Edwards, R. L.; Merrill, A. S. A Reconstruction of the Continental Shelf Areas of Eastern North America for the times 9,500 BP and 12,500 BP. Archaeology of Eastern North America 5:1-43; 1977.

Emery, K. O. Freshwater Peat on the Continental Shelf. Science 158:1301-1307; 1967.

Emery, K. O.; Garrison, L. E. Sea Levels 7,000 to 20,000 years ago. Science 157:684-687; 1967.

Emery, K. O.; Uchupi, E. Western North Atlantic Geology, Topography, Rock Structure, Water Life and Sediments. Memoir 17, American Association of Petroleum Geologists. Tulsa, OK; 1972.

Emery, K. O.; Personal communication. Woods Hole Oceanographic Institute, Woods Hole, Massachusetts; 1979.

Enos, P.; Perkins, R. D. Quaternary sedimentation in South Florida: Geol. Soc. America Memo 147:198; 1977.

Ewing, J. A. Wave-Induced Bottom Currents on the Outer Shelf: Marine Geology 15:M-31-M-35; 1973.

Fair, T.; Feit, D. M. The blizzard of 1978. Mariners Weather Log 22(4):255-260; 1978.

Fay, F. H.; Ray, C. Influence of Climate on the Distribution of Walruses, *Odobemus rosmarus* L. Evidence from Thermoregulatory Behavior; 1968.

Field, M. E. Buried strandline deposits on the Central Florida inner shelf. Geol. Soc. Amer. Bull. 85:57-60; 1974.

Field, M. E.; Duane, D. B. Geomorphology and sediments of the inner continental shelf. Cape Canaveral, FL; U.S. Coastal Engineering Research Center, Tech. Memo 42:87; 1974.

Field, M. E.; Duane, P. B. Post-Pleistocene history of the United States inner continental shelf: Significance to origin of barrier islands. Geol. Soc. Amer. Bull. 87:691-702; 1976.

Field, M. E.; Meisburger, E. P.; Stanley, E. A.; Williams, S. J. Late Quaternary peat deposits on the Atlantic inner shelf of the United States. Geol. Soc. Amer. Bull. The nearshore continental shelf from Miami to Palm Beach, Florida. U.S. Coastal Engineering Research Center, Tech. Memo 29:47; 90:618-628; 1979.

Fischer, A. G. Stratigraphic record of transgressing seas in light of sedimentation on the Atlantic coast of New Jersey. American Association of Petroleum Geologists Bull. 45:1656-1666; 1961.

FitzGerald, D. M. Ebb-tiday delta of Price Inlet, South Carolina: geomorphology, physical processes, and associated inlet shoreline changes: Hayes, M. O.; Kana, T, eds. Terrigenous Clastic Depositional Environments, Tech. Report No. 11 - CRD;11-143-11-157. Dept. of Geology, University of South Carolina; 1976.

Frey, D. G. Pollen-Succession in the sediments of Singletary Lake, North Carolina. Ecology 2:518-533; 1951.

Frey, D. G. Regional aspects of the late glacial and postglacial pollen succession of southeastern North Carolina. Ecological Monographs 23:289-313; 1953.

Frey, D. G. A time revision of the Pleistocene pollen chronology of southeastern North Carolina. Ecology 36:762-763; 1955.

Frison, G. C., editor. The Casper Site. Academic Press, New York; 1974.

Frison, G. C., et al. Paleo-Indian Procurement of Camelops on the Northwestern Plains. Quat. Res. 10:385-400; 1978.

Gazin, Charles L. Annotated list of fossil mammalia associated with human remains at Melbourne, Florida. Washington Acad. Sci. Jour. 40:397-404; 1950.

Gilmore, R. G. Fishes of the Indian River Lagoon and Adjacent Waters, Florida. Bull. Fla. Sta. Mus. Biol. Sci. 22:101-148; 1977.

Gadd, P. W.; Lavelle, J. W.; Swift, D. J. P. Estimates of sand transport on the New York shelf using near bottom current meter observations. Journal of Sedimentary Petrology 48:239-252; 1978.

Godfrey, P. J. Barrier beaches of the East Coast. Oceanus 19:27-40; 1976.

Godfrey, P. J.; Godfrey, M. M. Comparison of ecological and geomorphic interactions between altered and unaltered barrier island systems in North Carolina: Coates, D. R., ed. Coastal Geomorphology 239-358. Binghamton, N.Y.: State University of New York; 1973.

Goggin, J. M.; Sturtevant, W. C. The Calusa. A stratified, non-agricultural society with notes on sibling marriage: Explorations in Cultural Anthropology. Essays presented to George Peter Murdock; Goodenough, Ward H., eds. McGraw-Hill, NY; 1964.

Goldsmith, V. Coastal processes of a barrier island and adjacent ocean floor: Monomoy Island, Nauset Spit, Cape Cod, Massachusetts. Amherst, MA; University of Massachusetts. Dissertation, p. 469; 1972.

Guilday, J. E.; Martin, P. S.; McGrady, A. D. New Paris No. 4: A Pleistocene Core Deposit in Bedford County, Pennsylvania. Bull. Natl. Speleol. Soc. 26:121-194; 1964.

Guilday, J. E. The Baker Bluff Cave Deposit, Tennessee and the Late Pleistocene Faunal Gradient. Bull. Carn. Mus. Nat. Hist. 11:1-67; 1978.

Guilday, J. E.; Hamilton, H. W.; Parmalee, P. W. Caribou (*Rangerifer tarandus* L.) from the Pleistocene of Tennessee. Jour. Tennessee Acad. Sci. 50:109-112; 1975.

Guthrie, R. D. Paleocology of the large-mammal community in interior Alaska during the late Pleistocene. Amer. Midl. Nat. 79:346-363; 1968.

Hare, F. Kennedy. Quaternary Research 6:507-5127; 1976.

Harlow, R. F.; Jones, Jr., F. K. The White-Tailed Deer in Florida. Florida Game and Fresh Water Fish Commission. Tech. Bull. 9:1-240; 1965.

Harrison, W. Possible Late-Pleistocene Uplift, Chesapeake Bay Entrance: Journal of Geology 73:201-229; 1965.

Hay, O. P. Vertebrata mostly from Stratum No. 3 at Vero, Florida, together with descriptions of new species. Florida Geol. Survey, 9th Ann. Rept:43-68; 1917.

Hay, O. P. The Pleistocene of Eastern North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of longitude 95°. Carnegie Inst., Washington, D.C. Pub. No. 322; 1923.

Hay, O. P. The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of logitude 95°. Carnegie Inst., Washington, D.C. Pub. No. 322:1-499; 1923.

Hayes, M. O. Morphology of sand accumulations in estuaries: Cronin, L. E. ed. Estuarine Research, Geology and Engineering 11:3-22. New York: Academic Press; 1975.

Hayes, M. O. Kana, T. Terrigenous clastic depositional environments: Tech. Report No. 11CRD;302. Coastal Research Division, Dept. of Geology, University of South Carolina; 1976.

Haynes, C. W. Geochronology of Man-Mammoth Sites and Their Bearing on the Origin of the Llano Comples: Pleistocene and Recent Environments of the Central Great Plains. Wakefield Dart and Know Jones eds. University of Kansas Press; 1970.

Haynes, C. V. *Mammut americanum* at the Lehner Site. Soc. Vert. Paleo. New Notes, University of Arizona; 1975.

Haynes, C. V.; Hemmings, E. T. Mammoth bone shaft wrench from Murray Springs, Arizona. Science 159:186-187; 1968.

Hecht, A. D. Faunal and Oxygen Isotopic Paleotemperatures and the Amplitude of Glacial/Interglacial Temperature Changes in the Equatorial Atlantic, Caribbean Sea, and Gulf of Mexico. Quat. Res. 3:671-690; 1973.

Heiser, Robert F.; Cook, S. F. Fluorine and other chemical tests of some North American human and fossil bones. Am. Jour. Physical Anthropology 10:289-304; 1952.

Henry, V. J. Distribution and Occurrences of Reefs and Hardgrounds in the Georgia Bight (Abs.): Abstracts with Program, S.E. Geological Society of America 11:182; 1979.

Henry, V. J.; Harding, J. L. Geological evaluation of potential pipeline corridor sites along the Georgia Coast. Final Report Phase 1, Tasks I-A, B, C to the Georgia Office of Planning and Budget, p. 61; 1978.

Henry, V. J.; Giles, R. T. Distribution and occurrence of reefs and hardgrounds in the Georgia Bight: Final Report to USGS, p. 55. Woods Hole, MA; Office of Marine Geology; 1978.

Hibbard, W. et al. Quaternary Mammals of North America. Quaternary of the United States. Wright, H. E., Jr.; Frey, D. G., eds. 509-525. Princeton University Press, Princeton, NJ; 1965.

Hine, A. C. Lily Bank, Bahamas: History of an Active Ooline Sand Shoal: Jour. Sed. Petrology 47:1554-1581; 1977.

Hine, A. C.; Boothroyd, J. C. Morphology, processes, and recent sedimentary history of a glacial-outwash plain shoreline, southern Iceland: Jour. Sed. Petrology 48:901-920; 1978.

Hine, A. C.; Snyder, S.; Neuman, A. C.; Clark, T. A sea-level history and resulting inner Continental Shelf/coastal plain stratigraphy, Bogue Banks area, N.C.; Final Report to be submitted to the North Carolina Science and Technology Committee. In preparation.

Hine, A. C.; Wilbar, R. J.; Bane, J.; Lorenson, K.; and Neumann, A. C. in press. Off Bank Transport of Carbonate Sand Along Open Leaward Bank Margin: C. A. Nittrover Sedimantary Dynamics of Continental Shelfs. Elsweer Press, also in press with Marine Geology.

Hoffmeister, J. E.; Stockman, K. W.; Multer, H. G. Miami Limestone of Florida and its Recent Batamiar counterpart: Geol. Soc. America Bull. 78:175-190; 1967.

Holmes, F. S.; Leidy, Joseph. Post-Pleiocene Fossils of South Carolina. 122 pp. Russell and Jones, pub. Charleston, SC; 1860.

Hoyt, J. H. Barrier island formation. Geol. Soc. Amer. Bull. 78:1125-1136; 1967.

Hoyt, J. H.; Hails, J. R. Pleistocene Stratigraphy of Southeastern Georgia: Oaks, R. Q.; Dunbar, J. R. eds. Post Miocene Stratigraphy, Central and Southern Atlantic Coastal Plain 191-205. Logan, UT: Utah State University Press; 1974.

Hoyt, J. H.; Henry, V. J. Origin of capes and shoals along the southeastern coast of the United States. Geol. Soc. Amer. Bull. 82:59-66; 1971.

Hubbard, D. J.; Hine, D.; Breese, D.; Bezak, G. Preliminary seismic reflection investigation of Ft. Pierce Inlet and offshore continental shelf. Unpub. Tech. Rpt. submitted to Ashland Oil Corp. 40; 1975.

Hubbard, D. J.; Oertel, G.; Nummedal, D. The role of waves and tidal currents in the development of tidal-inlet sedimentary structures and sand body geometry: examples from North Carolina, South Carolina and Georgia: Journal of Sedimentary Petrology. In preparation.

Hunt, J. L. The geology and origin of Gray's Reef, Georgia continental shelf. Athens, GA: University of Georgia; Thesis, p. 83; 1974.

Hunt, R. E.; Swift, D. J. P.; Palmer, H. Construction shelf topography, Diamond Shoals, NC. Geol. Soc. America Bull. 88:299-311; 1977.

Irving, W.; Harrington, C. R. Upper Pleistocene radiocarbon-dated artifacts from the northern Yukon. Science 179:335-340; 1973.

Kirtley, D. W. Intertidal Reefs of *Sabellariidae* (Annelida polychaeta) along the Coast of Florida. Unpublished MS thesis. The Florida State University, Tallahassee, FL.

Komar, P. D. Beach processes and sedimentation. 429. Englewood Cliffs, NJ: Prentice Hall, Inc.; 1976.

Kowsman, R. O.; Costa, M. P. A. Sedimentacao Quaternaria da margem continental Brasileira e das areas oceanicas adjacentes. Projeto REMAC Publ. (Brazil) 8, 55 p.; 1979.

Kraft, J. C. Later Quaternary paleogeographic changes in the coastal environments of Delaware, Middle Atlantic Bight, related to archeologic settings. Ann. N.Y. Acad. Sci. 288:35-69; 1977.

Kraft, J. C. Sedimentary facies patterns and geologic history of a Holocene marine transgression. Geol. Soc. Amer. Bull. 82:2131-2158; 1971.

Kumar, N.; Sanders, J. E. Characteristics of shoreline storm deposits: Modern art and ancient examples: Jour. Sed. Petrology 46:145-162; 1976.

Lamb, H. H.; Lewis, R. P. W.; Woodroffe, A. World Climate from 8000 to 0 B.C., Royal Meteorological Society, London; 1966.

Lamb, H. H. Paleogeography, Paleoclimatology, Paleoecology 10:125-162; 1971.

Langfelder, J.; Stafford, D.; Amein, M. A reconnaissance of coastal erosion in North Carolina. 127. Raleigh, NC: Dept. of Civil Eng., North Carolina State University; 1968.

Larson, Lewis Henry, Jr. Aboriginal Subsistence Technology on the Southeastern Coastal Plain During the Late Prehistoric Period. (Vol. 1 & 2). Ph.D. University of Michigan; 1970.

Laughlin, W. S. Human Migration and Permanent Occupation in the Bering Sea Area. Jopkins, D. C. ed. The Bering Land Bridge, Stanford University Press; 1967.

Leidy, J. Remarks on vertebrate fossils from the phosphate beds of South Carolina. Jour. Acad. Nat. Sci. Phila. 1877:209-261; 1877.

Leidy, J. On the fossil horse of North America. Proc. Acad. Nat. Sci. Phila. III:262-266; 1874.

Leopold, E. B. in Martin, P. S.; Wright, Jr., H. E. Pleistocene Extinctions: The Search for a Cause. Yale; 1967.

Lighty, R. G. Submerged Early Holocene Barrier Reef: Proceedings, Third International Coral Reef Symposium. University of Miami 2:215-224; 1977.

Lorenz, Edward. The Nature in Theory of the General Circulation of the Atmosphere. World Meteorological Organization; 1967.

Luternauer, T. L.; Pilkey, O. H. Phosphorite grains: their application to the interpretation of North Carolina shelf sedimentation. Marine Geol. 5:315-320; 1967.

MacIntyre, I. G.; Blackwelder, B. W.; Land, L. S.; Stuckenrat, R. North Carolina shelf edge sandstone: age, environment of origin and relationship to pre-existing sea levels. Geol. Soc. Amer. Bull. 86:1973-1978; 1975.

MacIntyre, I. G.; Milliman, J. D. Physiographic Features on the Outer Shelf and Upper Slope, Atlantic Continental Margin Southeastern United States: Geological Society of America Bulletin 81:2577-2598; 1970.

MacIntyre, I. G.; Pilkey, O. H.; Stuckenrath, R. Relict oyster on the United States continental shelf: a reconsideration of their usefulness in understanding late Quaternary sea-level history. Geol. Soc. Amer. Bull. 89:277-282; 1977.

Marrinan, R. A. Assesment of Subsistence Strategy Evidenced by Shell Ring Sites. Bull. 19 Proc. 32nd S.E. Archeological Conf., Gainesville, FL, 1976.

Martin, P. S. Prehistoric Overkill. in Pleistocene Extinctions: The search for a cause. Martin, H. E.; Wright, H. E. eds. Yale University Press; 1967.

Martin, P. S.; Guilday, J. R. A Bestiary for Pleistocene Biologists. Martin, H. E.; Wright, H. E. eds. Yale University Press; 1967.

Maxwell, J. A.; Davis, A. B. Pollen Evidence of Pleistocene and Holocene Vegetation of the Allegheny Plateau, Maryland. Quaternary Research; 1973.

McTyre, A.; Kipp, N. G.; Be, A. H.; Crowley, T.; Kellogg, T.; Gardner, J. V.; Prell, W.; Ruddiman, W.F. Cline, R. M.; Hays, J. D. eds. Investigations of Late Quaternary Paleooceanography and Paleoclimatology, Memoir 145. Geological Society of America; 1976.

Meade, R. H. Landward transport of bottom sediments in the estuaries of the Atlantic Coastal Plain. Journal of Sedimental Petrology 39:229-234; 1969.

Meisburger, E. P. Shallow framework of inner continental shelf of Cape Fear Region, North Carolina (Abs). AAPG-SEPM Program and Abs. 92-93. Washington, D.C.; 1977.

Meisburger, E. P. Reconnaissance geology of the inner Continental Shelf, Cape Fear Region of North Carolina. U.S. Coastal Engineering Research Center, Technical Paper; 1978.

Meisburger, E. P. Reconnaissance geology of the inner continental shelf, Cape Fear region of North Carolina. CERC Tech. Rept. 79-3, 135 p.; 1979.

Meisburger, E. P.; Duane, D. B. Geomorphology and sediments of the inner continental shelf from Palm Beach to Cape Kennedy, Florida. U.S. Army Coastal Engineering Center, Tech. Memo 34:111; 1971.

Meisburger, E. P.; Field, M. E. Geomorphology, Shallow structure and sediments of the Florida Inner Continental Shelf, Cape Canaveral to Georgia. U.S. Army Coastal Engineering Center, Tech. Memo 54:119; 1975.

Milliman, J. D.; Emery, K. O. Sea levels during the past 35,000 years. Science 162:1121-1123; 1968.

Milliman, J. D. Atlantic Continental Shelf and Slope of the U.S.: petrology of the Sand Fraction -- Northern New Jersey to Southern Florida: U.S. Geol. Survey professional paper, 529J, 40 p.; 1972.

Mixon, R. B.; Pilkey, O. H. Reconnaissance geology of the submerged and emerged coastal plain province, Cape Lookout Quadrangle, North Carolina. U.S. Geol. Prof. Paper 859; 1976.

Moran, J. M. An Analysis of Periglacial Climate Indicators of Late Glacial Time in North America. Ph.D. Thesis, University of Wisconsin, Madison; 1972.

Morner, N. A. Eustasy and geoid changes. J. Geol. 84:123-151; 1976.

Morton, R. A.; Donaldson, A. C. Sediment distribution and evolution of tidal deltas along a tide-dominated shoreline. Wacheague, VA; Sedimentary Geology 10:285-299; 1973.

Mullins, H. T.; Neumann, A. C. Geology of the Miami Terrace and its paleo-oceanographic implications. Marine Geology 30:205-232; 1979.

Multer, H. G. Field Guide to some casonata rock environments. Madison, NJ; Dept. Earth Sciences, Fairleigh Dickinson University; 1971.

Multer, H. G. Field Guide to some carbonate rock environments, Florida Keys and Western Bahamas, p. 415. Dubuque, IA: Kendall/Hunt Pub. Co.; 1977.

Multer, H. G.; Milliman, J. D. Geologic aspects of Sabellarian reefs, south-eastern Florida: Bull. Marine Science 17(2):257-267; 1967.

Murray, S. P. Bottom Currents Near the Coast during Hurricane Camille: Journal of Geophysical Research 75:4579-4582; 1970.

Nummedal, D.; Oertel, G. F.; Hubbard, D. K.; Hine, A. C. Tidal inlet variability - Cape Hatteras to Cape Canaveral. Coastal Sediments, 1977, ASCE Charleston, SC 543-562; 1977.

Oceanus. Estuaries 19(5):1-72; 1976.

Oertel, F. G. Post-Pleistocene island and inlet adjustment along the Georgia Coast: Jour. Sed. Petrology 45:150-159; 1975.

Otvos, E. G. Development and migration of barrier islands, northern Gulf of Mexico. Geol. Soc. Amer. Bull. 81:241-246; 1970.

Palmer, H. A.; Stoltman, J. B. The Boaz Mastodon. A possible association of man with Mastodon in Wisconsin. Mid-continental Journal Int. Archeology 1:162-177; 1976.

Perkins, R. D.; Enos, Paul. Hurricane Betsy in the Florida - Bahama Area - Geologic effects and comparison with Hurricane Donna: Jour. Geology 76:716-717; 1968.

Pierce, J. W.; Colquhoun, D. J. Holocene evolution of a portion of the North Carolina coast. Geol. Soc. Amer. Bull. 81:3697-3714; 1970.

Pierce, J. W.; Nelson, D. D.; Colquhoun, D. J. Mineralogy of suspended sediment off the southeastern United States. Swift, D. J. P.; Duane, P. B.; Pilkey, O. H. eds. Shelf Sediment Transport 281-305. Stroudburg, PA; Hutchinson and Ross; 1972.

Pilkey, O. H.; Frankenberg, D. Relict-Recent Sediment Boundary on the Georgia Continental Shelf. Bull. Acad. Sci. 22:37-40; 1964.

Popenoe, Peter. Personal communication. U.S. Geological Survey, Woods Hole, Massachusetts; March and May 1979.

Ray, Clayton E. Additions to the Pleistocene mammalian fauna from Melbourne, Florida. Mus. Comp. Zool. Bull. 119:421-451; 1958.

Ray, Clayton E. A Glyotodont from South Carolina. Charleston Museum Leaflet 27:1-12; 1965.

Ray, Clayton E.; Cooper, B. N.; Benninghoff, W. S. Fossil mammals and pollen in a late Pleistocene deposit at Saltville, Virginia. Jour. Paleont. 41:608-622; 1967.

Ray, C. E.; Fay, F. H. Confluence of Climate and Distribution of Walruses; *Odobenus rosmarus* L. Evidence from Physiological Characteristics. Zoologica 53-19-32; 1968.

Ray, Clayton E. Personal communication. Department of Fossil Vertebrates, U.S. National Museum, Washington, D.C.; April 1979.

Richards, H. G. Structural and Stratigraphic Framework of the Atlantic Coastal Plain. Oaks, R.; Dubar, J.: Post Miocene Stratigraphy Coastal/Southern Atlantic Coastal Plain 11-20. Utah State University Press; 1974.

Robertson, J. S., Jr. Fossil Bison of Florida. Webb, S. David. ed. Pleistocene Mammals of Florida. Univ. Press of Fla. Gainesville, FL; 1974.

Roslund, E. The geographic ranges of the historic Bison in the Southeast. Ann. Assoc. Am. Geo. 50:395-407. 1960.

Roth, J. A.; Laerm, J. A late pleistocene vertebrate assemblage from Edisto Island, South Carolina. Brimleyana (Jour. North Carolina State Museum). 3:1-29; 1980.

Roth, Janet. Pleistocene vertebrates from Edisto Island, South Carolina. Athens, GA; University of Georgia, Thesis. 89 p.; 1979.

Rouse, Irving. A survey of Indian River archeology, Florida. Yale Univ. Pub. Anthropology 44:1-292; 1951.

Ruddiman, W. F.; Glover, L. K. Quaternary Research 5:361-389; 1975.

Schwartz, M. L. The Bruun theory of sea level rise as a cause of shore erosion. Jour. Geology 75:76-92; 1967.

Sellards, Elias H. Human remains and associated fossils from the Pleistocene of Florida. Florida Geol. Survey 8th Ann. Rept. 121-160; 1916.

Sellards, E. H. On the association of human remains and extinct vertebrates at Vero, Florida. Jour. Geology 25:4-24; 1917.

Sellards, E. H. Early Man in America. University of Texas Press; 1952.

Shepard, F. P. Submarine Geology. New York, Harper and Row Publishing Co.; 1973.

Sheridan, R. E.; Dill, G. E., Jr.; Kraft, J. C. Holocene sedimentary environment of the Atlantic inner shelf off Delaware. Geol. Soc. Amer. Bull. 85:1319-1328; 1974.

Shideler, G. L.; Swift, D. J. P. Seismic reconnaissance of Quaternary deposits of the Middle Atlantic Continental Shelf - Cape Henry, Virginia to Cape Hatteras, North Carolina. Marine Geology 12:165-185; 1972.

Shideler, G. L.; Swift, D. J. P.; Johnson, G. H.; Holliday, B. W. Late Quaternary stratigraphy of the inner Virginia Continental Shelf: a proposed standard section. Geol. Soc. Amer. Bull. 83:1787-1804; 1972.

Silvester, R. Coastal Engineering. Elsevier Pub., Amsterdam 2:339; 1974.

Slaughter, B. H. An Ecological Interpretation of the Brown Sand Wedge Local Fauna, Black Water Draw, New Mexico: An Hypothesis Concerning Late Pleistocene Extinction. Wendorf, F. ed. Paleo-Ecology of the Llano Estacado Museum of New Mexico Press 2:1-37. Santa Fe, NM; 1962.

Stahl, L.; Koczan, J.; Swift, D. J. P. Anatomy of a shoreface-connected ridge system on the New Jersey shelf; implications for genesis of the shelf surfician sand sheet. Geology 2:117-120; 1974.

Stanley, D. J.; Swift, D. J. P. Marine sediment transport and environmental management. New York: John Wiley and Sons; 1976.

Stewart, T. Dale. A re-examination of the fossil human remains from Melbourne, Florida, with further data on the Vero skull. Smithsonian Misc. Coll. 106(10):1-28; 1946.

Swift, D. J. P. Quaternary shelves return to grade. Marine Geology 8:5; 1970.

Swift, D. J. P. Barrier island genesis: evidence from the Middle Atlantic Shelf of N. America. Sedimentary Geol. 145:1-43; 1975.

Swift, D. J. P.; Freeland, G. L. Current lineations and sand waves on the inner shelf, Middle Atlantic Bight of North America: Journal of Sedimentary Petrology 48:1257-1266; 1978.

Swift, D. J. P.; Kofoed, J. W.; Saulsbury, P. J.; Sears, P. Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America. Swift, D. J. P.; Duane, D. G.; Pilkey, O. H. eds. Shelf Sediment Transport - Process and Pattern 399-574. Stroudsburg, PA; Dowden, Hutchinson and Ross; 1972.

Swift, D. J. P.; Sears, P. Estuarine and littoral depositional patterns in the surficial sand sheet central and southern Atlantic shelf of No. America. International Symposium on Interrelationship of Estuarine and Continental Shelf Sedimentation. Inst. Geol. du Bassin d'Aquitaine, Memo 7:171-189; 1974.

Thom, B. J. Coastal and Fluvial landforms: Harry and Marion Cos., So. California Technical Report No. 44. Coastal Studies Inst., Louisiana State University; 1967.

Tikhomiov, B. A. Natural Conditions and Vegetation in the Mammoth Epoch in Northern Siberia. Problems in the North (cited in Guthrie, R. D.; 1968) 1:168-188; 1958.

Twitchell, D. C.; Knebel, H. J.; Folder, D. W. Delaware River: evidence for its former extension to Wilmington Submarine Canyon. Science 195:483-484; 1977.

Uchupi, E. Atlantic continental shelf and slope of the United States - Physiography. U.S. Geol. Survey Prof. Paper 529-C:30; 1970.

U.S. Army Corps of Engineers. Shore protection manual, v. 1-3. Washington, D.C.; U.S. Government Printing Office; 1973.

U.S. Geological Survey. Water Resources Data for North Carolina Water Year 1977: USGS Water Data Report NC-77-1:395. Raleigh, NC; 1977.

Voorhes, M. R. The Watkins Quarry: A New Late Pleistocene Mammal Locality in Glenn County, Georgia. Georgia Academy of Science Bulletin. 29:128; 1971.

Watts, W. A. A pollen diagram from Mud Lake, Marion County, North-Central Florida. Geol. Soc. Amer. Bull. 80:631-642; 1969.

Watts, W. A. The full-glacial vegetation of northwestern Georgia. Ecology 51:17-33; 1970.

Watts, W. A. Postglacial and interglacial vegetation history of southern Georgia and Central Florida. Ecology 52:676-690; 1971.

Watts, W. A. The Late Quaternary Vegetation History of the Southeastern United States. Ann. rev. Ecol. syst. 11:387-409; 1980.

Watts, W. A. A late Quaternary record of vegetation from Lake Annie, South Central Florida. Geol. 3:344-346; 1975.

Webb, S. Davis, editor. Pleistocene Mammals of Florida. The Univ. Presses of Florida, Gainesville, FL; 1974.

Webb, S. Davis. "Fossil Vertebrates on the Shelf." Typescript; 1978.

Webb, T.; Clark, D. R. Calibrating micropaleontological data in climatic terms: a critical review. Am. NY Acad. Sci. 288:93-118; 1977.

Weigel, Robert D. Fossil Vertebrates of Vero, Florida. Fla. Geol. Surv. Spec. Pub. 10:1-59; 1962.

White, W. A. Drainage asymmetry and the Carolina capes. Geol. Soc. Amer. Bull. 77:223-240; 1966.

Whitehead, D. R. Northern Elements in the Pleistocene Flora of the Southeast. Ecology 44:403-406; 1963.

Whitehead, D. R. <u>in</u> Wright, Jr., H. E.; Frey, D. G. eds. The Quaternary of the U.S., Princeton; 1965.

Whitehead, D. R. Fossil pine pollen and full-glacial vegetation in Southeastern North Carolina. Ecology 45:767-776; 1964.

Whitehead, D. R. Studies of full-glacial vegetation and climate in Southeastern United States. Quaternary Paleoecology. Cushing, E. J.; Wright, Jr., H. E. eds. pp.237-248. Yale Univ. Press, New Haven, CO; 1967.

Whitehead, D. R. Development and environmental history of the Dismal Swamp. Ecol. Monog. 42:301-315; 1972.

Whitehead, D. R. Late-Wisconsin Vegetational Changes in Unglaciated Eastern North America. Quaternary Research 3:621-631; 1973.

Whitmore, F. Elephant teeth from the Atlantic Continental Shelf. Science 156:1477-1481; 1967.

Whitmore, Frank. Personal communication. U.S. National Museum, Washington, D.C.; (Dr. Whitmore has a dual appointment at USGS and at the National Museum); May 1979.

Williams, Stephen; Stoltman, James B. An Outline of Southeastern United States Prehistory with Particular Emphasis on the Paleo-Indian Era, The Quaternary of the United States, Wright, H. E., Jr.; Frey, David G. eds. pp. 669-683. Princeton, NJ; 1965.

Wilson, M. The Casper Local Fauna and its fossil bison. Frison 125-171; 1974.

Wing, E. S.; Brown, A. B. Paleonutriant: Method and Theory in Prehistoric Foodways. pp. 1-311, Academic Press, New York; 1979.

Woolsey, J. R. Neogene stratigraphy of the Georgia Coast and inner continental shelf. Dissertation. Athens, GA: University of Georgia; 1977.

Wormington, H. M. Ancient Man in North America. Denver Mus. Nat. Hist. Pop. Ser. 45:1-322; 1957.

Ziegler, J. M. Origin of the Sea Islands of the southeastern United States. Geograph. Rev. 49:222-237; 1959.