# Death Valley National Park Paleontological Survey

Torrey G. Nyborg and Vincent L. Santucci
Technical Report NPS/NRGRD/GRDTR-99/01

Death Valley National Park
Paleontological Survey

United States Department of the Interior•National Park Service•Geologic Resource Division

Copies of this report are available from the editors.
Geologic Resources Division
12795 West Alameda Parkway
Acadamy Place, Room 480
Lakewood, CO 80227
Please refer to: National Park Service D-178 (May 1999)

How to cite this document: Nyborg, T. G. and V. L. Santucci. 1999. The Death Valley National Park paleontological survey. National Park Service, Geological Resources Technical Report, NPS/NRGRD/GRDTR-99/01.

**Cover Illustration**

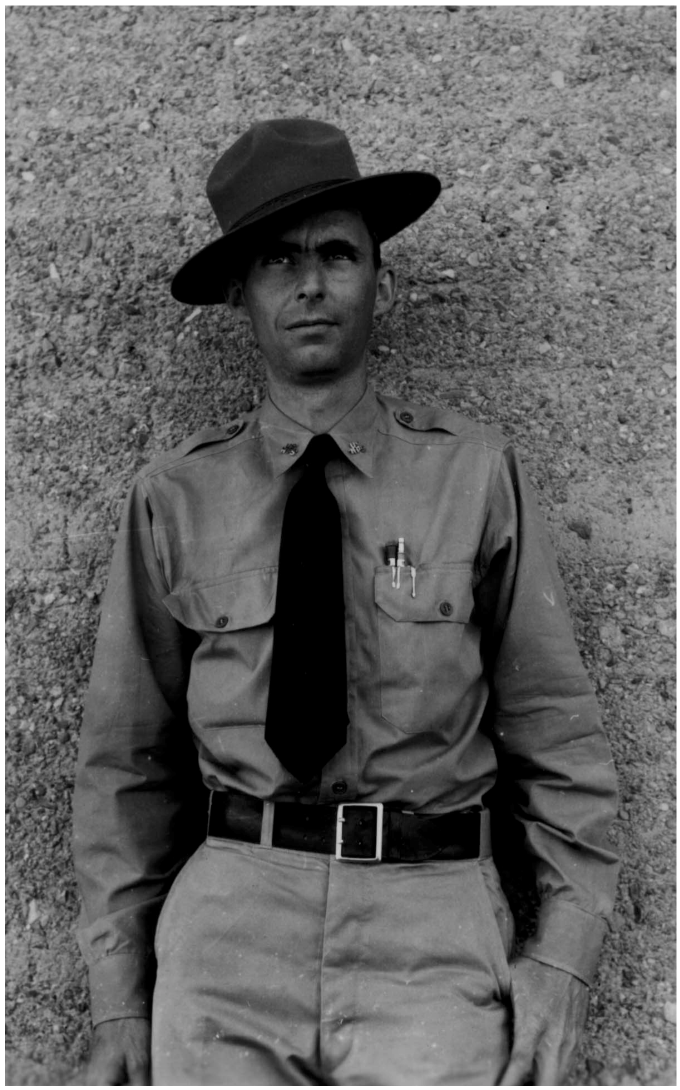
Fossil carnivore tracks from the late Miocene Copper Canyon Formation overlay boundary map of Death Valley National Park.

# THE DEATH VALLEY NATIONAL PARK PALEONTOLOGICAL SURVEY

Torrey G. Nyborg
and
Vincent L. Santucci

National Park Service
Geologic Resources Division
12795 West Alameda Parkway
Academy Place, Room 480
Lakewood, CO 80227

NPS/NRGRD/GRDTR-99/01
1999



This publication is dedicated to park ranger/geologist

H. Donald Curry
1908-1999

# Table of Contents

*"The excellent exposures of rock in Death Valley offer a challenge to any geologist who attempts to study the complex geologic history of the Valley"* (Troxel, 1970)

# INTRODUCTION

Recognizing the contributions that a paleontological survey could provide to the management at Death Valley National Park, a strategy was developed to begin work in the largest National Park Service unit in the continental United States (Figure 1). Overcoming the high temperatures and limited available funding, a comprehensive inventory of all currently known sources of information regarding Death Valley's geology and paleontology was initiated in 1998. The work was accomplished through the voluntary efforts of the principal investigator and the staff paleontologist for the National Park Service Geologic Resources Division.

By comparison to the other natural resources in Death Valley National Park, non-renewable fossil resources have received far less attention. Most of the credit for the initial understanding and recognition of the Death Valley geology and paleontology should rightfully go to Don Curry, the first ranger-naturalist at Death Valley. More recent work at the park includes research on Cambrian trilobites and Devonian fish. As this survey demonstrates, Death Valley contains very significant and diverse paleontological resources.

It has been our privilege to work in Death Valley National Park. We hope that this document helps to increase the awareness and status of Death Valley's paleontological resources and provide a baseline from which future projects can be planned. We believe that the information contained in this report can enhance management decision making relative to paleontological resource issues and perhaps pave the way to future discoveries in Death Valley.

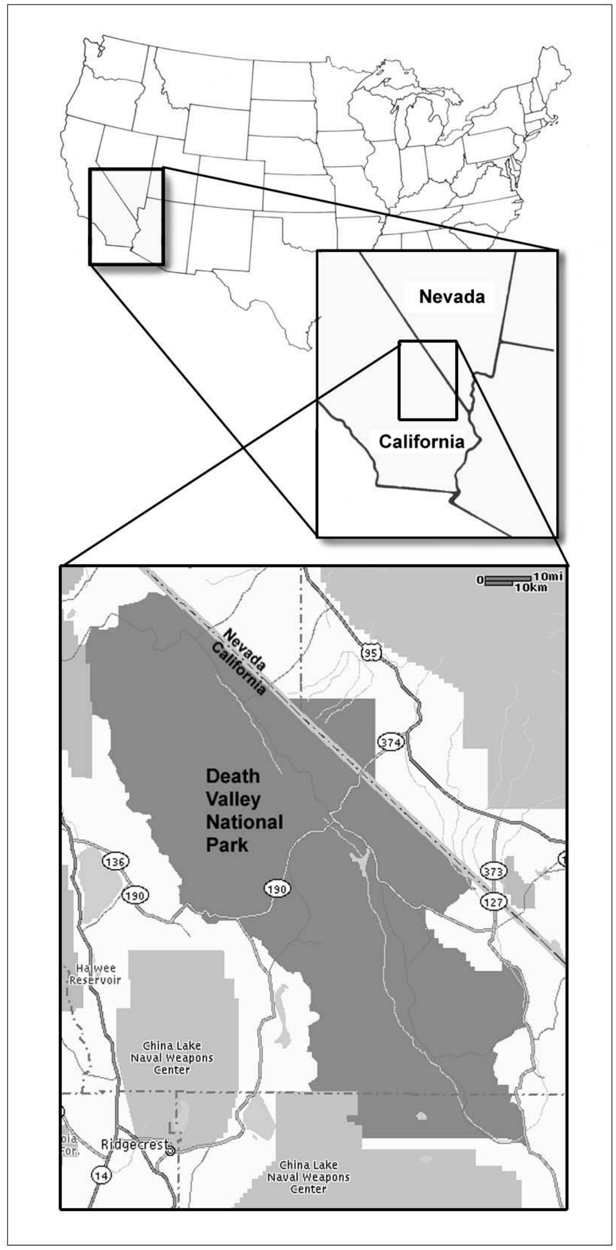



Figure 1: Location of Death Valley National Park.

## Historical Background

The search for gold and other minerals in the region drew a few prospectors into the Death Valley area in the late 1840s. The wealth of gold, silver, copper, lead and borate mineral deposits led to the establishment of mines in and around the valley. The first U.S. boundary commission visited Death Valley in 1861. The commission characterized the valley as "a vast and deep pit, of many gloomy wonders."

After the Civil War, the army's role in conducting topographic surveys was taken over by civilian parties. Ferdinand Hayden, John Wesley Powell and Clarence King were funded by Congress to initiate topographic and scientific surveys in the western territories. In 1867, the first military expedition into the Death Valley area was conducted under the command of Lieutenant C.E. Bendire. In an effort to regain some of its pre-war responsibility, the army established the United States Geographical Surveys West of the One-Hundredth Meridian. First Lieutenant George M. Wheeler was assigned command of this survey (Bartlett, 1962).

Wheeler recognized that the other surveys placed great emphasis upon geology, and the topographic work was coordinated by the needs of the geologist. Wheeler believed that a topographic map was more essential to national security than a geologic map. During 1871, the Wheeler Survey covered more than 72,000 square miles in the Great Basin of Nevada, eastern California, southwestern Utah, and portions of Arizona.

Wheeler's trip across Death Valley is documented in the Wheeler Survey Geographical Reports (1887) and in the writings of Frederick Loring (1871). During the 1871 survey, Wheeler's party produced the first detailed map of the Death Valley region. Fragmentary news items paint an unpleasant picture of the commander who walked the narrow edge of disaster many times, committed many errors in judgement, and in a few instances resorted to inexcusable cruelty to maintain order and achieve his objectives (Bartlett, 1962).

Death Valley's geologic and scenic beauty was first brought to the attention of the National Park Service in the late 1920's. With the support of Stephen T. Mather, Director of the National Park Service, President Hoover proclaimed Death Valley a national monument on February 11, 1933. In 1934, from the discovery of a titanothere skull and related bone material, Death Valley was again expanded to include the Nevada Triangle. With the passage of the Desert Protection Act of October 31, 1994, Death Valley increased its coverage by 1,200,000 acres and achieved the status of a national park. Death Valley National Park today preserves 3,336,000 acres that include world renowned and scientifically significant paleontological resources.

Geologist H. Donald Curry is credited as the first individual to recognize the significance of Death Valley's paleontological resources. Nicknamed "The Kid", Curry learned to map with the U.S. Geological Survey in 1930. In the fall of 1934, he was hired as a Park Naturalist at Death Valley National Monument. Curry's assignment was interrupted by his participation in World War II, but he was listed in the records of Death Valley National Monument until 1942.

Early geologic investigations in Death Valley are best summed up in the following passage, "The region, due in large measure perhaps to its inaccessibility and desolateness, has received in the main only reconnaissance study. However, the early investigations of the geology of the Grapevine and Funeral Mountains by Gilbert, Spurr, and by Ball elucidated much important information as part of the noteworthy contributions made by these surveys to an understanding of the stratigraphy and structure of southern Nevada and eastern California. Credit for the discovery of vertebrate fossils in the Tertiary series of the Grapevine and Funeral Mountains goes to H. Donald Curry" (Stock and Bode, 1935).

Until recently, there have been very few geologists working for the National Park Service. H. Donald Curry was one of the first professional geologists to wear the ranger uniform. He talked with the public during nightly programs and performed geologic work during the day. Curry made many paleontological resource discoveries at Death Valley including: Eocene titanothere remains from Titus Canyon, plant fossils in the Furnace Creek Formation, new species of Tertiary fossil fish, and three fossil vertebrate track localities, most notably the Copper Canyon Track Locality. During his short time at Death Valley, H. Donald Curry spent it wisely in the field (Figure 2). Therefore, we feel it is appropriate that we dedicate the Death Valley Paleontological Survey to H. Donald Curry, the man who first opened our eyes to the geologic significance and beauty of Death Valley.

## Significance of Death Valley's Paleontological Resources

Death Valley National Park preserves an extensive geologic record ranging from the Proterozoic through the Holocene. Over thirty fossiliferous stratigraphic units have been identified at Death Valley, containing fossil plants, invertebrates, vertebrates and trace fossils. The park museum collection provides a first glimpse into a record of life from the Death Valley area extending back over a billion years. Death Valley fossils occur in museums throughout the United States and include a number of fossil "type" specimens. A "type" specimen is a reference specimen used to define a particular genus or species.

The Proterozoic strata of Death Valley are richly fossiliferous, containing abundant algal fossils, stromatolites, microfossils, acritarchs, and a few trace fossils. Horodyski (1993) has reported on Ediacaran body and trace fossils outside of the park boundaries. Within the park's boundary, only one occurrence of a metazoan Proterozoic fossil has been reported (Langille, 1974), consisting of a small shelly fossil "*Cloudina*." Langille (1974) and Kauffman and Steidtmann (1981) have also reported on undescribed pseudofossils that may possibly be of metazoan origin, but their results are heavily contested. Within the deposits of Death Valley, a diverse shelly fauna precedes the first occurrences of trilobites (Signor et al., 1987). These pre-trilobite, shelly faunas are inferred to have a worldwide distribution. Studying these fossil should reveal new information regarding the pattern and processes of early invertebrate metazoan evolution and diversification (Signor et al., 1987).

In the 1880's, Charles Walcott explored an area north of Waucoba Springs within the Saline Valley Region of this report. He designated a 2,100 meter thick section comprising strata of the White-Inyo facies as the Lower Cambrian Waucoban Series (Walcott, 1895, 1908). This series includes nine geologic formations and contains some of the oldest known fossils of complex multi-celled organisms, including the oldest occurrences of trilobites. Trilobites within this series and other Cambrian deposits in

Figure 2: Geologist H. Donald Curry and Ranger Doudna mapping in Golden Canyon.

Death Valley National Park record scientifically important depositional settings.

Late Proterozoic and Proterozoic strata outcrop extensively throughout Death Valley National Park, including a nearly complete Paleozoic carbonate succession in the Panamint Range, and a complete Paleozoic succession from Pyramid Peak southeastward towards Death Valley Junction, at the southeastern end of the Funeral Mountains. These deposits preserve important Paleozoic faunal assemblages.

Two genera of rare Devonian fish were discovered in the Lippincott Member of the Lost Burro Formation (Elliott and Ilyes, 1996a, 1996b). The primitive pteraspid (agthanan) fish include the genus *Blieckaspis* and a newly described genus *Panamintaspis* from the Trail Canyon area of Death Valley National Park. These remains shed new light on the early evolution of fish in North America.

Late Eocene (Chadroian) assemblages of fossil mammals have been collected from the Titus Canyon Formation in Death Valley National Park. Fossilized remains of early rodents, carnivores, horses, rhinos, and artiodactyls have been discovered in a red calcareous mudstone unit (Stock and Bode, 1935). The locality is referred to as Titanothere Canyon based upon the discovery of a new species of titanothere referred to as *Protitanops curryi*. This specimen represents the first record of a titanothere west of the Rockies. A cast of the *Protitanops* skull is on exhibit at the Furnace Creek Visitor Center (Figure 3).

Fossil vertebrate tracks from the Tertiary are relatively rare by comparison to Mesozoic vertebrate tracks. A number of Late Tertiary vertebrate track sites are documented in Death Valley National Park (Curry, 1941). The most abundant, diverse, and well-preserved fossil vertebrate tracks are located in Copper Canyon. Fossil footprints of birds, camels, horses, cats, proboscidians and other vertebrate ichnotaxa are preserved in late Miocene lake deposits. The site is so scientifically significant, if it was not protected as part of Death Valley National Park,

**Significance of Death Valley's Paleontological Resources**

- Extensive geologic range of fossil record;
- Possible "Ediacara" fauna equivalent;
- 520 million year old trilobites;
- Type section of the Lower Cambrian Waucoban Series;
- Unparalleled Proterozoic and Cambrian sequence, with associated diagnostic and scientifically important faunal assemblages;
- Devonian fishes;
- Titanotheres and other fossil mammals in Eocene sediments;
- Mammal and bird tracks in Miocene and

Copper Canyon would be worthy for consideration as an independent national monument.

**Acknowledgements**

We have come to realize that there is far more to Death Valley National Park than we first anticipated. In addition to the significant and diverse paleontological resources, the park has an exceptionally high quality staff. It was this combination of fossil and human resources that engaged us to prioritize the Death Valley Paleontological Survey as the second such survey in the National Park Service.

Our initial contacts at Death Valley were the Chief of Resource Management Linda Greene and the former park archeologist Caven Clark. Linda and Caven requested assistance with park paleontological resource issues from the National Park Service Geologic Resources Division (GRD). In April 1998, GRD Paleontologist Vince Santucci first visited Death Valley, met with park staff, and began an initial assessment of the paleontological resources. Through Linda Greene's efforts, Torrey Nyborg was recruited as a paleontology intern through the National Park Service's Geologist-In-the-Parks program during the summer of 1998.

Many thanks to Superintendent Dick Martin and his staff at Death Valley National Park for providing support and suggestions to this survey. Corky Hays, Terry Baldino, Scot McElveen, Dick Anderson, John Stark, and Marilyn Pitassi were park staff who were especially helpful. Special thanks to Mel Essington for helping us understand the park's complex geology, and Charlie Callagan for orienting us on our initial visits to Copper Canyon and providing top-notch paleontological resource interpretation. Death Valley Curator, Blair Davenport, has been extremely helpful in tracking down and tying together the isolated building blocks of this survey. Blair provided reprints, photos, and many hours of her own

Figure 3: Composite view of the type specimen *Protitanops curryi* (adapted from Stock and Bode, 1935).

time to support our frequent requests for assistance and information.

An area of particular interest at Death Valley is Copper Canyon. We characterize this exceptionally well preserved and rich fossil vertebrate track locality as one of the "paleontological gems" of the National Park Service. Park naturalist/geologist H. Donald Curry was the first to discover and document the Copper Canyon Track Locality and another notable site at Titanothere Canyon. At ninety Don had many stories to share about Death Valley. It is to H. Donald Curry that this report is dedicated.

We recognize the important contribution park volunteer Reuben Scolnick has made to Death Valley through his long-term photodocumentation and mapping of the vertebrate track sites in Copper Canyon.

Bob Reynolds of the San Bernardino County Museum served as our mentor regarding paleontological resources in and around Death Valley National Park. Don Lofgren of the Raymond Alf Museum and Sam MacLeod of Los Angeles County Museum graciously provided information on specimens collected within Death Valley. Susan Sorrel proudly showed the authors fossil tracks near the southern end of Death Valley.

We appreciate the research efforts and suggestions from recent park researchers Dave Elliott, Whitey Hagadorn, Richard Miller, Jeffrey Mount, Allison Palmer, Don Prothero, Benny Troxel, and Steve Walsh. Additional thanks to Arvid Aase, Shawn Duffy, David Hays, Clay Kyte, Kris Thompson, Mark Schroeder, Dru Martin, and Chris Mead who provided technical support in the assembly of this document. Moreover, we extend our appreciation to the staff of the National Park Service Geologic Resources Division including Dave Shaver and Bob Higgins. In particular, many thanks are extended to Tim Connors for assembling the complex stratigraphic data into a reader- friendly format.

Finally, the writers wish to give a special thanks to our families, Bianca, Luke and Jacob Santucci, and Brant and Vonda Nyborg who have endured our efforts across the country and into the field.

## STRATIGRAPHY

### Geological History

Geologically, Death Valley preserves the transition zone between the northern and southern parts of the Great Basin extensional province (Hamilton, 1969). The park is also situated within a right lateral, strike-slip fault system which is associated with the boundary between the North American Plate and the Pacific Plate (Sheehan, 1988).

The southern Great Basin contains a virtually vegetation-free expanse of well-exposed Proterozoic and Cambrian formations in the western American Cordillera. Within Death Valley National Park, in areas such as Emigrant Pass, Titanothere Canyon, Waucoba Springs, and a spectacular section on the west side of the Last Chance Range, these formations are exposed in a continuous series.

Proterozoic deposition is inferred to have occurred during an extensional phase in which basins and uplands were formed by block faulting. Emergent areas existed in the vicinity of the Resting Spring, Nopah, and Kingston Ranges and the Panamint, Funeral, and Black Mountains (Wright and Troxel, 1966). These highlands were bordered by alluvial fans and braided fluvial systems, carrying detritus into tidally influenced basins (Poole et al., 1992, p. 16).

Uniform and systematic facies changes and the development of mixed carbonate and siliclastic units in the late Proterozoic, indicate lowering of the source area accompanied by a eustatic rise in sea level. These strata record deposition in nearshore marine intertidal, supratidal, and fluvial environments (Gustadt, 1968; Marian, 1979; Maud, 1979).

A regressive event, believed to represent an eustatic sea level fall during the Early Cambrian, marks the termination of the dominantly siliclastic phase of early Paleozoic sedimentation (Palmer, 1981). Subsequent sea level rise was coupled with continued continental margin subsidence. The changes in sea level, related to lithospheric cooling (Bond and Kominz, 1984), brought Paleozoic marine sedimentation eastward onto the cratonic platform for the first time. Significant algal growth occurred along the margin of the carbonate shelf.

During regressions, widespread shaly or silty marker units punctuate the carbonate facies and gradually grade upward into an increasingly carbonate succession (Palmer and Halley, 1979). The largest of these siliclastic-carbonate units are referred to as “Grand Cycles” (Aitken, 1966, 1978).

The passive-margin, shallow-marine sedimentation that was established by the Early Cambrian (Stewart, 1970) continued with one brief regressive event into the middle Ordovician. Middle Cambrian to early Ordovician sedimentary rocks record the development of a widespread and persistent carbonate platform (Poole et al., 1992, p. 20).

Throughout much of the Cambrian to Early Triassic, deposition in the form of carbonates continued on a fairly stable continental shelf, where large-scale coral-algal reefs developed (Hildreth, 1976). From the Middle Cambrian to the Permian, limestone deposits dominate, interrupted by sporadic silt deposition. The sea, which had covered much of Death Valley since the Precambrian time, withdrew from the southern Great Basin as the Sierra Nevada Mountains developed into a volcanic chain (Gordon, 1964).

Folds and thrust faults developed during the Middle Triassic to latest Jurassic. Additionally, late Jurassic to Early Cretaceous metamorphism affected wide regions in Death Valley (D.M. Miller et al., 1992, p. 225). In the Cretaceous, large scale eastward thrusting imbricated the Cambrian sequences along with large pieces of the younger Paleozoic carbonates (Taylor and Palmer, 1981). Evidence suggests that between the Late Cretaceous and the Eocene, uplift and subsequent large-scale erosion was widespread throughout the southeastern Great Basin Province (D. M. Miller et al, 1992, p. 225).

The Cenozoic sedimentary deposits of Death Valley consist of numerous sequences of alluvial fan deposits, lacustrine-playa sediments, and volcanic flows (Hunt, 1975). During the Eocene, river and lake deposits accumulated in local basins. In the Miocene, ash flows and other tuffs derived largely from the area of the Nevada Test Site blanketed Death Valley. Tectonic activity during the Miocene impacted Paleozoic rocks from the Black Mountains, northern Funeral Mountains, and parts of the Panamint Range (Hildreth, 1976).

Hewett (1956) and Garfunkel (1974) originally believed the region of southeastern California was a persistently stable block during middle and late Tertiary time. Recent work however, has demonstrated that the Death Valley region has undergone Mesozoic contraction and Cenozoic extension (Chapin, 1971; D. M. Miller et al., 1992; Dokka, 1986; Glazner et al., 1988; Link et al., 1993, p. 529). Mapped and inferred right-lateral strike-slip fault zones, active during the Mesozoic and Cenozoic, have brought together upper Proterozoic to middle Paleozoic rocks with a maximum right-lateral displacement for the Furnace Creek Fault at 100 km (Poole et al., 1992, p. 15)

During the Miocene, tensional fracturing of the imbricated crust in the Great Basin along with substantial subaerial volcanism, propagated large scale north-south oriented listric normal faults. Many of the older Proterozoic/ Cambrian structural blocks were rotated into their present attitudes (Taylor and Palmer, 1981). Tertiary erosion of these fault blocks is characteristic of the pattern of basins and ranges seen today. Right lateral strike-slip faulting along general east-west strikes in the Late Tertiary, along with continued erosion of the Basin and Range Province, are the most recent earth-shaping forces.

Volcanism returns to Death Valley during the Pliocene in the Black Mountains and Greenwater range. Lakes and fans develop along the Furnace Creek, Confidence Hills, and Panamint fault valleys. Fan and playa sedimentation occurs in Copper Canyon and Towne Pass area (Hildreth, 1976). Eruptions of basaltic lava capped plateaus near Ryan, Towne Pass, and Panamint Springs (Hardy, 1988).

In the Quaternary, deepening of Death Valley and Panamint Valley continued with active faulting and land-sliding on the range fronts. During the Pleistocene glaciation, the surface of Lake Manly stood 600 feet above the floor of Death Valley. The lake was approximately 100 miles long when "glaciers occupied mountains within an expanded Death Valley drainage system" (Sharp and Glazner, 1997). Ubehebe Crater eruptions, along with continued faulting and tilting of ranges, occurred during the Holocene (Hildreth, 1976).

Today Death Valley consists of a linear series of long, narrow, north-south trending, fault bounded troughs which are bordered on both sides by lofty mountains. Figure 4 is a composite stratigraphic column for Death Valley National Park.

## Facies Changes in Death Valley National Park

Late Proterozoic and Early Cambrian strata outcrop extensively throughout the southeastern Great Basin. These strata represent two distinct facies within Death Valley National Park, the White-Inyo facies, and the Death Valley facies (Nelson, 1978; Palmer and Nelson, 1981). The Death Valley facies, comprises nine formations that represent a mix of nearshore shallow marine and fluvial sediments. This facies is exposed throughout the southeastern parts of the park. The White-Inyo facies represents a more offshore environment and is exposed in the northwestern part of the park (Diehl, 1979; Mount, 1980). The facies change takes place across a zone of faulting within the Last Chance Range. The White-Inyo facies incorporates the exposures of the type section of the Lower Cambrian Waucoban Series and is comprised of nine formations. Outcrops are found at the northwest boundary of the park, and at the entrance to Cucomungo Canyon. Regional variations across the boundaries of these two facies will not be discussed in this report; for a complete coverage see Mount and Signor (1989a).

The late Lower Cambrian and Middle Cambrian White-Inyo facies and the Death Valley facies consist of alternating units of siliclastic and carbonate strata. The facies record episodic shifts in shelf depositional conditions in response to Cambrian sea level fluctuations. These sea level changes are referred to as "Grand Cycles." The cycles are regionally correlative and uniform depositional facies sequences that are typically comprised of one to two distinct and traceable trilobite zones (Aitken, 1966, 1978; Fritz, 1972; Palmer and Halley, 1979; Mount and Signor, 1992).

Within the later Middle Cambrian Bonanza King Formation, the region became part of a carbonate platform on a passive continental margin (Stewart, 1972). During that time, the area contained within Death Valley National Park was almost completely submerged, and deposition was uniform across the entire park (Poole et al., 1992, p. 20). In this report, this unit forms the base of the Composite Death Valley National Park facies (Figure 4).

Figure 4: Stratigraphic nomenclature of sedimentary units in Death Valley National Park (adapted from Hall, 1971; Nelson, 1978; Taylor and Palmer, 1981; Poole et al., 1992; Link et al., 1993; Hagadorn, personal communication, 1999).

| Era | Period | Epoch | Geologic Units in Composite Death Valley National Park facies: White-Inyo Facies | Geologic Units in Composite Death Valley National Park facies: Death Valley Facies |
|---|---|---|---|---|
| Cenozoic | Quaternary (1.8 to recent) | Holocene | Alluvial fan and lacustrine deposits | Alluvial fan and lacustrine deposits |
| | | Pleistocene | | |
| | | Pleistocene | Funeral Fm. | Funeral Fm. |
| | Tertiary (65 to 1.8 mya) | Pliocene | | |
| | | Miocene | Copper Canyon Fm. | Copper Canyon Fm. |
| | | | Furnace Creek Fm. | Furnace Creek Fm. |
| | | | Artist Drive Fm. | Artist Drive Fm. |
| | | Eocene | Titus Canyon Fm. | Titus Canyon Fm. |
| Paleozoic | Permian (286 to 245 mya) | | Owens Valley Fm. | Owens Valley Fm. |
| | | | Tihvipah Fm. Keeler Canyon Fm. | Tihvipah Fm. Keeler Canyon Fm. |
| | Pennsylvanian (325 to 286 mya) | | | |
| | | | Rest Spring Shale Lee Flat Limestone | Rest Spring Shale Lee Flat Limestone |
| | Mississippian (360 to 286 mya) | | Perdido Fm. | Perdido Fm. |
| | | | Tin Mountain Limestone | Tin Mountain Limestone |
| | Devonian (410 to 360 mya) | Upper | Lost Burro Fm. | Lost Burro Fm. |
| | | Middle | | |
| | | | Hidden Valley Dolomite | Hidden Valley Dolomite |
| | Silurian (440 to 410 mya) | | | |
| | Ordovician (505 to 440 mya) | | Ely Springs Dolomite | Ely Springs Dolomite |
| | | | Eureka Quartzite | Eureka Quartzite |
| | | | Pogonip Group | Pogonip Group |
| | Cambrian (544 to 505 mya) | Upper | Nopah Fm. | Nopah Fm. |
| | | Middle | Bonanza King Fm. | Bonanza King Fm. |
| | | | Monola Fm. | Carrara Fm. |
| | | Lower | Mule Spring Limestone | |
| | | | Saline Valley Fm. | |
| | | | Harkless Fm. | Zabriskie Quartzite |
| | | | Poleta FM. | Upper Wood Canyon Fm. |
| | | | Campito Fm. | Middle Wood Canyon Fm. |
| Neoproterozoic (900 to 544 mya) | | | Deep Spring Fm. | Lower Wood Canyon Fm. |
| | | | Reed Dolomite | Stirling Quartzite |
| | | | Wyman Fm. | Johnnie Fm. |
| | | | | Ibex Fm. |
| | | | | Noonday Dolomite |
| Mesoproterozoic (1600 to 900 mya) | | | | Pahrump Group: Kingston Peak Fm. |
| | | | | Pahrump Group: Beck Spring Dolomite |
| | | | | Pahrump Group: Crystal Spring Fm. |

**ROCK FORMATIONS EXPOSED IN DEATH VALLEY NATIONAL PARK**
Unit/Geologic Age, Lithology, and Representative Fossils
Geologic Units in the White-Inyo Facies
Exposures in northwest section of Death Valley

**Wyman Formation (Precambrian)**
Lithology: This formation consists of dark-gray phyllite and interbedded limestone/marble layers.
Fossils: Algae, trace fossils, including the trace fossil *Planolites* (Nelson, 1976), have been reported from the upper section of this formation (Alpert, 1976; Langille, 1974; Wiggett, 1975; Mount and Signor, 1985).

**Reed Dolomite Formation (Precambrian)**
Lithology: This formation consists of white to yellowish gray dolomite (Stewart, 1970), divided into lower, middle, and upper members (Nelson, 1962).
Fossils: Algae (Noble, 1934), the trace fossil *Planolites* (?), and tubular fossils have been reported from within this formation (Nelson, 1976). The problematic fossil *Wyattia* occurs in dolomites of the upper member (Taylor, 1966). Signor and Mount (1989) have reported laterally linked stromatolites from the lower member.

**Deep Spring Formation (Precambrian/Early Cambrian)**
Lithology:The formation represents a mixed carbonate-siliclastic depositional system (Parsons, 1996). This formation is divided into lower, middle, and upper members (Nelson, 1962). The Precambrian-Cambrian boundary has been established within the middle member of the Deep Spring Formation (Corsetti and Kaufmann, 1994; Runnegar et al., 1998; Parsons, 1996). This boundary has been determined by the presence of Neoproterozoic small shelly fossils, trace fossils, and carbon isotope stratigraphy.
Fossils: Stromatolites, the problematic fossil *Wyattia* (Cloud and Nelson, 1966; Nelson, 1976), a hyolith (Signor et al., 1989), and annelids (Signor and Mount, 1986) have been reported from the lowermost limestone member. A diverse pre-trilobite shelly assemblage (Signor and Mount; 1987; Signor et al., 1989) and trace fossils (Alpert 1975, 1976) including the first arthropod trace fossils *Rusophycus* and *Diplichnites* have been reported from this formation.

**Campito Formation (Early Cambrian)**
Lithology: This formation reflects a terrigenous clastic deposition (Mount, 1982), divided into two members, the Andrews Mountain Member and Montenegro Member (Nelson, 1962).
**Andrews Mountain Member**
Fossils: Olenellid trilobites (*Fallotaspis*) first appear within the middle of the member (Nelson, 1962). A number of ichnotaxa dominated by fodinichnid traces occur throughout the member (Alpert, 1975, 1976; Mount, 1982; Mount and Signor, 1992). Several body fossils have been reported by Signor and Mount (1989) from below the earliest trilobite occurrence. These early fossils include: the agglutinated fossil *Volborthella* ("*Campitius*") and the tubes *Platysolenites* and *Onuphionella*.
**Montenegro Member**
Fossils: The Montenegro member shows a steady increase and diversity in body fossils (Mount, 1982). Archaeocyathids (McKee and Gangloff, 1969), paiutitubulids, *Hyolithellis*, *Chancelloria*, *Microdictyon* (Onken and Signor, 1988), obolellid brachiopods (Mount, 1982), helicoplacoid echinoderms (Durham, 1993), hyolithids, trilobites, and trace fossils, (Nelson, 1976) are the most representative fossils within this member.

**Poleta Formation (Early Cambrian)**
Lithology: This formation is divided into three members and their lithologies are provided below (Nelson, 1976; Moore, 1976).
Fossils: McKee and Gangloff (1969) and Gangloff (1975) have reported large colonial-type archaeocyathids in carbonate beds throughout the formation.
**Lower Member**
Fossils: This member consists mainly of archaeocyathid-bearing bioclastic and biohermal limestone (Mount, 1982). Rowland (1978, 1979) divided the lower member into two general facies complexes: an oolitic shoal complex and a reef-lagoon complex. Archaeocyathids (McKee and Gangloff, 1969), hyolithid beds, eocrinoids (Firby and Durham, 1974), articulate brachiopods, and a small shelly fauna have been reported from this member (Onken and Signor, 1988; Signor and Mount, 1989).
**Middle Member**
Fossils: This member is a siliclastic dominated unit, with a trilobite bearing gray-green shale (Nelson, 1962). Within this member, archaeocyathids (McKee and Gangloff, 1969), hyoliths, brachiopods (Firby and Durham, 1974), edrioasteroids, eocrinoid plates, helicoplacoids (Nelson and Durham, 1966), and a diverse trilobite assemblage (Nelson, 1962; Seiple, 1984), have been reported.
**Upper Member**
Fossils: The upper member is a mottled blue-gray limestone (Nelson, 1962; Seiple, 1984). Archaeocyathids, trace fossils, and trilobites, are reported by McKee and Gangloff (1969) and Nelson (1976) from thin limestone beds within this member.

**Harkless Formation (Early Cambrian)**
Lithology: Within the Waucoba Springs section, the stratigraphic sequence consists of a dark gray to black siltstone, a massive brown vitreous quartzite, and a gray to gray-green siltstone shale (Nelson, 1962; Seiple, 1984). The formation is dominantly siliclastic with a lower carbonate unit.
Fossils: The carbonates at the base of the formation yield large archaeocyathids (McKee and Gangloff, 1969; Seiple, 1984). *Skolithos* are reported from the upper siltstone and quartzite layer (Signor and Mount, 1989). Brachiopods and the agglutinated fossil, *Salterella,* occur in a few of the siltstone layers (Signor and Mount, 1989). The trilobite *Paedeumias* occurs in the upper part of the formation (Nelson, 1976) and other fragmentary trilobites occur throughout the formation (Signor and Mount, 1989).

**Saline Valley Formation (Early Cambrian)**
Lithology: Massive buff to red-brown quartzite with minor beds of siltstone and sandy limestone are typical of the lower member. The upper member is a blend of brownish quartzite, gray silty shale, and sandy limestone (Nelson, 1962; Seiple, 1984).
Fossils: Trilobites occur in a olive green shale in the uppermost member of this unit (Firby and Durham, 1974; Seiple, 1984).

**Mule Spring Limestone Formation (Early Cambrian)**
Lithology: This is a dark blue to gray oncolitic limestone (Nelson, 1962; Seiple, 1984).
Fossils: Palmer and Nelson (1981) have identified the trilobites *Bristolia* and *Peachella* from the Mule Spring Limestone at Cucomungo Canyon. The alga *Girvanella* has been reported by Seiple (1984) from exposures at Waucoba Springs.

**Monola Formation (Middle Cambrian)**
Fossils: A diverse assemblage of trilobites have been reported from this formation (Nelson, 1976).

**ROCK FORMATIONS EXPOSED IN DEATH VALLEY NATIONAL PARK**

Unit/Geologic Age, Lithology, and Representative Fossils
Geologic Units in the Death Valley Facies
Exposures in south-east section of Death Valley

**Pahrump Group (Precambrian)**
Lithology: The Pahrump Group consists of a 3-4 km thick west to northwest trending sequence of carbonate and siliclastic strata (Hewitt, 1940; Wright and Troxel, 1966; Wright et al., 1974; Horodyski, 1993). This group consists of three formations: the Crystal Spring, Beck Spring, and Kingston Peak (Hewett, 1940).
Fossils: Cherts contain a diverse and well preserved assemblage of microfossils (Cloud et al., 1969; Licari, 1978).

**Crystal Spring Formation (Precambrian)**
Lithology: This formation consists of fan-delta and adjacent shallow marine deposits, which Roberts (1976) has divided into seven members.
Fossils: Stromatolites and poorly preserved filamentous microfossils have been reported from this formation (Howell, 1971; Roberts, 1976; Awramik et al., 1994). The middle member has been described by Roberts (1976) as “persistently stromatolite-bearing in a northern facies that occupies a belt from the Panamint Range to the Kingston Range.”

**Beck Spring Dolomite Formation (Precambrian)**
Lithology: This formation is divided into three informal members: a lower laminated member; a middle oolitic member; and an upper cherty stromatolitic member (Gustadt, 1968). Gustadt (1968) has interpreted this formation as a shallow marine environment.
Fossils: Stratiform stromatolites have been estimated to make up nearly 70% of this formation (Tucker, 1983). Abundant filamentous and spherical algal nannofossils (stromatolites) of at least 5 genera have been reported from upper member (Licari 1978).

**Kingston Peak Formation (Precambrian)**
Lithology: This formation is dominantly siliciclastic with several diamictite, and rare carbonate beds (Awramik et al., 1994). Awramik and others (1994) have interpreted this formation to be glacial in origin. Trough cross-bedded pebbly sandstones record braided fluvial and alluvial-fan deposition (Poole et al., 1992), which developed during extensional tectonics (R. H. Miller, 1985) under glacial conditions (R. H. Miller, 1982, 1985). R. H. Miller (1982) has divided the Kingston Peak Formation into four members.
Fossils: Eukaryotic taxa of algal affinity, along with “curious carbonate crusts” have been reported from the lower Kingston Peak chert (Pierce et al, 1994). Pierce and others (1994) believe that lower chert may contain at least 17 taxa of microfossils. Thin carbonate beds within the diamictite contain small columnar stromatolites, oncolites, and a silicified microbiota (Awramik et al., 1994).

**Noonday Dolomite Formation (Precambrian)**
Lithology: The Noonday Dolomite consists of algal, cryptalgal, and clastic dolostone that record deposition on a shallow-marine carbonate platform (Wright et al., 1978). This unit consists of a lower member of very finely crystalline, laminated, and relatively pure dolomite, and an upper member of silty dolomite, siltstone, and stromatolitic dolomite (Williams et al., 1976; Wright et al., 1978). The Noonday Dolomite it has been divided into three members (Cloud et al., 1974).
Fossils: Large domal stromatolites occur throughout this carbonate unit. Very large vertical tubes and concentrically banded algal mounds have been reported from the lower dolomite member (Wright et al., 1978).

**Ibex Formation (Precambrian)**
Lithology: This formation consists of thinly bedded siltstones and limestones, divided into four informal members (Wright et al., 1981). The Ibex Formation consists of a basal conglomerate derived from the Noonday Dolomite (Wright and Troxel, 1984). No fossils have been reported from this formation.

**Johnnie Formation (Precambrian)**
Lithology: This formation is a mixed carbonate and siliclastic sequence, believed to have been deposited in a shallow near-shore setting (Summa et al., 1991, 1993). Moore (1974) has separated this formation into a southern and northern facies.
Fossils: Three groups of stromatolites have been reported by Cloud and others (1969), within dolostones in the uppermost section of the formation (Summa et al., 1991). The lower carbonate member consists of domical and branching forms of stromatolites (Awramik et al., 1994).

**Stirling Quartzite Formation (Precambrian)**
Lithology: This unit represents interbedded fluvial and marine sequences (Hagadorn, personal communication, 1999). The formation consists of fine-grained, cross-stratified, locally conglomeratic sandstone, containing a medial interval of siltstone and carbonate rocks (Wertz, 1977, 1982). Stewart (1970) divided this formation into five informal members - A through E, from exposures throughout the Panamint Range, Funeral Mountains, and Starvation/Johnson Canyons.
Fossils: In the Funeral Mountains, the dolomite D member contains1 conical calcareous fossils, including the metazoan small shelly fossil *Cloudina* (Langille, 1974). Rare occurrences of the trace fossil *Planolites* have been reported from the E member (Wertz, 1982, 1983).

**Wood Canyon Formation (Precambrian/Early Cambrian)**
Lithology: The Precambrian-Cambrian boundary has been placed within the lowest section of the lower member of the Wood Canyon Formation (Horodyski, 1991; Corsetti, 1993; Horodyski et al., 1994; Runnegar et al., 1995, Runnegar, 1998). Exposures have been reported from the Panamint and Funeral Mountains, and along Blackwater and Echo Canyons (Hunt, 1975). The formation is divided into three informal members: a lower and upper brownish-weathering dolomite/limestone and a quartzite middle member (Stewart, 1966; Diehl, 1976). The lower member represents high water stand deposition with carbonate intervals (Prave et al., 1991; Horodyski et al., 1994; Runnegar et al., 1995). The uppermost carbonate bed of the lower member is overlain by the fluvially-dominated terrestrial braidplain and braid-delta facies of the middle member (Diehl, 1979; Fedo and Prave, 1991). The upper member represents dominately marine deposition (Fedo and Cooper, 1990), with abundant body and trace fossils typical of the Early Cambrian (Hunt, 1990; Fedo and Prave, 1991; Mount et al., 1991).
Fossils: Ediacaran fossils occur in the lowermost Wood Canyon Formation (Horodyski, 1993; refer to Paleontological Resources Near Death Valley of this report). Trace fossils are common throughout the siltstone beds, with Early Cambrian olenellid trilobites and *Skolithos* tubes in abundance in the upper member (Stewart, 1970). Signor and Savarese (1988) have reported trilobites, echinoderms, and hyoliths occurring in green siltstones that crop out above the archaeocyathan and olenellid-bearing limestones. Helicoplacoid echinoderms (Durham, 1993), and brachiopod molds and casts have also been reported from the upper member (Mount, 1982).

**Zabriske Quartzite Formation (Early Cambrian)**
Lithology: This formation consists of a light-colored, cliff forming quartzite, divided into two members: the upper Emigrant Pass Member, and the lower, informal, Resting Spring Member (Prave, 1988; Palmer and Halley, 1979). This formation outcrops extensively in the Panamint/Funeral Mountains, and along the Resting Spring Range.
Fossils: This formation consists of nearshore and foreshore deposits where ichnofossils including *Skolithos* tubes and some interbedded bioturbated siltstone have been collected (Prave and Wright, 1986; Prave, 1988).

**Carrara Formation (Early Cambrian)**
Lithology: The Carrara Formation is divided into nine members based on alternating siliclastic and carbonate facies (Palmer and Halley, 1979). The lower four members, and lower part of the fifth member, contain Early Cambrian olenellid trilobites. The remaining members contain a variety of Middle Cambrian trilobites. This formation contains one of the best stratigraphically documented trilobite faunas in North America. Four trilobite zones have been identified which span the Lower to Middle Cambrian boundary (Palmer and Halley, 1979).
Fossils: Concentrically structured algal ovoids (McAllister, 1970), columnar and branching stromatolites (Awramik et al, 1994), *Girvanella*, trilobites (Palmer and Halley, 1979), and the trace fossils: *Planolites*, *Cruziana*, *Rusophycus* (Bates, 1965), have been reported from this formation.
**Eagle Mountain Member**
Lithology: This member consists of a slope-forming green to gray-brown silty shale.
Fossils: This member is poorly fossiliferous, with only two species of *Olenellus* reported from the basal few meters at Titanothere and Echo Canyon (Palmer and Halley, 1979).

**Wood Canyon Formation (Precambrian/Early Cambrian)**
Lithology: The Precambrian-Cambrian boundary has been placed within the lowest section of the lower member of the Wood Canyon Formation (Horodyski, 1991; Corsetti, 1993; Horodyski et al., 1994; Runnegar et al., 1995, Runnegar, 1998). Exposures have been reported from the Panamint and Funeral Mountains, and along Blackwater and Echo Canyons (Hunt, 1975). The formation is divided into three informal members: a lower and upper brownish-weathering dolomite/limestone and a quartzite middle member (Stewart, 1966; Diehl, 1976). The lower member represents high water stand deposition with carbonate intervals (Prave et al., 1991; Horodyski et al., 1994; Runnegar et al., 1995). The uppermost carbonate bed of the lower member is overlain by the fluvially-dominated terrestrial braidplain and braid-delta facies of the middle member (Diehl, 1979; Fedo and Prave, 1991). The upper member represents dominately marine deposition (Fedo and Cooper, 1990), with abundant body and trace fossils typical of the Early Cambrian (Hunt, 1990; Fedo and Prave, 1991; Mount et al., 1991).
Fossils: Ediacaran fossils occur in the lowermost Wood Canyon Formation (Horodyski, 1993; refer to Paleontological Resources Near Death Valley of this report). Trace fossils are common throughout the siltstone beds, with Early Cambrian olenellid trilobites and *Skolithos* tubes in abundance in the upper member (Stewart, 1970). Signor and Savarese (1988) have reported trilobites, echinoderms, and hyoliths occurring in green siltstones that crop out above the archaeocyathan and olenellid-bearing limestones. Helicoplacoid echinoderms (Durham, 1993), and brachiopod molds and casts have also been reported from the upper member (Mount, 1982).

**Zabriske Quartzite Formation (Early Cambrian)**
Lithology: This formation consists of a light-colored, cliff forming quartzite, divided into two members: the upper Emigrant Pass Member, and the lower, informal, Resting Spring Member (Prave, 1988; Palmer and Halley, 1979). This formation outcrops extensively in the Panamint/Funeral Mountains, and along the Resting Spring Range.
Fossils: This formation consists of nearshore and foreshore deposits where ichnofossils including *Skolithos* tubes and some interbedded bioturbated siltstone have been collected (Prave and Wright, 1986; Prave, 1988).

**Carrara Formation (Early Cambrian)**
Lithology: The Carrara Formation is divided into nine members based on alternating siliclastic and carbonate facies (Palmer and Halley, 1979). The lower four members, and lower part of the fifth member, contain Early Cambrian olenellid trilobites. The remaining members contain a variety of Middle Cambrian trilobites. This formation contains one of the best stratigraphically documented trilobite faunas in North America. Four trilobite zones have been identified which span the Lower to Middle Cambrian boundary (Palmer and Halley, 1979).
Fossils: Concentrically structured algal ovoids (McAllister, 1970), columnar and branching stromatolites (Awramik et al, 1994), *Girvanella*, trilobites (Palmer and Halley, 1979), and the trace fossils: *Planolites*, *Cruziana*, *Rusophycus* (Bates, 1965), have been reported from this formation.
**Eagle Mountain Member**
Lithology: This member consists of a slope-forming green to gray-brown silty shale.
Fossils: This member is poorly fossiliferous, with only two species of *Olenellus* reported from the basal few meters at Titanothere and Echo Canyon (Palmer and Halley, 1979).

**ROCK FORMATIONS EXPOSED IN DEATH VALLEY NATIONAL PARK**
Unit/Geologic Age, Lithology and Representative Fossils
Geologic Units in the Composite Death Valley National Park Facies
Exposed throughout Death Valley National Park

**Bonanza King Formation (Middle Cambrian)**
Lithology: This formation is exposed throughout Death Valley National Park (McAllister, 1952; Sears, 1955; Hall, 1971). Hardy (1988) has divided the formation into three members.
Papoose Lake Member Fossils: The contact between the Nopah and Bonanza King Formation is well marked within the Death Valley area by a fossiliferous shale (Hardy, 1988), which contains the trilobite *Glossopleura* (Hall, 1971).
Informal Middle Member Fossils: Trilobite “hash beds”, with numerous fragments of *Ehmaniella*, and linguloid brachiopod beds occur within a shale layer (Hunt, 1975).
Banded Mountain Member: No fossils reported.

**Nopah Formation (Upper Cambrian)**
Lithology: The Nopah Formation is a large, cliff-forming carbonate unit which outcrops extensively throughout Death Valley National Park (Hall, 1971). Within the Death Valley area, the formation is divided into three members: the Dunderberg, Halfpint, and Smokey members (Cooper et al., 1982; Barnes and Christiansen, 1967).
Fossils: Basal shale and silty limestone beds of this formation, are persistently fossiliferous, characterized by trilobites, conodonts, and the brachiopod *Linnarssonella* (Hunt and Mabey, 1966; Hall, 1971). Trilobites have also been reported within the Ash Meadows area (Denny and Drewes, 1965).
**Dunderberg/Halfpint Members**
Lithology: Cooper and others (1982) divided these two members into seven distinct lithofacies from a study area in southeastern California and Nevada.
Fossils: The sponge *Hintzespongia* (?), spicule-like elements of *Chancelloria,* eocrinoid fragments, lingulid and acrotretid brachiopods, trilobites, and single-element species of paraconodonts and protoconodont have been reported from these members (Hazzard, 1937; Cooper et al., 1982).
**Smokey Member**
Lithology: This member is characterized by the black and buff colored banded dolomite (Barnes and Christiansen, 1967).
Fossils: Stromatolites and thrombolites are found within pelletal packstones and grainstones (Griffin, 1987). A dark dolomite above the middle of the Nopah Formation contains small-silicified Trempleauan gastropods, a singular problematic mollusk, *Matthevia* (Yochelson and Taylor, 1974; Stinchbomb and Darrough, 1995), and trilobites (Barnes and Christiansen, 1967; Hunt, 1975).

**Pogonip Group (Ordovician)**
Lithology: Nolan, Merriam and Williams (1956) divided the Pogonip Group into three members: the Goodwin, Ninemile, and Antelope Valley Limestone. These members represent a series of Ordovician carbonates, with a prominent and fossiliferous upper, cliff-forming limestone/dolomite member (Antelope Valley Limestone).
Fossils: Two primary fossil assemblages occur within the Grapevine Mountain region. The stratigraphically lower assemblage is dominated by trilobites and brachiopods. The stratigraphically higher assemblage is dominated by receptaculitids, the large gastropods *Palliseria robusta, Macrulites,* orthoconic and coiled nautiloids, and a species of graptolite (Foster, 1961). Receptaculites, echinoderm plates and oncolitic algae(?) occur in this formation at Dolomite Canyon (Hall, 1971). Trilobites, orthid brachiopods (Hunt, 1975), the mollusk *Ctenodonta*, and conodonts (R. H. Miller, 1982) have also been reported from this unit.

**Eureka Quartzite Formation (Ordovician)**
No fossils reported.

**Ely Springs Dolomite Formation (Ordovician/Silurian)**
Lithology: Exposures in Death Valley consist of a lower dark gray cherty dolomite and an upper light gray dolomite (Hall, 1971).
Fossils: The base of the lower unit is fossiliferous, consisting of silicified rhynchonellid brachiopods, conodonts, streptelasmid corals, and *Halysites* (Hall, 1971; R. H. Miller, 1982). At Lake Hill, the lower unit contains the cephalopod *Armenoceras* and several species of the brachiopod *Lepidocyclus* (Hall, 1971).

**Hidden Valley Dolomite Formation (Silurian/Devonian)**
Lithology: McAllister (1952) has divided this formation into three informal units.
Fossils: *Halysites, Favosites*, *Syringopora*, rugose corals, articulate brachiopods, conodonts, and crinoid debris have been reported from the lower cherty unit (Hazzard, 1937, 1954; Hunt, 1975; Haug, 1981; R. H. Miller and Hanna, 1972). *Pananmintaspis* and *Blieckaspis,* along with other pteraspidids, have been reported from the Lippincott Member, from exposures in the Trail Canyon area (Elliot and Ilyes, 1993, 1996a, 1996b).

**Lost Burro Formation (Middle/Upper Devonian)**
Lithology: McAllister (1952) identified five units within this formation.
Fossils: The middle member is characterized by the brachiopods *Cyrtospirifer, and Stringocephalus*, the stromatoporoids *Amphipora* and *Stromatopora,* and cladoporoid corals (Hall, 1971; McAllister, 1974). Youngquist and Heinrich (1966) reported conodonts, microgastropod steinkerns, sponge spicules, and fish remains from the uppermost unit. Denny and Drewes (1965) have reported crinoidal columns from the Ash Meadow area. Hunt (1975) has reported the occurrence of *Syringopora* from within this formation. The placoderm *Dunkleosteus*, a small cladodont, and cochliodont tooth have been reported from within this formation (Dunkle and Lane, 1971).

**Lippincott Member**
Lithology: This member is identified as a cherty argillaceous unit (Johnson et al., 1988).
Fossils: Elliott and Ilyes (1993, 1996a, 1996b) have reported Lower Devonian fish, the pteraspidids *Blieckaspis* and *Panamintaspis* from the Trail Canyon area. Denny and Drewes (1965) report crinoidal columnals, fragments of cephalopods, and gastropods from the Ash Meadow area.

**Tin Mountain Limestone Formation (Mississippian)**
Lithology: This formation consists of a lower lagoonal or mudflat limestone. Above this unit is an upper crinoidal limestone, which was deposited on an offshore bar or bank (Langenheim and Tischler, 1959).
Fossils: The upper part of this limestone is highly fossiliferous and characterized by the corals *Syringopora* and *Zaphrentites* (Hall, 1971). Other paleontological resources in this formation include: foraminifera, coelenterates, solitary/colonial corals, bryozoan, goniatite and orthceroid cephalopods, gastropods, pelecypods, crinoid stems, brachiopods, phillipsid trilobites, an annelid worm, and petrified wood (Peck, 1950; Denny and Drewes, 1965; Langenheim and Tischler, 1959; Hall, 1971; Hunt, 1975).

**Perdido Formation (Mississippian)**
Lithology: This formation consists of lower limestone and an upper siltstone members (Hall, 1971).
Fossils: The lower section of this formation contains Early Mississippian coral and the cephalopod *Cravenoceras* (Gordon, 1964). A hapsiphyllid tetracoral, *Triplophyllites* was collected immediately south of Rest Spring (Tischler 1956). Foraminifera (McAllister, 1970) and crinoid columns (Hall, 1971) have also been reported from this formation. Several thin limestone layers near the top of the formation at Quartz Spring are fossiliferous. Goniatite coquina beds, formed chiefly of the cephalopod *Cravenoceras hesperiam,* occur within this formation (Tischler, 1955; Gordon, 1964).

**Lee Flat Limestone Formation (Mississippian/Pennsylvanian)**
Lithology: This formation consists of white to light gray marble, which forms the prominent white bands north of Dolomite Canyon on the west face of the Panamint Range (Hall, 1971).
Fossils: Crinoid columnals are abundant within this limestone unit (Hall, 1971).

**Rest Spring Shale Formation (Mississippian/Pennsylvanian)**
Lithology: This formation consists of siltstone/shale exposures in northern part of Panamint Range in the Tucki Mountain Region.
Fossils: A poorly preserved brachiopod assemblage has been reported from exposures within this formation (Hunt and Mabey, 1966).

**Keeler Canyon Formation (Pennsylvanian/Permian)**
Lithology: This formation consists of alternating bluish-gray limestone and thin light-gray bands of marble (Hall, 1971).
Fossils: Fusilinids and crinoid columnals are found within the uppermost section of this formation. The middle section contains bryozoans and some brachiopods, while the lower section has no fossils reported (Hall, 1971).

**Tihvipah Formation (Pennsylvanian/Permian)**
Lithology: This formation consists of light gray limestone with spherical concretionary chert nodules (McAllister, 1952).
Fossils: The cephalopods: *Bisatoceras* and *Stenopronorites*, and scattered lenses of fusilinids have been reported by Gordon (1964) from exposures within this formation.

**Owens Valley Formation (Permian)**
Lithology: This formation consists of limestone, siltstone, and shale units (Hall, 1971).
Fossils: The fusilinids *Schwagerina* and *Pseudoschwagerina*, solitary corals, bryozoans, and gastropods have been reported from this formation (Hall, 1971).

**Titus Canyon Formation (Eocene)**
Lithology: This formation consists of conglomerates, sandstones, calcareous mudstones, algal limestones, and tuffaceous sandstones.
Fossils: Fossil mammals including: *Protitanops*, *Mesohippus*, *Colodon*, *Teletaceras*, *Protoreodon*, *Pambromylus*, and *Leptomeryx* have been recovered from a red calcareous mudstone in the lower section of this formation (Stock and Bode, 1935). *Fundulus* and *Cyprinodon* osteichthyes fish were collected by H. Donald Curry and reported by R. R. Miller (1945) from this formation. A number of turtle scutes, and rodent teeth and skull have also been reported by Stock (1949) from exposures within this formation.

**Artist Drive Formation (Miocene)**
Lithology: This formation has been divided into five informal divisions within the Furnace Creek area (McAllister, 1970).
Fossils: Diatoms occur within this formation (Cemen et al., 1985; Hardy, 1988).

**Furnace Creek Formation (Miocene)**
Lithology: This formation is divided into four members (Hardy, 1988).
Fossils: Diatoms and plants indicate a Miocene age for the Furnace Creek Formation (Hardy, 1988). The remains of a lateral leaf lobe *Lyonothamnus mohavensis* has been reported from the upper section of this formation (Axelrod, 1940). Stromatolites occur at several localities within the limestone deposits of the formation (Noble, 1934; Pitts, 1983; Awramik et al.,1994).

**Copper Canyon Formation (late Miocene)**
Lithology: This formation consists of basalt, alluvial and lacustrine deposits (Scrivner, 1984).
Fossils: Curry (1939, 1941), Scrivner (1984), Scrivner and Bottjer (1986), Santucci (1998), and Nyborg (1998) report on the abundant fossil vertebrate tracks preserved in the lacustrine strata within Copper Canyon.

**Funeral Formation (Pliocene/Pleistocene)**
Lithology: This formation consists predominately of cemented fan gravel, exposed in the Furnace Creek, Artist Drive, Mormon Point, and Emigrant Wash areas (Hardy, 1988). McAllister (1970) has divided this formation into two members. No fossils have been reported from this formation.

**Pleistocene & Holocene Deposits**
Lithology: Pleistocene and Holocene lacustrine and alluvial fan deposits occur throughout Death Valley.
Fossils: Clements (1973) has reported a partial mastodon tusk from within sedimentary deposits of Lake Rogers deposits.

# PALEONTOLOGICAL RESOURCES INVENTORY

This section provides a taxonomic inventory of paleontological resources from localities within Death Valley National Park. A more comprehensive list of fossil taxa are provided in appendix A of this report.

## Paleobotany

**Wyman Formation/Reed Dolomite (Precambrian).** —Algae have been reported from these formations by Firby and Durham (1974).

**Reed Dolomite (Precambrian)**. —Algae (Noble, 1934) and laterally linked stromatolites occur within the lower member of this formation (Signor and Mount, 1989).

**Deep Spring Formation (Precambrian)**. —Algae (Firby and Durham, 1974), the trace fossil *Plagiogmus*(?), and stromatolites (Nelson , 1976) are reported from this unit.

**Crystal Spring Formation (Precambrian)**. —The stromatolites: *Baicalia*, *Jacutophyton*, and *Conophyton*, along with poorly preserved filamentous microfossils have been reported from this formation (Howell, 1971; Roberts, 1976; Awramik et al., 1994).

**Beck Spring Dolomite (Precambrian)**. —Abundant filamentous and spheroidal algal nannofossils, cyst-like bodies of uncertain biogenicity, and partially silicified stromatolites have been reported from exposures in the Panamint Range (Licari, 1978). *Baicalia*, *Conophyton*, domical forms, and a variety of wavy-laminted to stratiform stromatolites have also been reported (Marian, 1979; Marian and Osborne, 1992).

**Noonday Dolomite (Precambrian)**. —Large domal stromatolites and very large vertical tubes are reported from the upper, middle and lower members (Cloud et al., 1974). Wright and others (1976) found that the lower dolomite member has concentrically banded algal mounds up to two hundred meters high and six hundred meters long.

**Johnnie Formation (Precambrian)**. —Stromatolites of the genera *Boxonia*, *Linella*, and *Paniscollenia* were identified by Cloud and others (1969) from exposures within this formation.

**Kingston Peak Formation (Precambrian)**. —Eukaryotic algae *Palaeosiphonella*, *Melanocryillium*, and a carbonate crust *Tenuocherta* were reported from the lower chert of this formation (Pierce et al., 1994). Thin carbonate beds within a diamictite layer contain small columnar stromatolites, oncolites, and a silicified microbiota (Awramik et al., 1994).

**Carrara Formation (Cambrian)**. —Oncolites generally formed by algae have been reported (McAllister, 1970). Stromatolites have also been reported from the Thimble Member of this formation (Palmer and Halley, 1979).

**Mule Spring Limestone (Cambrian)**. —Abundant fossil algae of the group *Girvanella*(?) occur within this formation (Seiple, 1984).

**Pogonip Group (Ordovician)**. —Oncolites were reported by Hall (1971) from the Pogonip Group in the vicinity of Dolomite Canyon and Lake Hill. Receptaculitids have been reported from exposures within the Grapevine Mountain region at several localities (Foster, 1961) and within the vicinity of Dolomite Canyon and south of Lake Hill (Hall, 1971).

**Tin Mountain Limestone (Mississippian)**. —Fossilized wood has been reported by Peck (1950) from exposures within this formation.

**Titus Canyon Formation (Eocene)**. —A distinct horizon of yellow and blue-gray algal limestones occurs in the middle section of this formation. This section has been referred to as the Algal Limestone Zone (Stock and Bode, 1935).

**Furnace Creek Formation (Miocene)**. —H. Donald Curry collected a lateral leaf lobe of a plant (Rosacea) identified as *Lyonothamnus mohavensis* in the upper portion of this formation. This species had a wide distribution throughout the western United States during the middle and late Tertiary. The genus is extant today on the Channel Islands off the California coast. The fossil specimen was found in association with some indeterminate grass-like or reed-like plants (Axelrod, 1940). These plants were first reported on by Spurr (1903). Stromatolites have also been reported within the limestone beds of this formation (Noble, 1934; Awramik et al., 1994).

**Ash Meadow area**. —An unnamed limestone and shale bed within the Tertiary formations of the Ash Meadow area contain algal markings and silicified plant stems within a cliff forming limestone unit (Denny and Drewes, 1965).

**Greenwater townsite**. —Fossil packrat midden collections near the Greenwater townsite have yielded many Holocene plant microfossils (Woodcook, 1986).

## Fossil Invertebrates

### Kingdom Protista

**Pahrump Group (Precambrian)**. —Microfossils have been reported from exposures within this unit (Cloud et. al, 1969; Licari, 1978).

**Tin Mountain Limestone (Mississippian)**. —Eight species of foraminifera have been reported by McAllister (1974) from exposures within this formation.

**Perdido Formation (Mississippian)**. —Nine species of foraminifera have been reported by McAllister (1974) from exposures within this formation.

**Keeler Canyon Formation (Pennsylvanian/Permian)**. —Fusulinids have been reported from the uppermost section of this formation (Hall, 1971).

**Tihvipah Limestone (Pennsylvanian/Permian)**. —Scattered lenses of fusulinids occur within this formation (Foster, 1961).

**Owens Valley Formation (Permian)**. —The fusulinids *Schwagerina* and *Pseudoschwagerina* have been reported (Hall, 1971) within the Panamint Range, exposed three miles north-northwest of Towne Pass under the Lemoigne thrust.

**Artist Drive/Furnace Creek Formation (Miocene)**. —Diatoms have been reported by Hardy (1988) from exposures within these formations.

## Kingdom Animalia

### Phylum Porifera

**Nopah Formation (Cambrian)**. —Spicule-like elements of *Chancelloria* and spicules from the sponge *Hintzespongia* (?) have been reported by Cooper and others (1982) from the Dunderberg Shale and Halfpint members of this formation.

**Lost Burro Formation (Devonian)**. —Sponge spicules occur within a conodont bed in the uppermost unit of this formation (Youngquist and Heinrich, 1966).

### Archaeocyatha

**Campito Formation (Cambrian)**. —Within the Waucoba Springs area, seventeen species of fifteen genera of archaeocyathids, have been identified by McKee and Gangloff (1969).

**Poleta Formation (Cambrian)**. —The most extensive archaeocyathid-bearing carbonate units have been reported from exposures within this formation (Gangloff, 1975).

**Harkless Formation (Cambrian)**. —Four genera of large, solitary archaeocyathids have been reported from exposures within this formation (McKee and Gangloff, 1969), including a large archaeocyathid genus *Cascinocyathus* (Seiple, 1984).

**Wood Canyon Formation (Cambrian)**. —Poorly preserved archaeocyathid specimens have been reported from exposures within the Grapevine Mountains (McAllister, 1970).

### Phylum Cnidaria

**Ely Springs Dolomite (Ordovician)**. —Streptelasmid corals and *Halysites* have been reported by from exposures within this formation (R. H. Miller, 1982).

**Echo Canyon**. —A middle Silurian assemblage of rugose and tabulate corals from an unnamed tributary northeast of Echo Canyon have been reported by Easton (1955).

**Hidden Valley Dolomite (Silurian/Devonian)**. —R. H. Miller and Hanna (1972) have reported the silicified corals *Halysites*, *Favosites*, *Syringopora*, and rugose corals from collections made at Lost Burro Gap (Hazzard, 1937, 1954; Haug, 1981).

**Lost Burro Formation (Devonian)**. —Cladoporoid corals from the middle section have been reported by Hall (1971). Hunt (1975) has also reported the occurrence of *Syringopora* from exposures within this formation. At Lost Burro Gap, within the Quartz Spring area, the middle section of the formation contains abundant stromatoporoids of the genus *Amphipora* and *Stromatopora* (Hall, 1971).

**Tin Mountain Limestone (Mississippian)**. —The upper section is highly fossiliferous, and is characterized by the corals *Syringopora* and *Zaphrentites* (Hall, 1971). At Town Pass and Lake Hill fourteen species of corals have been described by Hall (1971). Within the Rest Spring area, Peck (1950) has reported solitary and colonial forms of corals, and Langenheim and Tischler (1959) have reported several new species of coelenterates from within the Quartz Spring area. Corals are also common at the southernmost spur of the Funeral Mountains, in the Ash Meadow area (Denny and Drewes, 1965).

**Perdido Formation (Mississippian)**. —Outcrops in the vicinity of Panamint Canyon and Dolomite Canyon preserve a few poorly preserved solitary corals (Hall, 1971). A hapsiphyllid tetracoral, *Triplophyllites* was reported immediately south of Rest Spring (Tischler 1956).

**Owens Valley Formation (Permian)**. —Solitary corals have been reported within the Panamint Range, exposed three miles north-northwest of Town Pass under the Lemoigne thrust (Hall, 1971).

### Phylum Annelida

**Tin Mountain Limestone (Mississippian)**. —A species of the worm-like *Spirorbis* has been reported at Town Pass and at Lake Hill (Hall, 1971).

### Phylum Arthropoda

**Wood Canyon Formation (Cambrian)**. —Within exposures at Titanothere Canyon and the Daylight Pass area, olenellids (Figure 5) are common in the upper member (McAllister, 1970).

**Carrara Formation (Cambrian)**. —Contains the most complete representation of stratigraphically documented late Lower Cambrian and early Middle Cambrian trilobite faunal assemblages in North America. All nine members of the Carrara Formation preserve trilobites, making it one

Figure 5: Cambrian trilobite *Olenellus* sp. from Death Valley National Park.

of the most paleontological rich Cambrian formations in Death Valley (Palmer and Halley, 1979).

**Monola Formation (Cambrian)**. —A diverse trilobite assemblage from exposures within this formation has been reported by Nelson.

**Campito Formation (Cambrian)**. —The olenellid trilobite (*Fallotaspis*) first appears within the Andrews Mountain Member (Seiple, 1984). The Montenegro Member preserves a number of trilobites identified by McKee and Gangloff (1969) and Nelson (1976), including *Daguinaspis, Fallotaspis, Holmia, Holmiella,* "*Judomia*"*, Laudonia, and Nevadia,* from collections made from within the Waucoba Springs area.

**Poleta Formation (Cambrian)**. —Trilobites from the middle member include *Nevadella*, *Holmia*, *Fremontia*, *Laudonia*, and "*Judomia*" (McKee and Gangloff, 1969; Firby and Durham, 1974).

**Harkless Formation (Cambrian)**. —*Paedumias* and *Bonnia* have been reported from within this formation (Firby and Durham, 1974; Seiple, 1984).

**Saline Valley Formation (Cambrian)**. —An abundant trilobite assemblage including the genera: *Paedeumias, Bonnia, Bristolia, Fremontella*, *Ogygopsis, Olenellus, Olenoides*, and *Zacanthopsis* have been reported from the uppermost three meters of this formation (Firby and Durham, 1974; Seiple, 1984).

**Mule Spring Limestone (Cambrian)**. —Palmer and Nelson (1981) have identified the trilobites *Bristolia* and *Peachella* from exposures within this formation.

**Bonanza King Formation (Cambrian)**. —The trilobite *Glossopleura* occurs in the Papoose Lake Member (Hall, 1971), and Hunt (1975) has reported a trilobite assemblage within the middle shale layer. The trilobites *Alokistocare* and *Ehmania* occur within fossiliferous limestone beds at Ash Meadow (Denny and Drewes, 1965).

**Nopah Formation (Cambrian)**. —Cooper and others (1982) identified seventeen genera from thirty-six species of trilobites from the Dunderberg Shale and Halfpint members. This formation is dominated by two agnostid families, Agnostidae and Pseudagnostidae and by three nonagnostid subfamilies, Elviniiae, Aphelaspidinae and Pterocephaliinae. In the Ash Meadows area, several highly fossiliferous units, containing numerous trilobites, have been reported by Denny and Drewes (1965).

**Pogonip Group (Ordovician)**. —The trilobites *Protopliomerops* and *Kirkella* occur within the lower section (Hunt, 1975). Phillipsid trilobites at Towne Pass and at Lake Hill have been reported by Hall (1971), and several species of trilobites are reported by Foster (1961) from outcrops within the Grapevine Mountains.

## Phylum Mollusca

### Gastropods

**Reed Dolomite/Deep Spring Formation (Precambrian)**. —The pre-trilobite, problematic fossil *Wyattia* (Taylor, 1966) occurs in the upper Reed Dolomite and in the lowermost Deep Spring Formation (Cloud and Nelson, 1966). *Wyattia* is unknown outside of the White-Inyo facies (Signor et al., 1987).

**Nopah Formation (Cambrian)**. —The earliest gastropods include small silicified specimens preserved within this formation (Hardy, 1988).

**Pogonip Group (Ordovician)**. —The abundant and large gastropod *Palliseria robusta* and *Maclurites* occur within the Antelope Valley Limestone Member (Foster, 1961; Hunt, 1975; Hall, 1971). The mollusk *Ctenodonta* has been reported by R. H. Miller (1982) from this group.

**Lost Burro Formation (Devonian)**. —Microgastropod steinkerns are associated with a conodont-rich bed in the uppermost unit (Youngquist and Heinrich, 1966). Denny and Drewes (1965) have also reported gastropods from the uppermost unit in the Ash Meadow area.

**Tin Mountain Limestone (Mississippian)**. —At Town Pass and at Lake Hill fifteen species of gastropods have been reported by Hall (1971). Peck (1950) has also reported gastropods from exposures in the Rest Spring area.

**Owens Valley Formation (Permian)**. —Gastropods have been reported (Hall, 1971) within the Panamint Range, exposed three miles north-northwest of Towne Pass under the Lemoigne thrust.

## Cephalopods

**Harkless Formation (Cambrian)**. —The slender cephalopod(?) *Salterella* has been reported within the Waucoba Springs area (Seiple, 1984).

**Pogonip Group (Ordovician)**. —Orthoconic and coiled nautiloids from exposures within the Grapevine Mountains have been reported by Foster (1961).

**Ely Spring Dolomite (Ordovician)**. —At the base of the lower unit the cephalopod *Armenoceras* has been reported in the vicinity of Lake Hill (Hall, 1971).

**Lost Burro Formation (Devonian)**. —The uppermost section of the Lippincott Member contains fragments of cephalopods from collections made in the Ash Meadow area (Denny and Drewes, 1965).

**Perdido Formation (Mississippian)**. —Cephalopod-bearing beds are exposed in the Quartz Spring area. In the basal section of the Perdido Formation, concretions often contain the cephalopod *Cravenoceras merriami* (Gordon, 1964). Several thin limestone layers near the top of the formation are abundantly fossiliferous, with goniatite coquina beds formed chiefly of the cephalopod *Cravenoceras hesperiam* (Langenheim and Tischler, 1959).

**Tin Mountain Limestone (Devonian)**. —Goniatite and orthoceroid cephalods have been reported from exposures at Towne Pass and at Lake Hill (Hall, 1971).

**Tihvipah Limestone (Pennsylvanian/Permian)**. —The cephalopods: *Bisatoceras* and the partial specimen of *Stenopronorites* have been reported by Gordon (1964) from exposures within this formation.

## Pelecypods

**Pogonip Group (Ordovician)**. —The mollusk *Ctenodonta* has been reported from exposures within this formation (R. H. Miller, 1982).

**Tin Mountain Limestone (Mississippian)**. —Two species of pelecypods reported by Hall (1971) occur at Towne Pass and at Lake Hill. Pelecypods have also been reported from exposures in the Rest Spring/Quartz Spring area (McAllister, 1952).

## Phylum Brachiopoda

**Campito Formation (Cambrian)**. —Rowell (1977) has reported obolellid brachiopods in the upper part of the Montenegro Member. Brachiopods have also been reported from the Montenegro Member and Andrews Mountain Member (Firby and Durham, 1974; Mount, 1982).

**Wood Canyon Formation (Cambrian)**. —Brachiopod casts and molds have been reported by Mount (1982) from within the upper member.

**Poleta Formation (Cambrian)**. —McKee and Gangloff (1969) have reported brachiopods from the middle member. *Obolella* are abundant in the lower part of this formation (Rowell, 1977).

**Harkless Formation (Cambrian)**. —Brachiopods in a gray to gray-green siltstone and shale have been identified from exposures within the Waucoba Spring area (Seiple, 1984). *Obolella* is abundant in the lower section of this Formation (Rowell, 1977).

**Bonanza King Formation (Cambrian)**. —Linguloid brachiopods have been reported (Hunt, 1975) from within the middle part of this formation.

**Nopah Formation (Cambrian)**. —Acrotretid brachiopods of the genus *Linnarssonella* were reported by Hall (1971) from the north side of Dolomite Canyon. Cooper and others (1982) identified four species of lingulid and seven species of acrotretid brachiopods from the Dunderberg Shale and Halfpint Members of this formation.

**Pogonip Group (Ordovician)**. —The brachiopod *Anomalorthis* was reported by Hall (1971). Foster (1961) has reported on several species of brachiopods from exposures within the Grapevine Mountains.

**Ely Spring Dolomite (Ordovician)**. —At the base of the lower unit, silicified rhynchonellid brachiopods including *Zygospira*, *Paucicrura*, and *Plaesiomys,* have been identified. Several species of the brachiopod *Lepidocyclus* have been reported from exposures in the vicinity of Dolomite Canyon and the lower unit at Lake Hill (Hall, 1971).

**Hidden Valley Dolomite (Silurian/Devonian)**. —Brachiopods have been reported by Haug (1981) from exposures within this formation.

**Lost Burro Formation (Devonian)**. —The brachiopods *Cyrtospirifer*, *Stringocephalus*, and *Tentcospirifer* have been reported from exposures within this formation (Hall, 1971; McAllister, 1974).

**Tin Mountain Limestone (Mississippian)**. —Sixteen species of brachiopods at Towne Pass and at Lake Hill have been reported by Hall (1971). Brachiopods were collected from exposures in the Rest Spring area by Peck (1950), and at the southernmost spur of the Funeral Mountains (Denny and Drewes, 1965).

**Perdido Formation (Mississippian)**. —Brachiopods have been reported from exposures within the Quartz Spring area (Tischler, 1955; Gordon, 1964).

**Keeler Canyon Formation (Pennsylvanian/Permian)**. —Brachiopods have been reported from the middle section of this formation (Hall, 1971).

**Rest Spring Shale (Mississippian/Pennsylvanian)**. —A poorly preserved assemblage of brachiopods have been reported from exposures within this formation (Hunt and Mabey, 1966).

**Echo Canyon**. —Easton (1955) reported a middle Silurian assemblage of spirified, pentameroid, and rhynchonellid brachiopods from an unnamed tributary northeast of Echo Canyon.

### Phylum Bryozoa

**Tin Mountain Limestone (Mississippian)**. —Fenestellids and *Cystodictya* have been reported from exposures within the Tin Mountain Limestone (Peck, 1950; Langenheim, 1954; Hall, 1971).

**Keeler Canyon Formation (Pennsylvanian/Permian)**. —*Rhomborporella* has been reported from exposures within the middle section of the Keeler Canyon Formation (Hall, 1971).

### Phylum Echinodermata

**Wood Canyon Formation (Cambrian)**. —Helicoplacoid echinoderms (Durham, 1993) and other echinoderms (Signor et al., 1988) have been reported from exposures within this formation.

**Campito Formation (Cambrian)**. —Helicoplacoid echinoderms have been reported from the Montenegro Member of this formation (Taylor and Palmer, 1981; Onken and Signor, 1988; Durham, 1993).

**Carrara Formation (Cambrian)**. —Echinoderm fragments have been reported from the Pyramid Shale and Jangle Limestone members of this formation (Palmer and Halley, 1979).

**Poleta Formation (Cambrian)**. —Early Cambrian helicoplacoid echinoderms are most commonly found in the lower part of the middle member (Nelson, 1962). The lower member contains an edrioasteroid, and abundant disassociated plates of an eocrinoid (*Eocystites*?) (Nelson and Durham, 1966; Firby and Durham, 1974; Seiple, 1984).

**Nopah Formation (Cambrian)**. —Cooper and others (1982) have identified eocrinoid fragments from the Dunderberg Shale and Halfpint members of this formation.

**Pogonip Group (Ordovician)**. —Within the vicinity of Dolomite Canyon, unidentified echinoderm plates have been reported by Hall (1971). Foster (1961) has reported pelmatozoan columnals and cystoid plates from exposures at Grapevine Mountains.

**Hidden Valley Dolomite (Silurian/Devonian)**. —Abundant crinoid fragments have been reported by Hunt (1975) from exposures within this formation.

**Lost Burro Formation (Devonian)**. —Crinoid columnals have been reported from the uppermost section of the Lippincott Member in the vicinity of the Ash Meadow area (Denny and Drewes, 1965).

**Tin Mountain Limestone (Mississippian)**. —Crinoid stems have been reported by Hunt (1975) from exposures within this formation.

**Perdido Formation (Mississippian)**. —Exposures in Panamint Canyon and Dolomite Canyon contain crinoid columnals (Hall, 1971).

**Lee Flat Limestone (Mississippian/Pennsylvanian)**. —North of Dolomite Canyon, abundant crinoid columnals have been reported from this formation (Hall, 1971).

**Keeler Canyon Formation (Pennsylvanian/Permian)**. —Crinoid columnals are found within the uppermost section of this formation (Hall, 1971).

### Phylum Hemichordata

**Pogonip Group (Ordovician)**. —A species of graptolite was reported from exposures in the Grapevine Mountains (Foster, 1961).

### Incertae Sedis

**Deep Spring Formation (Precambrian)**. —Hyolithids have been reported from exposures within this formation (Signor and Saverase, 1988).

**Campito Formation (Precambrian)**. —Agglutinated tubes of *Platysolenites* and *Onuphionella*, and the *Volborthella*(?) ("*Campitius*") has been reported from exposures within this formation (Signor and Mount, 1989).

**Poleta Formation (Cambrian)**. —Hyolithid beds have been reported from the lower member of this formation (Onken and Signor, 1988).

**Wood Canyon Formation (Cambrian)**. —Hyolithids have been reported from exposures within this formation (Signor and Saverase, 1988).

**Nopah Formation (Cambrian)**. — *Matthevia* has been reported by Hardy (1988) from exposures within this formation. Historically this fossil has been assigned to different taxonomic placements as gastropods (Walcott, 1885) and chitons (Runnegar et al., 1979). Most recently, Stinchcomb and Darrough (1995) have classified it as a problematic mollusk.

### Pre-trilobite shelly fauna

**Deep Spring Formation (Precambrian)**. —A small shelly fauna has been reported from exposure within this formation (Onken and Signor, 1988), including the small shelly fossil *Cloudina* and associated shelly fossils *Nevadatubulus* and *Sinotubulites* (Parsons, 1996).

**Poleta Formation (Precambrian)**. —A small shelly fauna has been reported from exposures within this formation (Onken and Signor, 1988).

**Stirling Quartzite (Precambrian)**. —The Ediacaran Metazoan fossil *Cloudina* has been reported from exposures within this formation (Langille 1974).

## Fossil Vertebrates

### Phylum Chordata

**Nopah Formation (Cambrian)**. —Sixteen single-element species of paraconodonts with one species of protoconodont, comprising about seventy percent of the species of conodonts sampled from the Dunderberg Shale and Halfpint members have been identified by Cooper and others (1982) . Conodonts have also been reported by Hall (1971) on the north side of Dolomite Canyon.

**Pogonip Group (Ordovician)**. —Conodonts occur in the three members of this unit (R.H. Miller, 1982).

**Ely Spring Dolomite (Ordovician)**. —At the base of the lower unit the conodonts *Belodus*, *Paltodus*, *Plectodina*, were reported in the vicinity of Dolomite Canyon (Hall, 1971).

**Hidden Valley Dolomite (Silurian/Devonian)**. —R. H. Miller and Hanna (1972) have reported at least twenty-three species and fifteen genera of conodonts from collections made at Lost Burro Gap.

**Lost Burro Formation (Devonian)**. —Youngquist and Heinrich (1966) report conodonts from the uppermost sections of this formation.

### Class Pteraspidomorphi

**Lost Burro Formation (Devonian)**. —The remains of two genera and species of Devonian pteraspidids (agnathan fish) *Panamintaspis snowi* and *Blieckaspis priscillae* have been described from the Lippincott Member of this unit (Elliott and Ilyes, 1993, 1996a, 1996b). These vertebrates occur in a large channel cut into the Hidden Valley Dolomite. The specimens were collected from the Panamint Range in the Trail Canyon area. Additional indeterminate pteraspidid specimens were also collected in these Devonian sediments (Elliott and Ilyes, 1996a, 1996b).

### Class Placodermi

**Lost Burro Formation (Devonian)**. —Weathered disassociated remains of a Devonian arthrodire, cf. *Dunkleosteus terrelli,* have been reported from this unit within Cottonwood Mountain Region (Dunkle and Lane, 1971).

### Class Chondrichthyes

**Lost Burro Formation (Devonian)**. —A small cladodont shark tooth and cochliodont crushing tooth has been reported from this formation (Dunkle and Lane, 1971).

### Class Osteichthyes

**Titus Canyon Formation (Eocene)**. — Three type specimens, *Fundulus curryi*, *Fundulus eulepis*, and *Cyprinodon breviradius* were collected by Donald Curry within this formation in Titus Canyon (R. R. Miller, 1945).

### Class Reptilia

**Titus Canyon Formation (Eocene)**. —A number of turtle scutes were collected from this formation in Titus Canyon.

### Class Mammalia

#### Order Rodentia

**Titus Canyon Formation (Eocene)**. —A fragmentary left ramus representing a large species of paramyine rodent, a canid left ramus and fragmentary crown, and a nearly complete edentulous rodent skull was collected from deposits within this formation in Titus Canyon (Stock, 1949).

#### Order Perissodactyla

**Titus Canyon Formation (Eocene)**. —A few rare specimens of horse material, *Mesohippus*, were collected from the same horizon as the *Protitanops* specimen in Titus Canyon. A portion of the right mandible with molar teeth and right ramus of a *Colodon* was collected in the west fork of Titus Canyon (Stock, 1949). The holotype, *Teletaceras mortivallis* was collected from this unit in Titus Canyon. It is represented by a fragment of left ramus, teeth, and metapodial elements (Stock, 1949; Hanson 1989). Two titanotheres have been collected from deposits of this formation: the type specimen *Protitanops curryi*, and a poorly preserved portion of a possible menodontine titanothere skull (Stock, 1936).

"During the fall of 1934, Mr. Curry, while traveling over the little-used road between Rhyolite, Nevada, and the now deserted mining camp of Leadfield in Titus Canyon, Grapevine Mountains, saw and collected, in an outcrop of maroon or chocolate-colored, calcareous mudstones exposed in the face of a road-cut, a portion of a titanothere jaw with teeth. Later excavations (Figures 6) at this locality revealed additional lower jaw material as well as a splendidly preserved skull of a titanothere." (Stock and Bode, 1935).

### Order Artiodactyla

**Titus Canyon Formation (Eocene)**. —Several camel and camel-like specimens have been collected within this unit at Titus Canyon. These specimens include several individuals of agriochoerids, *Protoreodon transmontanus,* the type specimen *Poabromylus robustus* and two species of *Leptomeryx* (Stock, 1949; Mason, 1988).

### Other Vertebrate Material

The faunal assemblage from Titus Canyon provides the first good record of Chadronian terrestrial mammals from the Great Basin Province. Material collected during the mid-1930s was not studied until after World War II. A small collection of vertebrates was obtained from Titus Canyon in 1987 by Thomas Kelly. Kelly's collection included a partial left rhinocerotid ramus with molars. Another undescribed rhinocerotid specimen, collected by the University of California Berkeley field crew, 1987, may represent a new species (Mason, 1988).

Fossilized camel bones were uncovered during the construction of the Furnace Creek Visitor Center. A partial tusk from a mastodon has been reported by Clements (1973) from Pleistocene lacustrine deposits associated with Lake Rogers.

## Trace Fossils

Trace fossils (ichnites) are sedimentary structures resulting from biological activity, including: burrows, tracks, trails, footprints, resting marks, evidence of feeding activity, or fecal pellets. These are usually preserved in the form of a cast or mold and are rarely found with the actual organism responsible for making the particular trace.

**Wyman Formation (Precambrian)**. —Trace fossils of possible metazoan origin (Mount and Signor, 1985) and the trace fossil *Planolites* (Nelson, 1976) have been reported from exposures within the Waucoba Series.

**Reed Dolomite (Precambrian)**. —*Planolites* and unknown tubular fossils have been reported from exposures within the Waucoba Series (Alpert, 1975, 1976; Firby and Durham, 1974).

**Stirling Quartzite (Precambrian)**. —Conical calcareous fossils from exposures in the Funeral Mountains have been reported by Langille (1974) in the dolomite portions of the D member.

**Deep Spring Formation (Precambrian/Early Cambrian)**. —Trace fossils (Alpert, 1975, 1976; Firby and Durham, 1974), and *Rusophycus* and *Diplichnites* (Signor and Mount, 1989) have been reported from exposure within the Waucoba Series.

**Noonday Dolomite (Precambrian)**. —Very large tubes of possible *Skolithos* affinity have been reported from exposures within this formation (Wright et al., 1978).

**Campito Formation (Cambrian)**. —Possible metazoan trace fossils (Wigget, 1977) and a number of fodinichnid traces have bee reported from exposures within the Waucoba Series (Alpert, 1975, 1976; Mount, 1982; Mount and Signor, 1992).

**Poleta Formation (Cambrian)**. —Trace fossils have been reported from the upper member of this formation (Nelson, 1976).

**Wood Canyon Formation (Cambrian)**. —Abundant *Skolithos* trace fossils have been reported from exposures within this formation (Stewart, 1970).

**Zabriske Quartzite (Cambrian)**. —The trace fossil *Skolithos* has been reported from exposures within this formation (Prave and Wright, 1986; Prave, 1988).

**Carrara Formation (Cambrian)**. —Many types of trace fossils have been reported from exposures within this formation (Bates, 1965).

**Recommended Taxonomy Projects**

- Complete a thorough literature review and record all fossil taxa identified from the park;
- Inventory all Death Valley fossil colletions in the park museum and outside repositories;
- Identify any "type" fossil specimens from the park;
- Produce a paleo-taxa list of all known park fossil specimens;
- Create a paleo-taxa database including all known park fossils and associated data.

Figure 6: California Institute of Technology field crew in 1935 drilling a hole for the placement of dynamite in an vertebrate rich locality in Titanothere Canyon (top right). Blasting to remove overburden from the vertebrate rich beds in Titanothere Canyon (bottom right, LACM photo collection).

## Fossil Vertebrate Tracks

**Copper Canyon Formation (Eocene)**. —An abundant and diverse vertebrate track assemblage has been reported from within lacustrine deposits of Copper Canyon in the Black Mountains (Curry 1939, 1941; Figures 7A-F). The locality was first documented by Don Curry in 1937. Bauer originally mapped twenty track sites in 1941. Raymond Alf and Mary Leakey visited Copper Canyon in 1978. Scolnick added an additional twenty-one track sites during the 1980s. In 1984, Paul Scrivner conducted a morphological study of the Copper Canyon Track Locality for his master's thesis (Scrivner, 1984; Scrivner and Bottjer, 1986). Scrivner was the first to apply a morphological classification scheme to the tracks in the canyon. Nyborg (1998) expanded the total to fifty-six track sites within Copper Canyon. This trace fossil assemblage contains fossilized carnivore, camel, horse, mastodon and bird casts and molds (Alf, 1959, 1966; Santucci, 1998; Nyborg, 1998). Nyborg (1998) noted three

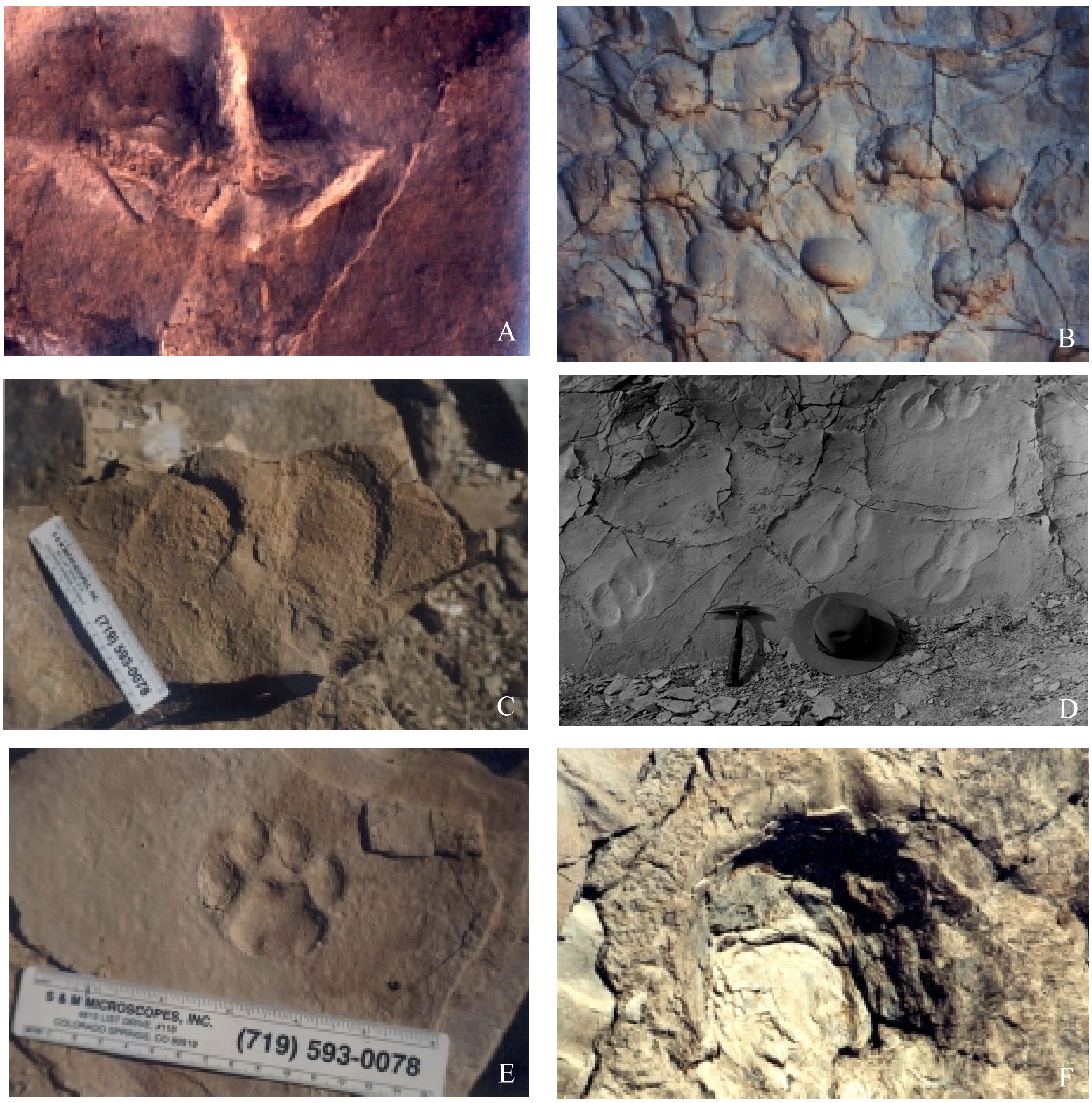



Figure 7: Composite of vertebrate tracks from Death Valley. A, *Avipeda* ichnospecies (cast) from the Cow Creek Track Locality; B, *Ovipeda* ichnospecies B (imprint) from the Copper Canyon Track Locality; C, *Hippipeda* ichnospecies A (imprints) from the Copper Canyon Track Locality at the "Carnivore Ridge" Sub-locality; D, Bioturbated trample tracks from the Copper Canyon Track Locality within the "Barnyard" Sub-locality; E, Undescribed Carnivore track from Copper Canyon Track Locality; and, F, *Proboscipeda* ichnospecies (imprint) from the Copper Canyon Track Locality.

additional localities within Death Valley which contain fossil vertebrate track assemblages including: Twenty Mule Team Canyon, Salt Creek, and Cow Creek. The precise stratigraphic units containing the tracksites at these three additional sites has not yet been determined, therefore their age is not currently known.

A comprehensive inventory and mapping of the Copper Canyon Track Locality is strongly recommended. Removal of particularly significant fossils, already out of their primary context (talus material), is also recommended. Casting of larger trackways will produce exact replicas for curation, research, and interpretation. Due to the scientific importance of Copper Canyon, continued guided tours into the canyon to view the tracks should be limited. Interpretation at the visitor center could utilize track casts and exhibits to minimize *in situ* theft or vandalism.

## LOCALITIES

Death Valley National Park has been divided into areas designated as regions. These regions are defined geographically based upon geomorphic features, landmarks, and park roads. Specific paleontological localities are organized within each region (see Death Valley Regional Map).

### Grapevine Mountains Region

The region extends along the eastern boundary between Highway 374 and Highway 267. Highway 267 defines the northern and western boundary of the region. It extends south along Highway 267 to its intersection with Highway 374. The southern boundary is along Highway 374. The Grapevine Mountains consist of highly faulted and folded Paleozoic marine sedimentary rocks, Tertiary continental deposits, and volcanic rocks (Foster, 1961). The mainly calcareous Lower Paleozoic rocks compose the western and central portions of the mountains.

The Wood Canyon Formation and the Campito Formation outcrop extensively throughout the Grapevine Mountain Region. Within these outcrops: trilobites, gastropods, nautiloids, brachiopods, pelmatozoa, cystoid plates, and archaeocyathid fossils occur (Foster, 1961; McAllister, 1970; Hall, 1971; Hunt, 1975).

**Titus/Titanothere Canyon**. —This area within the central portion of the Grapevine Mountains has yielded an important late Eocene vertebrate assemblage. The fossils indicate a Chadronian fauna (Stock, 1949). The locality was named after Morris Titus, a mining engineer who died in the canyon in 1905 while on a prospecting trip. Palmer and Halley (1979) have reported on a trilobite assemblage in the region.

**Daylight Pass**. —Olenellids are common in the upper member of the Wood Canyon formation, where it is exposed in Daylight Pass area (McAllister, 1970).

### Owlshead Mountain Region

This region extends along the southern park boundary west from Saratoga Spring, where it then turns north along the park's boundary up to the dirt road at Goler Canyon. The northern boundary extends east along this dirt road to the West Side Road, where the boundary continues along this road to Ashford Mill. The eastern boundary is along the Harry Wade Road between Ashford Mill and Saratoga Spring.

No known paleontological work or locality information has been reported from the Owlshead Mountain Region.

### Tucki Mountain Region

This region extends west along Highway 190 to Emigrant. It then extends down Emigrant Canyon and to the south near Aguereberry Point. From Aguereberry Point the boundary extends directly east to the boundary of the Central Death Valley Region. The boundary then extends north along the Central Death Valley Region up to Highway 190 where it follows this highway to Stovepipe.

Extensive geological fieldwork has been done in the Trail Canyon Region. Fossils have been collected from the Cambrian Bonanza King Formation and Devonian Lost Burro Gap Formation.

**Trail Canyon**. —The Bonanza King Formation outcrops extensively within the Trail Canyon area and between Tucki Mountain and Wildrose Canyon (Sears, 1955). Elliot and Ilyes, (1993, 1996a, 1996b) have reported on Devonian agnathans from the Lost Burro Formation from this locality.

### Wildrose Region

This region extends along the central and southern portions of the west park boundary between the Goler Canyon dirt road and the intersection of the Panamint Valley Road and Highway 190. The north boundary extends along Highway 190 to Emigrant. The boundary then extends south through Emigrant Canyon and east to Aguereberry. From Aguereberry Point the boundary extends due east to the northern intersection of the Badwater and West Side roads. The boundary then extends south along the West Side Road to the southern intersection of the Badwater and West Side roads. The southern boundary is the dirt road beginning in Warm Spring Canyon. Limited geologic work in this area has not documented any paleontological resources.

### Funeral Mountains Region

This region extends along the central portion of the eastern park boundary, between Highways 190 and 374. The northern boundary is along Highway 374 to its intersection with Highway 190. The boundary extends south and east along Highway 190 to the eastern park boundary.

Fossiliferous units in the Funeral Mountains Region include the Cambrian Carrara and Mississippian Tin Mountain Limestone Formations, and a series of Tertiary lacustrine units.

**Echo Canyon**. —Palmer and Halley (1979) have reported on trilobites from the Carrara Formation. Rugose and tabulate corals, and spirifer, pentameroid, and rhynchonellid brachiopods have been reported from mid-Silurian deposits (Easton, 1955).

**Cow Creek Track Locality**. —Tracks from this locality are preserved in a medium grained sandstone unit containing intermittent lacustrine beds, located just west of the Cow Creek housing facility. The site is limited in exposure and preserves a low diversity of fossil vertebrate tracks.

**Pyramid Peak**. —A diverse assemblage of trilobites and associated fauna is located within the exposures that make up Pyramid Peak (Palmer and Halley, 1979).

## Black Mountain Region

This region extends along the southern portion of the eastern park boundary. The northern boundary is highway 190 between the eastern park boundary and Furnace Creek. The western boundary is the Badwater Road from Furnace Creek to Ashford Mill and extending southeast from Ashford Mill along the Harry Wade Road to the southeast corner of the park.

This region consists of Tertiary lacustrine deposits interfingered with extrusive volcanics. The lacustrine deposits make up much of the Furnace Creek, Artist Drive and Copper Canyon Formations. These deposits contain important vertebrate tracks and other fossils.

**Copper Canyon Track Locality**. —Late Miocene lakebeds contain a well-preserved and diverse assemblage of fossil vertebrate tracks (Figure 8). This represents one of the worlds most important fossil mammal track localities, including: twelve bird ichnospecies, five cat ichnospecies, five camelid ichnospecies, three horse ichnospecies, one proboscidian ichnospecies, and one tridactyl track "cf. *Tapirpeda* n. sp." ichnospecies (Santucci and Nyborg, 1998).

**Twenty Mule Canyon Track Locality**. —Several camel tracks have been collected from this area and are in the park collections (Nyborg, 1998).

**Artist Drive**. —Hardy (1988) reports on paleobotanical fossils from this area.

## Central Death Valley Region

This region incorporates the central low-lying region of the park. Its eastern boundary extends along the West Side Road, south to the intersection of this road and the Badwater Road, where it extends north along this road. From the intersection of the Badwater Road and Highway 190, it extends northwesterly along Highway 190 and then Highway 267 to Grapevine. The boundary is situated due south to the entrance of Marble Canyon where it extends to the east along a dirt road to Stovepipe Wells. A few miles to the east of Stovepipe Wells, at about the Devils Cornfield, the boundary takes another shot to the south where it intersects with the West Side Road.

**Salt Creek Track Locality**. —The Salt Creek Track Locality is located within an isolated outcrop in the Central Death Valley Playa. (Curry, personal communication, 1998) has reported avian, artiodactyl, perissodactyl, and possibly proboscidian tracks from the lacustrine deposits within the Salt Creek area (Figure 8).

## Cottonwood Mountain Region

This region extends northwest from Grapevine along Highway 267 to Ubehebe Crater. The boundary extends along the dirt road to the Racetrack, taking a southeast turn at TeaKettle Junction. The boundary then continues down the dirt road through Hidden Valley. It then takes a direct shot east to the dirt road at Cottonwood Canyon where it follows this road up to Marble Canyon. The boundary then takes a straight shot north back up to Grapevine.

Highly fossiliferous formations include: Bonanza King Formation, Hidden Valley Dolomite, Lost Burro Formation, Tin Mountain Limestone, Perdido Formation, and Tihvipah Limestone (Peck, 1950; McAllister, 1952; Langenheim and Tischler, 1959; Gordon, 1964; Hall, 1971).

**Quartz Spring**. —Extensive cephalopod-bearing units (Langenheim and Tischler, 1959) and stromatoporoids (Hall, 1971), have been reported from this locality.

**Rest Spring**. —Gastropods (Peck, 1950) and hapsiphyllid tetracoral (Tischler, 1956) have been reported from this locality.

**Lost Burro Gap**. —Stromatoporoids (Hall, 1971), fifteen genera and twenty-three species of conodonts, and silicified corals (R. H. Miller and Hanna, 1972) have been reported from this locality.

## Panamint Springs Region

This region extends along the central western part of the park boundary. The south boundary extends along the park boundary to the intersection of the Panamint Valley Road and Highway 190. The boundary continues along Highway 190 from Panamint Springs up to Stovepipe Wells. From Stovepipe Wells, the boundary extends along the dirt road to Cottonwood Canyon. The northern boundary extends from Cottonwood Canyon Road directly west to the dirt road that extends through Hidden Valley.

**Dolomite Canyon**. —Solitary corals, trace fossils, brachiopods, echinoderm plates, crinoid columnals, and an extensive assemblage of conodonts have been reported from the north side of Dolomite Canyon (Hall, 1971).

**Lemoigne Mine**. —Solitary corals and gastropods have been reported by Hall (1971).

**Towne Pass**. —Fifteen species of gastropods, two species of pelecypods, orthoceroid cephalopods, bryozoan, and sixteen species of brachiopods have been reported from exposures at Towne Pass (Hall, 1971).

**Panamint Canyon**. —Solitary corals have been reported by Hall (1971).

**Lake Hill**. —Fifteen species of corals, fifteen species of gastropods, two species of pelecypods, cephalopods, bryozoan, and rhynchonellid brachiopods occur within the formations at Lake Hill (Hall, 1971)

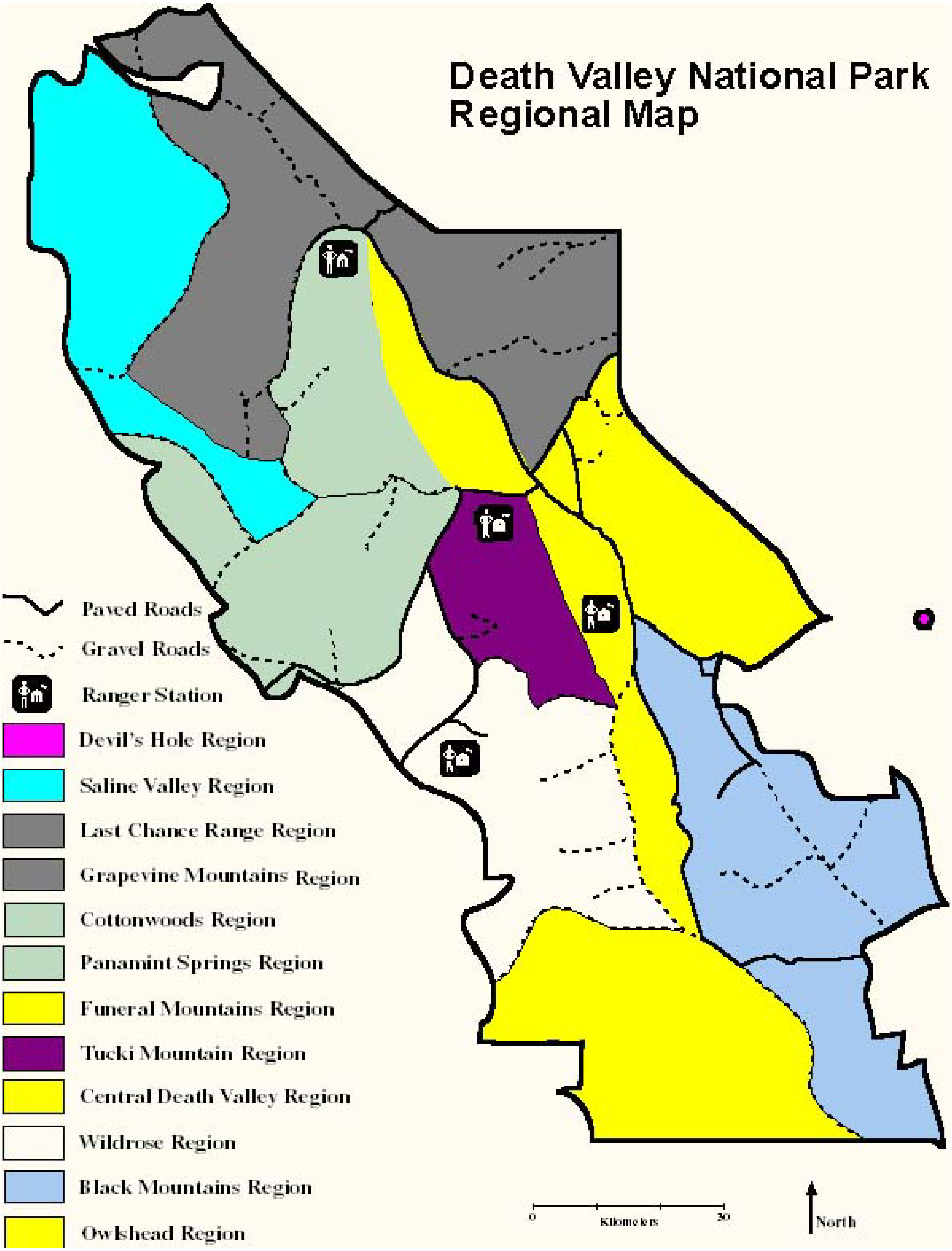
Figure 9: Geologist Donald Curry and Ranger Doudna excavating fossil vertebrate tracks at the Salt Creek Track Locality

## Last Chance Range Region

This region extends along the northern and eastern boundaries of the park and to the west to Big Pine Road, where it then follows the dirt road south through Eureka Valley. The boundary then cuts across the Saline Range to the Racetrack and the road that extends along Hidden Valley to the east. The boundary then extends northeast along the dirt road between the Racetrack and Ubehebe Crater. It then extends to the east along Highway 267 to Grapevine and the eastern park boundary.

**Last Chance Range**. —The massive carbonate buildup of the Cambrian system above the Carrara Formation is exposed in the southern portion of the Last Chance Region. According to Taylor and Palmer (1981), at that time, regional details of its internal stratigraphy had not yet been worked out, and it was found to be fossiliferous at only a few levels.

**Cucomungo Canyon**. —The formations typical of the White-Inyo facies are exposed within the entrance to this canyon.


Death Valley National Park
Regional Map
Paved Roads
Gravel Roads
Ranger Station
Devil's Hole Region
Saline Valley Region
Last Chance Range Region
Grapevine Mountains Region
Cottonwoods Region
Panamint Springs Region
Funeral Mountains Region
Tucki Mountain Region
Central Death Valley Region
Wildrose Region
Black Mountains Region
Owlshead Region
0
Kilometers
30
North

**Lake Rogers**. —A flat-lying Pleistocene lake which covered several square miles, from which Clements (1973) has reported part of a tusk from a mastodon.

### Saline Valley Region

This region extends along the northwestern boundary of the park up to and to the east to Big Pine Road, where it then follows the dirt road south through Eureka Valley. The boundary then cuts across the Saline Range to the Racetrack and the road that extends along Hidden Valley to the east. The southern boundary extends west from Hidden Valley bisecting Lee Flat and incorporating the Nelson Range.

Exposures within the Waucoba area include: the Campito Formation (Andrews Mountain Member and Montenegro Member), the Poleta Formation, the Harkless Formation, the Saline Valley Formation, and the Mule Spring Limestone (Seiple, 1984).

**Waucoba**. —This thick, well exposed and conformable sequence of lower Cambrian rocks in the White-Inyo Mountains of California was designated by Walcott (1895, 1908) as the type section of the Lower Cambrian Waucoban Series. This section contains some of the oldest known fossils of complex multi-celled organisms. The fossils include trilobites, brachiopods, mollusks, archaeocyathids, echinoderms, and trace fossils. The base of the Waucoban section is found one mile north of Waucoba Spring within the Campito Formation (Nelson, 1976). From its base, the section extends southeastward, encompassing strata 2,100 meters thick (Seiple, 1984).

### Devils Hole Region

This region is within Ash Meadow National Wildlife Refuge which extends the boundaries of Devils Hole.

**Recommended Mapping Projects**

- Establish a database for all known fossil localities within the park;
- Establish a standardized system for cataloging and identifying park fossil localities with cross-references for any previously used numbers or site names;
- Map all fossil localities with GPS and incorporate the data into a park-wide GIS system;
- Use digital mapping system to generate a paleontological locality map for the park.

**Ash Meadows**. —This quadrangle, which incorporates Devils Hole, contains the following formations: Bonanza King, Nopah, Lost Burro and Tin Mountain, which have fossils reported from them by Denny and Drewes (1965).

## INTERPRETATION

### Current Interpretive Program

The most recent Death Valley National Park interpretive prospectus was produced in 1990. There is a small section in the plan addressing paleontological resources that could be expanded. The current Death Valley National Park General Management Plan identifies the following interpretive theme, "the rocks found within Death Valley National Park represent all of the great eras of geologic time and include important fossil resources that provide a glimpse into ancient habitats and the prehistoric plants and animals that once lived here." There are currently no site bulletins developed for the park's paleontological resources. The park staff has historically been discouraged from "advertising" the fact that fossils exist in Death Valley (Baldino, personal communication, 1998).

A number of paleontological exhibits currently are on display at the Furnace Creek Visitor Center. A cast of a titanothere skull and other bones from Titus Canyon along with five fossil vertebrate track specimens are on display inside the visitor center. A camelid track-slab is located on the visitor center patio at Furnace Creek. Four additional fossil track-slabs are exhibited in the Borax Museum at the Furnace Creek Ranch, which is a non-National Park Service facility.

### Interpretive Themes

Fossils, paleontology, and the history of life on earth provide exciting opportunities for interpretation. Both children and adults are interested in fossils. If the public had a greater awareness of the significant paleontological resources that occur at Death Valley National Park, there would be more demands placed on park staff to provide increased interpretation about the fossils and the ancient ecosystems.

Public misconceptions, media misinformation, controversial scientific opinions, and discussions involving evolution and geologic time can present challenges when interpreting paleontology. These issues have often been encountered in some of the fossil parks such as Agate Fossil Beds National Monument, Badlands National Park, Dinosaur National Monument, Fossil Butte National Monument, Hagerman Fossil Beds National Monument, John Day Fossil Beds National Monument, and Petrified Forest National Park. Strategies associated with paleontological resource interpretation have been discussed at the previous National Park Service Fossil Resource Conferences. Specific training related to interpreting fossils has been conducted at many of the National Park Service units that preserve paleontological resources.

A variety of interpretive themes could be developed for Death Valley National Park's paleontological resources. Pick a moment in time when Death Valley's story is best told. The Death Valley story is dynamic and not yet complete. The fossil record of life provides evidence of ancient wildlife and vegetation. The present climate and landscape is not representative of those from the past. The fossilized remains of the plants and animals contain the secrets of Death Valley's past that remain to be discovered. Here are some examples of possible interpretive themes for Death Valley:

### Biological History of Death Valley

The public's interest in the modern animals and plants in Death Valley may indicate potential interest in the ancient life of the area.

### Geological History of Death Valley

Fossils provide information that helps geologists understand past geologic events, processes, and environmental conditions. Fossils can yield information related to ancient depositional environments (i.e., lake, stream, desert, etc.). The presence of fossils in a particular rock unit, along with the changes in fossils within successive layers, can provide valuable information about the past history of Death Valley.

### Paleoecology of Death Valley

The short-term changes evident at Death Valley can markedly influence the visitor's view of the park and provide for continued sources of public inquiry. The fossil record, dating back hundreds of millions of years, can assist the interpreter in presenting Death Valley as a dynamic and naturally evolving area. A greater understanding of Death Valley's past and how the recent setting has evolved may increase the public's appreciation of the park.

Fossil material from Death Valley includes some exceptionally well preserved specimens. Some of these specimens would be ideal for use in interpretive exhibits or programs. However, it is important to recognize that increasing public awareness of and interest in fossils should be accompanied by resource protection information. Specific paleontological resource locality data should not be given in interpretive contacts or through other public information. Slides or photos that would reveal the locations of sensitive fossil sites should not be used. Wayside exhibits should not be placed where they could direct the public to fossiliferous exposures.

**Recommended Interpretive Actions**

- Update interpretive planning documents to include paleontological resources and issues;
- Incorporate significant park paleontological resources in interpretive exhibits and displays;
- Develop geologic/paleontologic resource components for education programs;
- Provide paleontological resource training for interpretive staff;
- Continue park policy of not divulging paleontological localities to park visitors;

## PALEONTOLOGICAL RESOURCE MANAGEMENT

### National Park Service Policy

Fossils are non-renewable resources that require specific actions for appropriate management. Paleontological resource management on federal lands has gained considerable attention over the past decade and has gained recognition as an independent discipline by the scientific community and land management agencies.

National Park Service Management Policies state "Management actions will be taken to prevent illegal collecting [of fossil resources] and may be taken to prevent damage from natural processes such as erosion. Protection may include construction of shelters over specimens for interpretation *in situ*, stabilization in the field or collection, preparation, and placement of specimens in museum collections. The locality and geologic data associated with a specimen will be adequately documented at the time of specimen collection. Protection may also include, where necessary, the salvage collection of threatened specimens that are scientifically significant."

Within the National Park Service, paleontological resource management has received initial direction through the Natural Resources Management Guidelines (NPS-77). The National Park Service Geologic Resources Division provides service-wide support to assist parks with achieving some of the objectives outlined in NPS-77. Special management actions that are recommended in NPS-77 for paleontological resource sites include:

### Monitoring

Periodic re-examination of a known fossil localities should be conducted to assess site stability and the need for management action. Photodocumentation of the site is essential to monitor any changes.

### Cyclic Prospecting

In areas of high rates of erosion, periodic surveys should be undertaken to identify the exposure of any new fossil material at the surface and the loss of previous exposed material.

### Stabilization/Reburial

The management of *in situ* paleontological resources can be accomplished through a wide range of techniques and methodologies. In situations where the excavation of fossil material is not feasible, reburial of the material may be the appropriate interim management action. Reburial can stabilize or slow down the destructive forces of weathering and erosion.

### Excavation

The removal and collection of a fossil from a geologic context may be the appropriate action for management of *in situ* paleontological resources. Depending upon the scientific significance, immediate threats, or other variables, the careful collection of a fossil specimen may be warranted. Appropriate collecting permits must be secured in advance for any excavation or collection of paleontological resources.

### Closure

A fossil locality may be best managed through closure or restricted access to the area. Closed areas may be completely withdrawn from public use, restricted to ranger-led activities, or require special permit for entry (i.e., research).

### Patrols

Significant or well known fossil sites require periodic monitoring by park staff. Patrols may be important in preventing or reducing paleontological resource theft and vandalism.

Management of paleontological resources should be distinguished from the management of archeological resources. Paleontological resources are typically recognized as natural resources and should be managed accordingly. The Archeological Resources Protection Act (1979) and the NPS Cultural Resources Management Guidelines (NPS-28) provide guidance for cases when paleontological resources occur in an archeological context.

## Baseline Paleontological Resource Inventories

The inventory and monitoring of paleontological resources serves as the foundation of any paleontological resource management program. Without the baseline data available from a paleontological survey, any further actions or management decisions would be based upon insufficient information.

**Recommended Paleontological Resource Management Actions**

- Continue a paleontological resource inventory and monitoring program;
- Identify threats to the paleontological resources;
- Adopt the recommended RMP Project Statements for paleontological resources;
- Provide paleontological resource management training to park staff;
- Assign one member of the park staff to coordinate a paleontological resource management and

To complete a paleontological survey of Death Valley National Park, the following information is needed:

- Geographic data on fossil localities, including topographic coordinates, UTMs, the geographic extent of each locality, maps, GPS measurements, etc.;
- Stratigraphic data related to the geology at each locality, including the formations or subunits and the age of the units;
- Paleontological data related to the identification of paleo taxa present within park localities;
- Geologic data related to the lithology and depositional environment of the fossiliferous units.

All fossil localities should be documented using both ground and aerial photographs whenever possible. Ground photos should include close-up details showing the fossils, sedimentary structures, and general setting of the locality. Aerial photos should be at a scale appropriate to the physical characteristics of the locality.

Natural erosion is a major threat to all paleontological resources. Fossils exposed at the surface are subjected to physical and chemical forces that can often be destructive. Continued inventory and monitoring of fossil areas subject to significant erosion is recommended.

Construction and visitor use may generate increased levels of erosion. In some cases, however, these activities may also lead to the exposure of subsurface fossil material. The titanothere remains discovered by H. Donald Curry in

1934 in Titus Canyon were first uncovered during a road construction project (Stock and Bode, 1935).

The draft Death Valley National Park General Management Plan addresses paleontological resources as follows: "...little paleontological research has been initiated or funded by the National Park Service." Most research is accomplished by outside institutions that request and receive NPS research permits. The institutions, in exchange for the opportunity to study park resources, agree to provide information that the National Park Service can use to develop strategies for resource protection, management, and interpretation.

Paleontological resources, including both organic and mineralized remains in body or trace form, would be protected and preserved for public enjoyment, interpretation, and scientific research in accordance with park management objectives and approved resource management plans. Although paleontological research by the academic community would be encouraged and facilitated under research permits subject to NPS management criteria, the National Park Service would enhance its own knowledge of paleontological resources through comprehensive inventory and monitoring programs. To enhance the conservation and management of paleontological resources, the National Park Service would seek to develop collaborative partnerships with government agencies, academic institutions, and public and private organizations with paleontological resource management or research capabilities/expertise. Management actions would be taken to prevent illegal collecting. Actions also might be taken to prevent damage from natural processes such as erosion. Protection could include construction of shelters over specimens for interpretation *in situ*, stabilization in the field, or collecting, preparing, and placing of specimens in museum collections. Localities and geologic settings of specimens would be adequately documented when specimens were collected.

## Paleontological Resource Protection

The greatest damage to paleontological resources in the southwestern deserts is probably due to erosion (San Bernardino County Museum Department of Community and Cultural Resources memo). The actions of water, acids, and mineral growth affect fossils at the surface and down to several feet below the surface. Erosion should be considered the most damaging factor to the preservation of paleontological material.

A rapidly growing commercial interest in fossils has resulted in a lucrative fossil market, especially for vertebrate fossils. This escalating commercial market has led to an increase in unauthorized fossil collecting on federal lands. The removal of fossils or any other natural objects without a permit is illegal in National Park Service areas. However, the extremely large monetary rewards gained through the sale of fossils far exceed any potential penalties that can be levied through enforcement under 36 CFR.

Figure 10: Park naturalist examines vandalized track slab in Death Valley National Park.

The unauthorized removal of paleontological resources generally destroys the ability to obtain the appropriate and scientifically important data associated with the fossil. Generally, the poacher removes the fossil material and does not record stratigraphic, sedimentological, or other valuable data. Once fossils are removed from their geologic context, it can become very difficult to reconstruct the available information. The Society of Vertebrate Paleontology recommends that significant fossils near the surface should be removed to a museum or academic repository so that the specimens are available to the scientific community for study.

In November 1998, the first Paleontological Resource Protection training was provided to Death Valley National Park law enforcement staff. The training consisted of eight hours of classroom presentation and discussions, and eight hours in the field visiting a paleontological locality in the park. Visiting researchers should be encouraged to provide similar type training or lectures for Death Valley staff during their visits to the park.

There are a few known incidents of paleontological resource theft or vandalism at Death Valley National Park. The earliest evidence is contained in an early photo found in the park photographic archive collection. The photo caption suggests damage to a fossil track slab due to vandalism by a park visitor (Figure 10). In 1998, Park Ranger Henry Kodele prepared a case incident report documenting some unauthorized activities related to paleontological resources in Death Valley National Park. The report was well prepared and included a comprehensive narrative, site photos and a locality map. Additionally, the report included an estimate of costs for restoration of the disturbed paleontological locality.

Significant paleontological resources occur within the lands acquired in the 1994 park boundary expansion. These fossiliferous localities were previously administered by the Bureau of Land Management and were routinely visited by academic groups and fossil collectors. Collecting activities may continue to occur in these well-known localities in and around the monument. An article, recently published in a popular amateur rock collecting magazine, identifies an important Cambrian trilobite locality adjacent to Death Valley, as a place to collect fossil specimens (Seiple, 1999).

**Recommendations for Fossil Protection**

- Review park records relative to incidents of paleontological resource theft or vandalism;
- Assess the history of any paleontological collecting activities in newly acquired areas in Death Valley;
- Assess commercial values of paleontological resources preserved within the park;
- Participate in interagency cooperative efforts pertaining to fossil resource protection (i.e. Paleontological and Cultural Resources Action Team - a subgroup of the California Desert Managers Group: PACRAT);
- Provide paleontological resource

## RESEARCH

According to the National Park Service Natural Resource Management Guidelines (NPS-77), "Paleontological research by the academic community will be encouraged and facilitated under the terms of a permit…"

In Death Valley National Park a collecting permit is required for research that includes the field collection of fossils. A Special Use Permit (Form 10-114) is required for any other research. The Special Park Uses Guidelines (NPS-53) provide details on the issuance of permits and is currently being revised.

### CURRENT RESEARCH

There are two recent research projects involving Death Valley's paleontological resources. These recent projects include:

• Elliott, David "Early Devonian vertebrates from Death Valley". A new Devonian fossil fish locality was surveyed in the park and new early fish specimens were collected and described from the Panamint Range.

• Nyborg, Torrey, Santucci, Vincent, and Reynolds, Robert "Inventory and description of Tertiary vertebrate track sites in Death Valley National Park." This work is intended to provide baseline data on the diversity, distribution and interpretation of vertebrate track sites in the park. The project includes photodocumentation, mapping, GPS data acquisition, and track replication.

### PROPOSED RESEARCH

Background research, including bibliographic reviews and direct communication with paleontological researchers, has generated many ideas for future research projects at Death Valley National Park. The following projects are considered to have the highest priority:

**Coffin Canyon Survey**. —Coffin Canyon is an isolated canyon just north of Copper Canyon in the Black Mountains. Aerial photos show a thick lacustrine sequence in the canyon that appears similar to the fossiliferous sediments in Copper Canyon. Difficult access to Coffin Canyon has limited surveys of the sedimentary units in that area. There is a potential for the discovery of fossil vertebrate tracks similar to those preserved in the adjacent Copper Canyon.

**Paleomagnetic testing of Late Eocene/Oligocene sediments**. —The Titus Canyon formation contains an important assemblage of Late Eocene/Early Oligocene vertebrates. Similar fauna are known from a number of other localities in North America. Paleomagnetic testing, which has been unsuccessful in the past, would enable a greater correlation of the rocks and fossils preserved in these geographically separate areas.

**Lacustrine chronology of Death Valley**. —There are numerous late Tertiary and Quaternary lacustrine deposits in Death Valley National Park. Very little research has been directed towards the history and paleoecology of these lake systems. A detailed examination of the lacustrine stratigraphy, sedimentology, geochemistry, and mineralogy would greatly enhance the understanding and interpretation of the recent geologic history of Death Valley.

**Geologic Map of Death Valley**. —The single most important need for geology and paleontology at Death Valley National Park is the publication of a park-wide geologic map. This data would benefit future paleontological fieldwork and research.

**Further paleontological field work**. —Paleontological field work is recommended within the Devils Hole region of Death Valley National Park and a reported bird track locality just outside the parks east boundary in the Funeral Mountain section of Nevada (Troxel, personal communication, 1999).

## Permit System

Fossil parks within the National Park System often benefit from the information obtained through park-related research. New discoveries and interpretations of the resources have expanded park management's and the public's understanding of the resource significance.

The research permit serves as an administrative tool to help ensure resource protection by identifying the limitations on and responsibilities of researchers working in the park. The park management should ensure that information gained through research is obtained by the park, and that any specimens collected under a permit remain accountable and properly cataloged into a museum collection.

## Funding

Funding for paleontological research has traditionally been difficult to secure within the National Park Service. Fossils lack specific legislation for appropriation of funds to support paleontological resource projects. Most of the financial support for paleontological resource projects has come from park cooperating associations, park donation accounts, or from academic institutions. With limited funding for paleontological resource projects, the training and utilization of volunteers can be a valuable way to accomplish management objectives.

The National Park Service has moved toward a greater recognition of paleontological resources within the last few years. A staff position in Washington was created to oversee geologic and paleontologic resource issues. The newly created Geologic Resources Division in Denver is working towards securing sources of funding to support paleontological research in the national parks.

## Publication Needs

Communication with research geologists and paleontologists indicates that there is a wealth of unpublished paleontological resource data from Death Valley. Various sources of unpublished data should be obtained for park archives, and if possible published in some format. The NPS Geologic Resource Division has initiated a Technical Report series and published the Third NPS Paleontological Research Volume in 1998. Future volumes will be published annually and provide an outlet for reporting on paleontological research in the national parks.

In the future, the organization of a Geology/ Paleontology of Death Valley Symposium would provide a means to bring together researchers working in and around the park. As a companion to this meeting, a special publication could be produced to compile research. This publication would be an up to date reference for the interpretation of the park's paleontological resources.

## Literature Surveys

As a part of the Death Valley Paleontological Survey, searches on biological, geological, paleontological and government bibliographic databases were conducted to locate any published information related to paleontological resources at Death Valley. The research library at Death Valley provided access to copies of unpublished material and park archives. Current and past paleontological researchers were contacted directly to obtain copies of their published and unpublished research. The bibliographic information obtained through this search was cross-referenced with the collections at the park's research library.

# Collections and Curation

## Museum Collections

The Death Valley National Park collections include approximately 700 paleontological specimens. Of this total, 650 are manually and minimally cataloged, 22 are backlog, and only 35 have been entered into the ANCS+ database. Park fossil collections in outside repositories are not currently cataloged and only have accession record documentation in the ANCS+ system.

Fossil collections from Death Valley National Park are managed in four categories: museum storage within the curatorial facilities at park headquarters; on exhibit at the Furnace Creek Visitor Center; on exhibit in the Borax Museum at Furnace Creek Ranch; and in outside repositories. All of these collections should be evaluated in terms of the scope of the collection, security, and organization.

### Scope

Death Valley's fossil collection may be better refined through the data provided in this document. Currently, the collection lacks many of the representative fossil taxa known from the park. Representative specimens could be obtained either through future field collection, return of park specimens from collections outside of the park, or by obtaining replica casts of park specimens. Additionally, some of the paleontological specimens within park collections are poor quality and could be supplemented by higher quality material.

### Security

The park museum collections are maintained in reasonably secure facilities. Likewise, the paleontological locality data and field notes are well secured in the curatorial facilities at headquarters. Under the authority of the 1998 National Park Service Omnibus Act, paleontological resource locality data should not be publicly disclosed if the resource is rare or potentially threatened.

### Organization

Park fossil specimens are contained in a number of cabinets within the curatorial storage facilities. As the fossil collections expand, a different organization of specimens may be considered to accommodate research needs. Typically, paleontological collections are organized based either on taxonomy or stratigraphy. In larger collections with adequate storage space availability, stratigraphy should be the primary organizational division and taxonomy the secondary subdivision. Storage cabinets could be arranged according to the geologic time scale, and the stratigraphic unit (e.g., Devonian Lost Burro Formation) could be represented sequentially within each geologic time period. Within each stratigraphic unit, specimens could be organized taxonomically (e.g., invertebrates, vertebrates, etc.).

Routinely, researchers making collections of park fossils should provide copies of all field notes and sketches. These records may be valuable for future research and should be incorporated into the museum records.

## Photographic Archives

### Historic photos

A small collection of historic photographs associated with paleontology in Death Valley are curated into the park's museum collection. These include a few images of fossil vertebrate tracks from Copper Canyon, Cow Creek, and Salt Creek. An outstanding photodocumentation of the Copper Canyon tracks was undertaken by park volunteer Reuben Scolnik between 1979 and 1983. Scolnik mapped and photographed forty-one sites in Copper Canyon, providing an important baseline inventory. This work was expanded to fifty-six sites in the summer of 1998 by park paleontology intern Torrey Nyborg. Nyborg relocated Scolnik's localities and discovered numerous new localities in Copper Canyon. At each site, Nyborg obtained new photos and global positioning data.

Park curator Blair Davenport visited the Death Valley collections at the Los Angeles County Museum (LACM) in California. During her visit, she learned that the LACM possessed a number of historic photos related to paleontological work in Death Valley. Blair is in the process of obtaining copies of these photos for the Death Valley collections.

### Museum specimens

In early 1998, Vince Santucci photographed representative paleontological specimens in the Death Valley. Torrey Nyborg photographed all of the fossil track specimens in park collections, including those in museum storage, on exhibit at the Furnace Creek Visitor Center, and on exhibit at the Borax Museum. These efforts support NPS collection management policies and will facilitate future paleontological research. All remaining unphotographed fossil specimens in the collections should eventually be photographed. The park should seek to obtain photos of all known "type" fossil specimens from the park that are curated into outside repositories.

### Interpretive slides

A number of paleontological resource slides are located in the interpretive slide collection at Furnace Creek Visitor Center. This slide collection includes a number of images depicting *in situ* fossils from Death Valley National Park. There is very little information associated with these slides. Donald Curry has a few slides showing himself and another ranger in uniform mapping in Gold Canyon. Copies

**Recommendations for Park Fossil Collections**

- Secure staff/funds to complete cataloging backlog of paleontological specimens;
- Attempt to obtain field notes/records/ maps etc. for all paleontologic collections from within the park;
- Obtain photos of all park fossil specimens in park museum, on exhibit, and in all outside repositories;
- Review status of fossil specimens on loan;
- Obtain better quality and representative collections for parks collection;
- Prepare fossil specimen within collections for more efficient use of storage space.

**Recommendations for Photo Archives**

- Photodocument all specimens curated into the park's collections;
- Photodocument all Death Valley fossil specimens in outside collections;
- Attempt to locate historic photos of park fossils in outside collections (i.e., Smithsonian Institution, Los Angeles County Museum, Raymond Alf Museum, etc.);
- Photodocument all known fossil localities;

of these slides will be obtained for the park's interpretive and archival photographic collections.

## Fossil Collections in Outside Repositories

As part of the Death Valley Paleontological Survey, an intensive search was conducted for Death Valley specimens in outside repositories. A list of outside repositories with park collections is listed below. A number of "type" fossil specimens were documented from Death Valley during this inventory in outside collections. A list of "type" vertebrate fossil specimens from Death Valley are listed in Appendix B.

According to 36 CFR 2.5, all NPS museum objects placed on exhibits or stored in collections, including outside repositories, must be accessioned and cataloged into the park's museum collection. All undocumented collections within outside repositories should be thoroughly inventoried by the curator at Death Valley. For specimens collected prior to the establishment of Death Valley as a National Park Service unit, any available data should be recorded in order to obtain the highest level of resource information. Likewise, maintaining paleontological resource data from adjacent lands may be valuable to an understanding of the park's resources.

**Recommendations for Fossil Collections in Outside Repositories**

- Organize a meeting with park curatorand relevant staff to discuss issues related to managing the park's fossil collections within the park or outside repositories;
- Inventory the park's fossil collections and associated data or field notes stored in outside repositories and incorporate into the Death Valley collection curatorial database;
- Review status of recent park fossil collections and evaluate with regard to compliance with permits and NPS standards.

**Los Angles County Museum (LACM)**. —A number of Tertiary vertebrate fossils have been collected from the Titus Canyon Formation since the 1930s. Many of these specimens were collected by Chester Stock and originally stored at the California Institute of Technology (CIT). These specimens were later transferred to the LACM.

**Smithsonian Institution (USNM)**. —A few type specimens of Tertiary fossil fish from Death Valley are contained in the Smithsonian collections. Additionally, a number of Cambrian trilobite type specimens are at this institution.

**Field Museum of Natural History (FMNH)**. —A small collection of Devonian fish from Death Valley are in the Chicago Field Museum.

**Raymond Alf Museum**. —A number of Death Valley vertebrate tracks are on display at the Alf Museum in Claremont, California. There are few field notes or records associated with these specimens.

**United States Geological Survey (USGS)**. —A large number of Cambrian trilobites collected by Palmer and others are contained within the USGS collections at the Denver Federal Center.

**Museum of Paleontology, University of California, Berkeley (UCMP)**. —A small collection of mammals were collected from Titus Canyon in 1987 by Howard Hutchinson, Mark Mason, and Donald Savage.

**Department of Geology, Eastern Washington University, Cheney, Washington**.—Paleozoic invertebrates from Death Valley were collected by Linda McCollum.

**Stanford University Collections**. —A collection of Paleozoic cephalopods is retained at Stanford University.

## Paleontological Resources Near Death Valley

**Tecopa Basin**. —The basin consists of badlands and ancient lakebed sediments. These white lacustrine sediments are the remnants of the perennial Pleistocene Lake Tecopa. Several hundred feet of lake-sediments have accumulated within the basin. Fossil remains of mammoths, horses, camels, and rodents are found in the uppermost layers of lake deposits. Fossil mammal tracks occur near the town of Shoshone and a few locally collected fossils are on exhibit at the town museum. Ash layers within the lake sediments date Lake Tecopa to between 500,000 to nearly 3 million years ago (Hillhouse, 1987).

**Waucoba lakebed**. —Charles Walcott of the U.S. Geological Survey first reported the Waucoba lacustrine embayment deposits. The light-colored lakebeds tilt gently to the west. Fossil gastropods are preserved in the lacustrine sediments and radiometric dating yield evidence that Waucoba Lake began to form about 2 to 3 million years ago (Bachman, 1978).

**Gold Point**. —Twelve species of trilobites were reported from a locality near Gold Point, Nevada (Palmer, 1964).

Well-preserved specimens of the families Olenellidae, Oryctocephalidae, Ogygopsidae, Dorypygidae, Zacanthoididae, and Ptychopariidae have been reported. Palmer (1964) believes that this fauna may represent the largest single assemblage of trilobites yet described from Lower Cambrian beds in North America.

**Westgard Pass**. —Echinoderms associated with the trilobite zones of the White-Inyo facies have been reported by Durham and Caster (1963). The echinoderms represent a new class of Helicoplacoidea including two new species *Helicoplacus gilberti* and *H. curtisi*. Coral-like microfossils have been reported from the Montenegro Member of the Campito Formation, and the lower member of the Poleta Formation within the vicinity of Westgard Pass (Tynan, 1983). This assemblage includes a new order (Paiutiida), a new family (Paiutitubulitidae), and the following taxa: *Paiutitubulites variabilis*, *P. durhami*, and *Cambrotubulites trisepta*. Firby and Durham (1974) have reported the *Volborthella Campitius titanius*, trilobites, inarticulate brachiopods, archeocyathids, and numerous ichnofossils from Montenegro and Andrews Mountain members of the Campito Formation from exposures within the Westgard Pass area. In the White-Inyo Mountains, the trace fossil *Bergaueria* (Alpert, 1976) and *Westgardia gigantea,* a "large, valve-shaped fossil of uncertain affinity" (Rowland and Carlson, 1983) have been reported from exposures at Westgard Pass.

**Ediacaran-Type Fossils**. —New assemblages of Ediacaran type fossils from the Stirling Quartzite and the lower member of the Wood Canyon Formation, have undergone recent research (Horodyski, 1991; Corsetti, 1993; Horodyski et al., 1994; Runnegar et al., 1995; Runnegar, 1998). From within these formations, a new assemblage of soft-bodied fossils and elongate tube-like fossils has been reported (Waggoner and Hagadorn, 1997; Hagadorn and Wagonner, 1998). The small shelly fossil *Cloudina,* described by Langille (1974), is the only known occurrence of unquestionably metazoan Proterozoic fossils in Death Valley National Park.

**White-Inyo Mountains**. —The Upper Proterozoic to Lower Cambrian strata of the White-Inyo facies, comprise more than 6000 meters of principally siliclastic sedimentary rocks, of which the upper 2000 meters contain olenellid trilobites (Nelson, 1976). This succession is widely exposed in the surrounding Death Valley area and can be seen within Death Valley National Park across a zone of faulting within the Last Chance Range in the most northern section of the park. A good exposure of White-Inyo facies can be observed at the entrance of Cucomungo Canyon where there are good exposures from the Harkless Formation through the Mule Spring Limestone (Taylor and Palmer, 1981).

Lower Cambrian strata in the White-Inyo facies are divided into three trilobite zones, plus a lowermost pre-trilobite interval. The three trilobite zones: the *Fallotaspis*, *Nevadella*, and *Bonnia-Olenellus,* first described by Fritz (1972) are named and defined by the occurrence of these trilobite genera.

Exposures within the White-Inyo Mountains have produced simple horizontal traces from the Wyman Formation (Alpert, 1976). Moderately well-preserved pre-trilobite shelly fossils occur in the Deep Spring Formation (Signor et al., 1987). Trilobites, and archaeocyathans, occur in the Campito Formation (Signor and Mount, 1986).

"Two fragmentary specimens of frondose Ediacaran soft-bodied fossils occur within the middle member of the Lower Cambrian Poleta Formation in the White Mountains of California" (Hagadorn, personal communication, 1999). Brachiopods, helicoplacoids, archeocyathids, trilobites, and the trace fossils*, Skolithos* and *Taphrhelminthopsis*, have also been reported from the middle member of the Poleta Formation (Durham and Caster, 1963; McKee and Gangloff, 1969; Alpert, 1975; Moore, 1976; Nelson, 1976; Hagadorn, 1994).

**Funeral Mountains. —**A Late Tertiary vertebrate track locality has been reported within the Funeral Mountains just outside of the eastern boundary of Death Valley National Park (Troxel, personal communication, 1999).

**Hines Ridge**. —This ridge preserves the "best exposures of Precambrian-Cambrian transition in the southwestern Great Basin" (Mount and Signor, 1989b, p. 92). These formations contain a similar paleoenvironmental assemblage of earliest Cambrian, pre-trilobite shelly fauna as seen in other White-Inyo facies localities, such as Westgard Pass and the "type" Waucoba Springs section.

**Andrews Mountain**. —This locality within the White-Inyo Mountains contains the trace fossil *Bergaueria* (Alpert, 1976).

**Horse Thief Springs**. —Horodyski and Mankiewicz (1990) reported on a possible late Proterozoic alga - *Tenuocharta cloudii* from chert and dolomite exposures within the Beck Spring Dolomite. Horodyski (1993) reported a "vase-shaped" microfossil, possibly *Melanocyrillium* in medium gray silty mudstones near the contact of the Beck Spring Dolomite and Kingston Peak Formation. They were found associated with the sheet-like alga *Tenuocharta cloudii*. Horodyski (1993) believes that this transitional unit may represent a "distinct lithostratigraphic unit" that may be traceable throughout the exposures of the Kingston Peak Formation, including those within Death Valley. Carbonaceous, non-branching tubular microstructures identified as *Girvanella* are interpreted as probable cyanophytes and are described by Licari (1978). A number of chroococacean cyanophytes, nostocacean cyanophytes, chlorococcalean chlorophytes, chlorophytes, and chrysophytes have been reported.

**Mt. Dunfee**. —A pre-trilobite shelly fauna has been described by Gevirtzman and Mount (1986) from the lower member of the Deep Spring Formation. This fauna consists of *Coleoloides*, *Sinotubulites*, *Salanytheca* and the ichnofossils *Paleophycus* or *Planolites*, *Neonerites*, *Scolicia*, and *Bergaueria*. The fauna is similar to the pre-trilobite shelly fauna found in Deep Spring exposures in Death Valley.

**Lake Manly**. —This is the name given to all late Pleistocene (240,000 - 10,500 years before present) lake bodies placed within the Death Valley area. Lacustrine deposits occur on the western front of the Black Mountains nearly to Artists Drive and along the Badwater Road on the flank of Copper Canyon. Faint strandlines cross the west face of low hills north of the park's residential complex at Cow Creek. Geologic data indicates that Lake Manly fluctuated frequently. It appears that there was no outlet to the lake (Collier, 1990). The maximum depth was between five to six hundred feet. Well developed strandlines occur throughout the valley. These strandlines probably extended up to one hundred miles long and was seven to eight miles wide. The strandlines indicate that pluvial conditions in the valley were extensive due to cooler and wetter conditions in the desert.

**Other Areas**. —Other National Park Service areas with paleontological resources near Death Valley include Joshua Tree National Monument, Lake Mead National Recreation Area, and Mojave National Preserve. The only known dinosaur tracks from California occur just south of Death Valley National Park (Reynolds, personal communication, 1998).

## References

Aitken, J. D. 1966. Middle Cambrian to Middle Ordovician cyclic sedimentation, southern Rocky Mountains of Alberta. Bulletin of the Canadian Petroleum Geologist, 14:405-411.

Aitken, J. D. 1978. Revised models for depositional Grand Cycles, Cambrian of the southern Rocky Mountains, Canada. Bulletin of the Canadian Petroleum Geologist, 26:515-542.

Alf, M. 1959. Mammal footprints from the Avawatz Formation, California. Bulletin of Southern California Academy of Science, 58(1):1-7.

Alf, M. 1966. Mammal trackways from the Barstow Formation, California. Bulletin of Southern California Academy of Science, 65:258-264.

Alpert, S. P. 1975. *Planolites* and *Skolithos* from the upper Precambrian-Lower Cambrian, White-Inyo Mountains, California. Journal of Paleontology, 49(3):508-521.

Alpert, S. P. 1976. Trilobite and star like trace fossils from the White-Inyo Mountains, California. Journal of Paleontology, 50(2):226-239.

Axelford, D. I. 1940. A record *Lyonothamnus* in Death Valley, California. Journal of Geology, 48(5):526-531.

Awramik, S. M., F. A. Corsetti, and R. S. Shapiro. 1994. Pre-symposium excursion: Death Valley region. Death Valley International Stromatolite Symposium, 43p.

Bachman, S. B. 1978. Pliocene-Pleistocene break-up of the Sierra Nevada - White Inyo Mountains block and formation of Owens Valley. Geology, 6(46):1-463.

Bates, E. E. 1965. Stratigraphic analysis of the Cambrian Carrara Formation Death Valley Region, California-Nevada. Unpubl. M.S. Thesis, University of California, Los Angeles, 228p.

Barnes, H. and Christiansen, R. L. 1967. Cambrian and Precambrian rocks of the Groom District, Nevada, southern Great Basin. U.S. Geological Survey Bulletin, B1224-G, p. 1-34.

Bartlett, R. 1962. Great surveys of the American west. University of Oklahoma Press, Norman, p. 333-349.

Bond, G. C., and M. A. Kominz. 1984. Evidence for thermal subsidence and eustatic sea level change from the lower Paleozoic miogeocline in western North America. Geological Society of America Bulletin, 95:155-173.

Byers, F. M. Jr., H. Barnes, F. G. Poole, and R. J. Ross Jr. 1961. Revised subdivision of Ordovician system at the Nevada Test Site and vicinity, Nevada. U. S. Geological Survey Professional Paper, 424-C(189):106-110.

Carroll, R. L. 1987. Vertebrate Paleontology and Evolution. Freeman Company Publishers, New York, 698p.

Cemen, I., L. A. Wright, and R. Drake. 1985. Stratigraghy and sedimentary environments of the Artist Drive Formation, Furnace Creek Basin, Death Valley, California. The Geological Society of America, Abstracts with Programs, 17(6):347.

Chapin, C. E. 1971. Asymmetry of the Rio Grande rift; tectonic implications. Geological Society of America, Abstracts with Programs, 3 (7):765-767.

Christiansen, R. L., R. S. Yeats, with contributions from S. A. Graham, W. A., A. R. Niem, and P. D. Snavely Jr. 1992. Post-Laramide geology of the U.S. Cordilleran region, p. 261-406. *In* B. C. Burchfiel, P. W. Lipman, and M. L. Zoback (eds.), The Cordilleran Orogen: Conterminous U.S. The Geology of North America, Volume G-3, Geological Society of America.

Clements, T. 1973. Geological story of Death Valley. Death Valley '49er's Inc., Publication No.1., 58p.

Cloud, P. E. Jr. 1968. Pre-Metazoan evolution and origins of the Metazoa, p. 1-72. *In* E. T. Drake (ed.), Evolution and Environment. A Symposium Presented on the Occasion of the One-Hundredth Anniversary of the Foundation of the Peabody Museum of Natural History at Yale University, Yale University Press.

Cloud, P., G. R., Licari, L. A. Wright, and B. W. Troxel. 1969. Proterozoic eucaryotes from eastern California. Proceedings of the National Academy of Science, 62:623-630.

Cloud, P. E., Jr., and Nelson, CA. 1966. Phanerozoic-Cryptozoic and related transitions; New evidence. Science, 154(3750):766-770.

Cloud, P. E., and M. A. Semikhatov. 1969. Proterozoic stromatolite zonation. American Journal of Science, 267:1017-1061.

Cloud, P., L. A. Wright, E. G. Williams, P. E. Diehl, and M. R. Walter. 1974. Giant stromatolites and associated vertical tubes from the Upper Proterozoic Noonday Dolomite, Death Valley region, eastern California. Geological Society of America Bulletin, 85:1869-1882.

Collier, M. 1990. An introduction to the geology of Death Valley. Death Valley Natural History Association, Death Valley, California, 60p.

Cooper, J. D., R. H. Miller, and F.A. Sundberg. 1982. Environmental stratigraphy of the part of the Nopah Formation (Upper Cambrian), southwestern Great Basin, p. 97-114. *In* J. D. Cooper, B. W. Troxel and L. A. Wright (eds.), Geology of Selected Areas in the San Bernardino Mountains, Western Mojave Desert, and Southern Great Basin, California. The Death Valley Publishing Company, Shoshone, California.

Cornwall, H. R., and F.J. Kleinhampl. 1961. Geology of the Bare Mountain Quadrangle, Nevada. U.S. Geological Survey Quadrangle Map GQ-157.

Corsetti, F. A. 1993. Recognition of potential stratigraphic breaks in poorly-fossiliferous sections using carbon-isotope stratigraphy: Neoproterozoic-Cambrian units, White-Inyo Region, eastern California-western Nevada. PaleoBios, 9:211-219.

Corsetti, F. A., and A. J. Kaufman. 1994. Chemostratigraphy of Neoproterozoic-Cambrian units, White-Inyo region, eastern California and western Nevada: Implications for global correlation and faunal distribution. Palaios, 9:211-219.

Curry, D. H. 1939. Tertiary and Pleistocene mammal and bird tracks in Death Valley. Geological Society of America Bulletin, 50(12):1971-1972.

Curry, D. H. 1941. Mammalian and avian ichnites in Death Valley. Geological Society of America Bulletin, 52(12):1979.

Dennison, R. H. 1953. Early Devonian fishes from Utah, Part II, Heterostraci. Fieldiana, Geology 11:265-287.

Denison, R. H. 1970. Revised classification of Pteraspidiae with description of new forms from Wyoming. Fieldiana, Geology, 20:1-41.

Denny, C. S., and H. Drewes. 1965. Geology of the Ash Meadows Quadrangle Nevada-California. Geological Survey Bulletin, 1181-L:1-56.

Diehl, P. E. 1976. Stratigraphy and sedimentology of the Wood Canyon Formation, Death Valley area, California. California Division of Mines and Geology, Special Report, 106:51-62.

Diehl P. E. 1979. The stratigraphic, depositional environments, and quantitative petrography of the Precambrian-Cambrian

Wood Canyon Formation, Death Valley. Unpubl. dissertation, Pennsylvania State University, 430p.

Dunkle, D. H., and N. G. Lane. 1971. Devonian fishes from California. Kirtlandia, (15), 5p.

Dokka, R. K. 1986. Patterns of early Miocene crustal extension, central Mojave Desert, California, p. 75-95. *In* L. Mayer (ed.), Extensional Tectonics of the Southwestern United States; A Perspective on Processes and Kinematics. Geological Society of America, Special Paper, 208.

Durham, J. W. 1993. Observations on the Early Cambrian helicoplacoped echinoderms. Journal of Paleontology, 67(4):590-604.

Durham, J. W. and K. E. Caster. 1963. Helicoplacoidea: a new class of echinoderms. Science, 140:1109-1119.

Easton, W. H. 1955. Silurian fauna from the Funeral Range, Death Valley, California. Geological Society of America Bulletin, 66(12):1665-1666.

Elliott, D. K., and R. R. Ilyes. 1993. Lower Devonian vertebrates from the Lippincott Member of the Lost Burro Formation in Death Valley National Monument, p. 40. *In* V.L. Santucci (ed.), National Park Service Paleontological Research Abstract Volume No. 1, NPS/NRPEFO/NRTR-93/11.

Elliott, D. K., and R. R. Ilyes. 1996(a). Lower Devonian vertebrate biostratigraphy of the western United States. Modern Geology, 20:253-262.

Elliott, D. K., and R. R. Ilyes. 1996(b). New Early Devonian Pteraspidids (Agnatha, Heterostraci) from Death Valley National Monument, southeastern California. Journal of Paleontology, 70(1):152-161.

Fedo, C. M., and J. D. Cooper. 1990. Bradied fluvial to marine transition: the basal Lower Cambrian Wood Canyon Formation, southern Marble Mountains, Mojave Desert, California. Journal of Sedimentary Petrology, 60:220-234.

Fedo, C. M., and A. R. Prave. 1991. Extensive Cambrian braidplain sedimentation: Insights from the southwestern U.S.A. Cordillera, p. 227-235. *In* J. D. Cooper, and C. H. Stevens (eds.), Paleozoic Paleogeography of the Western United States, II. Pacific Section SEPM.

Firby J. B., and J. W. Durham. 1974. Molluscan radula from earliest Cambrian. Journal of paleontology, 48(6):1109-1119.

Foster, M. F. 1961. Ordovician receptaculitids, trilobites, and brachiopods from the Grapevine Mountains, Unpubl. M.S. Thesis, University of California, Los Angeles, 121p.

Foster, M. 1973. Ordovician receptaculitids from California and their significance. Lethaia, 5:35-65.

Fritz, W. H. 1972. Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwestern Canada. Canada Geological Survey Bulletin, 212:1-90.

Gangloff, R. A. 1975. Archaeocyatha from California and Nevada, a challenge for the paleoecologist. Geological Society of America, Abstracts with Program, 7(7):1082.

Garfunkel, Z. 1974. Model of the late Cenozoic tectonic history of the Mojave Desert, California, and for its relation to adjacent areas: Geological Society of America Bulletin, 85:1931-1944.

Gevirtzman, D. A., and J. F. Mount. 1986. Paleoenvironments of an earliest Cambrian (Tommotian) shelly fauna in the southwestern Great Basin, U.S.A. Journal of Sedimentary Petrology, 56(3):412-421.

Glazner, A. F. 1988. Stratigraphy, structure, and potassic alterations of Miocene volcanic rocks in the Sleeping Beauty area, central Mojave Desert, California. Geological Society of America Bulletin, 100:424-435.

Gordon, M. Jr. 1964. California Carboniferous Cephalopods. U. S. Geological Survey Professional Paper, Contributions to Paleontology, 483-A:1-25.

Griffin, K. M. 1987. A comparison of the depositional environments of Upper Cambrian thrombolites and stromatolites of the Nopah Formation, Death Valley region, California, and modern stromatolites of the Bahamas. Geological Society of America, Abstracts with Programs, p. 446-447.

Gustadt, A. M. 1968. Petrology and depositional environments of the Beck Springs Dolomite (Precambrian), Kingston Range, California. Journal of Sedimentology and Petrology, 38(4):1280-1289.

Hagadorn, J. W., C. W. Pridgen, and D. J. Bottjer. 1994. *Taphrhelminthopsis*: trace fossils of large soft-bodied Early Metazoans from the Lower Cambrian Poleta Formation, White-Inyo Mountains, California. Geological Society of America, Abstracts with Programs, 26:56.

Hagadorn, J. W., and B. M. Wagonner. 1998. Venedian-Lower Cambrian faunas from the southwestern U.S. Geological Society of America, Abstracts with Programs, 30(7):A233.

Hague, A. 1883. Geology of the Eureka district, Nevada. U. S. Geological Survey, 3rd Annual Report, p. 237-290.

Hall, W. E. 1971. Geology of the Panamint Butte Quadrangle, Inyo County, California. U. S. Geological Survey Bulletin 1229, 67p.

Hall, W. E., and E. M. MacKevett Jr. 1958. Economic geology of the Darwin Quadrangle, Inyo County, California. California Division of Mines, Special Report, 3:237-290.

Hamilton, W. 1961. Origin of the Gulf of California. Geological Society of America Bulletin, 72:1307-1318.

Hamilton, W. 1969. Mesozoic California and the underflow of Pacific mantle. Geological Society of America Bulletin, 80:2409-2430.

Hanson, B. C. 1989. *Teletaceras radinskyi*, a new primitive Rhinocerotid from the Late Eocene Clarno Formation of Oregon, p. 391-395. *In* D. R. Prothero, and R. M. Schoch (eds.), The Evolution of Perissodactyls. Oxford University Press, New York.

Hardy, K. J. 1988. Stratigraphy and geologic history of the Death Valley region a brief introduction, p. 63-76. *In* E. M. Gath, J. L. Gregory, J. R. Sheehan, E. J. Hardy, and J. Kirk (eds.), Geology of the Death Valley Region, Annual Field Trip Guidebook 16, South Coast Geological Society, Inc.

Haug, G. A. 1981. Early Silurian depositional environments of the lower unit of the Hidden Valley Dolomite, Great Basin. Unubl. M.S. Thesis, San Diego State University, San Diego, California.

Hazzard, J. C. 1937. Paleozoic section in the Nopah and Resting Springs Mountains, Inyo County, California. California Journal of Mines and Geology, 33(4):273-339.

Hazzard, J. C. 1954. Rocks and structures of the northern Providence Mountains, San Bernardino County, California. California Mines and Geology Bulletin, 170:27-35,

Hazzard, J. C., and J. F. Mason. 1936. Middle Cambrian formations of the Providence and Marble Mountains, California. Geology Society of American Bulletin, 47(2):229-240.

Hewett, D. F. 1940. New formations to be used in the Kingston Range, Ivanpah Quadrangle, California. Washington Academy of Science Journal, 30:239-240.

Hewett, D. F. 1956. Geology and mineral resources of the Ivanpah

Quadrangle, California and Nevada. U.S. Geological Society of America Special Paper 275, 172p.

Hildreth, W. 1976. Death Valley Geology. Death Valley National Historic Association, 72p.

Hillhouse, J. W. 1987. Late Tertiary and Quaternary geology of the Tecopa basin, southeastern California. U. S. Geological Survey, Miscellaneous Investigation Series, Map I-1228.

Horodyski, R. J. 1991. Late Proterozoic megafossils from southern Nevada. Geological Society of America, Abstracts with Programs, 23:163.

Horodyski R. J. 1993. Paleontology of Proterozoic shales and mudstones: examples from the Belt Supergroup, Chuar Group and Pahrump Group, western USA, p. 241-278. *In* B. Nagy, J. S. Leventhal, and R. F. Grauch (eds.), Metalliferous Black Shales and Related Ore Deposits. Precambrian Research, 61.

Horodyski, R. J., J. G. Gehling, S. Jensen, and B. Runnegar. 1994. Ediacaran fauna and earliest Cambrian trace fossils in a single parasequence set, southern Nevada. Geological Society of America, Abstracts with Programs, 26(2):60.

Horodyski R. J., and C. Mankiewicz. 1990. Possible Late Proterozoic skeletal algae from the Pahrump Group, Kingston Range, southeastern California. Journal of Science, 290-A:149-169.

Howell, D. G. 1971. A stromatolite from the Proterozoic Pahrump Group, eastern California. Journal of Paleontology, 45:48-51.

Huddle, J.W. 1970. Revised descriptions of some late Devonian polygnathid conodonts. Journal of Paleontology, 44(6):1029-1040.

Hunt, C. B. 1975. Death Valley: geology, ecology, and archaeology. University of California Press, 234p.

Hunt, C. B., and D. R. Mabey. 1966. General geology of Death Valley, California - stratigraphy and structure. U. S. Geological Society, Professional Paper, 494-A, 162p.

Hunt, D. L. 1990. Trilobite faunas and biostratigraphy of the Lower Cambrian Wood Canyon Formation, Death Valley region, California. Unpubl. M.S. Thesis, University of California, Davis, 140p.

Johnson, J. G., C. A. Sandberg, and F. G. Poole. 1988. Early and Middle Devonian Paleogeography of western United States, p. 161-182. *In* N. J. McMillan, A. F. Embry and D. J. Glass (eds.), Devonian of the World, Volume 1: Regional Synthesis. Canadian Society of Petroleum Geologists Memoir 14.

Kauffman, E. G., and J. R. Steidtmann. 1981. Are these the oldest metazoan trace fossils? Journal of Paleontology, 55:923-947.

Langenheim, R. L. Jr. 1954. Preliminary report of fossil investigations: Death Valley National Monument. Unpubl. Report, Death Valley Library, 8p.

Langenheim, R. L. Jr., and H. Tischler. 1959. Stratigraphy and paleontology of the Tin Mountain Limestone and Perdido Formation, Quartz Spring area, Death Valley National Monument, Inyo County, California. Geological Society of America, Abstracts with Programs, 70(12):1635.

Langille, G. B. 1974. Earliest Cambrian-latest Proterozoic ichnofossils and problematic fossils from Inyo County, California. Unpubl. Dissertation, State University of New York, Binghamton. 194p.

Licari, R. R. 1978. Biogeology of the Late Pre-Phanerozoic Beck Spring Dolomite of eastern California. Journal of Paleontology, 52 (4):767.

Link P. K., Christie-Blick, N., Devlin, W. J., Elston, D. P., Horodyski, R. J., Levy, M. G., Miller, J. M. G., Pearson, R. C., Prave, A., Stewart, J. H., Winston, D., Wright, L. A., and Wrucke, C. T. 1993. Middle and Late Proterozoic stratified rocks of the western U.S. cordillera, Colorado Plateau, and Basin and Range Province, p. 463-595. *In* J. C., Reed, M. E., Bickford, R. S., Houston, P. K., Link, D. W., Rankin, P. K., Sims, and W. R., Van Schmus (eds.), Precambrian: Conterminous U.S., The Geology of North America, Volume C-2, Geological Society of America.

Loring, F. 1871. Into the Valley of Death, p. 574-75. *In* Appleton's Journal of Literature, Science, and Art, VI(138).

Maud, R. L. 1979. Stratigraphy and depositional environments of the carbonate-terrigenous member of the Crystal Spring Formation, Death Valley California. Unpubl. M.S. Thesis, Pennsylvania State University, 221p.

Marian, M. L. 1979. Sedimentology of the Beck Spring Dolomite, eastern Mojave Desert, California. M.S. Thesis, University of Southern California, Los Angeles, 216p.

Marian, M. L. 1992. Petrology, petrochemistry, and stromatolites of the middle to late Proterozoic Beck Spring Dolomite, eastern Mojave Desert, California, p. 2595-2609. *In* Randy, J. (ed.), Precambrian Sedimentation-Sedimentation Precambrian. National Research Council of Canada, Ottawa, Ontario, 29(12).

Mason, M. A. 1988. Mammalian paleontology and stratigraphy of the early to middle Tertiary Sespe and Titus Canyon Formations, southern California. Unpubl. Dissertation, University of California, Berkeley, 257p.

McAllister, J. F. 1952. Rocks and structure of the Quartz Spring area, northern Panamint Range, California. California Division of Mines and Geology, Special Report 25, 38p.

McAllister, J. F. 1955. Geology of the mineral deposits in the Ubehebe Quadrangle, Inyo County, California. California Division of Mines, Special Report 42, 63p.

McAllister, J. F. 1970. Geology of the Borate Area, Death Valley, Inyo County, California, p. 84-90. *In* Guidebook: Death Valley Region, California and Nevada, prepared for the 70th annual meeting of the Cordilleran Section, the Geological Society of America, field trip number 1.

McAllister, J. F. 1974. Silurian, Devonian, and Mississippian Formations of the Funeral Mountains in the Ryan Quadrangle, Death Valley Region, California. U. S. Geological Survey Bulletin 1386, 35p.

McKee, E. H., and R. A. Gangloff. 1969. Stratigraphic distribution of archaeocyathids in the Silver Peak Range and the White and Inyo Mountains, western Nevada and eastern California. Journal of Paleontology, 43(3):716-726.

Merriam, C. W., and C. A. Anderson. 1942. Reconnaissance survey of the Roberts Mountains, Nevada. U. S. Geological Society of America Bulletin, 53:1675-1728.

Merriam C. W., and W. E. Hall. 1957. Pennsylvanian and Permian rocks of the southern Inyo Mountains, California. U.S. Geological Survey Bulletin 1061-A, 15p.

Miller, D. M., T. H. Nilsen, and W. L. Bilodeau. 1992. Late Cretaceous to early Eocene geologic evolution of the U.S. Cordillera, p. 205- 260. *In* B. C. Burchfiel, P. W. Lipman, and M. L. Zoback (eds.), The Cordilleran Orogen: Conterminous U.S. The Geology of North America, Volume G-3, Geological Society of America.

Miller, R. H. 1976. Revison of upper Ordovician, Silurian, and lower Devonian stratigraphy, southwestern Great Basin. Geological Society of America Bulletin, 87:961-968.

Miller, R. H. 1978. Early Silurian to Early Devonian conodont biostratigraphy and depositional environments of the Hidden Valley Dolomite, southeastern California. Journal of Paleontology, 52(2):323-344.

Miller, R. H. 1982. Ordovician and Silurian stratigraphy and depositional environments, Nopah Range, southwestern Great Basin, p. 117-128. *In* J. D. Cooper, B. W. Troxel, and L. A. Wright (eds.), Geology of Selected Areas in the San Bernardino Mountains, Western Mojave Desert, and Southern Great Basin, California. The Death Valley Publishing Company, Shoshone, California.

Miller, R. H., and F. M. Hanna. 1972. Silurian conodonts from Death Valley, California: preliminary report. Journal of Paleontology, 46(6):922-924.

Miller, R. H., and E. A. Paden. 1976. Upper Cambrian stratigraphy and conodonts from eastern California. Journal of Paleontology, 50(4):590-597.

Miller, R. R. 1945. Paleontology - four new species of fossil cyprinodont fishes from eastern California. Journal of the Washington Academy of Sciences, 35(10):315-321.

Moore, J. N. 1974. Stratigraphic comparison of the Precambrian Wyman and Johnnie Formation in the western Great Basin, California. Geological Society of America, Abstracts with Programs, 6:222-223.

Moore, J. N. 1976. Depositional environments of lower Paleozoic rocks in the White-Inyo Range, Inyo County, California: A field trip road log, p. 1-12. *In* J. N. Moore, and A. E. Fritsche (eds.), Depositional Environments of Low Paleozoic Rocks in the White-Inyo County, California. Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography, Field Guide 1.

Mount, J. F. 1980. The environmental stratigraphy and depositional systems of the Precambrian(?) -Cambrian Campito Formation, eastern California and western Nevada: Unpubl. Dissertation, University of California, Santa Cruz, 239p.

Mount, J. F. 1982. Earliest Cambrian Paleoenvironments of the Southern Great Basin, p. 187- 194. *In* J. D. Cooper, B. W. Troxel, and L. A. Wright (eds.), Geology of Selected Areas in the San Bernardino Mountains, Western Mojave Desert, and Southern Great Basin, California. The Death Valley Publishing Company, Shoshone, California.

Mount, J. F., D. L. Hunt, L. R. Greene, and J. Dienger. 1991. Depositional systems, biostratigraphy and sequence stratigraphy of Lower Cambrian Grand Cycles, southwestern Great Basin, p. 206-226. *In* J. D. Cooper, and C. H. Stevens (eds.), Paleozoic Paleogeography of the Western United States, II. Pacific Section, SEPM.

Mount, J. F., and P. W. Signor. 1989a. Paleoenvironmental context of the metazoan radiation event and its impact on the placement of the Precambrian-Cambrian Boundary: Examples from the southwestern Great Basin, U.S.A., p. 39-46. *In* N. Christie-Blick, and M. Levy (eds.), Late Proterozoic and Cambrian Tectonics, Sedimentation, and Record of Metazoan Radiation in the Western United States. 28th International Geological Congress Field Trip Guidebook T331, American Geophysical Union.

Mount, J. F., and P. W. Signor. 1989b. Description of field trip stops, p. 88-99. *In* N. Christie-Blick, and M. Levy (eds.), Late Proterozoic and Cambrian Tectonics, Sedimentation, and Record of Metazoan Radiation in the Western United States. 28th International Geological Congress Field Trip Guidebook T331, American Geophysical Union.

Mount, J. F., and P. W. Signor. 1985. Early Cambrian innovation in shallow subtidal environments: Paleoenvironments of Early Cambrian shelly fossils. Geology, 13:730-733.

Mount, J. F., and P. W. Signor. 1992. Faunas and facies-facts and artifact paleoenvironmental controls on the distribution of Early Cambrian faunas, p. 27-51. *In* J. H. Lipps, and P. W. Signor (eds.), Origin and Early Evolution of the Metzoa. Plenum Press, New York.

Nelson, C. A. 1962. Lower Cambrian-Precambrian succession, White-Inyo Mountains, California. Geological Society of America Bulletin, 73(1):139-144.

Nelson, C. A. 1976. Late Precambrian-Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary, depositional environments of Lower Paleozoic rocks in the White-Inyo Mountains, Inyo County, California. Pacific Coast Paleontology Field Guide, 1:31-32.

Nelson, C. A. 1978. Late Precambrian-Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary. Geological Magazine, 115(2):121-126.

Nelson, C. A., and J. W. Durham. 1966. Guidebook to fieldtrip to Pre-Cambrian Succession White-Inyo Mountains, California. Guide for Geological Society of America Annual Meeting Fieldtrip.

Noble, L. F. 1934. Rock formations of Death Valley, California. Science, 80(2069):173-178.

Noble, L. F. and L. A. Wright. 1954. Geology of the central and southern Death Valley region, California. California Division Mines Bulletin, 170(2):143-160.

Nolan, T. B. 1929. Notes on the stratigraphy and structure of the northwest portion of the Spring Mountains, Nevada. American Journal of Science, 5th series, 17:461-472.

Nolan, T. B., C. W. Merriam, and J. S. Williams. 1956. The stratigraphic section in the vicinity of Eureka, Nevada. U. S. Geological Survey Professional Paper 276, 77p.

Nolan, T. B., Merriam, C. W., and Williams, J. S. 1956. The stratigraphic section in the vicinity of Eureka, Nevada. U. S. Geological Survey, Professional Paper 1044-9612, 77 p.

Nyborg, T. G. 1998. Paleontological resource management: Systematic recording and preservation of vertebrate tracks within Copper Canyon, Death Valley National Park, California. Unpubl. Death Valley National Park library, 37p.

Onken, B. R., and P. W. Signor. 1988. Lower Cambrian stratigraphic paleontology of the southwestern Great Basin (White-Inyo Mountains of eastern California and Esmeralda County, Nevada). Bulletin of Southern California Paleontology Society, 20:131-150.

Palmer, A. R. 1964. An unusual Lower Cambrian trilobite fauna from Nevada. U. S. Geological Survey Professional Paper, 483-F:1-12.

Palmer, A. R. 1981. On the correlatibility of Grand Cycle tops, p. 193-197. *In* M. E. Taylor (ed.), Short Papers for the Second International Symposium on the Cambrian System. U.S. Geological Survey, Open-File Report, 81-743.

Palmer, A. R. 1982. The Carrara Formation in Southern Great Basin, p. 195-195. *In* J. D. Cooper, B. W. Troxel, and L. A. Wright (eds.), Geology of Selected Areas in the San Bernardino Mountains, Western Mojave Desert, and Southern Great Basin, California. The Death Valley Publishing Company, Shoshone, California.

Palmer, A. R,. and R. B. Halley. 1979. Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin. U. S. Geological Survey, Professional Paper 1047, 131p.

Palmer, A. R., and C. A. Nelson. 1981. Lower and Middle Cambrian stratigraphy and paleontology of the southern Great Basin, California and Nevada, p. 1-10. *In* M. E. Taylor, and A. R. Palmer (eds.), Cambrian Stratigraphy and Paleontology of the Great Basin and Vicinity, Western United States. Second International Symposium on the Cambrian System, Guidebook for Field Trip, number 1.

Parsons, S. M. 1996. Sequence stratigraphy and biostratigraphy of the lower member of the Deep Spring Formation; implications for the Neoproterozoic-Cambrian boundary in the Basin and Range Province, Western United States. M.A. Thesis, University of Nevada, Las Vegas, Nevada.

Peck, J. H. Jr. 1950. Paper on fossils collected from Tin Mountain, Death Valley. Death Valley National park Library, Death Valley, California.

Peterson, O. A. 1931. New species from the Oligocene of Uinta. Annals of Carnegie Museum, 21:61-78.

Pierce, D. E., and S. M., Awramik. 1994. Age and significance of microfossils from the Meso-Neoproterozoic Pahrump Group, eastern California. Geological Society of America, Abstracts with Programs, 26 (2):81.

Pitts, K. L. 1983. Pliocene lacustrine stromatolites of the Furnace Creek Formation, Death Valley, California. Unpubl. M. A. Thesis, University of California, Los Angeles, California, 93p.

Poole, F. G., J. H. Stewart, A. R. Palmer, C. A. Sandberg, R. J. Madrid, J. R. Reuben Jr., L. F. Hintze, M. M. Miller, and C. T. Wrucke. 1992. Latest Precambrian to latest Devonian time; development of a continental margin, p. 9-56. *In* B. C. Burchfiel, P. W. Lipman, and M. L. Zoback (eds.), The Cordilleran Orogen: Conterminous U.S. The Geology of North America, Volume G-3, Geological Society of America.

Prave, A. R. 1984. Stratigraphy, sedimentology, and petrography of the Lower Cambrian Zabriskie Quartzite in the Death Valley region, southeastern California and southwestern Nevada, 193p.

Prave, A. R. 1988. Sedimentology and stratigraphy of the Lower Cambrian Zabriskie Quartzite in the Death Valley region, California and Nevada, p. 88-101. *In* J. F. Gregory, and E. J. Baldwin (eds.), Geology of the Death Valley region, Meeting of the South Coast Geological Society, Field Trip.

Prave, A. R., C. M. Fedo, and J. D. Cooper. 1991. Lower Cambrian depositional and sequence stratigraphic framework of the Death Valley and eastern Mojave Desert regions, p. 147-170. *In* M. J. Walawender, B. B. Hannan (eds.), Geologic Excursions in California and Mexico: Guidebook for 1991 Geological Sociey of America Meeting. Geological Society of America.

Prave, A. R., and L. A. Wright. 1986. Isopach pattern of the Lower Cambrian Zabriskie Quartzite, Death Valley region, California-Nevada; how useful in tectonic reconstructions?, Geology, 14(3):251-254.

Runnegar, B., J. G. Gehling, R. J. Horodyski, S. Jensen, and P. L. Knauth. 1995. Base of the Sauk Sequence is a global eustatic event that lies above the Precambrian-Cambrian boundary. Geological Soceity of America, Abstracts with Programs, 27(6):330.

Roberts, M. T. 1976. Stratigraphy and depositional environments of the Crystal Spring Formation, southern Death Valley region, California. California Division of Mines and Geology, Special Report, 106:35-44.

Rowell, A. J. 1977. Early Cambrian brachiopods from the southwestern Great Basin of California and Nevada. Journal of Paleontology, 51(1):68-85.

Rowland, S. M. 1978. Environmental stratigraphy of the Lower Member of the Poleta Formation (Lower Cambrian), Esmeralda County, Nevada. Unpubl. Dissertation, University of California, Santa Cruz, 124p.

Rowland, S. M. 1979. Charles Walcott and the North American Lower Cambrian type section at Waucoba Spring. Geological Society of America, Abstracts with Programs, 11(3):125.

Rowland, S. M., and S. J. Carlson. 1983. *Westgardia gigantea*, a new Lower Cambrian fossil from eastern California. Journal of Paleontology, 57(6):1317-1320.

Runnegar, B., J. G. Gehling, R. J. Horodyski, S., Jensen, and P. L. Knauth. 1995. Base of the Sauk sequence is a global eustatic event that lies just above the Precambrian-Cambrian boundary. Geological Society of America, Abstracts with Programs, 27:330.

Runnegar, B., J. G. Gehling, R. J. Horodyski, S., Jensen, and P. L. Knauth. 1998. Precambrian-Cambrian boundary in the southern Great Basin, California and Nevada and the base of the Sauk sequence. Geological Society of America, Abstracts with Programs, 30(3):63

Runnegar, B., Pojeta, J. Jr., Taylor, M. E., and Collins, D. 1979. New species of the Cambrian and Ordovician chitons *Matthevia* and *Chelodes* from Wisconsin and Queensland: evidence for the early history of polyplacophoran mollusks. Journal of Paleontology, 53(6):1374-1394.

Sando, W. J. 1969. Corals, p. 257-343. *In* E. D. McKee, and R. C. Gutschick (eds.), History of the Redwall Limestone of Northern Arizona, Geological Society of America Memorandum 114.

Santucci, V. L. 1998. Paleontological resource management of the Copper Canyon Fossil Track Site, Death Valley National Park. Geologic Resources Division, National Park Service, 9p.

Santucci, V. L., A. P. Hunt, and M. P. G. Lockley. 1998. Fossil vertebrate tracks in National Park Service areas. Dakoterra, 5:107-114.

Sharp, R. R., and A. F. Glazner. 1997. Geology underfoot in Death Valley and Owens Valley. Mountain Press Publishing Company Missoula, Montana, 312p.

Scrivner, P. J. 1984. Stratigraphy , sedimentology and vertebrate ichnology of the Copper Canyon Formation (Neogene), Death Valley National Monument. Unpubl. M.S. Thesis, University of California, Los Angeles, 334p.

Scrivner, P. J. and D. J. Bottjer. 1986. Neogene avian and mammalian tracks from Death Valley National Monument, California: their context, classification and preservation. Paleogeography, Paleoclimantology, Paleoecology, 56:285-331.

Sears, D. H. 1955. Geology of central Panamint Range (California), Bulletin of the American Association of Petroleum Geologists, 39(1):140.

Seiple, E. 1984. Fossils and formations of the Lower Cambrian type Waucoban Section. California Geology, 37(7):149-153.

Seiple, E. 1999. Gold Point trilobites: just north of Death Valley are some 540 million-year-old treasures. Rock and Gem Magazine, 29(2) 72-75.

Sheehan, J. R. 1988. Overview of the tectonics of Death Valley, California, p. 161-177. *In* Geology of the Death Valley Region, annual field trip guidebook, 16. South Coast Geological Society, Inc.

Signor, P. W., and J. F. Mount. 1986. Lower Cambrian stratigraphic paleontology of the White-Inyo Mountains of eastern California and Esmeralda County, Nevada. *In* Nello Pace Symposium Volume, White Mountain Research Station, University of California Press, Berkeley.

Signor, P. W., and J. F. Mount. 1989. Paleontology of the Lower Cambrian Waucoba Series in Eastern California and Nevada, p. 47-53. *In* N. Charity-Blick, and M. Levy (eds.), Late Proterozoic and Cambrian Tectonics, Sedimentation, and Record of Metazoan Radiation in the Western United States. 28th International Geological Congress Field Trip Guidebook T331, American Geophysical Union.

Signor, P. W., J. F. Mount, and B. R. Onken. 1987. A pre-trilobite shelly fauna from the White-Inyo Region of eastern California and western Nevada. Journal of Paleontology, 61(3):425-438.

Signor, P. W. and M. Savarese. 1988. Paleoecological and biostratigraphic implications of archaeocyathan biohems and associated faunas in the Wood Canyon Formation, Death Valley, California. Geological Society of America, Abstracts with Programs, 20(3):231.

Skipp, B. 1969. Foraminifera, p. 173-255. *In* E. D. McKee , and R. C. Gutschick (eds.), History of the Redwall Limestone of northern Arizona. Geological Society of America, Memorandum 114.

Spurr, J. E. 1903. Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California. U.S. Geological Survey Bulletin 208, p. 229.

Stewart, J. H. 1966. Correlation of the Lower Cambrian and some Precambrian strata in the southern Great Basin, California and Nevada. U. S. Geological Survey, Professional Paper, 550-C:66-72.

Stewart, J. H. 1970. Upper Precambrian and Lower Cambrian strata in the southern Great Basin, California and Nevada. U. S. Geological Survey, Professional Paper 620, 206p.

Stewart, J. H. 1972. Initial deposits of the Cordilleran geosyncline; evidence of a late Precambrian (<850 my.) continental separation. Geological Society of America Bulletin, 83:1345-1360.

Stinchcomb, B. L., and Darrough, G. 1995. Some molluscan problematic from the upper Cambrian-lower Ordovician of the Ozark Uplift. Journal of Paleontology, 69(1):52-65.

Summa, C. L., J. B. Southard, and J. P. Grotzinger. 1991. Stratigraphy and sedimentology of the late Proterozoic Johnnie Formation, eastern California and western Nevada. Geological Society of America, Abstracts with Program, 23 (5):347.

Summa, C. L., J. B. Southard, and J. P. Grotzinger. 1993. Distinctive cross-stratification in amalgamated storm event beds; Neoproterozoic upper Johnnie Formation, eastern California, Geological Society of America, Abstracts with Programs, 25 (6): 67.

Stock, C. 1936. Titanotheres from the Titus Canyon Formation, California. Proceedings of the National Academy of Sciences, 22(11):656-661.

Stock, C. 1949. Mammalian Fauna from the Titus Canyon Formation, California. Contributions to Paleontology, Carnegie Institute of Washington Publication, 584(VIII):231-244.

Stock, C., and F. Bode. 1935. Occurrence of lower Oligocene mammal bearing beds near Death Valley, California. Proceedings of the National Academy of Sciences, 21(10):571-579.

Taylor, M. E. 1966. Pre-Cambrian mollusk-like fossils from Inyo County, California. Science, 153:198-201.

Taylor, M. E., and A. R. Palmer. 1981. Cambrian stratigraphy and paleontology of the Great Basin and vicinity, western United States. Second International Symposium on the Cambrian System, Guidebook for Field Trip 1, 44p.

Tischler, H. A. 1955. Devonian and Mississippian stratigraphy of the Rest Spring area, California. Geological Society of America Bulletin, 66 (12, Part 2): 1665-1666.

Tischler, H. A. 1956. A new Mississippian tetracoral from Death Valley, California. Journal of Paleontology, 30(1):110-111.

Troxel, H. A. 1970. Guide to selected features of Death Valley region, p. 40-54. *In* J. W. Gasch, and R. A. Matthew (eds.), Geologic Guide to the Death Valley Area, California, Annual Field Trip Guidebook of the Geologic Society of Sacramento, Sacramento, California

Troxel, B. W. 1982. Basin facies (Ibex Formation) of the Noonday Dolomite, southern Saddle Peak Hills southern Death Valley, California, p. 43-48. *In* J. D. Cooper, B. W. Troxel, and L. A. Wright (eds.), Geology of selected areas in the San Bernardino Mountains, western Mojave Desert, and southern Great Basin, California. The Death Valley Publishing Company, Shoshone, California.

Tucker, M. E. 1983. Diagenesis, geochemistry, and origin of a Precambrian dolomite: Beck Spring Dolomite of eastern California. Journal of Sedimentary Petrology, 53:1097-1119.

Tynan, M. C. 1983. Coral-like microfossils from the Lower Cambrian of California. Journal of paleontology, 57(6):1188-1211.

Waggoner, B. M., and J. W. Hagadorn. 1997. Ediacaran fossils from western North America: Stratigraphic and biogeographic implications. Geological Society of America, Abstracts with Programs, 29(6):A30.

Walcott, C. D. 1885. Note on some Paleozoic pteropods. American Journal of Science, 30:17-21.

Walcott, C. D. 1895. Lower Cambrian rocks in eastern California. American Journal of Science, 49:142-144.

Walcott, C. D. 1908. Cambrian sections of the Cordilleran area. Smithsonian Miscellaneous Collection, 53:167-230.

Wertz, W. E. 1977. Cross-bedding patterns and petrography of the Stirling Quartzite, Death Valley region, California and Nevada. Geological Society of America, Abstracts with Programs, 9:526.

Wertz, W. E. 1982. Stratigraphy and sedimentology of the Stirling Quartzite, Death Valley area, California and Nevada, p. 165-170. *In* J. D. Cooper, B. A. Troxel, and L. A Wright (eds.), Geology of Selected Areas in the San Bernardino Mountains, Western Mojave Desert, and Southern Great Basin, California. Geological Society of America, Cordilleran Section, Guidebook Fieldtrip 9. Death Valley Publishing Company, Shoshone, California.

Wertz, W. E. 1983. The depositional environments and petrography of the Sterling Quartzite, Death Valley region, California and Nevada: Unpubl. Dissertation, University Park, Pennsylvania State University, 193p.

Wheeler, G. M. 1887. Geographical and geological explorations and surveys west of the 100th meridian, American Journal of Science, 7:388-391.

Wheeler, H. E. 1948. Late Precambrian-Cambrian stratigraphic cross section through southern Nevada. University of Nevada Bulletin, 42(3), Geology of Mines Series 47, 58p.

Wigget, G. 1975. Ecology, ethnology, and biostratigraphy of early metazoan faunas in eastern California. Ph.D. Dissertation, University of California, Davis, 347p.

Wigget G. 1977. Late Proterozoic-Early Cambrian biostratigraphy, correlation, and paleoenvironments, White-Inyo facies, California-Nevada. California Division of Mines and Geology, Special Report, 129:87-92.

Williams, E. G., L. A. Wright, and B. W. Troxel. 1976. The Noonday Dolomite and equivalent stratigraphic units, southern Death Valley Region, California. California Division of Mines and Geology, Special Report, 106:45-50.

Wood, R., A. Y. Zhuravlev, and F. Debrenne. 1992. Functional biology and ecology of Archaeocyatha. Palaios 7:131-156.

Woodcook, D. 1986. The late Pleistocene of Death Valley; a climatic reconstruction based on macrofossils data. Paleogeography, Paleoclimantology, Paleoecology, 57:273-283.

Wright, L. A., and B. W. Troxel. 1966. Strata of Late Precambrian-Cambrian age, Death Valley region, California-Nevada. American Association of Petroleum Geologist Bulletin, 50:846-857.

Wright, L. A., and B. W. Troxel, E. G. Williams, M. T. Roberts, and P. E. Diehl. 1976. Precambrian sedimentary environments of the Death Valley region, eastern California. California Division of Mine and Geology, Special Report, 106:7-15.

Wright, L. A., B. W. Troxel, B. C. Burchfield, R. Chapman, and T. Labotka. 1981. Geologic cross section from the Sierra Nevada to the Las Vegas Valley, eastern California to western Nevada. Geological Society of America, map and chart series, MC-28M.

Wright, L. A., and B. W. Troxel. 1984. Geology of the northern half of the Confidence Hills 15-minute Quadrangle, Death Valley region, eastern California; the area of the Amargosa chaos. California Division of Mines and Geology, Map Sheet 34, scale 1:48,000.

Wright, L. A., E. G. Williams, and P. Cloud. 1974. Stratigraphic cross-section through the Noonday Dolomite, War Eagle mine area, southern Nopah Range, California, p. 36. *In* Guidebook; Death Valley Region, California and Nevada, Death Valley Publishing Comapny, Shoshone, California.

Wright, L. A., E. G. Williams, and P. Cloud. 1978. Algal and cryptalgal structures and platform environments of late pre-Phanerozoic Noonday Dolomite, eastern California. Geological Society of America Bulletin, 89:321-333.

Yochelson, E. L., J. F. McAllister, and A. Reso. 1965. Stratigraphic distribution of the Late Cambrian mollusk *Matthevia* (Walcott, 1885). Geological Survey Research 1965, U. S. Geological Survey, Professional Paper, 525-B:73-78.

Yochelson, E. L., and M. E. Taylor. 1974. Late Cambrian *Matthevia* (Mollusca, Matthevida) in North America. Geological Society of America, Abstracts with Programs, p. 88.

Youngquist, W., and A. M. Heinrich. 1966. Late Devonian conodonts from the Lost Burro Formation of California. Journal of Paleontology, 40(4):974-975.

# APPENDIX A:

## Death Valley Paleo-Species List

The names cited here are uncritically compiled from the literature and may not always be the current correct generic identifications.

### Paleobotany

#### Stromatolites

*Baicalia* sp. (Cloud et al., 1969) .................... Crystal Spring Fm.
*Boxonia gracilis* (Cloud and Semikhatov, 1969) ........ Johnnie Fm.
*Conophyton sp.* (Cloud et al., 1969) .............. Crystal Spring Fm.
(Marion and Osborne, 1992) ..... Beck Spring Do.
*Jacutophyton* sp. (Howell, 1971) ................... Crystal Spring Fm.
*Linella ukka* (Cloud and Semikhatov, 1969) ............. Johnnie Fm.
*Paniscollenia* sp. (Cloud et al., 1969) ....................... Johnnie Fm.
*Stratifera* sp. (Marion and Osborne, 1992) ......... Beck Spring Do.
Unident. Stromatolites (Licari, 1978) .................. Beck Spring Do.
(Cloud et al., 1974) ............. Noonday Do.

#### Dasyclad Algae (Receptaulids)

*Ischadites mammillaris* (Foster, 1973) ................. Pogonip Group

#### Algae generic

*Girvanella*(?) sp. (Seiple, 1984) .......................... Mule Spring Ls.
(Palmer and Halley, 1979) ............ Carrara Fm.
(Hall, 1971) .............................. Pogonip Group
*Palaeosiphonella* sp. (Pierce et al., 1994) ....... Kingston Peak Fm.
*Melanocryillium* sp. (Pierce et al., 1994) ........ Kingston Peak Fm.
*Tenuocharta cloudinii* (Pierce et al., 1994) ..... Kingston Peak Fm.

#### Plant Macrofossils

*Abundacapsa impages* (Licari, 1978) .................. Beck Spring Do.
*Batiola mammillaris* (Foster, 1961) ........................ Campito Fm.
*Beckspringia communis* (Licari, 1978) ................ Beck Spring Do.
*Bullasphaera variegata* (Licari, 1978) ................. Beck Spring Do.
*Calamites* sp. (Langenheim, 1954) ........................... Perdido Fm.
*Congloboxella troxelli* (Licari, 1978) ................... Beck Spring Do.
*Coleogyne ramosissima* (Woodcook, 1986) Greenwater townsite
*Erodium sp.* (Woodcook, 1986) ................... Greenwater townsite
*Eurotia lanata* (Woodcook, 1986) ............... Greenwater townsite
Fossil wood (Peck, 1950) ........................................... Tin Mt. Ls.
*Grayia spinosa* (Woodcook, 1986) ............. Greenwater townsite
*Haplopappus laricifoliu* (Woodcook, 1986) Greenwater townsite
*Larrea tridenttata* (Woodcook, 1986) .......... Greenwater townsite
*Latisphaera wrightii* (Licari, 1978) ....................... Beck Spring Do.
*Lyonothamnus mohavensis* (Spurr 1903) ....... Furnace Creek Fm.
*Maculosphaera kingstonensis* (Licari,1978) ........ Beck Spring Do.
*Palaeosiphonella cloudii* (Licari,1978) ................ Beck Spring Do.
*Sphaeralcea ambigua* (Woodcook, 1986) .... Greenwater townsite
*Stromatopora* sp. (Hall, 1971) ............................. Pogonip Group
*Tetradymis spinosa* (Woodcook, 1986) ....... Greenwater townsite
*Thamnosma montana* (Woodcook, 1986) ... Greenwater townsite

### Fossil Invertebrates

#### Phylum Protista

##### Class Sarcodina

###### Order Foraminiferida

*Bathysiphon* sp. (Skipp, 1969) .................................. Tin Mt. Ls.
*Calcisphaera pachysphaerica* (Skipp, 1969) ........... Perdido Fm.
Diatoms (Hardy, 1988) ............... Artist Drive/Furnace Creek Fm.
*Earlandia* sp. (Skipp, 1969) .................................... Perdido Fm.
*Earlandia minima* (Skipp, 1969) ................................ Tin Mt. Ls.
*Endothyra bowmani* (Skipp, 1969) .......................... Perdido Fm.
Fusilinids sp. (Foster, 1961) ................................... Tihvipah Ls.
(Hall, 1971) ............................ Keeler Canyon Fm.
*Globoendothyra tomiliensis* (Skipp, 1969) ............... Perdido Fm.
*Latiendothyra parakosvensis* (Skipp, 1969) ............. Tin Mt. Ls.
*Palaeospiroplectammina parva*(?) (Skipp, 1969) ...... Tin Mt. Ls.
*Septaglomospiranella primaeva* (Skipp, 1969) .......... Tin Mt. Ls.
*Stacheia* sp. (Skipp, 1969) ........................................ Perdido Fm.
*Pseudoschwagerina sp.* (Hall, 1971) Owens Valley Fm.
*Pseudoschwagerina moranensis*(?) (Hall, 1971) ...........................
Owens Valley Fm.
*Schwagerina sp.* (Hall, 1971) ........................... Owens Valley Fm.
*Schwagerina hessinsis*(?) (Hall, 1971) ............ Owens Valley Fm.
*Tetrataxis* sp. (Skipp, 1969) .................................... Perdido Fm.
*Tetrataxis eominima* (Skipp, 1969) ........................... Perdido Fm.
*Tuberitina* sp. (Skipp, 1969) .................................... Tin Mt. Ls.

#### Phylum Porifera

*Chancelloria* sp. (Cooper et al., 1982) ........................ Nopah Fm.
*Hintzespongia*(?) sp. (Cooper et al., 1982) ................. Nopah Fm.

##### Class Archaeocyatha (Wood et al., 1992)

*Ajacicyathus* sp. (McKee and Gangloff, 1969) ............ Poleta Fm.
*Ajacicyathus ichnusae* (McKee and Gangloff, 1969) ......................
Campito/Poleta Fm.
*Annulofungia* sp. (McKee and Gangloff, 1969) ............................
Campito/Poleta Fm.
*Archeocyathus* sp. (McKee and Gangloff, 1969) ...........................
Campito/Poleta/Harkless Fm.
*Archeocyathus atlanticus* (McKee and Gangloff, 1969) Poleta Fm.
*Archeocyathus*(?) *arborensis* (McKee and Gangloff, 1969) ...........
Poleta Fm.
*Archeocyathus yavorskii* (McKee and Gangloff, 1969) Poleta Fm.
*Archaeopharetra*(?) sp. (McKee and Gangloff, 1969) Poleta Fm.
*Cambrocyathus* sp. (McKee and Gangloff, 1969) .........................
Campito/Poleta/Harkless Fm.
*Copleicyathus* sp. (McKee and Gangloff, 1969) ...... Campito Fm.
Coscinocyathidae(?) (McKee and Gangloff, 1969) ...... Poleta Fm.
*Coscinocyathus* sp. (McKee and Gangloff, 1969) .... Harkless Fm.
*Erbocyathus* sp. (McKee and Gangloff, 1969) ............. Poleta Fm.
*Ethmophyllum* sp. (McKee and Gangloff, 1969) ............................
Campito/Poleta Fm.
*Ethmophyllum whitneyi* (McKee and Gangloff, 1969) ...................
Campito/Poleta Fm.
*Metethmophyllum meeki* (McKee and Gangloff, 1969) .................
Campito/Poleta/Harkless Fm.
*Nevadacyathus septaporus* (McKee and Gangloff, 1969) .............
Campito Fm.
*Protopharetra* sp. (McKee and Gangloff, 1969) ......... Poleta Fm.
*Protopharetra*(?) *raymondi* (McKee and Gangloff, 1969) ............
Campito/Poleta Fm.
*Pycnoidocyathus* sp. (McKee and Gangloff, 1969) ........................
Campito/Poleta/Harkless Fm.
*Pynoidocyathus ceratodictyoides* (McKee and Gangloff, 1969) .....

Campito Fm.
*Retilamina* sp. (Signor and Mount, 1989) ................ Harkless Fm.
*Robustocyathus*(?) *argentus* (McKee and Gangloff, 1969) ............ Campito/Poleta Fm.
*Rotundocyathus* sp. (McKee and Gangloff, 1969) ....... Poleta Fm.
*Rotundocyathus weeksi* (McKee and Gangloff, 1969) .................... Campito/Poleta Fm.
*Syringocyathus*(?) sp. (McKee and Gangloff, 1969) Campito Fm.
*Syringocyathus*(?) *inyoensis* ............ (McKee and Gangloff, 1969) Poleta Fm.
*Syringocnematidae* sp. (McKee and Gangloff, 1969).................... Campito/Poleta Fm.

### Unknown taxonomic placement

Lophophylloid (Tischler, 1954) ................................ Tin Mt. Ls.
*Miniscophyllum* sp. (Langenheim and Tischler, 1959)Tin Mt. Ls.
*Ryderophyllum* sp. (McAllister, 1974) ............. Hidden Valley Do.
*Siphonophrentis invaginatus* (McAllister, 1974) ......................... Hidden Valley Do.

## Phylum Cnidaria

### Class Anthozoa

#### Order Rugosa

*Amplexus* sp. (Sudo, 1969) ........................................ Tin Mt. Ls.
*Breviphrentis invaginatus* (McAllister, 1955) Hidden Valley Do.
*Breviphyllum lonensis* (McAllister, 1974) ....... Hidden Valley Do.
*Brachyelasma* sp. (McAllister, 1974) ............. Hidden Valley Do.
*Caninia* sp. (Langenheim, 1954; Sudo, 1969) ............ Tin Mt. Ls.
*Caninia corniculum* (Tischler, 1954) .................. Lost Burro Fm.
*Caninophyllum incrassatum* (Langenheim and Tischler, 1959) ...... Tin Mt. Ls.
*Clisiophyllum* sp. (Langenheim and Tischler, 1959) ... Tin Mt. Ls.
*Cyathaxonia* sp. (Sudo, 1969) ............... Tin Mt. Ls./Perdido Fm.
*Ekvasophyllum* sp. (Langenheim and Tischler, 1959) Tin Mt. Ls.
*Enygmophyllum* sp. (Hall, 1971) ................................ Tin Mt. Ls.
*Homalophyllites* sp. (Sudo, 1969) ............................. Tin Mt. Ls.
*Lithostrotionella* sp. (Hall, 1971) ............................... Tin Mt. Ls.
*Lophophyllidium* sp. (Langenheim and Tischler, 1959) ................ Tin Mt. Ls.
(Langenheim, 1954) ................ Perdido Fm.
*Koninckophyllum* sp. (Langenheim and Tischler, 1959) ................ Tin Mt.Ls.
*Meniscophyllum* sp. (Tischler, 1954) ...................... Tin Mt. Ls.
*Menophyllum* sp. (Hall, 1971) .................................. Tin Mt. Ls.
*Papiliophyllum elegantulus* (McAllister, 1974) Hidden Valley Do.
*Rotiphyllum* sp. (Langenheim and Tischler, 1959) ..... Tin Mt. Ls.
*Rylstonia* sp. (Langenheim 1954; Sudo, 1969) ........... Tin Mt. Ls.
*Syringaxon*(?) sp. (McAllister, 1974) ............. Hidden Valley Do.
*Streptelasma* sp. (McAllister, 1954) ................... Ely Springs Do.
streptelasmid corals (R. H. Miller, 1982) ............ Ely Springs Do.
*Triplophyllites* sp. (Langenheim, 1954) ...................... Perdido Fm.
*Tryplasma* sp. (McAllister, 1974) ................... Hidden Valley Do.
*Vesiculophyllum* sp. (Sudo, 1969) .............................. Tin Mt. Ls.
*Zaphrentites* sp. (Hall, 1971) .................................... Tin Mt. Ls.
(Langenheim, 1954; Sudo, 1969) ... Perdido Fm.

#### Order Tabulata

*Alveolites* sp. (McAllister, 1974) .................... Hidden Valley Do.
*Cladopora* sp. (McAllister, 1974) .................. Hidden Valley Do.
cladoporoid corals (Hall, 1971) ............................ Lost Burro Fm.
*Favosites* sp. (McAllister, 1974) .................... Hidden Valley Do.
*Halysites* sp. (McAllister, 1974) ..................... Hidden Valley Do.
(R. H. Miller, 1982) ....................... Ely Springs Do.
*Halysites catenularia* (R. H. Miller and Hanna, 1972) ................... Hidden Valley Do.
*Pleurodictyum* sp. (Peck, 1950) ................................. Tin Mt. Ls.
*Romingeralla* sp. (McAllister, 1974) .............. Hidden Valley Do.
*Syringopora* sp. (Hunt, 1975) .............................. Lost Burro Fm.
*Syringopora surcularia* (Hall, 1971) .......................... Tin Mt. Ls.

#### Order Conulariida

*Conularia* sp. (Peck, 1950) ....................................... Tin Mt. Ls.

## Phylum Annelida

### Class Polychaetia

#### Order Sedentarida

*Platysolenites* sp. (Firby and Durham, 1974) ........... Campito Fm.
(Signor and Mount, 1986) ..... Deep Spring Fm.
*Proterebella* sp. (Firby and Durham, 1974) ............. Campito Fm.
*Spirorbis* sp. (Hall, 1971) .......................................... Tin Mt. Ls.

#### Order Errantida

*Onuphionella* sp. (Signor and Mount, 1986) ...... Deep Spring Fm.
Annelind(?) (Bates, 1965) ......................................... Carrara Fm.

## Phylum Arthropoda

### Class Trilobita

#### Order Agnostida

*Agnostus tumidosus* (Cooper et al., 1982) ................... Nopah Fm.
*Geragnostus* cf. (Foster, 1961)
*G. callaveiformis* .......................................... Antelope Valley Ls.
(Foster, 1961) .............................. Ninemile Fm.
*Homagnostus sp.* (Hunt, 1975) .................................. Nopah Fm.
*Homagnostus obesus* (Cooper et al., 1982) ................ Nopah Fm. Devils Hole region
*Homagnostus tumidosus* ................................. Devils Hole region
*Pseudagnostus communis* (Cooper et al., 1982) ......... Nopah Fm. Devils Hole region
*Pseudagnostus*(?) *acutus* (Cooper et al., 1982) ........... Nopah Fm.
*Trinodus elspethi* (Foster, 1961) .............................. Campito Fm.

#### Order Redlichiida

*Bristolia sp.* (Nelson, 1976) .............................. Saline Valley Fm.
(Nelson, 1978) .............Carrara Fm./Mule Spring Ls.
*Bristolia anteros* (Palmer and Halley, 1979) ............... Carrara Fm.
*Bristolia bristolensis* (Palmer and Halley, 1979) ........ Carrara Fm.
*Bristolia fragilis* (Palmer and Halley, 1979) ............... Carrara Fm.
*Daguinaspis* sp. (Nelson, 1976) .............................. Campito Fm.
*Crassifimbra* sp. (Nelson, 1978) ............................... Carrara Fm.
(Nelson, 1978) Mule Spring Ls./Saline Valley Fm.
*Crassifimbra walcotti* (Bates, 1965) ................. Carrara Formation
*Fallotaspis* sp. (Nelson, 1976) ................................ Campito Fm.
*Fallotaspis longa* (Firby and Durham, 1974) ........... Campito Fm.
*Fallotaspis tazemmourtensis*(?) (Firby and Durham, 1974) ........... Campito Fm.
*Fremontella sp.* (Nelson, 1978) ....... Carrara Fm./Mule Spring Ls.
*Fremontia sp.* (Bates, 1965) ...................... Carrara/Harkless Fm.
(Nelson, 1978) ............................ Mule Spring Ls.
(Seiple, 1984) ...................................... Poleta Fm.
*Fremontia fremonti* (Bates, 1965) ............................. Carrara Fm.
*Holmia* sp. (Nelson, 1976) ..................................... Campito Fm.
*Laudonia sp.* (Nelson, 1976) ..................................... Poleta Fm.
(McKee and Gangloff , 1969) ........... Campito Fm.
*Judomia* sp. (Nelson, 1976) .................................... Campito Fm.

(Signor and others, 1988) ............ Wood Canyon Fm.
*Nevadia* sp. (Seiple, 1984) ....................................... Campito Fm.
*Nevadia weeksi* (Firby and Durham, 1974) ............ Campito Fm.
*Nevadella* sp. (Nelson 1976) ........................................ Poleta Fm.
*Olenellus* sp. (Nelson, 1976; Seiple, 1984) .................................
Saline Valley/Poleta Fm.
(Nelson, 1978) Carrara/Harkless Fm./Mule Spring Ls.
*Olenellus arcuatus* (Palmer and Halley, 1979) ........... Carrara Fm.
*Olenellus clarki* (Palmer and Halley, 1979) ................ Carrara Fm.
*Olenellus cylindricus* (Palmer and Halley, 1979) ........ Carrara Fm.
*Olenellus fremonti* (Palmer and Halley, 1979) ............ Carrara Fm.
*Olenellus gilberti* (Palmer and Halley, 1979) .............. Carrara Fm.
*Olenellus howelli*(?) (Bates, 1965) .............................. Carrara Fm.
*Olenellus multinodus* (Palmer and Halley, 1979) ........ Carrara Fm.
*Olenellus nevadensis* (Palmer and Halley, 1979) ........ Carrara Fm.
*Olenellus puertoblancoensis* (Palmer and Halley, 1979) ...............
Carrara Fm.
*Paedeumias sp.* (Nelson, 1976) ........................ Saline Valley Fm.
(Taylor and Palmer 1981) ........... Mule Spring Ls.
(Nelson, 1976; Seiple, 1984) ........... Harkless Fm.
*Paedeumias clarki* (Bates, 1965) ................................ Carrara Fm.
*Paedeumias brachycephalus* (Bates, 1965) ................ Carrara Fm.
*Paedeumias nevadensis* (Bates, 1965) ....................... Carrara Fm.
*Peachella sp.* (Palmer and Halley 1979) .................... Carrara Fm.
*Peachella brevispina* (Nelson, 1978) ................... Mule Spring Ls.
*Peachella iddingsi* (Palmer and Halley 1979) ............ Carrara Fm.
*Wanneria* sp. (Bates 1965) ........................................ Carrara Fm.
(Nelson, 1976) ............................ Saline Valley Fm.

## Order Corynexochida

*Bonnia* spp. (Palmer and Halley, 1979) ...................... Carrara Fm.
*Fieldaspis*(?) sp. (Palmer and Halley, 1979) ............... Carrara Fm.
*Glossopleura walcotti* (Palmer and Halley, 1979) ...... Carrara Fm.
*Mexicaspis radiatus* sp. (Palmer and Halley, 1979) ... Carrara Fm.
*Ptarmiganoides hexacantha* (Palmer and Halley, 1979) ................
CarraraFm..
*Zacanthoides*(?) sp. (Palmer and Halley, 1979) .......... Carrara Fm.

## Order Ptychopariida

*Alokistocare* sp. (Nelson, 1978) ............................... Monola Fm.
(Bates, 1965) .................................. Cararra Fm.
*Alokistocarella*(?) *brighamensis*(?) (Bates, 1965) ...... Cararra Fm.
*Ampyx virginiensis*(?) (Foster, 1961) ................... Pogonip Group
*Apachia prima* (Cooper et al., 1982) ........................... Nopah Fm.
*Apachia butlerensis* (Cooper et al., 1982) ................... Nopah Fm.
*Aphelaspis haguei* (Cooper et al., 1982) ...................... Nopah Fm.
*Aphelaspis subditus*(?) (Cooper et al., 1982) ............... Nopah Fm.
*Bathyurellus pogonipensis* (Foster, 1961) ................ Campito Fm.
*Blountia bristolensis* (Cooper et al., 1982) .................. Nopah Fm.
(Bates, 1965) ........................... Carrara Fm
*Carolinites genacinaca* (Foster, 1961) ................. Pogonip Group
*Cernuolimbus depressus*(?) (Cooper et al., 1982) ...... Nopah Fm.
*Cernuolimbus granulosis* (Cooper et al., 1982) .......... Nopah Fm.
Devils Hole region
*Cernuolimbus laevifrons* (Cooper et al., 1982) ........... Nopah Fm.
Devils Hole region
*Cernuolimbus orygmatos* .............................. Devils Hole Region
*Cernuolimbus semigranulosis* ........................ Devils Hole region
*Ceratocephala lacinata*(?) (Foster, 1961) ........... Pogonip Group
*Dicanthopyge qudrata* (Cooper et al., 1982) ............. Nopah Fm.
*Dimeropygiella caudanodosa* (Foster, 1961) ....... Pogonip Group
*Dunderbergia*(?) *anyta*(?) (Cooper et al., 1982) .......... Nopah Fm.
*Dunderbergia brevispina* (Cooper et al., 1982) .......... Nopah Fm.
*Dunderbergia nitida*(?) (Cooper et al., 1982) ............. Nopah Fm.
*Dunderbergia polybothra* (Cooper et al., 1982) .......... Nopah Fm.
Devils Hole region
*Dunderbergia variagranula* (Cooper et al., 1982) ...... Nopah Fm.
Devils Hole region
*Ehmaniella* sp. (Hunt, 1975) .......................... Bonanza King Fm.
*Ehmaniella*(?) *hebes* (Bates 1965) ............................. Carrara Fm.
*Elburgia* sp. (Cooper et al., 1982) ............................. Nopah Fm.
*Elburgia granulosa* (Cooper et al., 1982) .................. Nopah Fm.
*Elburgia intermedia* (Cooper et al., 1982) .................. Nopah Fm.
*Elburgia quinnensis* (Cooper et al., 1982) .................. Nopah Fm.
Devils Hole region
*Elvinia* sp. (Hunt, 1975) ............................................ Nopah Fm.
*Elvinia roemeri* (Cooper et al., 1982) ......................... Nopah Fm.
*Hystricurus genalatus* (Foster, 1961) .................. Pogonip Group
*Kirkella* sp. (Hunt, 1975) ................................... Pogonip Group
*Mexicella* sp. (Palmer and Halley, 1979) .................... Carrara Fm.
*Mexicella mexicana* (Palmer and Halley, 1979) .......... Carrara Fm.
*Mexicella grandoculus* (Palmer and Halley, 1979) ..... Carrara Fm.
*Nileus californicus* (Foster, 1961) ........................ Pogonip Group
*Nyella clinolimbata* (Palmer and Halley, 1979) ........... Carrara Fm.
*Onchocephalus* sp. (Nelson, 1978) ........................... Carrara Fm.
(Nelson, 1978) .................... Mule Spring Ls.
*Onchocephalus thia* (Bates, 1965) ............................. Carrara Fm.
*Pachyaspis typicalis* (Bates, 1965) ............................ Carrara Fm.
*Proetus* sp. (Tischler, 1954) ........................................ Tin Mt. Ls.
*Pterocephalia concava* (Cooper et al., 1982) ............. Nopah Fm.
Devils Hole region
*Pterocephalia elongata* (Cooper et al., 1982) .............. Nopah Fm.
*Pterocephalia sanctisabae* (Cooper et al., 1982) ......... Nopah Fm.
Ptychopariid (Palmer and Halley, 1979) .................... Carrara Fm.
*Remopleurides acuminatus* (Foster, 1961) ........... Pogonip Group
*Remopleurides plaesiourus*(?) (Foster, 1961) ..... Pogonip Group
*Syspacephalus* sp. (Nelson, 1978) ............................ Monola Fm.
(Nelson 1976) ...................... Saline Valley Fm.
*Syspacephalus obscurus* (Palmer and Halley, 1979) .. Carrara Fm.
*Volocephalina connexa* (Palmer and Halley, 1979) ..... Carrara Fm.
*Volocephalina contracta* (Palmer and Halley, 1979) ... Carrara Fm.

## Order Phacopida

*Cybelopsis* sp. (Foster, 1961) ............................. Pogonip Group
*Ectenonotus westoni*(?) (Foster, 1961) ................. Pogonip Group
*Kawina*(?) sp. (Foster, 1961) .............................. Pogonip Group
*Protopliomerops* sp. (Hunt, 1975) ....................... Pogonip Group
*Pseudomera barrandei*(?) (Foster, 1961) ........... Pogonip Group
(Foster, 1973) ........... Pogonip Group
*Rossaspis*(?) sp. (Foster, 1961) ........................... Pogonip Group

## Order Odontopleurida

*Albertella* sp. (Taylor and Palmer, 1981) .................... Cararra Fm.
*Albertella nitida*(?) (Bates, 1965) ............................... Cararra Fm.
*Bonnia* sp. (Bates, 1965) ........................................... Carrara Fm.
(Nelson, 1976) ....................................... Harkless Fm.
(Nelson, 1978) ....... Saline Valley Fm./Mule Spring Ls.
*Dicanthaspis* sp. (Foster, 1961) ........................... Pogonip Group
*Fieldaspis furcata*(?) (Bates, 1965) ............................ Carrara Fm.
*Glossopleura* sp. (Nelson, 1978) ............................. Monola Fm.
(Bates, 1965) ................................ Carrara Fm.
*Mexicaspis radiatus* (Palmer and Halley, 1979) ......... Carrara Fm.

*Olenoides* sp. (Nelson, 1976) ............................ Saline Valley Fm.
*Ogygopsis* sp. (Nelson, 1976) ..... Saline Valley Fm./Harkless Fm.
(Palmer and Halley, 1979) .................. Carrara Fm.
(Taylor and Palmer 1981) ............ Mule Spring Ls.
(Nelson, 1978) .................................. Monola Fm.
*Oryctocephalus* sp. (Nelson, 1978) ........................... Monola Fm.
*Plagiura minor* (Palmer and Halley, 1979) ................. Carrara Fm.
*Plagiura cercops*(?) (Palmer and Halley, 1979) .......... Carrara Fm.
*Schistometopus* sp. (Palmer and Halley, 1979) .......... Carrara Fm.
*Stephenaspsis*(?) sp. (Nelson, 1976) .................. Saline Valley Fm.
*Zacanthoides* sp. (Palmer and Halley, 1979) .............. Carrara Fm.
*Zacanthopsis* sp. (Nelson, 1976) ....................... Saline Valley Fm.
*Zacanthopsis levis* (Bates, 1965) ................................ Carrara Fm.

**Unknown Taxonomic Placement**

*Flexilimbus porrectus* (Foster, 1961) ................ Pogonip Group
*Goldfieldia* sp. (Nelson, 1976) ......................... Saline Valley Fm.
*Holmiella* sp. (Nelson, 1976) ................................... Campito Fm.
*Minupeltis conservator* (Cooper et al., 1982) ............. Nopah Fm.
*Morosa extensa* (Cooper et al., 1982) ......................... Nopah Fm.
*Prehousia* sp. .................................................. Devils Hole region
*Prehousia alata*(?) (Cooper et al., 1982) ..................... Nopah Fm.
*Prehousia diverta* (Cooper et al., 1982) ...................... Nopah Fm.
*Prehousia indenta* (Cooper et al., 1982) ...................... Nopah Fm.
*Prehousia prima* (Cooper et al., 1982) ........................ Nopah Fm.
*Proveedoria* sp. (Bates, 1965) ................................... Carrara Fm.
*Pseudosaratogia leptogranulata* ..................... Devils Hole region
*Quadrastria infrequens* (Foster, 1961) ............. Pogonip Group
*Sigmocheilus grata* (Cooper et al., 1982) ................... Nopah Fm.
*Sigmocheilus notha* (Cooper et al., 1982) ................... Nopah Fm.
*Simulolenus wilsoni* . ...................................... Devils Hole region
*Strigambitus blepharina* (Cooper et al., 1982) ........... Nopah Fm.
Devils Hole region
*Strigambitus transversus* (Cooper et al., 1982) ......... Nopah Fm.
*Strigambitus utahensis* (Cooper et al., 1982) ............ Nopah Fm.

**Ostracodes**

**Subclass Ostracoda**

**Order Podocopida**

*Acratia similaris*(?) (McAllister, 1974) ...................... Tin Mt. Ls.
*Bairdia* sp. (McAllister, 1974) .................................. Tin Mt. Ls.
*Monoceratina elongata*(?) (McAllister, 1974) ........... Tin Mt. Ls.
*Monoceratina virgata* (?) (McAllister, 1974) ............. Tin Mt. Ls.

**Order Paleocopida**

*Amphissites similaris*(?) (McAllister, 1974) .............. Tin Mt. Ls.
*Kirkbyella annensis*(?) (McAllister, 1974) ................. Tin Mt. Ls.
*Kirkbyella reticulata*(?) (McAllister, 1974) ................ Tin Mt. Ls.
*Roundyella* (McAllister, 1974).................................... Tin Mt. Ls.
*Scrobicula crestiformis* (McAllister, 1974)................ Tin Mt. Ls.
*Tetrasacculus stewartae*(?) (McAllister, 1974) .......... Tin Mt. Ls.

**Unknown Taxonomic Placement**

*Acanthoscapha*(?) *banffensis* (McAllister, 1974) ..... Tin Mt. Ls.
*Graphiadactyllis moridget* (McAllister, 1974) ........... Tin Mt. Ls.
*Kummerowia* sp. (McAllister, 1974) ....................... Tin Mt. Ls.
*Psilokirkbyella ozarkensis*(?) (McAllister, 1974) ...... Tin Mt. Ls.
*Rectobairdia confragosa*(?) (McAllister, 1974) ........ Tin Mt. Ls.
*Shivaella macallisteri* (McAllister, 1974) ................. Tin Mt. Ls.

**Phylum Mollusca**

**Class Gastropoda**

**Subclass Prosobranchia**

**Order Archaeogastropoda**

*Anomphalus* sp. (Hall, 1971) ...................................... Tin Mt. Ls.
*Baylea*(?) sp. (Hall, 1971) .......................................... Tin Mt. Ls.
*Bellerophon*(?) sp. (Hall, 1971) ................................. Tin Mt. Ls.
*Euconia*(?) sp. (R. H. Miller, 1982) ..................... Pogonip Group
*Euomphalus*(?) sp. (Foster, 1973) ...................... Pogonip Group
*Liospira* sp. (R. H. Miller, 1982) ......................... Pogonip Group
*Loxomena*(?) sp. ................................... Tin Mountain Limestone
(Langenheim, 1954; Tischler, 1954)
*Maclurites* sp. (Foster, 1961) ............................ Pogonip Group
(Hunt, 1975) ............................... Pogonip Group
*Maclurites magnus* (Foster, 1961) ...................... Pogonip Group
*Matherella* sp. (Yochelson et al., 1965) ....................... Nopah Fm.
*Mitrospira longwelli* (R. H. Miller, 1982) ............ Pogonip Group
*Mourlonia* sp. (Hall, 1971) ......................................... Tin Mt. Ls.
*Murchisonia* sp. (Langenheim, 1954; Hall, 1971) ..... Tin Mt. Ls.
*Naticopsis* sp. (Hall, 1971) ......................................... Tin Mt. Ls.
*Orecopia ambiguum* (McAllister, 1974) .............. Lost Burro Fm.
*Palliseria longwelli* (Foster, 1961) ...................... Pogonip Group
(Foster, 1973) ....................... Pogonip Group
*Palliseria robusta* (Foster, 1961) ....................... Pogonip Group
(Foster, 1973) ........................ Pogonip Group
*Platyceras* sp. (Langenheim, 1954; Yochelson, 1965) Tin Mt. Ls.
*Platyceras* (*platystoma*) sp. (Tischler, 1954) Tin Mt. Ls.
*Rhineoderma*(?) sp. (Yochelson, 1965) Tin Mt. Ls.
*Scaevogrya* sp. (Yochelson et al., 1965) ...................... Nopah Fm.
*Straparolus* sp. (Hall, 1971) ...................................... Tin Mt. Ls.
*Straparolus utahensis* (Hall, 1971) ............................ Tin Mt. Ls.
*Straparolus subplanus* (Langenheim, 1954) ............... Tin Mt. Ls.
*Strepsodiscus* sp. (Yochelson et al., 1965) .................. Nopah Fm.
*Worthenia* sp. (Langenheim, 1954) ........................... Perdido Fm.
(Peck, 1950) ........................................ Tin Mt. Ls.

**Gastropoda incertae sedis**

Microgastropod steinkerns (Youngquist and Heinrich, 1966) ........
Lost Burro Fm.
*Wyattia* (Taylor, 1966) ................................................... Reed Fm.

**Class Bivalvia**

**Subclass Protobranchia**

**Order Nuculoida**

*Ctenodonta* sp. (R. H. Miller, 1982) .................... Pogonip Group

**Order Pterioida**

*Caneyella wapanuckensis*(?) (Peck, 1950) ................. Tin Mt. Ls.

**Order Pholadomyoida**

*Grammysia*(?) sp. (Peck, 1950) ................................ Tin Mt. Ls.

**Unknown Taxonomic Palcement**

*Platyceras* sp. (McAllister, 1974) ................... Hidden Valley Do.

**Class(?) Mattheva**

*Matthevia* sp. (Hardy, 1988) ..................................... Nopah Fm.

**Class Cephalopoda**

**Subclass Nautiloidea**

**Order Barrandeocerida**

*Cyrtoceras cessator* (Gordon, 1964) ......................... Perdido Fm.

**Order Nautilida**

*Girtyoceras*(?) sp. (Peck, 1950) ................................ Tin Mt. Ls.

*Liroceras*(?) sp. (Gordon, 1964) .............................. Perdido Fm.

### Order Orthocerida

*Mitorthoceras clinatum* (Gordon, 1964) .................... Perdido Fm.
*Mitorthoceras perfilosum* (Gordon, 1964) ................ Perdido Fm.
*Mooreoceras* sp. (Peck, 1950) .................................. Tin Mt. Ls.

### Subclass Actinoceratoidea

### Order Actinocerida

*Armenoceras* sp. (Hall, 1971) .................... Ely Springs Dolomite
*Rayonnoceras* sp. (Peck, 1950) ................................ Tin Mt. Ls.
*Rayonnoceras solidiforme* (Gordon, 1964) ..................................
Perdido Fm./Rest Spring Shale
*Rayonnoceras*(?) *vaughanianum* (Langenheim, 1954) ..................
Perdido Fm.

### Subclass Bactritoidea

### Order Bactritoidea

*Bactrites* sp. (Peck, 1950) ........................................... Tin Mt. Ls.
*Bactrites carbonarius* (Gordon, 1964) ...................... Perdido Fm.
*Stenopronorites* sp. (Gordon, 1964) ......................... Tihvipah Ls.

### Subclass Ammonoidea

*Bisatoceras greenei* (Gordon, 1964) ......................... Tihvipah Ls.
*Eumorphoceras paucinodum* (Gordon, 1964) ........... Perdido Fm.
*Prolecanites* (*Rhipaecanites*)? sp. (Gordon, 1964) .... Perdido Fm.

### Cephalopoda generic:

Coiled nautoloid (Foster, 1961) ........................... Pogonip Group
Orthoconic nautiloids (Foster, 1961) ................... Pogonip Group
(Foster, 1973) ................... Pogonip Group

### Taxa doubtfully classified as nautiloids:

*Anthracoceras macallisteri* (Gordon, 1964) ............. Perdido Fm.
*Cravenoceras* sp. (Langenheim, 1954) ...................... Perdido Fm.
*Cravenoceras hesperium* (Gordon, 1964) ................. Perdido Fm.
(Peck, 1950) ...................... Tin Mt. Ls.
*Cravenoceras inyoense* (Gordon, 1964) .................... Perdido Fm.
*Cravenoceras merriami* (Gordon, 1964) ................. Perdido Fm.
(Gordon, 1964) .......... Rest Spring Shale
(Peck, 1950) ........................ Tin Mt. Ls.
*Cravenoceras nevadense* (Gordon, 1964) ................. Perdido Fm.
(Peck, 1950) ...................... Tin Mt. Ls.
*Delepinoceras californicum* (Gordon, 1964) ............ Perdido Fm.

## Phylum Brachiopoda

### Class Inarticulata

### Order Lingulida

*Lingula* sp. (McAllister, 1952) .................................Nopah Fm.
*Lingulella* sp. (Foster, 1961) .................................. Campito Fm.
(Cooper et al., 1982) ........................... Nopah Fm.
Devils Hole region
*Lingulella amphora*(?) .................................... Devils Hole region
*Linglulella kanabensis* (Bates, 1965) ......................... Carrara Fm.
(Cloud, 1968) ............. Wood Canyon Fm.
(Rowell, 1977) ........................ Poleta Fm.
*Obolus* sp. (McAllister, 1952) ...................................Nopah Fm.

### Order Acrotretida

*Acrotreta idahoensis*(?) (McAllister, 1952) ...............Nopah Fm.
*Anglulotreta trinagularis* (Cooper et al., 1982) ...........Nopah Fm.
*Apsotreta expansa* (Cooper et al., 1982) .....................Nopah Fm.
Devils Hole region
*Apsotreta stricta* .............................................. Devils Hole region
*Conotreta* sp. (Foster, 1961) .............................. Pogonip Group
*Linnarssonella girtyi* (Cooper et al., 1982) ................. Nopah Fm.
*Scaphelasma septatum*(?) (Foster, 1961) ............. Pogonip Group
*Spinulothele dubia* (Rowell, 1977) ............................... Poleta Fm.

### Order Obolellida

*Obolella* sp. (Rowell, 1977) .......................... Poleta/Harkless Fm.
(Firby and Durham, 1974) ................. Campito Fm.
*Obolella excelsis* (Rowell, 1977) ............................. Campito Fm.
*Obolella vermilionensis* (Rowell, 1977) .................. Campito Fm.

### Order Paterinida

*Mickwitzia occidens* (Rowell, 1977) ........................ Harkless Fm.
*Micromitra* sp. (Firby and Durham, 1974) ............. Campito Fm.

### Class Articulata

### Order Orthida

*Dalmanella* sp. (Hazzard, 1937) ......................... Ely Springs Do.
*Hesperonomia* sp. (R. H. Miller, 1982) .............. Pogonip Group
*Nisusia* sp. (Rowell, 1977) ...................................... Campito Fm.
*Nisusia montanaensis* (Bates, 1965) .......................... Carrara Fm.
*Orthambonites eucharis* (Foster, 1961) .............. Pogonip Group
*Orthis* sp. (R. H. Miller, 1982) ........................... Pogonip Group
*Orthidiella longwelli* (Foster, 1961) .................... Pogonip Group
*Paucicrura*(?) sp. (Hall, 1971) ........................... Ely Springs Do.
*Plaesiomys* sp. (Hall, 1971) ................................ Ely Springs Do.
*Platystrophia* sp. (Hazzard, 1937) ...................... Ely Springs Do.
*Pompeckium argenteum* (Rowell, 1977) ...................... Poleta Fm.
*Rhipidomella* sp. (McAllister, 1974) ........................ Tin Mt. Ls.
*Rhipidomella michelini*(?) (Hall, 1971) ...................... Tin Mt. Ls.
*Rhipidomella nevadensis* (Hall, 1971) ........... Keeler Canyon Fm.

### Order Strophomenida

*Buxtonia*(?) sp. (Hall, 1971) ...................................... Tin Mt. Ls.
*Chonetes* sp. (Langenheim, 1954; Hall, 1971) ............ Tin Mt. Ls
*Dictyoclostus* sp. (Langenheim, 1953) ...................... Perdido Fm.
(Langenheim and Tischler, 1954) ... Tin Mt. Ls.
*Fardenia* sp. (McAllister, 1974) .................... Hidden Valley Do.
*Ingria cloudi* (Foster, 1961) ................................ Pogonip Group
*Leptaena* sp. (McAllister, 1974) ..................... Hidden Valley Do
*Marginifera* sp. (Langenheim, 1954) ........................ Perdido Fm.
*Nervostrophia* sp. (Langenheim, 1954) ..................... Tin Mt. Ls.
*Orthotetes* sp. (Langenheim, 1954) ............................ Tin Mt. Ls.
*Productella* sp. (Hall, 1971) .............................. Lost Burro Fm.
(Hall, 1971) .................................... Tin Mt. Ls.
*Productus* sp. (Peck, 1950) ...................................... Tin Mt. Ls.
*Productoid* sp. (McAllister, 1974) ............................ Tin Mt. Ls.
(McAllister, 1974) .............................Perdido Fm.
*Rhipidium* sp. (McAllister, 1974) Hidden Valley Do.
*Schizophoria* sp. (Hall, 1971) ................................... Tin Mt. Ls.
*Schuchertella* sp. (Langenheim, 1954) ...................... Perdido Fm.
(McAllister, 1974) ......................... Tin Mt. Ls.
*Schuchertella rubra*(?) (McAllister, 1974) ................ Tin Mt. Ls.
*Sowerbyella* sp. (Hall, 1971) .............................. Ely Springs Do.

### Order Rhynchonellida

*Camarotoechia* sp. (Gordon and Langenheim, 1954) Tin Mt. Ls.
*Leiorhynchus*(?) sp. (McAllister, 1974) ..................... Tin Mt. Ls.
*Paryphorhynchus*(?) sp. (Langenheim and Tischler, 1959) ...........
Tin Mt. Ls.
*Rhynchonellid* sp. (McAllister, 1974) ....................... Tin Mt. Ls.
*Rhynchopora* sp. (Hall, 1971) .................................. Tin Mt. Ls.

*Rhynchotrema*(?) sp. (Hall, 1971) ........................ Ely Springs Do.
*Rhynchotrema argenturbica* (Hazzard, 1937) ..... Ely Springs Do.

### Order Spiriferida

*Athyris*(?) sp. (Tischler, 1954) .................................. Tin Mt. Ls.
*Atrypa* sp. (Langenheim and Tischler, 1959) ............ Tin Mt. Ls.
*Atrypina* sp. (McAllister, 1974) .................... Hidden Valley Do.
*Brachythyrus suborbicularis*(McAllister, 1974) ........ Tin Mt. Ls.
*Choristites* sp. (Langenheim, 1954) ........................... Tin Mt. Ls.
*Choristites glennfoxi* (Tischler, 1954) ........................ Tin Mt. Ls.
*Cleiothyridina* sp. (Langenheim, 1954) ..................... Tin Mt. Ls.
*Cleiothyridina hirusta*(?) (Tischler, 1954) ................. Tin Mt. Ls.
*Cleiothyridina obmaxima*(?) (Hall, 1971) .................. Tin Mt. Ls.
*Composita* sp. (McAllister, 1974) ........................... Tin Mt. Ls.
*Crurithyris* sp. (Hall, 1971) .......................... Keeler Canyon Fm.
*Cyrtina* sp. (Hall, 1971) ............................................ Tin Mt. Ls.
*Cyrtospirifer* sp. (Langenheim and Tischler, 1959) .... Tin Mt. Ls.
*Dimegelasma* sp. (McAllister, 1974) ....................... Tin Mt. Ls.
*Eospirifer* sp. (McAllister, 1974) .................. Hidden Valley Do.
*Eumetria* sp. (McAllister, 1974) .............................. Tin Mt. Ls.
*Hustedia* sp. (McAllister, 1974) .............................. Tin Mt. Ls.
(Hall, 1971) ............................ Keeler Canyon Fm.
*Imbrexia* sp. (McAllister, 1974) .............................. Tin Mt. Ls.
*Martinia*(?) sp. (McAllister, 1974) ......................... Tin Mt. Ls.
*Mucrospirifer*(?) sp. (Tischler, 1954) ....................... Tin Mt. Ls.
*Neospirifer*(?) sp. (Langenheim, 1954) .................... Perdido Fm.
*Punctospirifer*(?) sp. (Hall, 1971) ............................ Tin Mt. Ls.
*Spirifer* sp. (McAllister, 1974) ................................. Tin Mt. Ls.
(Langenheim, 1954) ............................... Perdido Fm.
*Spirifer centronatus*(?) (McAllister, 1974) ................ Tin Mt. Ls.
*Spirifer grimesi*(?) (Tischler, 1954) .......................... Tin Mt. Ls.
*Spirifer strigosus* (Tischler, 1954) ....................... Lost Burro Fm.
*Thaeroodonta*(?) sp. (Hall, 1971) ...................... Ely Springs Do.
*Torynifer* sp. (Hall, 1971) ......................................... Tin Mt. Ls.
*Unispirifer* sp. (McAllister, 1974) ............................ Tin Mt. Ls.
*Zygospira* sp. (Hall, 1971) ................................. Ely Springs Do.

### Order Terbratulida

*Cranaena* sp. (McAllister, 1974) ............................ Tin Mt. Ls.
*Dielasma*(?) sp. (Hall, 1971) .................................... Tin Mt. Ls.

### Class Uncertain

### Order Kutorginida

*Kutorgina perugata* (Rowell, 1977) ............................ Poleta Fm.

### Unknown Taxonomic Placement

*Acrospirifer kobehana* (McAllister, 1974) ...... Hidden Valley Do.
*Apsotreta* sp. (Hunt, 1975) ......................................... Nopah Fm.
*Cleiothyridina devonica*(?) (McAllister, 1974) ... Lost Burro Fm.
*Conchidium* sp. (McAllister, 1974) ............... Hidden Valley Do.
*Gypidula loweryi*(?) (McAllister, 1974) .......... Hidden Valley Do.
*Meristella robertsinsis* (McAllister, 1974) ...... Hidden Valley Do.
*Physotretra* sp. ............................................... Devils Hole region
*Resserella* sp. (McAllister, 1974) ...................... Lost Burro Fm.
*Setigerites* sp. (McAllister, 1974) ............................ Perdido Fm.
*Striatifera* sp. (McAllister, 1974) ............................ Perdido Fm.
*Swantonia weeksi* (Rowell, 1977) ................................ Poleta Fm.
*Symphysurina woosteri* (Foster, 1961) ................ Pogonip Group
*Stringocephalus* sp. (McAllister, 1974) .............. Lost Burro Fm.
*Tenticospirifer cyrtiniformis* (McAllister, 1974) .. Lost Burro Fm.
*Tylothyris raymondis*(?) (McAllister, 1974) ......... Lost Burro Fm.

## Phylum Bryozoa

### Order Cryptostomata

*Fenestella* sp. (Langenheim, 1954) .......................... Tin Mt. Ls.
*Rhomborporella* sp. (Hall, 1971) .................. Keeler Canyon Fm.

### Order Cystoporata

*Cystodictya* sp. (Hall, 1971) ..................................... Tin Mt. Ls.

### Unknown Taxonomic Placement

*Polypora* sp. (Hall, 1971) ............................ Keeler Canyon Fm.

## Phylum Echinodermata

### Class Eocrinoidea

(*Eocystites*?) (Nelson, 1976) ........................................ Poleta Fm.
(Cooper et al., 1982) ............................. Nopah Fm.

### Class Helicoplacoidea (Nelson, 1976) .......... Poleta Fm.

(Taylor and Palmer, 1981; Durham, 1993) Campito Fm.

### Subphyllum Crinozoa

### Class Crinoidea

### Order Cladida

*Hypselocrinus pleis*(?) (Tischler, 1954) ...................... Tin Mt. Ls.

### Echinoderm generic

Cystoid plates (Foster, 1961) ............................. Pogonip Group
Echinoderm plates (Hall, 1971) ........................... Pogonip Group
Pelmatozoan columnals (Foster, 1961) ................ Pogonip Group

## Phylum Hemichordata

### Dendroid Graptolites

*Dictyonema* sp. (Foster, 1961) ............................ Pogonip Group
*Mongraptus* sp. (McAllister, 1974) ................ Hidden Valley Do.

## Incertae Sedis

Hyolithids (Mount, 1982) ................................ Campito Fm.
(Signor and Saverase, 1988) ..... Deep Spring Fm.
(Signor and Saverase, 1988) Wood Canyon Fm.
(Onken and Signor, 1988) .................... Poleta Fm.

### Agglutinated tubes

*Campitius* (Firby and Durham, 1974) ............... Campito Fm.
(Signor and Mount, 1989) .................... Poleta Fm.
*Platysolenites* (Signor and Mount, 1989) ........ Campito Fm.
*Onuphionella* (Signor and McMenamin, 1988) Campito Fm.
*Salterella* (Signor and Mount, 1989) .............. Harkless Fm.

### Small Shelly Fossils

*Bemella* (Signor and Mount, 1989) ..................... Poleta Fm.
*Chancelloria* (Signor and Mount, 1989) ............ Poleta Fm.
*Hyolithellus* (Signor and Mount, 1989) ........... Campito Fm.
*Lapworthella* (Signor and Mount, 1989) ............ Poleta Fm.
*Microdictyon* (Signor and Mount, 1989) ......... Campito Fm.
paiutitubulids (Signor and Mount, 1989) ......... Campito Fm.
(Signor and Mount, 1989) ............. Poleta Fm.

### Pre-trilobite shelly fauna

*Cloudina* (Parsons, 1996) ......................... Deep Spring Fm.
(Langille 1974) ............................ Stirling Quartzite
*Nevadatubulus* (Parsons, 1996) ................ Deep Spring Fm.
(Signor and Mount, 1989) ............ Reed Fm.
*Sinotubulites* (Parsons, 1996) ................... Deep Spring Fm.

## Fossil Vertebrates

### **Phylum Chordata** (conodonts)

#### Order Condontophorida

*Acodus cambricus* (R. H. Miller and Paden, 1976) .... Nopah Fm.
*Acodus unicostatus* (R. H. Miller and Hanna, 1972) ...................... Hidden Valley Do.
*Ambalodus* sp. (R. H. Miller, 1982) .............. Hidden Valley Do.
*Aphelognathus* sp. (R. H. Miller, 1982) .............. Ely Springs Do.
*Aulacognathus* sp. (R. H. Miller, 1982) .......... Hidden Valley Do.
*Belodella* sp. (R. H. Miller, 1978) .................. Hidden Valley Do.
*Belodina* sp. (R. H. Miller, 1982) ........................ Ely Springs Do.
*Belodus ornatus* (Hall, 1971) ............................... Ely Springs Do.
*Carniodus* sp. (R. H. Miller, 1982) ................. Hidden Valley Do.
*Coelocerodontus burkei* (R. H. Miller and Paden, 1976) .............. Nopah Fm.
*Cordylodus* sp. (McAllister, 1974) ..................... Lost Burro Fm.
*Delotaxis*(?) sp. (R. H. Miller, 1982) .............. Hidden Valley Do.
*Distacodus obliquicostatus*(?) (R. H. Miller and Hanna, 1972) ..... Hidden Valley Do.
*Distacodus palmeri* (Cooper et al., 1982) ................... Nopah Fm.
*Diadelognathus nicolli* (R. H. Miller, 1982) .... Hidden Valley Do.
*Distomodus* sp. (R. H. Miller, 1982) .............. Hidden Valley Do.
*Distomodus kentuckyensis* (R. H. Miller, 1982)Hidden Valley Do.
(R. H. Miller, 1982) .... Pognip Group
*Drepanodus* sp. (R. H. Miller and Hanna,1972)Hidden ValleyDo.
*Elictognathus* sp. (McAllister, 1974) ........................ Tin Mt. Ls.
*Euprioniodina* sp. (Mcallister, 1974) .... Perdido Fm./Tin Mt. Ls.
*Exchognathus* sp. (R. H. Miller and Hanna, 1972) ...................... Hidden Valley Do.
*Falcodus* sp. (McAllister, 1974) .............................. Tin Mt. Ls.
*Furcata* sp. (R. H. Miller, 1982) .......................... Pogonip Group
*Furnishina asymmetrica* (Cooper et al., 1982) ............ Nopah Fm.
*Gnathodus punctatus* (McAllister, 1974) ................... Tin Mt. Ls.
*Gnathodus texanus* (McAllister, 1974) ..................... Perdido Fm.
*Hadrognathus* sp. (R. H. Miller, 1982) .......... Hidden Valley Do.
*Hadrognathus irregularis* (R. H. Miller, 1978) Hidden Valley Do.
*Hertzina*(?) sp. (Cooper et al., 1982) ......................... Nopah Fm.
*Hibbardella* sp. (Youngquist and Heinrich, 1966) ...... Tin Mt. Ls.
*Hindeodella* sp. (McAllister, 1974) .......................... Tin Mt. Ls.
(McAllister, 1974) .......................... Perdido Fm.
(McAllister, 1954) ..................... Lost Burro Fm.
*Hindeodella confluens*(?) (R. H. Miller and Hanna, 1972) ............ Hidden Valley Do.
*Icriodus latericrescens* (R. H. Miller, 1976) .... Hidden Valley Do.
*Icriodus symmetricus* (McAllister, 1974) ....... Hidden Valley Do.
*Juanognathus*(?) (R. H. Miller, 1982) ................. Pogonip Group
*Leptochirognathus* sp. (R. H. Miller, 1982) .......... Pognip Group
*Ligonodina* sp. (McAllister, 1974) ............................ Tin Mt. Ls.
(R. H. Miller, 1976) ................... Ely Springs Do.
*Lonchodina* sp. (McAllister, 1974) .......................... Perdido Fm.
(R. H. Miller and Hanna, 1972) Hidden Valley Do.
*Lonchodina fluegeli*(?) (R. H. Miller and Hanna, 1972) ................ Hidden Valley Do.
*Multioistodus* sp. (R. H. Miller, 1982) .................. Pognip Group
*Muellerina pomeranensis* (Cooper et al., 1982) .......... Nopah Fm.
*Nogamiconus cambricus* (Cooper, 1982) .................... Nopah Fm.
*Neoprioniodus* sp. (R. H. Miller and Hanna, 1972)....................... Hidden Valley Do.
*Neoprioniodus costatus*(?) (R. H. Miller and Hanna, 1972) ........... Hidden Valley Do.
*Neoprioniodus planus* (R. H. Miller, 1982) .... Hidden Valley Do.
(R. H. Miller, 1976) .........Ely Springs Do.
*Neospathognathodus* sp. (R. H. Miller and Hanna, 1972) ............ Hidden Valley Do.
*Neospathognathodus celloni* (R. H. Miller and Hanna, 1972) ........ Hidden Valley Do.
*Oistodus multicorrigatus* (R. H. Miller, 1982) ...... Pognip Group
*Oneotodus gallatini* (Cooper et al., 1982) ................... Nopah Fm.
*Oneotodus tennuis* (Cooper et al., 1982) ..................... Nopah Fm.
*Oulodus* sp. (R.H. Miller, 1982) ......................... Ely Springs Do.
*Ozarkodina adiutricis* (R. H. Miller and Hanna, 1972) ................ Hidden Valley Do.
*Ozarkodina crassa*(?) (McAllister, 1974) ....... Hidden Valley Do.
Ozarkodina excavata(?) (R. H. Miller, 1982) .. Hidden Valley Do.
*Ozarkodina fundamentata*(?) (McAllister, 1974) ......................... Hidden Valley Do.
*Ozarkodins hanoverensis* (R. H. Miller, 1982) Hidden Valley Do.
*Ozarkodina media* (R. H. Miller, 1976) .......... Hidden Valley Do.
*Palmatolepus sp.* (Youngquist and Heinrich, 1966) .... Tin Mt. Ls.
*Palmatolepus distorta* (Youngquist and Heinrich, 1966) .............. Lost Burro Fm.
*Paltodus*(?) sp. (R. H. Miller andHanna,1972) Hidden Valley Do.
(Hall, 1971) ................................ Ely Springs Do.
*Panderodus* sp. (R. H. Miller, 1982) .................. Ely Springs Do.
*Panderodus acostatus* (McAllister, 1974) ...... Hidden Valley Do.
*Panderodus serratus* (R. H. Miller, 1982) ...... Hidden Valley Do.
*Panderodus simplex* (R. H. Miller and Hanna, 1972) .................. Hidden Valley Dm.
*Panderodus unicostatus* (McAllister, 1974) .... Hidden Valley Do.
*Plectodina* sp. (Hall, 1971) ................................ Ely Springs Do.
*Polycaulodus* sp. (R. H. Miller, 1982) ................... Pognip Group
*Polygnathus* sp. (Youngquist and Heinrich, 1966) .... Tin Mt. Ls.
*Polygnathus communis* (McAllister, 1974) ................ Tin Mt. Ls.
*Polygnathus inornatus* (McAllister, 1974) ................. Tin Mt. Ls.
*Polygnathus inornatus*(?) (McAllister, 1974) ............ Tin Mt. Ls.
*Polygnathus linguiformis* (Youngquist and Heinrich, 1966) .......... Lost Burro Fm.
(R. H. Miller, 1976) Hidden Valley Do.
*Polygnathus symmetricus* (McAllister, 1954) ........... Tin Mt. Ls.
*Prioniodina* sp. (McAllister, 1974) .......................... Perdido Fm.
*Prioniodus evae* (R. H. Miller, 1982) .................... Pognip Group
*Proconodontus*(?) sp. (Cooper et al., 1982) ................ Nopah Fm.
*Prooneotodus gallantini* (Cooper et al., 1982) ........... Nopah Fm.
*Prooneotodus rotundatus* (Cooper et al., 1982) .......... Nopah Fm.
*Prooneotodus tenuis* (Cooper et al., 1982) .................. Nopah Fm.
*Prosagittodontus dunderbergiae* (Cooper et al., 1982) Nopah Fm.
*Prosagittodontus eureka* (Cooper et al., 1982) .......... Nopah Fm.
*Protpanderodus* sp. (R. H. Miller, 1982) ............. Pogonip Group
*Pseudobelodina* sp. (R. H. Miller, 1982) ............. Pogonip Group
*Pseudognathodus* sp. (Cooper et al., 1982) ............... Nopah Fm.
*Pterospathodus* sp. (R. H. Miller and Hanna, 1972) ...................... Hidden Valley Do.
*Pterospathodus amorphognathoides* (R. H. Miller, 1978) ........... Hidden Valley Do.
*Sagittodontus* sp. (Cooper et al., 1982) ....................... Nopah Fm.
*Sagittodontus dahlmani* (Cooper et al., 1982) ............ Nopah Fm.
*Sagittodintus eureka* (Cooper et al., 1982) .................. Nopah Fm.
*Sagittodintus furnishi* (Cooper et al., 1982) ................. Nopah Fm.
*Scandodus* sp. (Cooper et al., 1982) ........................... Nopah Fm.
*Scolopodus cornutiformis*(?) (R. H. Miller, 1982) Pognip Group
*Siphonodella cooperi* (McAllister, 1974) ................... Tin Mt. Ls.

*Siphonodella obsoleta* (McAllister, 1974) .................. Tin Mt. Ls.
*Spathognathodus* sp. (R. H. Miller and Hanna, 1972) .................. Hidden Valley Do.
(McAllister, 1974) ..................Perdido Fm.Tin Mt. Ls.
*Spathognathodus anteposicornis*(?) (McAllister, 1974) ............... Tin Mt.Ls.

*Spathognathodus celloni* (R. H. Miller, 1976) . Hidden Valley Do.
*Spathognathodus polinclinatus* (R. H. Miller, 1976) ..................... Hidden Valley Do.
*Spathognathodus primus*(?) (R. H. Miller and Hanna, 1972) ........ Hidden Valley Do.
*Spathognathodus tyrolensis* (R. H. Miller and Hanna, 1972) ........ Hidden Valley Do.
*Synprioniodina silurica*(?) (R. H. Miller and Hanna, 1972) .......... Hidden Valley Do.
*Taphrognathus varians* (McAllister, 1974) .............. Perdido Fm.
*Tetraprioniodus*(?) sp. (R. H. Miller, 1982) ......... Pogonip Group
*Trianguloidus*(?) (R. H. Miller, 1982) .................. Pogonip Group
*Trichonodella* sp. (R. H. Miller and Hanna, 1972) ........................ Hidden Valley Do.
*Trichonodella excavata* (R. H. Miller and Hanna, 1972) ............... Hidden Valley Do.
*Trichonodella papilio* (R. H. Miller and Hanna, 1972) .................. Hidden Valley Do.
*Walliserodus debolti* (R. H. Miller, 1978) ....... Hidden Valley Do.
*Westergaardodina bicuspidata* (Cooper et al., 1982) .. Nopah Fm.
*Westergaardodina moessebergensis* (Cooper et al., 1982) ........... Nopah Fm.
*Zygognathus*(?) sp. (Hall, 1971) .......................... Ely Springs Do.

**Class Agnatha**

**Order Pteraspidiformes**

**Family Pteraspidae**

*Panamintaspis snowi* (Elliott and Ilyes, 1996) ..... Lost Burro Fm.
*Blieckaspis priscillae* (Elliott and Ilyes, 1996) ..... Lost Burro Fm.

**Class Placodermi**

**Order Arthrodira**

**Family Dinichthyidae**

*Dunkleosteus terrelli* (Dunkle and Lane, 1971) .... Lost Burro Fm.

**Class chondrichthyes**

**Subclass Elasmobranchii**

cladodont (Dunkle and Lane, 1971) ..................... Lost Burro Fm.

**Subclass Holocephali**

**Family Cochliodontidae**

Cochliodont (Dunkle and Lane, 1971) .................. Lost Burro Fm.

**Class Osteichthyes**

**Order Cyprinodontiformes**

**Family Cyprinodontidae**

*Fundulus curryi* (R. R. Miller, 1945) .............. Titus Canyon Fm.
*Fundulus eulepis* (R. R. Miller, 1945) ............. Titus Canyon Fm.
*Cyprinodon breviradius* (R. R. Miller, 1945) Titus Canyon Fm.

**Class Reptilia**

**Order Chelonia** (Stock, 1949)......... Titus Canyon Fm.

**Class Mammalia**

**Order Rodentia**

**Family Paramyida** (Stock, 1949) Titus Canyon Fm.

**Order Carnivora**

**Family Canidae** (Stock, 1949) ....... Titus Canyon Fm.

**Order Perissodactyla**

**Family Brontotheriidae**

*Protitanops curryi* (Stock, 1936) ..................... Titus Canyon Fm.

**Family Equidae**

*Mesohippus* sp. (Stock, 1949) ......................... Titus Canyon Fm.
*Mesohippus westoni* (Mason, 1988) ............... Titus Canyon Fm.

**Family Helaletidae**

*Colodon* sp. (Stock, 1949) ............................... Titus Canyon Fm.

**Family Rhinocerotidae**

*Teletaceras mortivallis* (Stock, 1949) ............. Titus Canyon Fm.

**Order Artiodactyla**

**Family Agriochoeridae**

*Protoreodon transmontanus* (Stock, 1949) .... Titus Canyon Fm.

**Family Protoceratidae**

*Poabromylus robustus* (Stock,1949) ............... Titus Canyon Fm.

**Family Leptomerycidae**

*Leptomeryx blacki* (Stock,1949) ...................... Titus Canyon Fm.
*Leptomeryx* cf. *yoderi* (Mason, 1988) ........... Titus Canyon Fm.

## Trace Fossils

*Archaeonassa* sp. (Nelson, 1976) ............................ Harkless Fm.
*Arthrophycus* sp. (Nelson, 1976) ............................ Harkless Fm.
*Asteriocites*(?) sp. (Nelson, 1976) ......................... Campito Fm.
*Astropolithon*(?) sp. (Nelson, 1976) ........................ Campito Fm.
*Belorhaphe* sp. (Nelson, 1976) ................................ Campito Fm.
*Bergaueria* sp. (Nelson, 1976) ............................... Harkless Fm.
*Cochlichnus* sp. (Nelson, 1976) .............................. Campito Fm.
*Cruziana* sp. (Alpert, 1976) .............................. Deep Spring Fm.
*Dactyloidites* sp. (Nelson, 1976) ............................. Campito Fm.
*Diplichnites* sp. (Signor and Mount, 1989) ........ Deep Spring Fm.
(Nelson, 1976) ............................... Campito Fm.
(Cooper et al., 1982) ......................... Nopah Fm.
*Helminthopsis* sp. (Nelson, 1976) ........................... Campito Fm.
*Laevicyclus* sp. (Nelson, 1976) ............................... Harkless Fm.
*Monocraterion* sp. (Mount, 1982) ........................... Campito Fm.
(Nelson, 1976) ........................... Harkless Fm.
*Phycodes* sp. (Nelson, 1976) ................................... Campito Fm.
*Planolites* sp. (Nelson, 1976) ................................... Wyman Fm.
(Alpert, 1975, 1976) ................................ Reed Do.
(Alpert, 1976) ............................. Deep Spring Fm.
(Bates, 1965) ....................................... Carrara Fm.
*Psammichnites*(?) sp. (Nelson, 1976) ...................... Harkless Fm.
*Rusophycus* sp. (Signor and Mount, 1989) ........ Deep Spring Fm.
(Nelson, 1976) ............................... Harkless Fm.
*Scolicia* sp. (Nelson, 1976) ...................................... Campito Fm.
(Mount, 1982) ...................................... Campito Fm.
(Nelson, 1976) ...................................... Harkless Fm.
*Skolithos* sp. (Wright et al., 1978) .......................... Noonday Do.
(Stewart, 1970) ......................... Wood Canyon Fm.
(Prave and Wright, 1986) .......... Zabriske Quartzite
*Teichichnus* sp. (Nelson, 1976) ............................... Campito Fm.
(Nelson, 1976) ......................... Saline Valley Fm.
*Zoophycos* sp. (Nelson, 1976) ................................. Campito Fm.

# APPENDIX B:

## Death Valley Vertebrate Fossil Specimens In Outside Repositories

This appendix provides information regarding vertebrate fossil specimens collected from Death Valley National Park. The first group of specimens consists of type specimens. The second group is a systematic listing and descriptions of other significant vertebrate fossils from the park.

**INSTITUTIONAL LIST:**
Field Museum of Natural History (FMNH)
Natural History Museum of Los Angeles County (LACM)
United States National Museum (USMN-Smithsonian Institution)

**Systematic Type Specimen List:**

Class Pteraspidomorphi
Subclass Heterostraci
Order Pteraspidiformes
Family Pteraspididae

*Panamintaspis snowi*
(FMNH-PF 14146)

**Park:** Death Valley National Park.
**Locality:** Trail Canyon area of Panamint Range.
**Material:** Large dorsal shield and elongated rostrum.
**Author:** Elliott and Ilyes, 1996.
**Article:** Journal of Paleontology, 70(1):152-161.
**Paratypes:** FMNH-PF 14147-14177.
**Description:** The remains of this primitive fish were collected from the basal part of the Lippincott Member of the Lost Burro Formation. This is a large pteraspidid with a slender dorsal shield and elongate rostrum. The type specimen is from Death Valley. There are a number of paratypes including FMNH-PF 14147-14177. The genus name is based upon the locality in the Panamint Mountains and the species is named in honor of J.C. Snow, who first recognized the presence of vertebrates in the Lost Burro Formation (Elliott and Ilykes, 1996).

Class Osteichthyes
Subclass Actinopterygii
Order Cyprinodontiformes
Family Cyprinodontidae

*Fundulus curryi*
(LACM (CIT) 10239)

**Park:** Death Valley National Park.
**Locality:** 3 miles SE of Chloride Cliffs in Funeral Mountains.
**Material:** Excellent specimen except for crushed cranium.
**Collector:** Donald Curry.
**Author:** R.R. Miller, 1949.
**Article:** Journal of Washington Acadamy of Science, 35(10):315321.
**Paratypes:** LACM 10240, 10247, 10249.
**Description:** The type is an excellent specimen except for a crushed cranium. Specimens LACM 10240, 10247 and 10249 are designated as paratypes and are from the same locality in Death Valley. There is some question regarding the unit from which these specimens were collected. They were originally reported from the Upper Eocene Titus Canyon Formation; however the fish were actually collected several miles from Titus Canyon proper within the same unit where the titanothere material was obtained. The fish locality was 3 miles southeast of Chloride Cliffs in the Funeral Mountains. The species name *curryi* is in honor of Death Valley park naturalist Donald Curry who collected the original specimen (R. R. Miller, 1945).

*Fundulus eulepis*
(USNM 16883)

**Park:** Death Valley National Park.
**Locality:** 6 miles southeast of Furnace Creek Ranch in the Black Mountains.
**Material:** Partial specimen.
**Collector:** Donald Curry (12/5/35).
**Author:** R.R. Miller, 1949.
**Article:** Journal of Washington Acadamy of Science, 35(10):315-321.
**Paratypes:** USNM 16884, 16885.
**Description:** Collected by Don Curry on December 5, 1935. The partial specimen was collected approximately 6 miles southeast of Furnace Creek Ranch in the Black Mountains. USNM 16884 and 16885 are designated as paratypes for this species. The species name *eulepis* means "well scaled" in reference to the close-set, numerous scales present on the holotype (R. R. Miller, 1945).

*Cyprinodon breviradius*
(LACM (CIT) 10245)

**Park:** Death Valley National Park.
**Locality:** 3 miles SE of Chloride Cliffs in Funeral Mountains.
**Material:** Nearly complete specimen except for head.
**Collector:** Donald Curry.
**Author:** R.R. Miller, 1949.
**Article:** Journal of Washington Acadamy of Science, 35(10):315-321.
**Description:** Collected by Don Curry from the same locality as *Fundulus curryi* in Death Valley National Park. The specimen is nearly complete except that the head is missing. The name *breviradius* means short-rayed, and refers to the short rays of the dorsal and anal fins (R. R. Miller, 1945).

Class Mammalia
Order Perissodactyla
Family Brontotheriidae

*Protitanops curryi*
(holotype - LACM 1854)

**Park:** Death Valley National Park.
**Locality:** Titus Canyon east of Thimble Peak.
**Material:** Skull and jaws.
**Collector:** Donald Curry.
**Author:** Stock, 1936.
**Article:** Proceedings of the National Academy of Sciences, 22(11):656-661.
**Description:** The type specimen of *Protitanops curryi* was collected in 1934 from the Titus Canyon Formation in Titus Canyon east of Thimble Peak. The skull and jaws were originally in the collections at the California Institute of Technology and later transferred to the Los Angeles County Museum. This specimen is large, brachycephalic, has strong zygomata, reduced incisors, and

developed horns. The Death Valley specimen is overall more similar to the White River titanotheres. However, the long and broad nasals, narrow and deeply incised naso-maxillary notch and type of horns are distinctly different from the White River titanotheres (Stock, 1936).

Family Rhinocerotidae

*Teletaceras mortivallis*

(holotype – LACM 3564)

**Park:** Death Valley National Park.
**Locality:** Titus Canyon.
**Material:** A fragment of left ramus and teeth.
**Collector:** Chester Stock.
**Author:** C. Stock, 1949.
**Article:** Contributions to Paleontology, Carnegie Institute of Washington Publication, 584(VIII):231-244.
**Description:** A fragment of left ramus and teeth represents the holotype for this species. A number of metapodial elements were also found in association with the ramus and assigned to *Teletaceras mortivallis*. The metapodials resemble the proportions of *Subhyradocodon* but are smaller. The Titus Canyon ramus and lower molars are similar to those in *Teletaceras rhinocerinus*. Overall characters indicate that *T. mortivallis*, if a distinct species, represents a true rhino intermediate between those of the Uinta and the middle Washakie from Wyoming (Stock, 1949). An additional ramus with $P_4$-$M_2$ (LACM 61303) was collected from Titus Canyon (Hanson 1989).

Order Artiodactyla

Family Agriochoeridae

*Protoreodon transmontanus*

(holotype – LACM 3558)

**Park:** Death Valley National Park.
**Locality:** Titus Canyon.
**Material:** Partial right maxillary.
**Collector:** Chester Stock.
**Author:** C. Stock, 1949.
**Article:** Contributions to Paleontology, Carnegie Institute of Washington Publication, 584(VIII):231-244.
**Description:** Several individuals of agriochoerids have been collected from Titus Canyon and represent the most abundant mammal fossil known from the locality. The holotype consists of a partial right maxillary with upper $P^2$-$M^1$. The Titus Canyon specimens resemble *Agriochoerus minimus* from Montana, but are slightly larger in size. However, *P. transmontanus* is considerably smaller that the species of agriochoerids from the White River and John Day formations (Stock, 1949).

Family Protoceratidae

*Poabromylus robustus*

(holotype – LACM 3569)

**Park:** Death Valley National Park.
**Locality:** Titus Canyon.
**Material:** left ramus, teeth, and a number of metapodial elements.
**Collector:** Chester Stock.
**Author:** C. Stock, 1949.
**Article:** Contributions to Paleontology, Carnegie Institute of Washington Publication, 584(VIII):231-244.
**Description:**

The type specimen from Titus Canyon consists of a partial left ramus with lower $P_2$-$M_1$. The specimen is larger, more robust, and has distinct differences in $P_4$ from *Poabromylus kayi* from the upper beds of the Duchesne River Formation. According to Stock (1949), there are many similarities between *P. robustus* and *P. kayi*. There has been some controversy regarding the taxonomic identity of *Poabromylus*. Peterson previously considered the genus to be a camelid (Peterson, 1931). More recent taxonomic revisions indicate that *Poabromylus* is a member of the Protoceratidae (Carroll, 1987).

**SYTEMATIC VERTEBRATE LIST:**

Class Pteraspidomorphi or Class Agnatha? (inventory)
Subclass Heterostraci
Order Pteraspidiformes
Family Pteraspididae

*Blieckaspis priscillae*

(holotype – FMNH-PF 867)

The type specimen was described from the Water Canyon Formation near Dry Lake in northern Utah (Denison, 1953, 1970). The material collected from Death Valley provides information regarding the dorsal shield (FMNH 14178), additional shield fragments (FMNH-PF 14179-14184), three immature ventral shields (FMNH-PF 14185-14187), and four body scales (FMNH-PF 14188-14191). The Death Valley specimens were collected from the Lippincott Member of the Lost Burro Formation near the Trail Canyon area (Elliott and Ilyes, 1996). Additional indeterminate pteraspidid specimens were also collected in these Devonian sediments.

**Class Placodermi**

Order Arthrodira

Family Dinichthyidae

cf. *Dunkleosteus terrelli*

Weathered disassociated remains of a Devonian arthrodire have been reported from the Lost Burro Formation in the Cottonwood Region (Dunkle and Lane, 1971). The fragmentary elements of dermal armor include a right posterior dorsal lateral plate and a left interolateral plate identified as *Dunkleosteus.*

**Class Chondrichthyes**

Subclass Elasmobranchii

A small cladodont shark tooth has been reported from the Devonian Lost Burro Formation (Dunkle and Lane, 1971). This specimen is contained within the collections at the Cleveland Museum of Natural History.

Subclass Holocephali

Family Cochliodontidae

An isolated unidentified cochliodont crushing tooth was collected from the Devonian Lost Burro Formation (Dunkle and Lane, 1971).

**Class Reptilia**

Order Chelonia

A number of turtle scutes were collected in the Titus Canyon Formation in Titus Canyon. These chelonian scutes are in the collections of the Los Angeles County Museum.

**Class Mammalia**

Order Carnivora

A partial left ramus with a fragment of the $M_2$ crown of a canid was collected in Titus Canyon. The limited amount of material (CIT 3568) does not enable identification beyond that of

Order Perissodactyla

Family Brontotheriidae

A poorly preserved portion of a possible menodontine titanothere skull (LACM 2007) was collected in the west fork of Titus Canyon. The tentative identification as a menodontine titanothere is based upon the elongate molars and the basal cross section of the horn.

Family Equidae

*Mesohippus* sp.

A few rare specimens of horse material were collected from the same horizon as the *Protitanops* specimen in Titus Canyon. This material represents the earliest equid material from the Great Basin Province and is smaller than *Mesohippus bairdii* of the White River. The best-preserved specimens include a lower $M_3$ (LACM 3562) and a calcaneum (LACM 3563). According to Stock (1949), this material suggests a horse intermediate in size between *Epihippus* of the Uinta and *Mesohippus bairdi*.

*Mesohippus westoni*

(referred specimen - UCMP131820)

Mason (1988) described right dentary fragments and a left partial dentary with $P_1$-$M_3$ that were collected in Titus Canyon by a Berkeley field crew in 1987.

Family Helaletidae

*Colodon* sp.

A portion of the right mandible with molar teeth and right ramus (LACM 3567) was collected in the west fork of Titus Canyon. According to Stock (1949), this specimen is slightly smaller than *Colodon dakotensis* and larger than *C. occidentalis*.

Family Leptomerycidae

*Leptomeryx blacki*

(holotype – LACM 3560)

The Titus Canyon type specimen consists of a fragmentary ramus with molar teeth. *Leptomeryx blacki* is smaller than *L. evansi* and lacks a diastema between the alveoli of $P_1$ and $P_2$. Stock (1949), suggested that the molar cusp pattern and the occlusal surface enamel is similar to the pattern exhibited in other species of *Leptomeryx*.

*Leptomeryx* cf. *yoderi*

(referred specimen-UCMP 131821)

Mason (1988) described a left dentry fragment with $P_4$-$M_3$ collected in Titus Canyon by members of a University of California, Berkeley field crew in 1987.

# APPENDIX C:

## PALEONTOLOGICAL LOCALITIES WITHIN DEATH VALLEY NATIONAL PARK

**Stanford University Collection Sites** (Gordon, 1964):

FL 5: Tihvipah Limestone, Cottonwood Region. Originally collected by McAllister (1937).

FL 15: Perdido Formation, Cottonwood Region. Originally collected by McAllister (FL 15 - August, 1937, Fl5A - September, 1937).

FL 23: Perdido Formation, Cottonwood Region. Originally collected by McAllister (1938).

FL 27: Perdido Formation, Cottonwood Region. Originally collected by McAllister (1938).

FL 36A: Perdido Formation, Cottonwood Region. Originally collected by McAllister (1938).

FL 36B: Perdido Formation, float block from top limestone - same locality as FL 36A.

FL 36C: Rest Spring Shale, concretion from basal few feet - same locality as FL 36A.

FL 38/SU 2776: Perdido Formation, top limestone bed, float blocks with goniatites, Cottonwood Region. Originally collected by McAllister (1938).

10 E8: Perdido Formation, top limestone bed. Float block from same locality as FL38. Originally collected by J. F. McAllister (1938).

**Cleveland Museum of Natural History**

A small collection of Devonian fish from the Lost Burro Formation. Fossil material includes fragmentary placoderm remains, a small cladodont shark tooth, and a unidentified cochliodont.

**US Geological Survey Collection Sites**

A large listing of localities from the Silurian, Devonian, and Mississippian Formations of the Funeral Mountains is given by McAllister (1974).

**Cephalopods** (Gordon, 1964):

15783 PC (field number U644): Perdido Formation, Cottonwood Region. Originally collected by J. F. McAllister (1946).

19804 PC (field number U377): Tihvipah Formation, Cottonwood Region. Originally collected by E. M. MacKevett (1944).

19806 PC (Merriam locality 2001): Large orthoconic cephalopod from unknown locality and horizon in the Cottonwood Mountains. This is presumably from the uppermost Perdido Formation, near Rest Spring, Cottonwood Region. Originally collected by Lawrence Dietz (1950).

**University of California - Berkeley, Museum of Paleontology** (Foster, 1961, 1973).

Locality D-249 Antelope Valley Limestone (Pogonip Group). In gray limestone containing numerous silicified brachiopods mainly *Orthidiella longwelli.*

Fauna: brachiopods, orthoconic nautiloids, cystoid plates and pelmatozoan columnals.

Locality D-251 Antelope Valley Limestone/Ninemile Formation (Pogonip Group). Probably stratigraphically above locality D-249. Fauna: receptaculitids, trilobites, gastropods, orthonic nautiloids and algae (*Batiola mammillaris*).

Locality D-252 Pogonip Group

Fauna: coiled nautiloids.

Locality D-253 Pogonip Group. In interbedded, pale brown, silty limestone and gray limestone: beds are almost vertical.

Fauna: graptolites, brachiopods, trilobites and pelmatozoan columnals.

Locality D-254 Antelope Valley Limestone (Pogonip Group), pinkish silty limestone.

Fauna: trilobite fragments.

Locality D-255 Antelope Valley Limestone (Pogonip Group), in medium light gray limestone with local areas of red-brown limestone.

Fauna: Orthoconic nautiloids.

Locality D-256 Antelope Valley Limestone (Pogonip Group), in gray limestone with pink, silty partings.

Fauna: trilobite fragments.

Locality D-257 Pogonip Group.

Fauna: nautoloid? fragments

Locality D-258 Pogonip Group. Float, from unit 2.

Fauna: nautoloid? fragments and calcareous algae.

Locality D-259 Pogonip Group. Float, from unit 3.

Fauna: brachiopods.

Locality D-260 Pogonip Group. In upper 3 feet of unit 5.

Fauna: orthoconic nautiloids.

Locality D-261 Pogonip Group. Float, from unit 6.

Fauna: variety of brachiopods and trilobites.

Paleozoic fossils from the Tin Mountain Limestone in the vicinity of Rest Spring area have been collected by Peck (1950) for the University of California Museum of Paleontology.

Conodonts described by Miller (1978) from the Hidden Valley Dolomite of Death Valley are included within the collections at the University of California Museum of Paleontology.

Fossils collected from Tin Mountain by Peck (1950) were collected for the University of California Museum of Paleontology.

Receptaculitids are very comon at a locality in the Grapevine Mountains, where specimens have been collected by the University of California Museum of Paleontology, locality number D-251.

The occurrence of the Late Cambrian problematic mollusk *Matthevia* (Walcott) have been reported extensively in the Nopah Formation of Death Valley, where the United States Geological Society has collections in Denver:

3814-CO/3815 Nopah Formation, Funeral Mountains, California.

3818-CO Nopah Formation, Funeral Mountains, California.

4399-CO/4400-CO/4401-CO/4402-CO/4403-CO/4406-CO Nopah Formation, N 19° W from Pyramid Peak, Funeral Mountains, California.

4453-CO Nopah Formation, S 39° E from Pyramid Peak, Funeral Mountains, California.

4454-CO Nopah Formation, S 23° W from Pyramid Peak, Funeral Mountains, California.

4455-CO Nopah Formation.

**Oregon Museum of Natural History**

The conodonts reported by Youngquist and Heinrich (1966) are cataloged at the University of Oregon Musuem of Natural History, number 26687.

**United States National Museum**

*Obolella excelsis* (Walcott) - holotype USNM 52208a, ventral valve, internal mold USNM locality 53. From sandstone exposures within the Waucoba series, inferred from the upper part of the Montenegro Member, Campito Formation (Rowell, 1977).

# APPENDIX D

## RMP Statements

Project Statement DEVA-N-012.000
Last Update: 01/31/97 Priority: 999
Initial Proposal: 1994

Title: MANAGE PALEONTOLOGICAL RESOURCES
Funding Status: Funded: 0.00 Unfunded: 0.00
Servicewide Issues: N23 (PALEONTOLOGY)
Cultural Resource Type: OBJC (Object)
N-RMAP Program codes: P00 (Paleontological Resource Management)
10-238 Package Number :

Problem Statement

The vast area encompassed by the boundaries of Death Valley National Park incorporates the complex geology which makes the area unique. The geologic ages of the formations and lithologic units exposed in the park range from the late Precambrian to recent. This broad range of units, expectedly, hosts a immense array of fossilized plant and animal remains representative of their evolutionary progression through that extended range of geologic time, thereby providing evidence of both the relative ages of the formations and of the prevailing environmental conditions. Those fossil assemblages are an integral part of the unusual scientific and educational features for which the lands were set aside for preservation by the National Park Service.

The vast majority of existing knowledge concerning fossil remains in Death Valley has been provided from investigations by non-NPS scientists. Generally, large concentrations of fossils of interpretive significance are not known in the park, except for Copper Canyon and one location near Trail Canyon. This may be due in part to a previous lack of emphasis on these resources. Certainly the discovery of the skull of a subspecies of Titanothere, in what is know known as Titanothere Canyon, is indicative of the potential for further substantial paleontological finds from those and similarly aged formations.

The inventory and monitoring of the paleontological resources has been identified as a element of the long range management of the resources of Death Valley. A literature and museum collection survey would undoubtedly provide a wealth of information on the knowledge of the paleontological attributes of Death Valley. Dependent upon the information supplied from a literature and collections survey, it may be necessary to prepare a Paleontology Resources Management Plan to provide for the protection of selected fossil sites within the park.

Description of Recommended Project or Activity

The preferred alternative for the management of the paleontological resources of Death Valley National Park incorporates the inventory and monitoring of those resources. An extensive preliminary list of species has been prepared which provides an appreciation of the extent of these resources which have been identified in the park. The preparation of a more complete inventory will permit the designation of those resource areas at which monitoring will be justified and appropriate.

The inventory work should include the detailed mapping and identification of selected sites such as the area containing the exposures of fossil tracks in Copper Canyon. Objectives of the mapping should be sufficient documentation to provide for monitoring and the determination of natural deterioration and vandalism of the multiple elements of the site. The inventory work should include the generation of appropriate steps of intervention and protection for specific elements, such as possible protection of the mastodon tracks and stabilization of the saber toothed cat track slab.

Action on this project should include an extensive literature and specimen survey of the park’s libraries and museum collections. Paleontological collections and data located in non-NPS institutions and obtained from previous research projects in Death Valley should be examined. Data, and in some cases the fossils themselves, should be returned to the NPS for inclusion in the park’s museum collection. Cataloging of existing specimens is difficult and should be guided by specialists in the various disciplines of paleontology.

BUDGET AND FTEs:

-----------------------------FUNDED------------------------------

| Source | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|
| | | Total: | 0.00 | 0.00 |

----------------------------UNFUNDED----------------------------

| Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|
| | Total: | 0.00 | 0.00 |

(Optional) Alternative Actions/Solutions and Impacts
(No information provided)

Compliance codes : EXCL (CATEGORICAL EXCLUSION)
ARPA (ARCH. RES. PROT. ACT.)

Explanation: 516 DM6 APP. 7.4 E(2)

Project Statement DEVA-N-012.001
Last Update: 02/08/99 Priority: 47
Initial Proposal: 1994

Title: MANAGE PALEONTOLOGICAL RESOURCES
Sub-title: LIT & COLLECTIONS SURVEY
Funding Status: Funded: 0.00 Unfunded: 20.00
Servicewide Issues: N23 (PALEONTOLOGY)
C46 (ACCOUNTBLY)
Cultural Resource Type: OBJC (Object)
N-RMAP Program codes : P00 (Paleontological Resources Management)
10-238 Package Number : 16

Problem Statement

The park has not been adequately surveyed for the existence, identification, location, and condition of paleontological collections. Specimens may be found in-situ in field locations considered "at-risk", within NPS offices and buildings, or, located in regional or national, non-NPS repositories. The potential for their loss or damage is high. Both the Scope of Collection Statement and research on the potential collections themselves are needed to evaluate this material for inclusion into the park's museum collection in order to avoid accessioning inappropriate materials into the collection. Cross-referencing existing records and contacts with subject matter experts requires significant time and effort.

The park's museum collection of paleontological specimens consists of approximately 700 specimens. Of this amount, 22 are backlog, 650 are manually and minimally cataloged, and only 35 have been entered into the ANCS database. Park paleontological collections stored in repositories are not cataloged, and only their accession documentation is in ANCS. A backlog and recataloging project is necessary to appropriately catalog these objects and bring park specific resources to standards.

The storage of paleontological specimens in the park and at off-site repositories does not meet NPS museum storage standards. Deficiencies include inadequate storage space, lack of appropriate environmental controls, and the need for minimal security and fire detection. The proper storage of these specimens requires appropriate storage equipment and supplies, environment, security, and preservation. Ensuring NPS standard storage conditions are met will help assure the specimens long-term preservation and integrity. The purchase of new supplies and equipment and the monitoring of storage conditions will address these deficiencies.

The problems to be solved have been documented as deficiencies in the park's completed DOI Checklist for Preservation, Protection, and Documentation of Museum Property, the current CMR, the Park's Draft (1996) Museum Management Plan, the Park's Resources Management Plan, and the Park's (Draft) Paleo Resources Management Plan. Deficiencies will need to corrected as per NPS-28, Cultural Resources Management Guideline and the Museum Handbook, Part II. Lack of accountability and proper storage of these collections may result in management needs not being met. Failure to comply may also precipitate an inspection by the GAO and the IG. In addition, uncataloged and undocumented collections and data are not available for research and educational purposes.

Term personnel or contract personnel will be required to supplement existing staff resources.
This process is expected to require twelve months to complete.

Description of Recommended Project or Activity

Determine workload. Program funding and priorities for NPS staff or museum professionals to conduct survey for paleontological collections. Specify the number and type of subject matter experts, the need for additional staff, and list the sites, buildings, files, and repositories to review. Develop survey in relation to park's Scope of Collection Statement, revising SOCS and RMP if necessary. Complete survey and document results. Accession appropriate materials into museum collection and arrange for their cataloging and disposition.

Program funding and priorities to fully catalog (according to standards) the Park's complete paleontological collection stored at the various repositories and within the park. Maintain entries in ANCS for these paleontological records and require backup copies of the database to append into the park's ANCS database. Use the records to complete required annual inventories, Collection Management Reports, and submissions to the National Catalog. Use the data in ANCS to create additional inventories and reports.

Program funding and priorities to request the purchase and installation of new museum storage equipment and supplies. Purchase and install upgrades, consulting with museum specialists on appropriate makes and models. Follow recommendations made in the Park's Collection Storage Plan and Museum Management Plan.

Costs for fully cataloging and recataloging paleo specimens is based on the Museum Handbook, Part II, Appendix B. For cataloging existing collections (700 specimens), at $7.00/specimen: $4,900.00.

BUDGET AND FTEs:

-----------------------------FUNDED------------------------------

| Source | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|
| | Total: | | 0.00 | 0.00 |

----------------------------UNFUNDED-----------------------------

| | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|
| Year 1: | RES | One-time | 20.00 | 0.00 |
| | Total: | | 20.00 | 0.00 |

(Optional) Alternative Actions/Solutions and Impacts

No Action. The location and existence of paleontological collections and their history will continue to be poorly documented or unknown. Archives and specimens that can significantly increase the value of the museum collection will be lost through disposal, damage, or theft. The park will not be meeting its mandate to preserve and protect cultural resources under its management authority.

The accountability program may not meet Departmental and NPS standards for the control and accountability of museum property. The lack of catalog records may cause problems with accounting for and tracking specimens, and with specimen identification and research value.

Paleontological collections may be stored in substandard conditions which may result in object deterioration and loss. Lack of new shelving, cabinets, polyethylene bags, document boxes, etc. may cause current problems to escalate.

Compliance codes : EXCL (CATEGORICAL EXCLUSION)
ARPA (ARCH. RES. PROT. ACT.)

Explanation: 516 DM6 APP. 7.4 E(2)
Project Statement DEVA-N-012.002
Last Update: / / Priority: 76
Initial Proposal: 1994

Title: MANAGE PALEONTOLOGICAL RESOURCES
Sub-title: SURVEY & MAP PALEO SITES
Funding Status: Funded: 0.00 Unfunded: 12.00
Servicewide Issues: N23 (PALEONTOLOGY)
Cultural Resource Type: OBJC (Object)
N-RMAP Program codes : P00 (Paleontological Resources Management)
10-238 Package Number :

Problem Statement

Please refer to project statement #012.000 for a general overview on this project statement.

Description of Recommended Project or Activity
(No information provided)

BUDGET AND FTEs:

-----------------------------FUNDED------------------------------

| Source | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|
| | | Total: | 0.00 | 0.00 |

----------------------------UNFUNDED-----------------------------

| | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|
| Year 1: | MON | Recurring | 6.00 | 0.00 |
| Year 2: | MON | Recurring | 6.00 | 0.00 |
| | | Total: | 12.00 | 0.00 |

(Optional) Alternative Actions/Solutions and Impacts
(No information provided)

Compliance codes : EXCL (CATEGORICAL EXCLUSION)
ARPA (ARCH. RES. PROT. ACT.)

Explanation: 516 DM2 APP. 2, 1.6
Project Statement DEVA-N-012.003
Last Update: 02/11/99 Priority: 88
Initial Proposal: 1994

Title: MANAGE PALEONTOLOGICAL RESOURCES
Sub-title: PREPARE PALEO MNGMNT PLAN
Funding Status: Funded: 6.00 Unfunded: 30.00
Servicewide Issues : N23 (PALEONTOLOGY)
Cultural Resource Type: OBJC (Object)
N-RMAP Program codes : P00 (Paleontological Resources Management)
10-238 Package Number :

Problem Statement

Please refer to project statement #012.000 for a general overview on this project statement.

Description of Recommended Project or Activity

A Paleontological Resources Management Plan will be developed for the park, either on contract or by a central office such as DSC.

BUDGET AND FTEs:

-----------------------------FUNDED-----------------------------

| | Source | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|---|
| 1996: | PKBASE-NR | ADM | One-time | 6.00 | 0.10 |
| | | | Total: | 6.00 | 0.10 |

----------------------------UNFUNDED----------------------------

| | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|
| Year 1: | ADM | One-time | 30.00 | 0.00 |
| | | Total: | 30.00 | 0.00 |

(Optional) Alternative Actions/Solutions and Impacts
(No information provided)

Compliance codes : EXCL (CATEGORICAL EXCLUSION)
ARPA (ARCH. RES. PROT. ACT.)

Explanation: 516 DM6 APP. 7.4 B(4)
Project Statement DEVA-N-012.004
Last Update: 02/13/98 Priority: 777
Initial Proposal: 1994

Title: MANAGE PALEONTOLOGICAL RESOURCES
Sub-title: IMPLEMENT PALEO MGNT PLAN
Funding Status: Funded: 15.00 Unfunded: 0.00
Servicewide Issues : N23 (PALEONTOLOGY)
Cultural Resource Type: OBJC (Object)
N-RMAP Program codes : P00 (Paleontological Resources Management)
10-238 Package Number :

Problem Statement

Please refer to project statement #012.000 for a general overview on this project statement.

Description of Recommended Project or Activity
(No information provided)

BUDGET AND FTEs:

-----------------------------FUNDED------------------------------

| | Source | Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|---|---|
| 1997: | PKBASE-NR | MON | Recurring | 10.00 | 0.10 |
| 1998: | PKBASE-NR | MON | Recurring | 5.00 | 0.00 |
| | | | Total: | 15.00 | 0.10 |

----------------------------UNFUNDED-----------------------------

| Activity | Fund Type | Budget ($1000s) | FTEs |
|---|---|---|---|
| | Total: | 0.00 | 0.00 |

(Optional) Alternative Actions/Solutions and Impacts
(No information provided)

Compliance codes : EXCL (CATEGORICAL EXCLUSION)
ARPA (ARCH. RES. PROT. ACT.)

Explanation: 516 DM6 APP. 7.4 E(2)

As the nation's principal conservation agency, the Department of Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoors recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The departement also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-1056 May 1995