National Park Service
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Mojave Desert Network

Paleontological Resource Inventory and Monitoring
MOJAVE DESERT NETWORK



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On the Cover:
Fossil vertebra of a small camel, possibly from the genus *Hemiauchenia*. The bone was found and collected in February 2003 from the Pinto Basin in Joshua Tree National Park by Kathleen Springer, Senior Curator of Geological Sciences for the San Bernardino County Museum. The fossil is currently housed at the San Bernardino County Museum. For more information regarding Pinto Basin fossils, see the Joshua Tree National Park section in this report. Photograph courtesy of Eric Scott, San Bernardino County Museum.

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INTRODUCTION

Paleontological resources are the remains of past life preserved in a geologic context. These fossils are non-renewable resources that possess scientific and educational values.

Establishment of baseline paleontological resource data is essential for the appropriate management of fossils found within National Park Service areas. Although over 160 National Park Service areas have been identified with paleontological resources, only a small percentage of these parks have adequate baseline paleontological resource data.

In conjunction with the National Park Service Geologic Resources Division and a number of Inventory & Monitoring Networks, either baseline or comprehensive paleontological resource inventories have been initiated in dozens of parks servicewide. This report represents paleontological resource inventory and monitoring data compiled for the parks within the Mojave Desert Network.

The Mojave Desert Network is comprised of seven National Park Service areas: Death Valley National Park, Grand Canyon- Parashant National Monument, Great Basin National Park, Joshua Tree National Park, Lake Mead National Recreation Area, Manzanar National Historic Site, and Mojave National Preserve. These parks are located in Arizona, California, and Nevada.

Fossiliferous geologic units within the network parks range from the Precambrian to the Recent. Significant fossils of invertebrates, vertebrates, plants, and traces occur within most of the network parks. These paleontological resources include early metazoans (primitive animals) from the Precambrian, Paleozoic marine invertebrates, primitive Devonian fish, perhaps some of the finest assemblages of Tertiary mammals tracks in the world, and a variety of ice age mammal remains.

The wide variety and abundance of fossils in the Mojave Desert Network deem these areas to be among some of the more paleontologically significant in the National Park Service.

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METHODS AND INVENTORY STRATEGIES

In order to better document fossil occurrences and to provide baseline paleontological resource data in National Park Service areas, the NPS Geologic Resources Division (GRD) and the NPS Inventory and Monitoring Program (I&M) have established three paleontological resource inventory strategies. These strategies include: comprehensive park- specific paleontological resource inventories, servicewide thematic paleontological resource inventories, and Inventory & Monitoring Network based baseline paleontological resource inventories, each established with their own goals and objectives.

Comprehensive park inventories are designed to identify all known paleontological resources within a single park unit. Comprehensive park inventories involve the assembly of a team of specialists from within the NPS and from educational institutions and cooperators. These specialists work together with the park to identify and address all aspects of the paleontological resources within the targeted park, including resource management, museum curation, law enforcement, and interpretation. The goals and objectives of a park-specific paleontological resource inventory are detailed by Santucci (2000). An important component of many comprehensive paleontological inventories is to provide paleontology- specific training for park staff. Such park- specific comprehensive paleontological resource inventories have been completed at Yellowstone NP (first park to complete inventory), Arches NP, Bighorn Canyon NRA, Death Valley NP, Grand Teton NP, Santa Monica NRA, Walnut Canyon NM, and Zion NP.

Service- wide thematic paleontological resource inventories are designed to compile data regarding specific types of paleontological resources which occur in parks throughout the NPS. The first thematic paleontological resource inventory accomplished was an inventory of fossil vertebrate tracks from NPS areas (Santucci, et al., 1998). Through this thematic inventory, a total of nineteen NPS units were identified as preserving fossil vertebrate tracks. Subsequent discoveries have increased the number of parks identified with fossil vertebrate tracks to twenty- five. Another example of a thematic paleontological resource inventory is the inventory of paleontological resources associated with NPS caves (Santucci, et al., 2001). Fossils occur in two contexts relative to caves. First, fossils can be preserved in the marine limestones in which caves develop. Second, the remains of Ice Age animals and plants that either lived, died or were transported into caves after death, are common types of cave fossils. The NPS Cave Paleontological Resource study initially identified thirty- five parks with cave fossils.

The third paleontological resource inventory strategy is the Inventory & Monitoring Network- based inventory strategy. Network- based paleontological resource inventories are designed to compile baseline paleontological resource data for each of the parks assigned to a particular network. Network- based inventories have been completed for one- third of the 32 I&M Networks including: the Eastern Rivers and Mountains, Greater Yellowstone, Mediterranean Coast, Mojave Desert, National Capital Region, Northeast Coastal and Barrier, Northern Colorado Plateau, Rocky Mountain, Southern Plains, and Southwestern Alaska networks. A similar paleontological inventory is underway for the Upper Columbia Basin Network is scheduled for completion during FY2005.

The Network- based paleontological inventories are funded directly by the individual networks. Funds are used to provide stipends or salary for contractors, interns, or paleontological technicians who perform data mining activities. A brief summary outlining the basic techniques used to put together an I&M Network-based inventory is presented below.

The most valuable component of any paleontological resource inventory is an intensive literature search. Various databases contain citations for geology or paleontology themed publications. GeoRef, established by the American Geological Institute, is the primary database for geology references and contains millions of references from the mid 1700's through today. GeoRef, available in both online or CD- ROM versions, is accessible at many major university libraries. The NPS NatureBib (which supercedes PaleoBib) is an internet based database for scientific citations presented as bibliographic references. NatureBib is a work in progress and does not yet contain a comprehensive paleontology bibliography. The USGS Library in Reston, Virginia is a premier repository for geologic publications, and houses most of the publications obtained for the network- based paleontological resource inventories. Additionally, museum libraries such as the

Smithsonian Institution's National Museum of Natural History, and university libraries provide access to a wide range of geological and paleontological publications. Individual state geological surveys are also excellent sources of information and geologists familiar with local geology and paleontology.

The literature search also includes gray (unpublished) literature, searches of individual park files, museum archives, local newspapers, etc. These are often excellent sources of anecdotal information about park resources. In addition to literature searches, interviews with park staff, university faculty, geologists from the USGS and state surveys, and even local amateur geologists or paleontologists can yield information regarding park paleontological resources. These interviews frequently result in capturing data that may otherwise be undocumented and potentially lost or unrecognized.

As part of the bibliographic searches, a search for geologic maps associated with each park is undertaken. Tim Connors, a geologist with the NPS Geologic Resources Division, maintains a database of geological map coverage for many parks in the NPS. In addition, the USGS National Geologic Map Database (NGMDB; see citation below in References section) lists maps for a given geographic area or place name. The NGMDB also provides information on where to obtain maps. Geologic maps show the type of rocks and the associated geological formations present within a park area. These maps, alone, will often indicate the potential for paleontological resources to occur within a park. Fossils, with only rare exceptions, are found in sedimentary rocks such as sandstones, shales, and limestones. Fossils, with few exceptions, are not found within igneous rocks (volcanic, or of molten origin) or metamorphic rocks (mechanically and chemically altered) due to the extreme heat and/or pressure associated with the origin and history of these rocks types. The nomenclature for geologic formations can be confusing. The NGMDB also includes a searchable lexicon of valid geologic formation names. This lexicon provides a basic summary for each formation and summarizes current and past usage of the various formation names found in the literature. It also provides an annotated bibliography for each formation. The lexicon is very useful in cleaning up nomenclatural confusion.

The information from all these various sources for each park is then compiled and summarized in a written report and are developed into individual datasets. The reports undergo peer review by professional geologists, paleontologists, and staff from each park, for accuracy before being submitted to the network. This report is designed to consolidate baseline paleontological resource data for each park to support management operations and decision- making. Therefore, the reports are written in NPS language and in additional to the scientific information, the reports address issues of resource management, protection, and interpretation.

The paleontological resource inventory reports synthesize information regarding the scope and significance of fossils documented from each park. Fossils are assessed and organized based upon taxonomy, stratigraphy, and paleoecology. Taxonomically, paleontological resources can be divided into four groups: paleobotany (fossil plants), invertebrates (animals without backbones), vertebrates (animals with backbones), and trace fossils (evidence of biological activity such as track, trace, burrow, etc.). Stratigraphically, fossils typically have a finite span and occurrence in geologic time (a geologic time scale is included in Appendix A). The period between the first occurrence and final occurrence of a fossil species is referred to as the stratigraphic range zone. Thus specific groups of fossils may be identified directly with a particular stratigraphic unit or stratigraphic range. Likewsie, rock units often represent specific ancient sedimentary depositional environments. Paleoecologically, fossil groups may occur primarily, or in some instances only, in specific environmental conditions (temperature, aquatic, terrestrial, etc.). Thus many fossils may be useful as indicators of past environmental conditions. The reports are organized stratigraphically presenting the geologic and paleontologic information chronologically from oldest to youngest. Important fossils documented from localities outside a park are often reported in the park inventory, as this data may indicate the potential for fossils in similar stratigraphic units exposed in park boundaries.

Given the tremendous diversity of past life, the existence of life for over a billion years, and the range of environments that life has adapted, there are a broad spectrum of research interests in paleontology. It is not surprising that most of what is to be learned about the history of life remains to be discovered. Through research, over 170 NPS areas have been identified as containing paleontological resources. However, the paleontological research for a particular park may vary widely from an incidental fossil discovery to over a century of intensive paleontological investigations. The inventory reports include information on the history

of paleontological research, descriptions of current cooperative projects, identification of any museum or universities serving as respositories for park fossils, and a comprehensive list of publications related to paleontological research associated with the park. Organizationally, the reports include any and all bibliographies that may be associated to a park's paleontological resources. However, bibliographic data are subdivided in the report into those cited in the narrative (Refernces Cited) and other associated bibliographies (Additional References). Formal datasets are established for associated paleontological collections, research, or activities.

Our knowledge of the fossil record is only a good as our previous field season. The potential for new paleontological discoveries is proportionally related to our understanding as managers and stewards of this non- renewable evidence of life from the past. We believe that the baseline information provided in these reports and the resulting increased understanding of paleontological resources will inevitably result in paving the way for future fossil discoveries in NPS areas.

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Smithsonian Institution Libraries Catalog: http://www.siris.si.edu/
Topozone (access to all U.S. topographic maps): http://www.topozone.com
U.S. Geological Survey: http://www.usgs.gov
U.S. Geological Survey National Geologic Map Database (NGMDB): http://ngmdb.usgs.gov/
U.S. Geological Survey Library Catalog: http://igsrglib03.er.usgs.gov:8080/#focus

DEATH VALLEY NATIONAL PARK

Death Valley National Park (DEVA) was originally established as a national monument in 1933. The park boundary was expanded and redesignated a national park in 1994. DEVA is the largest unit of the National Park Service in the lower 48 states. The park preserves a low- elevation desert ecosystem, almost completely surrounded by high mountain ranges. As the lowest point in the Western Hemisphere, the park has also been designated a Biosphere Reserve. The park includes Scotty's Castle and the remnants of gold and borax mining.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The first comprehensive paleontological resource inventory of all the various fossils and previous paleontological research from within DEVA was completed by Nyborg and Santucci (1999). Fossil resources at DEVA have been extensively studied for over 100 years and have produced more than 200 articles in a variety of scientific publications (National Park Service, 2002).

DEVA preserves an extensive geologic record ranging from the Proterozoic through the Holocene. Over thirty fossiliferous stratigraphic units have been identified in DEVA, 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 DEVA 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. An important Proterozoic metazoan fossil has been reported from within the park's boundary (Langille, 1974a), consisting of a small shelly fossil "*Cloudina*." Langille (1974a) 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 DEVA, 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).

These Mesoproterozoic and Neoproterozoic formations are categorized as either Death Valley facies or White- Inyo facies. The Death Valley facies is comprised of nearshore shallow marine and fluvial sediments and the White- Inyo facies represents a more offshore environment. The Death Valley facies includes the Pahrump Group (Crystal Spring, Beck Spring, and Kingston Peak formations), Noonday Dolomite, Ibex Formation, Johnnie Formation, Stirling Quartzite, and Lower Wood Canyon Formation. Fossils within the Pahrump Group consist of diverse and well- preserved microfossils within cherts, stromatolites, and other algal material (Awramik et al., 1994; Cloud et al., 1969; Howell, 1971; Licari, 1978; Pierce et al., 1994; Roberts, 1976; Tucker, 1983). The Noonday Dolomite contains algal, cryptalgal, and clastic dolostone, as well as large domal stromatolites (Wright et al., 1978). No fossils have been reported from the thinly bedded siltstone and limestone Ibex Formation. Various stromatolites have been recorded from the mixed carbonate and siliclastic sequences of the Johnnie Formation (Awramik et al., 1994; Cloud et al., 1969; Summa et al., 1991). The Stirling Quartzite contains the metazoan shelly fossil, *Cloudina*, and rare occurrences of the trace fossil *Planolites* (Langille, 1974a, 1974b; Wertz, 1982).

The Neoproterozoic units found within the White- Inyo facies are the Wyman Formation, Reed Dolomite, and Deep Spring Formation. The Wyman Formation is composed of dark- gray phyllite and interbedded limestone and marble layers (Nyborg and Santucci, 1999). Algae and trace fossils have been reported from the Wyman Formation (Alpert, 1976; Langille, 1974; Mount and Signor, 1985; Nelson, 1976; Wiggett, 1975). The Reed Dolomite consists of white to yellowish- gray dolomite (Stewart, 1970). Algae, trace fossils, tubular fossils, and stromatolites have been found within the Reed Dolomite (Nelson, 1976; Noble, 1934; Signor and Mount, 1989; Taylor, 1966). The Deep Spring Formation is composed of mixed carbonate and siliclastic

deposits (Parsons, 1996). Fossils from the Deep Spring Formation include stromatolites, a hyolith, annelids, pre- trilobite shelly assemblage, and significant trace fossils (Alpert, 1975, 1976; Signor et al., 1987; Signor and Mount, 1986).

During the 1880's, Charles Walcott explored an area north of Waucoba Springs within the Saline Valley Region. He designated a 2,100 meter (6,890 feet) 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 DEVA record scientifically important depositional settings.

The Cambrian deposits found within the Death Valley facies are the Middle and Upper Wood Canyon formations, Zabriskie Quartzite, Carrara Formation, Bonanza King Formation, and Nopah Formation. The Middle and Upper Wood Canyon formations have produced ediacaran, trilobite, echinoderm, brachiopod, and trace fossils (Durham, 1993; Horodyski, 1993; Mount, 1982; Signor and Savarese, 1988; Stewart, 1970). The Zabriskie Quartzite contains nearshore and foreshore deposits that include bioturbation and *Skolithos* tubes (Prave, 1988; Prave and Wright, 1986). The Carrara Formation consists of nine fossiliferous members. These members primarily contain trilobites, although echinoderms, stromatolites, and trace fossils have also been reported (Awramik et al., 1994; Bates, 1965; Palmer and Halley, 1979). Two members of the Bonanza King Formation are fossiliferous. The Papoose Lake Member contains *Glossopleura* trilobites and the Informal Middle Member contains trilobite "hash beds" and linguloid brachiopod beds (Hall, 1971; Hunt, 1975). A variety of fossils are found within the Nopah Formation. Stromatolites, trilobites, brachiopods, conodonts, sponges, eocrinoids, gastropods, and additional fossil material have been reported (Barnes and Christiansen, 1967; Cooper et al., 1982; Denny and Drewes, 1965; Griffin, 1987; Hall, 1971; Hazzard, 1937; Hunt, 1975; Hunt and Mabey, 1966; Stinchcomb and Darrough, 1995; Yochelson and Taylor, 1974).

The Cambrian units within the White- Inyo facies consist of the Campito Formation, Poleta Formation, Harkless Formation, Saline Formation, Mule Spring Formation, and Monola Formation. The terrigenous Campito Formation contains the earliest trilobite occurrences, archaeocyathids, helicoplacoid echinoderms, hyolithids, and trace fossils (Alpert 1975, 1976; Durham, 1993; McKee and Gangloff, 1969; Mount, 1982; Mount and Signor, 1992; Nelson, 1962, 1976; Onken and Signor, 1988; Signor and Mount, 1989). The Poleta Formation contains bioherms, archaeocyathids, hyolithid beds, eocrinoids, articulate brachiopods, edrioasteroids, helicoplacoids, trilobites, and trace fossils within its three members (Firby and Durham, 1974; Gangloff, 1975; McKee and Gangloff, 1969; Mount, 1982; Nelson, 1962; Nelson and Durham, 1966; Onken and Signor, 1988; Rowland, 1978, 1979; Seiple, 1984; Signor and Mount, 1989). The Harkless Formation consists of siltstone, quartzite, and shale (Nelson, 1962; Seiple, 1984). Large archaeocyathids, brachiopods, trilobites, and trace fossils are found within the Harkless Formation (Nelson, 1962; McKee and Gangoff, 1969; Seiple, 1984; Signor and Mount, 1989). Massive quartzite, siltstone, and sand limestone comprise the Saline Valley Formation (Nelson, 1962; Seiple, 1984). The uppermost member of the Saline Valley Formation contains trilobites in olive- green shale (Firby and Durham, 1974; Seiple, 1984). The Mule Spring Limestone is a dark blue- gray oncolitic limestone that contains algae and trilobites (Nelson, 1962; Palmer and Nelson, 1981; Seiple, 1984). Lastly, the Monola Formation contains a diverse assemblage of trilobites (Nelson, 1976).

The remaining fossiliferous units in DEVA are all considered part of the Death Valley facies.

The Ordovician Pogonip Group is comprised of three carbonate members. The Pogonip Group members have produced fossil assemblages of trilobites, brachiopods, receptaculitids, gastropods, orthoconic and coiled nautiloids, graptolites, echinoderms, and conodonts (Foster, 1961; Hall, 1971; Miller, 1982).

The Ely Springs Dolomite Formation spans in age from the Ordovician to the Silurian. The formation consists of dark gray, cherty dolomite and a light gray dolomite. Silicified rhynchonellid brachiopods, cephalopods, streptelasmid corals, *Halysites*, and conodonts are all found in the lower unit of the Ely Springs Dolomite (Hall, 1971; Miller, 1982).

The Silurian to Devonian Hidden Valley Dolomite Formation contains various corals, articulate brachiopods, crinoid debris, and conodonts within a lower cherty unit (Haug, 1981; Hazzard, 1937, 1954; Hunt, 1975; Miller and Hanna, 1972).

The Devonian Lost Burro Formation contains abundant fossil material. Brachiopods, stromatoporoids, corals, microgastropods, sponge spicules, crinoid columns, conodonts, and fish remains have been discovered from this formation (Denny and Drewes, 1965; Hall, 1971; Hunt, 1975; McAllister, 1974; Youngquist and Heinrich, 1966). Specific fish remains include the placoderm *Dunkleosteus*, a small cladodont, and a cochliodont tooth (Dunkle and Lane, 1971). Two genera of rare Devonian fish were discovered in the Lippincott Member of the Lost Burro Formation (Elliott and Ilyes, 1993, 1996a, 1996b). These primitive pteraspid (agthanan) fish include the genus *Blieckaspis* and a newly described genus *Panamintaspis* from the Trail Canyon area of DEVA. These remains shed new light on the early evolution of fish in North America.

The Tin Mountain Limestone and Perdido formations are both fossiliferous Mississippian units exposed within the park. The Tin Mountain Limestone Formation consists of a lower lagoonal or mudflat limestone, above which is a crinoidal limestone that was deposited on an offshore bar or bank (Langenheim and Tischler, 1959). Abundant fossils are found within these limestones, including: foraminifera, coelenterates, corals, bryozoans, cephalopods, gastropods, pelecypods, crinoids, brachiopods, trilobites, an annelid worm, and petrified wood (Denny and Drewes, 1965; Hall, 1971; Hunt, 1975; Langenheim and Tischler, 1959; Peck, 1950). The Perdido Formation is composed of a limestone member and a siltstone member (Hall, 1971). Fossils found within the Perdido Formation include foraminifera, crinoid, coral, and cephalopod material, as well as a goniatite coquina bed (Gordon, 1964; Hall, 1971; McAllister, 1970; Tischler, 1955).

The Lee Flat Limestone and the Rest Spring Shale constitute the Mississippian to Pennsylvanian units exposed within the park. The white to light- gray marble Lee Flat Limestone preserves abundant crinoid columnals (Hall, 1971). The siltstone and shale deposits of the Rest Spring Shale Formation contain poorly preserved brachiopods (Hall, 1971).

The Keeler Canyon and Tihvipah formations are both Pennsylvanian to Permian in age. The Keeler Canyon Formation is composed of alternating limestones and marbles preserving fusilinid, crinoid, brachiopod, and bryozoan material (Hall, 1971). Gordon (1964) reports cephalopods and fusilinids from the Tihvipah Formation that consists of limestones and chert nodules (McAllister, 1952).

The Permian Owens Valley Formation is composed of limestone, siltstone, and shale units (Hall, 1971). Reported fossils from the Owen Valley Formation are fusulinids, solitary corals, gastropods, and bryozoans (Hall, 1971).

The Eocene Titus Canyon Formation consists of conglomerates, sandstones, calcareous mudstones, algal limestones, and tuffaceous sandstones (Nyborg and Santucci, 1999). Late Eocene (Chadronian) assemblages of fossil mammals have been collected from the Titus Canyon Formation in DEVA. Fossilized remains of early rodents, carnivores, horses, rhinos, and artiodactyls have been discovered in a red calcareous mudstone unit (Stock and Bode, 1935). Miller (1945) reported on the remains of an osteichthyes fish and Stock (1949) reported on turtle scutes, rodent teeth, and a rodent skull from the Titus Canyon Formation. A locality within the Titus Canyon Formation referred to as Titanothere Canyon received its name based upon the discovery of a new species of titanothere referred to as *Protitanops curryi* (Nyborg and Santucci, 1999). 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.

There are three Miocene units exposed within DEVA: the Artist Drive, Furnace Creek, and Copper Canyon formations. Diatoms have been reported from the Artist Drive Formation (Cemen et al., 1985; Hardy, 1988). The Furnace Creek Formation preserves diatoms, stromatolites, and plant material, including a lateral leaf lobe of *Lyonothamnus mohavensis* (Axelrod, 1940; Awramik et al., 1994; Hardy, 1988; Noble, 1934; Pitts, 1983). The Copper Canyon Formation is composed of basalts, alluvial sediments, and lacustrine deposits (Scrivner, 1984). The lacustrine deposits have received significant scientific attention due to the preservation of abundant and diverse fossil vertebrate tracks (Curry, 1939, 1941; Nyborg, 1998; Santucci, 1998; Scrivner, 1984; Scrivner and Bottjer, 1986; Sarjeant and Reynolds, 1999; Sarjeant and Reynolds, 2001; Sarjeant, et al., 2002).

Fossil vertebrate tracks from the Tertiary are relatively rare by comparison to Mesozoic vertebrate tracks. Fossil footprints of birds, camels, horses, cats, proboscidians and other vertebrate ichnotaxa are preserved in late Miocene lacustrine deposits within Copper Canyon. The site is so scientifically significant, if it was not protected as part of DEVA, Copper Canyon would be worthy for consideration as an independent national monument (Nyborg and Santucci, 1999).

Small and large vertebrate fossils from Lake Tecopa, immediately adjacent to Death Valley, provide examples of taxa, habitats, and changes in hydrology and structure from the late Pliocene to late Pleistocene (Reynolds, 1987, 1991, 1999, 2001; Woodburne and Whistler, 1991). The youngest fossiliferous deposits found within DEVA are Pleistocene and Holocene lacustrine and alluvial fan deposits. A partial mastodon tusk was discovered within sedimentary deposits of Lake Rogers (Clements, 1973).

COOPERATIVE PROJECTS:

- National Park Service's Geologic Resources Division geologic resource inventory and paleontological resource inventory for Death Valley National Park (February 2002).
- Death Valley Paleontological Survey conducted by Torrey Nyborg and Vincent Santucci (1999).
- Paleontological Resource Management of the Copper Canyon Fossil Track Site at Death Valley National Park by Vincent Santucci (1998).
- Copper Canyon Track Site Inventory, Mapping, and Replication Project conducted by Torrey Nyborg, Robert Reynolds, and Vincent Santucci (1999).
- Devonian Fish Locality Research in Death Valley National Park conducted by David Elliot (1990- 1996).
- Development of a paleontological locality database for Death Valley National Park by Torrey Nyborg (2003- ongoing).

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DS- DEVA-XXX — Death Valley Paleontological Survey. 1999- 2002. (field notes; photographs; hard copy data; GIS maps; publication; GIS paleo locality maps). Originated by Nyborg and Santucci; status: Inactive.

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GRAND CANYON - PARASHANT NATIONAL MONUMENT

Grand Canyon - Parashant National Monument (PARA) was established in 2000 to preserve the plateaus, valleys, and canyons situated on the northern edge of the Grand Canyon. The Monument is jointly administered by the Bureau of Land Management and the National Park Service. The NPS administered portions of the Monument were previously within Lake Mead National Recreation Area. Paleontological resources are specifically mentioned in the enabling legislation.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The NPS administered portions of Grand Canyon - Parashant NM can be divided into three areas including the eastern, central, and western units. The eastern unit includes: an eastern boundary extending from near Mount Emma towards the Colorado River between Lava Falls Rapids and Whitmore Rapids, and a western boundary at Andrus Canyon. The central unit extends from Andrus Canyon on the east to Tincanebitts Canyon on the west, including a number of southward projecting peninsulas including Mollies Nipple, Price Point, Kelly Point, Amos Point, Suicide Point, Twin Point, and Burnt Canyon Point. The central unit represents the southern portions of the Shivwits Plateau that forms the northern rim of the Grand Canyon. Southward projecting, erosional peninsulas are dissected from primarily Paleozoic strata on the north side of the Colorado River. The rim formed by the Lower Permian Toroweap and Kaibab formations delineates the boundary between Grand Canyon NP (GRCA) and PARA. GRCA occurs below this stratigraphic landmark. The western unit of PARA is separated from the other portions by the Grand Wash Cliffs, which represents the physiographic break between the Colorado Plateau and the Basin and Range Province.

The most recent and comprehensive paleontological resource data for PARA has been compiled by Caitilin McCraken and Jim I. Mead from the Quaternary Studies Program at Northern Arizona Univeristy (McCraken and Mead, 2003). Geologic maps of the areas now administered by PARA were recently produced by the United States Geological Survey (Billingsley and Workman, 2000; Billingsley and Wellmeyer, 2002).

The oldest geologic units containing paleontological resources within PARA are lower and middle Cambrian formations collectively referred to as the Tonto Group. In ascending order, the Tapeats Sandstone, Bright Angel Shale, and Muav Limestone are fossiliferous units within the Tonto Group and overlie Early Proterozoic igneous and metamorphic rocks. The Tapeats Sandstone is a medium- to coarse-grained marine sandstone and is found within the inner canyon. Middleton and Elliot (1990) report on a number of ichnogenera (trace fossils) from the Tapeats including: *Arenicoloides, Corophioides, Skolithos,* and *Cruziana*. The Bright Angel Shale is a marine mudstone shale overlying the Tapeats. Fossils from the Bright Angel Shale include: sponges, gastropods, conchostracans, trilobites, and a large number of trace fossil types (Middleton and Elliot, 1990). The uppermost unit in the Tonto Group is the Muav Limestone. The Muav is a cliff-forming, dolomitic, marine limestone consisting of six members defined by McKee and Resser (1945). Fossils are somewhat rare in the Muav Limestone, however, a rich Pleistocene / Holocene paleontological record is preserved within caves developed in the limestone (Kenworthy et al., 2004; Santucci et al., 2001).

The Temple Butte Formation is a Middle to Upper Devonian carbonaceous unit. The eastern exposures of the Temple Butte are largely freshwater limestones and in the west are more dolomitic (Beus, 1980). The dolomitic facies in the west contain marine invertebrate fossils including corals, stromatoporoids, brachiopods, gastropods, crinoids, and conodonts (Bues, 1990). Bony plates of freshwater fish, including *Bothreolepis* and "placoganoid" fish are documented from the eastern facies (Beus, 1990).

Devonian fish are reported from a locality in the Virgin Mountains in Nevada, just west of PARA (Johnson, 1995; Johnson, 1997). Arthrodires and antiarches were discovered within the Mountain Springs Formation. The fossil material occurs within channel deposits and is interpreted as a nearshore environment by Johnson (1997).

The Redwall Limestone is a Mississippian marine limestone and dolomite that forms prominent cliffs in the canyon (McKee, 1963). The Redwall Limestone is subdivided into a number of members including from oldest to youngest: Whitmore Wash Member, Thunder Springs Member, Mooney Falls Member, and Horseshoe Mesa Member. Marine invertebrates are found throughout most of the members of the Redwall including: foraminifera, corals, bryozoans, brachiopods, gastropods, cephalopods, pelecypods, crinoids, blastoids, and conodonts (Beus, 1990). A rich Pleistocene / Holocene paleontological record is preserved within caves developed in the limestone (Kenworthy et al., 2004; Santucci et al., 2001).

The Surprise Canyon Formation is an Upper Mississippian unit that represents sedimentary deposits within channels and karst features formed in the Redwall Limestoine (Billingsley and Beus, 1999). The Surprise Canyon consists of siltstones and sandstones with interbedded limestones and dolomites. Beus (1999) reports on plant macrofossils and palynomorphs from the Surprise Canyon Formation. A diversity of invertebrates and trace fossils occur within this unit including: foraminifera, corals, bryozoans, brachiopods, gastropods, cephalopods, pelecypods, trilobites, crinoids, starfish, and conodonts. Vertebrate fossils are also reported from the Surprise Canyon Formation including shark's teeth and tetrapod bones (Martin and Barrick, 1999; Billingsley and Beus, 1999).

The Callville Limestone is a Pennsyvlanian through Lower Permian limestone unit defined by Hintze (1986). There are no reports of fossils from the Callville Limestone.

The Supai Group consists of Upper Mississippian through Lower Permian units including in ascending order: Watahomigi, Manakacha, and Wescogame formations (McKee, 1975, 1982). The Supai Group is composed primarily of shale with interbedded limestones and capped by a sandstone. The western facies of the Supai Group is dominated by marine lithologies and fossils, primarily invertebrates. The eastern facies of the Supai Group represents an ancient muddy river delta which includes the remains of fossil invertebrates, amphibians, reptiles, and terrestrial plants.

The Queantopweap Sandstone is a very localized Lower Permian unit in PARA (Billingsley and Workman, 2000; Billingsley and Wellmeyer, 2002). This sandstone is fine- grained and cross- stratified. There are no reports of fossils associated with the Queantopweap Sandstone.

The Esplande Sandstone (McKee, 1975) and Pakoon Limestone (McNair, 1951) are Lower Permian units which consist of calcareous sandstone, interbedded siltstone, and limestone beds. The sands display some low- angle cross- bedding. Marine fossils are present primarily in the Pakoon Limestone including: foraminifera, fusulinids, corals, bryozoans, brachiopods, gastropods, echinoderms, shark's teeth, plants, and *Scoyenia* traces (McKee, 1982). There is also a report of unidentified quadrupedal animal tracks from within this stratigraphic unit (McKee, 1982).

The Hermit Shale is a Lower Permian unit consisting of thin siltstone and sandstone beds. Well preserved fossilized ferns, conifers, and other plants are documented from the Hermit Shale (White, 1927a, 1927b, 1929, 1930). Gilmore (1926, 1927, 1928) produced a series of classic papers on Late Paleozoic vertebrate tracks from the Grand Canyon including those found in the Hermit Shale.

The Coconino Sandstone is a Permian cross- bedded sandstone unit that has been interpreted as aeolian dune deposits. Vertebrate and invertebrate trace fossils have been documented and studied from within the Coconino Sandstone (Gilmore, 1926, 1927, 1928).

The Lower Permian Toroweap Formation is the oldest unit identified within the eastern and central portions of PARA. This formation occurs stratigraphically below the Kaibab Limestone, with the largest exposures at Twin Point and Kelly Point. Sorauf and Billingsley (1991) identify from oldest to youngest, the Seligman Member, Brady Canyon Member, and the Woods Ranch Member. The Brady Canyon Member is a fossiliferous limestone unit.

The Lower Permian Kaibab Limestone is the predominant unit throughout the central portion of PARA (NPS). In ascending order, the Fossil Mountain Member and the Harrisburg Member are defined by Sorauf

and Billingsley (1991). The Kaibab Formation is a fossiliferous marine limestone unit widely exposed throughout northwestern Arizona and within the Grand Canyon.

Isolated erosional channels of Early Triassic Moenkopi Formation cut into the Kaibab in Green Spring Canyon (upper Surprise Canyon) and on the eastern rim above Spring Canyon. This includes the conglomeratic Timpoweap Member and the lower red member of the Moenkopi Formation (Wenrich, et al., 1996). Rounded, fossiliferous limestone cobbles derived from the Kaibab are found within the Moenkopi.

Above the Moenkopi Formation are a few other Mesozoic and Cenozoic units that occur in the Parashant area. However, there are either no or limited exposures of these formations in the NPS administered portions of the monument. These units include: Chinle Formation, Kayenta Formation, Moenave Formation, Navajo Sandstone, Willow Tank Formation, Horse Spring Formation, Rocks of Grand Wash Trough, and Muddy Creek Formation. McCracken and Mead (2003) provide an excellent summary of paleontological resources associated with these geologic units.

Miocene and Pliocene basalts and andesitic basalts cover a large portion of the Shivwits Plateau in the Monument. The basalts cover the older Paleozoic strata in a large area extending between Mount Dellenbaugh to Blue Mountain.

During 2002, the Quaternary Sciences Program (QSP) at Northern Arizona University was contracted to inventory paleontological resources associated with the caves in PARA. Three field trips were organized by Dr. Jim Mead (QSP) and Kyle Voyles (PARA) and collectively visited and documented nearly two and one-half dozen localities. Mead (2003) prepared an interim report including site assessments and recommendations for long term management and study. Physical remains of both plants and animals, along with scats, pellets, and middens, were documented from many of the caves and other sites visited during the survey. A number of dried carcasses (mummies), including snake, rabbit, and coyote, were discovered. Radiocarbon samples were obtained from a number of localities. Mead's report recommends additional assessments to continue at PARA.

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GREAT BASIN NATIONAL PARK

Great Basin National Park (GRBA) preserves a remnant icefield on the 3,982 meter (13,063 feet) Wheeler Peak in Nevada. The park contains an ancient bristlecone forest and the cavernous network of Lehman Caves. Lehman Caves National Monument, established in 1922, was originally designated to protect the Lehman Caves. The monument was later incorporated into Great Basin National Park in 1986.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The geologic formations of Great Basin National Park range from Precambrian metamorphic rocks to Quaternary unconsolidated deposits. The oldest known fossiliferous units within GRBA include the Pioche Shale, Notch Peak Formation, Pole Canyon Limestone, and the Pogonip Group from the Cambrian period (approximately 543 to 490 million years ago). Simonson, Laketown, and Fish Haven Dolomites from the Ordovician to the Devonian periods (490 to 354 million years ago) have also been recorded as fossil producing units. The Devonian Guilmette Formation and Devonian to Mississippian Joana Limestone and Chainman Shale are additional fossiliferous formations. The Ely Limestone (354 to 248 million years ago) is considered to be extremely fossiliferous. In addition, other fossiliferous sediments have been identified from Quaternary glacial deposits and cave deposits. Although there are many fossiliferous units within GRBA, very few paleontological investigations have occurred within the park. Two specimens are maintained in the park's museum collections and two known permits were issued for paleontological investigations. Most of the descriptions of the fossiliferous units are taken from areas outside the park boundaries, but exposures of these units occur within the park and likely contain similar assemblages.

The Pioche Shale (Cambrian) is best known for containing abundant trilobites. Specimens of olenelloid and ptychoparioid trilobites are common, including *Olenellus* sp. and *Glossopleura* sp. (Hintze, 1988). The GRBA museum collections contain one trilobite specimen which was presumably collected from the Pioche Shale.

The Notch Peak Formation (Cambrian) is exposed in the southern portion of the park. Fossil stromatolites (algae) are found in this Upper Cambrian deposit. In addition, marine fossils include the mollusks *Matthevia* sp. and *Billingsella* sp., as well as the trilobites *Missisquoia* sp., *Saukiella* sp., *Eurekia* sp., and *Idahoia* sp. have been identified from the Notch Peak Formation (Hintze, 1988).

Generally massive, pale gray to white, the Pole Canyon Formation (Cambrian) underwent low grade metamorphism and is now a low grade marble (Harris, et. al, 1995). The metamorphism erased much of the Pole Canyon's fossil record, although scattered Paleozoic invertebrates have been found (Kurt Pfaff, personal communication, 1998).

The Pogonip Group (Cambrian) has produced a variety of fossil specimens. Most abundant are trilobite specimens of *Symphysurina* sp., *Lachnostoma* sp., *Pseudocybele* sp., *Protopliomerella* sp., *Presbynileus* sp., and *Leiostegium* sp.. In addition, algal heads, ostracodes, and brachiopods *Orthambonites* sp. and *Hesperonomia* sp. are also documented (Hintze, 1988).

Within the park, several dolomitic deposits have not yet been differentiated. These include the Fish Haven, Laketown, Sevy, and Simonson Dolomites. Outside the park however, fossils have been recorded from the equivalent dolomite units. The Fish Haven Dolomite contains the corals *Streptelasma* and *Catenipora* (Hintze, 1988). Dasycladacean algae, corals, and brachiopods are found in the Laketown Dolomite (Hintze, 1988). In particular, the corals *Halysites* and *Favosites* and brachiopods *Pentamerus* and *Virgiana* have been identified (Hintze, 1988). The Sevy Dolomite, originally described by Osmond (1954) and studied by Smith (1989), has been noted to contain vertebrate fauna. The Simonson Dolomite has an abundance of stromatoporoids and also contains conodonts and brachiopods (*Stringocephalus*) (Hinzte, 1988). Although some fossils are reported from these formations, the process of dolomitization may have altered and/or destroyed most fossils.

The Late Devonian Guilmette Formation, which contains shallow, subtidal platform limestones, produces both invertebrate and vertebrate fauna (Reed, 2000). This formation has been subject to low- grade, post-Paleozoic metamorphism (Nelson, 1966) which may have altered and/or destroyed fossil material. Faunal material from the Guilmette Formation reflects deposition from fore- reef, reef, and back- reef environments (Phelps and Droser, 2000). Massive reef beds exceeding 20 meters (66 feet) in thickness contain stromatoporoids, subordinate colonial rugose corals, and tabulate corals extend laterally on a kilometer scale within the Guilmette Formation. The stromatoporoids in particular, are quite abundant and display a variety of morphologies including descriptions of "spaghetti" or "cauliflower" shaped (Hintze, 1988). Additionally, smaller biofabric beds of brachiopods, gastropods, and solitary rugose corals exist (Phelps and Droser, 2000). A small sedentary echinoderm, edrioasteroid, was also reported by Bell and Petersen (1976).

The Chainman Shale and Joana Limestone, Mississippian formations, are also described as fossiliferous (Hintze, 1988). The common fossils found in the Chainman Shale include brachiopods and mollusks, specifically *Goniatites* and *Cravenoceras* ammonites. Hintze (1988) specifically reports the Chainman Shale as fossiliferous in the Northern Snake Range. Horn corals are reported from the Joana Limestone (Hintze, 1988).

The fossiliferous Ely Limestone spans the Upper Mississippian to the Lower Permian periods. In the Northern Snake Range, Hintze describes the Ely Limestone as "cherty" and "fossiliferous". The abundant marine fossil material includes corals, bryozoans, brachiopods, gastropods, and fusilinids. Fiero (1986), indicates that fusulinids are particulary characteristic of the late Paleozoic in Great Basin. Particular fossil fusulinid genera in the Ely Limestone include *Pseudofusulina*, *Pseudoschwagerina*, and *Wedekindellina* (Hintze, 1988). Spnges of the genus *Chaetetes* and the foraminifera genera *Endothyra* and *Millerella* also exist (Hintze, 1988).

Quaternary paleontological investigations within GRBA have centered around unconsolidated glacial deposits, tree ring analysis, and remains found within the Lehman Caves. Although paleoecology is mentioned in a GRBA permitted research project, the primary focus of the study appears to be on describing the glacial deposits (Van Hoesen and Orndorff, 2001). Another GRBA permitted project listed in the Investigator's Annual Report database concentrated on utilizing D/H ratios in fossil cellulose to understand temperature variations. However, this project was terminated before completion.

The paleontology of Lehman Caves has been reported by Charles Rozaire (1964) and summarized in Santucci, Kenworthy, and Kerbo (2001). The following paragraphs are taken from this 2001 report.

In 1938, S.M. Wheeler initiated an archeological excavation at Lehman Cave. During this excavation, 29 human and 219 animal bones were recovered from within Lehman Cave. The animal bones represent a wide diversity of fauna including remains of *Ovis* sp., *Odocoileus* sp., *Canis* sp., *C. latrans*, *Vulpes fulva*, *V. macrotis*, *Taxidea taxus*, *Lepus* sp., *Sylvilagus* sp., *Marmota* cf. *flaviventris*, *Felis rufus*, *Neotoma* sp., *N. cinerea*, a grouse and a snake. A variety of small and large unidentified mammal remains were also found during the excavation (Rozaire, 1964).

A second excavation was undertaken during 1963 under the direction of Dr. Charles Rozaire. This project focused on the fluvial deposits within the original entrance area of Lehman Caves. Rozaire's excavations produced additional fauna which were identified by A. Ziegler of the Museum of Vertebrate Zoology, University of California, Berkeley. The remains included: various bats of the genus *Myotis, Citellus* sp., and other sciurids, *Thomomys* sp., *Martes americana*, *Ovis canadensis*, *Antilocarpa americana*, *Equus*, *Gopherus* cf. *agassizi*, and *Centrocercus urophasianus*. Unidentified amphibian, bird, and rodent remains were also recovered during the excavation. The shell of a desert tortoise was discovered during the excavation and may represent a Native American trade item. The bones were scattered, disarticulated, and exhibited evidence of rodent gnawing. Large mammal remains may have been brought into the cave as the remains of a kill. The animal bones are reported to date back to the Pleistocene (Rozaire, 1964).

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DATA SETS:

DS- GRBA-XXX	Great Basin National Park Paleontological Archives. 5/1985 – present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.
DS- GRBA-XXX	Great Basin National Park Files, Archive, Museum Records. 10/1964 – present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Great Basin National Park; status: Active.
DS- GRBA-XXX	Inventory of Paleontological Resources Associated with National Park Service Caves. 1997- 2001. (field notes; photographs; publication). Originated by Santucci, Kenworthy, and Kerbo; status: Inactive.
DS- GRBA-XXX	Paleoecology, Paleoclimate, Glacial Chronology, and Regional Correlation of Late Quaternary Glaciations in Great Basin National Park. 2001. (data, reports, publications). Originated by Van Hoesen, John; status: Unknown.

JOSHUA TREE NATIONAL PARK

Joshua Tree National Monument was proclaimed on August 10, 1936 to preserve southern California desert ecosystem, scenic geologic features, and the park's namesake Joshua Trees. The Monument was redesignated Joshua Tree National Park on October 31, 1994.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

Geologically, Joshua Tree represents a structurally complex landscape. The oldest rocks date to the Precambrian which are overlain by younger Mesozoic and Cenozoic deposits. The geologic scenery has been sculptured by a variety of processes including tectonics, exfoliation, and erosion. Alluvial fans, sand dunes, and playa lakes reflect a history of dramatic climatic and geologic changes (Trent and Hazlett, 2002).

A formal paleontological resource scoping session was conducted at JOTR in March 2000. Retired Quaternary geologist John Emerson was recruited as a Geologist- In- Park (GIP) intern to compile any paleontological resource data from the park and surrounding area (Emerson, 2001).

Significant Quaternary paleontological resources have been documented from within and near the area now administered as Joshua Tree National Park. The first reports of fossils from this area date to the early part of the 1900's. The principal fossil localities occur in three areas including: the Pinto Basin, on the west side of the park; Campbell Hill on the northeast side of Twentynine Palms; and, Gypsum Ridge, on the west side of the Twentynine Palms Marine Corps Base. Additional fossil localities occur within the Tertiary- Quaternary gravels along Highway 62 between Yucca Valley and Twentynine Palms.

The earliest known paleontological collections from JOTR were obtained from Pinto Basin. Elizabeth and William Campbell described archeological sites along the banks of Pinto Wash in the southeastern Pinto Basin that contain both Pleistocene and Holocene fossils (Campbell and Campbell, 1935). The sites were situated on broad flat areas on either side of the lower eight kilometers (five miles) of Pinto Wash. They suggested that the elevated terrace, which borders both sides of the wash, was the bank of an old stream or lake. Extinct horse and camel bones were found enclosed in the fine sediment comprising the floor of the flat terrace area. Artifacts and midden bones were found in association with these Pleistocene bones. The Campbells were not able to determine if the archeological sites and the Pleistocene fossils were contemporaneous.

Scharf (1935) summarized the Quaternary geology of the eastern part of the Pinto Basin. The oldest depositional unit described by Scharf is the "Pinto formation". This unit consists of clay, silt, sand and a few gravel lenses that are interbedded with basalt flows. The fine- grained sediments were interpreted as lacustrine deposits. There are thick exposures of this formation on the ridge at the northeast end of the Eagle Mountains and in the hill between the Eagle and Coxcomb Mountains. Scharf considered the lacustrine silt and clay to be correlative with the interbedded sediment and basalt on either side of the basin outlet. The lake deposits were considered Pleistocene on the basis of the horse and camel bones. Ongoing studies (Emerson, 2001; Jefferson, personal communication, 2003; Scott, personal communication, 2004) suggest that the fossil- bearing sedimentary deposits are distinct from the exposures interbedded with basalts.

In 1972, G. Jefferson initiated an assessment of the Quaternary geology, geomorphology, and vertebrate paleontology of the eastern Pinto Basin. Jefferson examined the area described by the Campbells using three different methods: surface collections, subsurface excavations, and survey of stratigraphic exposures along the banks of the wash. Jefferson concluded that the Holocene midden deposits, small mammal bones, and lithic artifacts were resting on the Pleistocene "Pinto formation". He determined that these deposits were separated by a profound unconformity. The large mammal bones in the older lacustrine deposits were permineralized, darker in color, and easily differentiated from the Holocene faunal assemblage. Jefferson (1972) identified bone fragments from five different taxa: *Equus* sp. cf. *E. conversidens;, Camelops* sp.; *Ovis* sp.; *Hemiauchenia* sp.; and *Equus* sp. (large- size). Jefferson identified these taxa as early Rancholabrean in age. However, E. Scott believes that based upon the overall scrappiness of the assemblage, the lack of *Bison*, and the opinion that *Equus* specimens were not diagnostic to species, there is no justification to refer to the fauna

from Pinto Basin as Rancholabrean (Scott, personal communication, 2004). These faunal remains were originally reposited in the Department of Geology, University of California, Riverside in the 1970s and have recently transferred to the Museum of Paleontology, University of California, Berkeley. There is also a collection of vertebrates from Pinto Basin at the Los Angeles County Museum.

Schroth (1990) reviewed Jefferson's earlier work and presented a faunal list and radiocarbon dates from the Campbell sites in Pinto Basin. Mammoth, horse, and camel remains were reported as additional fauna from the lacustrine sediments of the "Pinto formation" *(sensu lato)*.

Recent work in the Pinto Basin has been conducted by the staff at the San Bernardino County Museum. Field survey teams identified four new localities, resulting in a total of nineteen *in situ* and seventeen "float" localities (Scott, 2003). A total of 87 fossil specimens were recovered during the survey including large and small horses and camels (E. Scott, personal communication, 2003). The first discovery of a carnivoran in the Pinto Basin was made during the field survey, in the form of a partial carnivore incisor (cf. *Canis*, wolf- sized). Additionally, large chunks of enamel were identified as the first proboscidian remains from Pinto Basin.

Fossil vertebrates were originally reported from the Campbell Hill locality during 1918 by an individual named Noble and later by E. Schenck (Bassett and Kupfer, 1964). The first fossil collection obtained from this locality was made by L.P.J. Moffler in 1935. This collection was sent to G. E. Lewis of the U.S. Geological Survey for identification. Lewis tentatively identified the remains as *Hemiauchenia* sp. (previously referred to as *Tanupolama* sp.) and *Odocoileus* sp. However, the present location of these fossils is unknown.

John Kelly of Twentynine Palms, and J. Bacheller later collected additional fossils from the Campbell Hill locality. Bacheller (1978) and Jefferson (1986,1991a) independently reported that the Campbell Hill and Twentynine Palms gravel pits yielded a diverse late Pleistocene fauna. The following taxa were identified from these localities: *Gopherus* sp.; *Megalonyx* sp.; *Nothrotheriops* sp.; *Thomomys* sp.; *Taxidea taxus*; *Smilodon* sp cf. *S. fatalis; Felis concolor; Mammuthus sp.; Equus* sp. (small size); *Equus* sp. (large size)*; Camelops sp.; Hemiauchenia* sp.; *Odocoileus* sp. cf. *O. virginianus; Capromeryx* sp.; *Bison* sp.; *Ovis* sp. cf. *O canadensis*. Paleontologist Robert Reynolds assigned these taxa to the Rancholabrean (Reynolds, personal communication, 2000). George Jefferson was the first to suggest an early Rancholabrean age for the fauna (Scott, personal communication, 2004). Recent studies by Scott and Cox (2002) support an early Rancholabrean interpretation for the fauna. Jefferson (1992) discusses more than four localities in the 29 Palms area. Reynolds (personal communication, 2004) refers to localities with Bishop Ash within the section as Irvingtonian.

Paleontological resources are also known from localities just outside of JOTR, indicating the potential for similar resources within park boundaries. A single horse (*Equus* sp.) tooth fragment was identified in a conglomerate outside of the park in Yucca Valley (Grimes, 1987). Miocene (Clarendonian) fossils in the pioneer town sediments north of Joshua Tree National Monument have been described by Reynolds (1992). A Late Pliocene – Early Pleistocene (Irvingtonian / Blancan) fauna has been collected from the Gypsum Ridge locality outside of the park. The assemblage includes fish, amphibians, reptiles (*Hesperotestudo* sp., giant tortoise), birds and mammals and is currently being studied by H. Wagner at the San Diego Natural History Museum. Wagner (2000; Wagner and Prothero, 2002a, 2002b) specifically identifies fish, salamanders, frogs, toads, *Hesperotestudo* sp., snakes, shore birds, rails, *Paramylodon harlani, Nothrotheriops texanus*, insectivores, *Neotoma* (*Paraneotoma*) sp., *Erethizon* sp., *Ondatra idahoensis*, *Sigmodon minor medius*, lagomorphs, carnivores, perissodactyls and artiodactyls from Gypsum Ridge. Wagner (in press) provides a revised Plio- Pleistocene taxa including the occurrence of *Mammut* and a new species of *Repomys*. The presence of *Mammut* is highly significant, as Pleistocene records of this genus are almost unheard of from the Mojave Desert (Scott, personal communication, 2004).

In addition to the Pinto Basin fossil specimens, JOTR's museum collections include fossils from sites outside the park boundaries. These include fossil bone and tooth fragments of camel, horse, and turtle from the Old Clays District north of the park, a fossilized tusk from the Avawatz Mountains just south of Death Valley National Park, fossilized bone fragments from the Soda Lake area, and a few other fossilized bone fragments from neighboring localities. In addition, JOTR maintains a collection of extinct *Protoyucca shadishii* from Blowout Mountain in northwestern Nevada. These specimens are anatomically similar to the modern Joshua tree.

COOPERATIVE PROJECTS:

- National Park Service's Geologic Resources Division paleontological resource scoping session for Joshua Tree National Park (March, 2000)
- Regional Paleontological Reconnaissance Surveys Conducted by Dr. Robert Reynolds of the San Bernardino County Museum (1980s- 1990s).
- Paleontological Survey of the Pinto Basin by George Jefferson (1972).
- Pinto Basin Paleontological Surveys by Eric Scott and others, San Bernardino County Museum (2003 and is ongoing).

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DS- JOTR- XXX Los Angeles County Museum of Natural History (LACM) Paleontological Collections from Joshua Tree National Monument. 1930s - 1970s. (field notes; photographs; museum specimens). Originated by LACM field crews; status: Active.

DS- JOTR- XXX San Bernardino County Museum (SBCM) Paleontological Collections from Joshua Tree National Park. 1980s - present. (field notes; photographs; museum specimens). Originated by Dr. Robert Reynolds; status: Active.

DS- JOTR- XXX University of California, Riverside Paleontological Collections from Joshua Tree National Park. 1970s - present. (field notes; photographs; museum specimens). Originated by Dr. Michael Woodburn; status: Active.

DS- JOTR- XXX San Bernardino County Museum in Redlands, California Paleontological Collections and Research. 2003 - present. (hard copy data; field notes; photographs; maps; museum specimens). Originated by Eric Scott; status: Active.

LAKE MEAD NATIONAL RECREATION AREA

Lake Mead National Recreation Area (LAME) was the first national recreation area established by an act of Congress. It was originally designated as Boulder Dam National Recreation Area on October 13, 1936. It was administered through a cooperative agreement between the National Park Service and the Bureau of Reclamation. On August 11, 1947, the site was renamed Lake Mead NRA. The recreation area includes both Lake Mead (above Hoover Dam) and Lake Mohave (below Hoover Dam) both formed by the construction of Davis Dam. There total park acreage consists of 1.5 million acreas of desert and mountains, of which the lakes account for 186,700 acres.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

Geologically Lake Mead NRA contains some of the oldest rocks in this geographic region. These consist largely of Precambrian metamorphic rocks and large igneous plutons. Stratigraphically, there are formational / facies changes which are evident traversing east to west within LAME, particularly across the Grand Wash Cliff. U.S. Geological Survey geologist Susan Beard has provided a preliminary stratigraphic correlation charts for the Lake Mead area (Figures 1 and 2) (Beard, personal communication 2003). The stratigraphic column produced by Beard is referenced in this report.

The oldest sedimentary rocks are Cambrian marine transgressive strata. The basal unit is the Tapeats Sandstone, a Lower to Middle Cambrian, medium- to coarse- grained, marine sandstone found within the Grand Canyon, Lake Mead, and Frenchman Mountain sections of LAME. Middleton and Elliot (1990) report on a number ichnogenera (trace fossils) from the Tapeats including: *Arenicoloides, Corophioides, Skolithos,* and *Cruziana*.

The Tapeats Sandstone is overlain by Cambrian shale and limestone units. Beard (personal communication, 2003) identifies the Bright Angel Shale in the Grand Canyon and Lake Mead sections of LAME. On Frenchman Mountain the age- equivalent stratigraphic units from oldest to youngest are locally referred to as the Pioche Shale, Lyndon Limestone, and Chisholm Shale. The Bright Angel Shale is a marine mudstone shale overlying the Tapeats. Fossils from the Bright Angel Shale include: sponges, gastropods, conchostracans, trilobites, and a large number of trace fossil types (Middleton and Elliot, 1990).

Between the Late Cambrian and Early Permian, a shallow sea submerged the area. A continued regional subsidence resulted in thick accumulations of sediments, primarily carbonates forming limestones and dolomites. Naming of these rock units varies geographically. At Frenchman Mountain, Virgin Mountains, and in the Grand Canyon, these late Cambrian limestones are known as the Muav Limestone. The Muav Limestone is a cliff- forming, dolomitic, marine limestone consisting of six members defined by McKee and Resser (1945). Fossils are somewhat rare in the Muav Limestone, however, a rich Pleistocene / Holocene paleontological record is preserved within caves developed in the limestone (Kenworthy et al., 2004; Santucci et al., 2001).

In the Muddy Mountains the stratigraphic equivalent unit to the Muav Limestone is referred to as the Bonanza King Formation. Two members of the Bonanza King Formation are fossiliferous. The Papoose Lake Member contains *Glossopleura* trilobites and the Informal Middle Member contains trilobite "hash beds" and linguloid brachiopod beds.

Two stratigraphic units occur on Muddy Mountain and the Dry Lake Thurst area in the western portion of LAME. The Nopah Formation is a Late Cambrian unit containing a variety of fossils. Stromatolites, trilobites, brachiopods, conodonts, sponges, eocrinoids, gastropods, and additional fossil material have been reported regionally from the Nopah. The Pogonip Group is an Upper Cambrian − Lower Ordovician unit overlying the Nopah Formation in the Muddy Mountain and Dry Lake Thrust areas. This unit has a produced a variety of fossil specimens. Most frequent are trilobite specimens of *Symphysurina* sp., *Lachnostoma* sp., *Pseudocybele* sp., *Protopliomerella* sp., *Presbynileus* sp., and *Leiostegium* sp.. In addition, algal heads, ostracodes, and brachiopod *Orthambonites* sp. and *Hesperonomia* sp. are also noted.

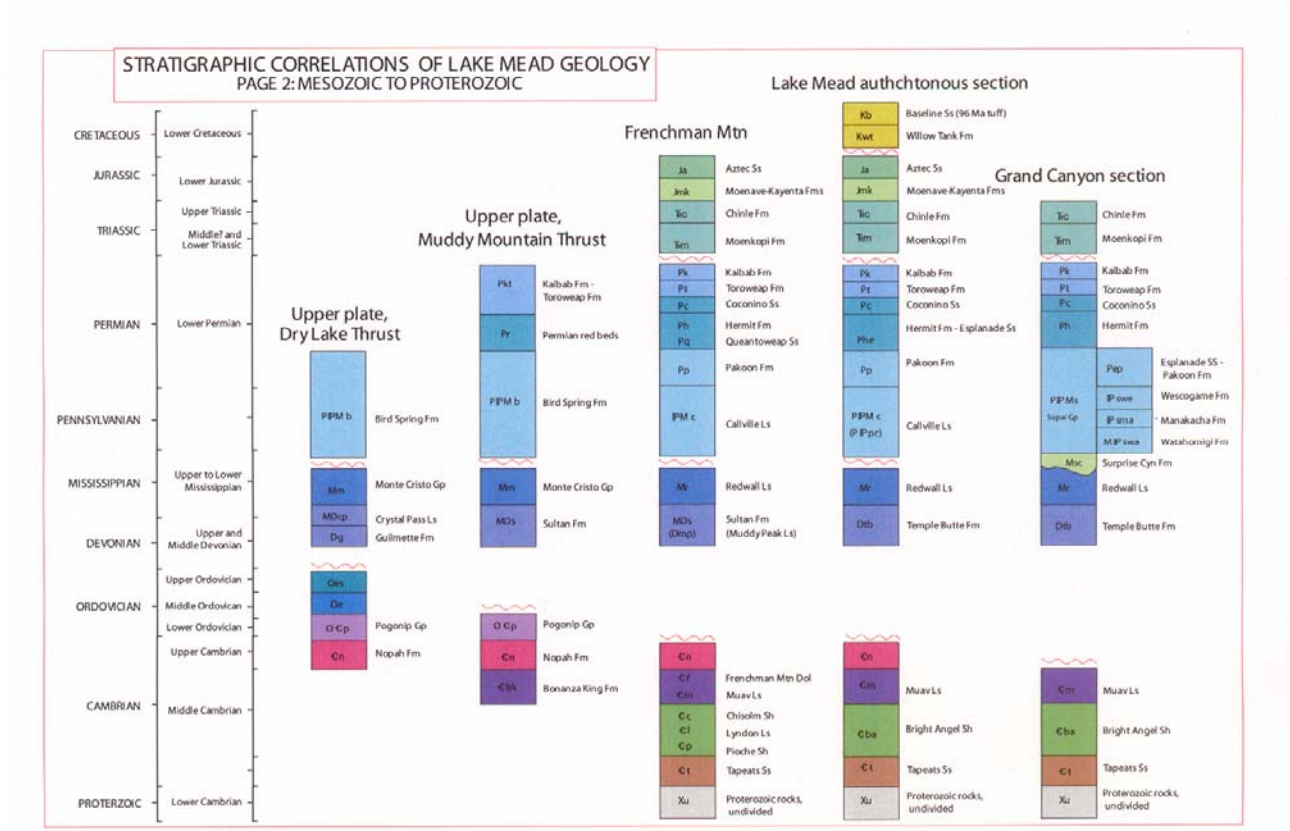


Figure 1. Mesozoic to Proterozoic stratigraphic correlation chart for Lake Mead National Recreation Area produced by U.S. Geological Survey geologist Susan Beard (personal communication, 2003).

Beard (personal communication, 2003) reports the Temple Butte Formation as the Middle to Upper Devonian carbonaceous unit in the Grand Canyon and Lake Mead sections of LAME. Beard further reports the Sultan Formation as the age- equivalent unit on Frenchman Mountain and Muddy Mountain. In the eastern portions of LAME exposures of the Temple Butte grade from largely freshwater limestones and in the west are more dolomitic (Beus, 1980). The dolomitic facies in the west contain marine invertebrate fossils including corals, stromatoporoids, brachiopods, gastropods, crinoids, and conodonts (Bues, 1990). Bony plates of freshwater fish, including *Bothreolepis* and "placoganoid" fish are documented from the eastern facies (Beus, 1990). The remains of placoderm fish, both antiarchs and arthrodires, have been discovered in the Devonian Mountain Springs Formation (H. Johnson, personal communication, 2003).

Beard (personal communication, 2003) reports the Redwall Limestone as the Mississippian marine limestone unit in the Grand Canyon and Lake Mead sections of LAME (McKee, 1963). Beard further reports the Monte Cristo Group as the age- equivalent units on Frenchman Mountain and Muddy Mountain. The Redwall Limestone is subdivided into a number of members including from oldest to youngest: Whitmore Wash Member, Thunder Springs Member, Mooney Falls Member, and Horseshoe Mesa Member. Marine invertebrates are found throughout most of the members of the Redwall including: foraminifera, corals, bryozoans, brachiopods, gastropods, cephalopods, pelecypods, crinoids, blastoids, and conodonts (Beus, 1990). A rich Pleistocene / Holocene paleontological record is preserved within caves developed in the limestone (Kenworthy et al., 2004; Santucci et al., 2001).

A number of Mississippian through Permian limestones exhibit geographic name changes within LAME. These include the Callville Limestone (Mississippian- Pennsylvanian), Pakoon Formation (Pennsylvanian – Permian), and Bird Spring Group (Permian) known locally in the western portion of Lake Mead, whereas,

they are respectively known as the Supai Group in the Grand Canyon. The Supai Group consists of Upper Mississippian through Lower Permian units including in ascending order: Watahomigi, Manakacha, and Wescogame formations (McKee, 1975, 1982). The Supai Group is composed primarily of shale with interbedded limestones and capped by a sandstone unit. The Grand Canyon portion of the Supai Group is dominated by marine lithologies and fossils, primarily invertebrates.

According to Beard (2003, personal communication) the Calville and Pakoon limestones (McNair, 1951) are the age- equivalent units in the Lake Mead and Frenchman Mountain areas of the recreation area. The Callville Limestone is a Pennsyvlanian through Lower Permian limestone unit defined by Hintze (1986). There are no reports of fossils from the Callville Limestone. Marine fossils are present primarily in the Pakoon Limestone including: foraminifera, fusulinids, corals, bryozoans, brachiopods, gastropods, echinoderms, shark's teeth, plants, and *Scoyenia* traces (McKee, 1982). Further west in LAME, the Bird Spring Formation is the age- equivalent unit on Muddy Mountain and Dry Lake Thrust areas. Rugose and tabulate corals are described from the Bird Spring Group (Permian) from Clark County, Nevada (Wilson and Langenheim, 1993).

The Hermit Shale is a Lower Permian unit consisting of thin siltstone and sandstone beds. In the western portion of LAME on Muddy Mountain the Hermit Shale equivalent are a series of red beds (Beard, 2003, personal communication). Well preserved fossilized ferns, conifers, and other plants are documented from the Hermit Shale (White, 1927a, 1927b, 1929, 1930). Gilmore (1926, 1927, 1928) produced a series of classic papers on Late Paleozoic vertebrate tracks from the Grand Canyon including those found in the Hermit Shale.

During the Permian the shallow seas retreated and the region evolved into an arid coastal plain. Clastic sedments accumulated forming the Coconino Sandstone. The Coconino Sandstone is a Permian cross-bedded sandstone unit that has been interpreted as aeolian dune deposits. Vertebrate and invertebrate trace fossils have been documented and studied from within the Coconino Sandstone (Gilmore, 1926, 1927, 1928).

Another Permian transgression resulted in the deposition of the Toroweap and Kaibab formations. The Lower Permian Toroweap Formation occurs stratigraphically below the Kaibab Limestone (Sorauf and Billingsley (1991) identify from oldest to youngest, the Seligman Member, Brady Canyon Member, and the Woods Ranch Member. The Brady Canyon Member is a fossiliferous limestone unit. The Lower Permian Kaibab Limestone is the predominant unit. In ascending order, the Fossil Mountain Member and the Harrisburg Member are defined by Sorauf and Billingsley (1991). The Kaibab Formation is a fossiliferous marine limestone unit widely exposed throughout northwestern Arizona and within the Grand Canyon.

According to Beard (2003, personal communiation), the Triassic Moekopi Formation, Chinle Formation, and Triassic / Jurassic Aztec Sandstone occur in the Lake Mead and Frenchman Mountain sections of the recreation area. Isolated erosional channels of Early Triassic Moenkopi Formation cut into the Kaibab Limestone. The Moekopi contains both invertebrate and a few vertebrate remains and trace fossils. The Chinle Formation is a rich fossiliferous unit containing fresh water invertebrates, vertebrates, and plants. Large, well preserved logs of fossils trees are preserved on bedding plains (vertical) in the Chinle Formation. There are a couple of known areas of large petrified logs to the north of Northshore road near the Bowl of Fire, as well as, scatters of smaller pieces in locations along Lakeshore Road (K. Rohde, personal communication, 2004). Additionally, ther are very large logs within the nearby Valley of Fire State Park. The Aztec Sandstone is equivalent to the Navajo Sandstone in Arizona and Utah. Ocassional ichnofossils are found in the Aztec including the only known dinosaur tracks from California (Reynolds, 1989). West of Overton, footprints of quadrupeds and possible bipeds are found in the Aztec Sandstone.

Two Cretaceous units are reported from LAME including the Willow Tank Formation and the Baseline Sandstone. There are no reports of fossils from these units in or around the Lake Mead area.

The Horse Spring Formation is a Miocene unit exposed within LAME. Camel, canid, felid and bird tracks are reported from the Thumb Member of the Horse Spring Formation (Jones, 2002; Kissel, 1998; Kissel, et al., 1998, Sarjeant and Reynolds, 1999, 2001). Numerous tracks are located just outside of the recreation boundary, however, this track- bearing unit extends into LAME in the Calville Wash area. The transition

from the Muddy Creek Formation (Hemphillian) to the White Narrows Formation (Early Blancan) in southern Nevada is described by Reynolds and Lindsay (1999).

The LAME archives contain a series of documents, dated from 1941, which reference a Pleistocene fossil locality just north of the recreation area. A large collection of vertebrate fossils were obtained from this ancient lake deposit known as the Glendale Locality. The fossils were examined by vertebrate paleontologist Robert W. Wilson (California Institute of Technology) during the late 1930s. Wilson identified the following taxa including: fish, turtle, bird, rodents, beaver, rabbit, camel, deer, antelope, mountain sheep, and a proboscidean. The faunal list in the LAME archives includes a reference indicating the fossil collection was returned to the National Park Service in Boulder City on August 24, 1939.

During the early 1980s a Pleistocene mammoth leg bone was discovered near the Virgin River within the recreation area. The bone was exposed in a gravel deposit along an arroyo bank. In 1987, a vist to the site resulted in the recovery of additional limb bones and a maxillary tooth. Continued monitoring of the site led to the discovery of tusk, rib, and other bone fragments. The site was eventually excavated in 1991. Assessment of the fossil material by Dr. Larry Agenbroad (Northern Arizona University) led to the identification of the bones as the first Columbian Mammoth (*Mammuthus columbi*) from Clark County, Nevada (Agenbroad, et al., 1992; Agenbroad and Brunelle, 1993).

Both the Muav and Redwall limestones are cavernous containing caves and rock shelters. Two well-documented caves, Muav Cave and Rampart Cave, were originally within the boundaries of LAME. However, boundary changes in 1975 now place the caves within Grand Canyon National Park. Pleistocene / Holocene packrat (*Neotoma)* middens are common in these caves and rock shelters. Formal paleontological studies within the shelters or on the middens have not been undertaken.

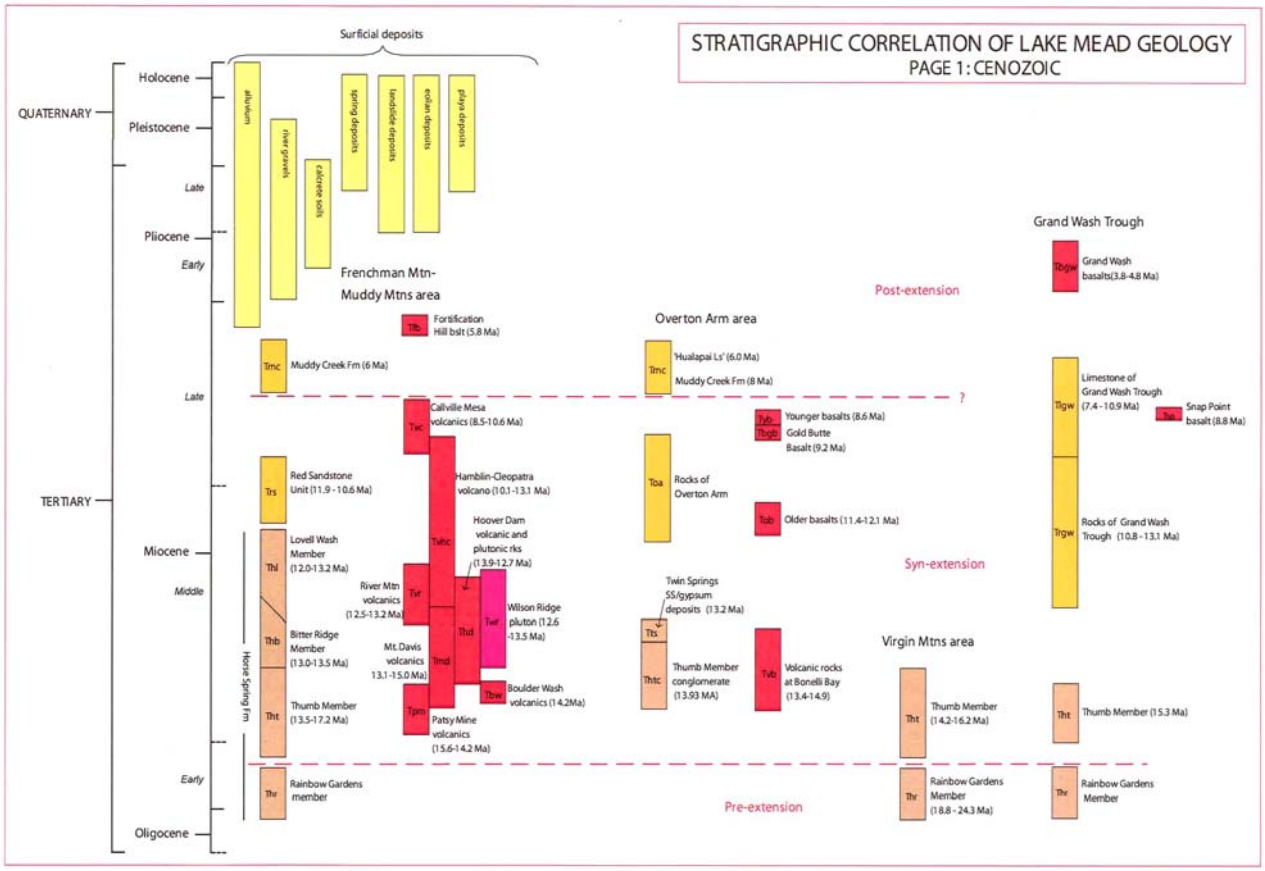


Figure 2. Cenozoic stratigraphic correlation chart for Lake Mead National Recreation Area produced by U.S. Geological Survey geologist Susan Beard (personal communication, 2003).

COOPERATIVE PROJECTS:

- National Park Service's Geologic Resources Division geologic resource inventory and paleontological resource inventory for Lake Mead National Recreation Area (February 2002).
- Preliminary Paleontological Inventory Assessment for Lake Mead National Recreation Area - Vincent L. Santucci (2000 and is ongoing).

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DATA SETS:

DS- LAME-XXX	Lake Mead National Recreation Area Paleontological Archives. 5/1985 − present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.
DS- LAME-XXX	Lake Mead National Recreation Area Files, Archive, Museum Records. 1936 − present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Lake Mead National Recreation Area; status: Active.
DS- LAME-XXX	Inventory of Paleontological Resources Associated with National Park Service Caves. 1997- 2001. (field notes; photographs; publication). Originated by Santucci, Kenworthy, and Kerbo; status: Inactive.

DS- LAME-XXX	Vertebrate Tracks of Lake Mead National Recreation Area. 1999- 2002. (field notes; photographs; hard copy data; Master's Thesis). Originated by Kissell-Jones, Michele, Las Vegas Museum of Natural History; status: Active.
DS- LAME-XXX	Virgin Mammoth Excavation. Early 1990s. (field notes; photographs; publication; maps). Originated by Agenbroad, Larry; Northern Arizona University, status: Inactive.

MANZANAR NATIONAL HISTORIC SITE

Manzanar National Historic Site (MANZ) was established on March 3, 1992 to interpret and protect the historical, cultural, and natural resources associated with the relocation and internment of Japanese-Americans during World War II. Approximately 800 acres of rock gardens, utility systems, foundation blocks, and other remnants are preserved at the historic site in the Owens Valley of eastern California.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The geology of Owens Valley consists primarily of erosional debris and Quaternary alluvium. Owens Valley is a basin bordered by a series of faults that constantly produce erosional debris that buttress the fault scarp (Sharp and Glazner, 1997). The valley formed at least 760,000 years ago due to the age of the volcanic Bishop Tuff, one of the major components of the valley fill (Sharp and Glazner, 1997).

There have been no paleontological investigations at the park and currently there is no record of known paleontological resources at Manzanar National Historic Site. The potential for future paleontological resource discoveries appears to be extremely limited.

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MOJAVE NATIONAL PRESERVE

Mojave National Preserve (MOJA) was established on October 31, 1994 to protect the fragile habitat of the desert tortoise, vast open spaces, and historic mining operations in the Mojave Desert. MOJA encompasses 1.6 million acres of arid desert and mountains in southern California.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

Mojave National Preserve is geologically complex. Situated in the Mojave Desert Province and a portion of the Basin and Range Province, the preserve encompasses a wide array of geological features spanning from the Precambrian to the Recent. Although there has been limited paleontological research conducted within the area administered as the Preserve, fossils are documented from many of the ranges within or near MOJA including: Providence Mountains, New York Mountains, Clark Mountain, Stripped Mountain, Old Dad Mountains, Hackberry Mountains, Ivanpah Mountains, Kelso Mountains Marl Mountains, Castle Mountains and Cow Holes. Nearby are the Shadow Mountains, Avawatz, Mescals, Lucy Grays, Bristol Mountains, Ord Mountain, Halloran Hills, Soda Mountains, Alvords, Clipper Mountains, Spring Mountains, Little Piutes, and Piute Valley.

Some of the oldest rocks within MOJA are Late Proterozoic or Neoproterozoic in age. Although limited work has been conducted on these Precambrian units in the preserve, stromatolites have been reported from within the preserve. Field reconnaissance, mapping, and paleontological resource assessment are recommended for the Proterozoic units at MOJA.

A series of Paleozoic limestones and dolomites occur within MOJA. These units represent shallow marine deposits formed on the western part of the craton and contain the carbonate remains of organisms inhabiting these Paleozoic seas. Today these limestones are exposed in some of the uplifted ranges of the Mojave Desert. Some of the best exposures of these limestones occur in the Providence Mountains. A number of caves, such as Mitchell Caverns, are formed in these marine limestones. Hewett (1956) reports on a large number of Paleozoic invertebrate species from various stratigraphic units and localities in the area now part of MOJA.

Clark (1921) reported on two horizons of Cambrian fossils from the Bristol Mountains along the southwest boundary of MOJA. A number of specimens were collected by Clark and reposited at the University of California, with the type specimens later forwarded to the Smithsonian Institution National Museum of Natural History. Resser (1928) identified this fauna as Middle Cambrian, including brachiopods and trilobites, but did not identify the fossil- bearing formation. Resser recognized the Bristol Mountain locality as the most southerly and westerly occurrence of Cambrian beds in the United States.

Numerous investigators report on fossil localities from Lower Cambrian units in MOJA. Paleontologically rich sites occur within the Latham Shale, Chambliss Limestone, and Wood Canyon Formation in the Providence Mountains. An abundant and well- preserved trilobite fauna (olenellids), rare soft- bodied metazoans, priapulids, and the giant arthropod *Anomalocaris*, have been identified in the Latham Shale (Briggs and Mount, 1982; Sundberg, 1983; Gaines, 1999a). Hazzard (1933, 1954) documented the occurrence of *Paedeumias mohavensis, P. clarki, Mesonacis* sp., and *M. insolens* within the Lower Cambrian Latham Shale in the Providence Mountains. Hazzard further reported on the presence of *Ethmophyllum sp. Obolus sp. Alokistocare sp., Agnostus sp.*, and a cystoid plate from the Cambrian Cornfield Spring Formation.

The fossils from the Marble Mountains collected by John Hazzard were turned over to Colin Crickmay for identification and study (Hazzard, 1933). Crickmay produced a list of the fossils which include specimens from the lower and middle Cambrian, Mississippian, Pennsylvanian, and Permian.

Mason and others (1937) report on a sequence of Cambrian faunas from the Providence Mountains including Lower Cambrian taxa: *Olenellus, Paedumias,* and *Paterina;* Middle Cambrian taxa: *Ehmania, Lingulella, Glossopleura, Clavaspidella, Zacanthoides, Alokistocare, Syspacephalus, Kochaspis,* and possibly *Albertella.*

Mount (1974, 1976, 1980a, 1980b) provides a detailed biostratigraphic zonation of Lower Cambrian units in the Marble and Providence Mountains. Mount identifies thirty- five invertebrate species from the Latham Shale, Chambliss Limestone, and Cadiz Formation. These are divided from oldest to youngest *Bonnia-Olenellus, Plagiura-Poliella, Albertella,* and *Glossopleura* zones.

Hazzard (1954) reports on *Girvanella sp., Hyolithes sp., Paterina prospectenis, Olenellus bristolensis,* and *O. fremonti* from the Lower Cambrian Chambliss Limestone in the Providence Mountains. *Girvanella* sp. is also documented from Chambliss Limestone localities in the Providence Mountains by Stewart (1970). Hazzard and Mason (1936) studied the Cambrian Cadiz Formation in the Providence Mountains and identified the following fossil taxa: *Alokistocare sp., Clavaspidella sp.,* and *Bathyuriscus sp.*

Trace fossils are common within Cambrian units in the Providence and Kelso Mountains. Stewart (1970) reports on worm trails in the Latham Shale and *Skolithos* traces in the Wood Canyon Formation. Dunne (1972) identifies trace fossils in all three members of the Wood Canyon Formation, *Skolithos* in the Zabriski Quartzite, and fragments in the Carrara Formation. Fedo and Cooper (2001) document *Taphrhelminthopsis* trails in the lower member of the Wood Canyon Formation and thin, densely burrowed *Skolithus* piperock at the top of the middle member in the Kelso Mountains. Additionally, Hagadorn and others (2000) report on an Early Cambrian Ediacaran- type fauna from the Kelso Mountains.

The upper portion of the Halfpint Member of the Nopah Formation (Late Cambrian) is interpreted as "Algal Bank" and subtidal deposits in the New York and Providence Mountains (Cooper et al., 1981). Sponge spicules, brachiopods, trilobites, and condonts have been documented from localities in the Nopah in both mountainous areas (Miller et al., 1981).

Brown (1989, 1995) reports on various fossil occurrences in the New York Mountains. These include stromatoporoids near the base of the Valentine Member of the Sultan Limestone (Devonian), abundant crinoidal debris, bryozoans, and brachiopods occur in the Dawn Member of the Monte Cristo Limestone (Mississippian), and crinoids from the Lower and Bullion members of the Bird Spring Formation (Permian).

Evans (1971) reports on Mississippian syringoporid corals from the Monte Cristo Limestone in the Striped Mountain area. Additionally, corals, brachiopods, and crinoids are documented from the Permian Bird Spring Formation in the Striped Mountain area (Evans, 1971).

Thompson and Hazzard (1940, 1946) report on seventeen species of fusilinids, including *Schubertella kingi* and *Schwagerina* sp., from the Permian Bird Spring Formation in the Providence Mountains. Thompson and others (1946) also identified fusilinids from the Providence Mountains. Wilson (1994a, 1994b) studied a Permian fauna from the Providence Mountains including fusilinids, corals, bryozoans, brachiopods, mollusks, echinoids, and crinoids.

J.C. Hazzard was involved in extensive fieldwork in the Providence Mountains. Hazzard (1938) reports on well- preserved foraminifera from the Permian Bird Spring Formation in the Providence Mountains. Hazzard (1954) reports on Lower Triassic fossils from the Moenkopi Formation exposed in the Providence Mountains. The species include: *Monotis thynesiana, Pscudomonotis hinnitides, Myophoria curvirostis, Stephanites sp.* and *Subcolunbites sp.*

During the middle to late Mesozoic a belt of granitic mountains developed parallel to the western continental plate margin. These constitute subsurface components of an ancient volcanic island arc system formed through tectonic plate interactions. The granites are the intrusive rocks that cooled at depth and have more recently become exposed and eroded into massive features in the Sierra Nevada Mountains and in Granite Mountains of the Mojave Desert.

California's only dinosaur tracks occur in the Jurassic Aztec Sandstone in the eastern Mojave Desert near the MOJA (Reynolds, 1989; Reynolds and Weasma, 2002a, 2002b, 2003; Fleck and Reynolds, 1996). Originally identified by Evans (1958), over one hundred track panels have been identified containing either bipedal coeleurosaurid or quadrupedal tracks. Invertebrate traces are also found in the dinosaur track bearing

panels. Dunal deposits stratigraphically equivalent to the Aztec Sandstone occur within the Preserve and have the potential to contain track fossils (Weasma, personal communication, 2004).

An explosive and eruptive phase in the Mojave area occurred around 18.5 to 17.5 million years ago (McCurry, et al., 1995). Evidence of a powerful eruptive event is found in the Eastern Mojave from within the Woods Mountains. Volcanic deposits, including tuffs and rhyolitic flows, are remnants of this volcanically active period that blanket numerous plateaus and mountains in the Mojave. The Woods Mountain caldera is a collapsed magma chamber is a feature of this eruptive period.

More recent volcanic activity is apparent in the form of cinder cones, lava flows, lava tubes, and other features in the Cima volcanic area. This volcanic activity spanned a period between 7.5 million years ago to 100,000 years before present. Approximately 150 square kilometers of this volcanic field have been designated as a National Natural Landmark.

Reynolds and others (1995) and Wilkerson and others (1995) report on a number of rare Miocene (Hemingfordian) mammal species (rhinoceros, camel, canids, felids) from below the Tuff of Wild Horse Mesa at Hackberry Wash. Hackberry Wash is in the southern end of Lanfair Valley. The fossils occur within a series of Miocene intervolcanic lacustrine and fluvial deposits. Hazzard (1954) references *Sequoidendron* sp. from silts below the Tuff at Wild Horse Mesa. *Sequoia langdorffia* wood, conifer needles, ostracods, and flamingo tracks are reported from the Miocene Winkler Formation at Wild Horse Mesa (Reynolds et al., 1995). Petrified wood is reported from Tertiary deposits in the Providence Mountains including Barber Canyon, Beecher Canyon, and Hackberry Wash (Reynolds, personal communication, 2004; Strong, 1966). There are also possible petrified wood (*Sequoia)* deposits from Barber Canyon and at the mouth of Beecher Canyon.

Studies of the Barstow Formation (Baker, 1911; Merriam, 1919) have developed a framework of Hemingfordian / Barstovian Land Mammal Age (LMA) species for the Mojave Desert from which the Barstovian Land Mammal Age was proposed (Wood, et al., 1941). A collection of important specimens were obtained through screen- washing of sediments by C.L. Baker in 1911. Recent studies of small mammals at the Hemingfordian / Barstovian LMA transition (Lindsay, 1972, 1991; Reynolds, 1987, 1991a, 1991b; Reynolds, et al., 1991c) have show that Hemingfordian / Barstovian LMA sediments are present throughout the central and eastern Mojave Desert (Reynolds, 1992). Miocene sediments known to represent this interval, and deserving of further research are known from within MOJA at Hackberry Wash, Jacks Well, and Wild Horse Mesa. Similar fossiliferous sediments, but outside MOJA, are located in the Clipper Mountains, Little Piute Mountains, Halloran Hills, Avawatz Mountains, and Northern Cady Mountains.

Mid- Miocene (Clarendonian and Hemphillian LMA) sediments with body fossils and tracks are known from the Avawatz Mountains (Reynolds and Whistler, 1990; Whistler and Reynolds, 1991; Reynolds, 1999). Tischler (1960a, 1960b) also reports on Mio- Pliocene vertebrate fossils recovered from intervolcanic deposits in the Mojave Desert.

Plio- Pleistocene deposits adjacent to MOJA reflect what might be present within the Preserve. These are located at Valley Wells (Reynolds and Jefferson, 1988; Reynolds, et al., 1991), Piute Valley Spring Mounds (Jefferson, 1991a), the deposits at Cadiz and Archer (Reynolds, et al., 2003) and at Old Spring in the northern Sacramento Mountains (Jefferson, 1991a).

The modern basin and range landscape is dominated by arid desert features. Playa lakes and sand dunes come and go in the basins through the action of wind and the limited amount of precipitation. Two expansive lakes (Lake Mojave I and II) existed in the area now identified by Silver Lake and Soda Lake playas. The two lakes collectively existed from about 18,000 years ago until it completely dried out about 8,700 years ago. Lacustrine sediments and dunes associated with Lake Mojave hold an important record of habitat sensitive late Pleistocene fossils (Reynolds, 2004). Pleistocene vertebrate and habitat sensitive invertebrate fossils are known from Sands, where Kelso Wash enters southern Soda Lake (Jefferson, 1991a; Reynolds, et al., 2003).

A small portion of the Mojave Desert dunes are designated the Kelso Dunes National Natural Landmark. This dune complex contains some very high dunes reaching 160 meters. Lancaster (1995) describes conditions causing the development of late Pleistocene dunes (18,000 – 9,500 ybp) and these contain a record of fossil vertebrates on the west side of Old Dad Mountain and Kelso Wash (Reynolds, et al., 2003).

Rancholabrean mammals including horse, camel, and mammoth are reported from Pleistocene sands in the Mojave Desert (Jefferson 1971, 1991a, 1991b, 1991c). Jefferson (1991a) reports on vertebrate fauna from Mitchell Caverns. A small collection of Pleistocene vertebrates are accessioned in the MOJA museum collections. These include *Neotoma* sp., *Reithrodomys* sp., and *Gila bicolor* (T. Weasma, personal communication, 2003).

Santucci and others (2001) reference caves in the area surrounding MOJA that contain extensive paleontological resources. Mitchell Caverns, located within Mitchell Caverns State Park, has yielded the partially articulated skeleton of the ground sloth *Nothrotheriops* (G. McDonald, personal communication, 2001). Newberry Cave also contains *Nothrotheriops* remains that were radiocarbon dated to approximately 11,600 years B.P. (G. McDonald, personal communication, 2001). Screen washing of fossil- bearing sediments from Kokoweef Cave has yielded over 200,000 skeletal elements. At least 87 species (from 41 families) are represented in Kokoweef Cave (Reynolds, et. al, 1991a). Charcoal from Kokoweef Cave was radiocarbon dated to approximately 9,830 years B.P., implying a Late Pleistocene/Early Holocene age for the fauna (Reynolds, et. al, 1991a). Antelope Cave preserves the remains of 34 vertebrate families in an assemblage similar to that of Kokoweef Cave (Reynolds, et. al, 1991b). Quien Sabe Cave preserves the disarticulated bones of 21 small vertebrate species (Whistler, 1991). Schuiling Cave discoveries include 28 Late Pleistocene vertebrate species of reptiles, birds, and mammals (Downs, et. al, 1959). Jefferson (1991) presents a summary of Rancholabrean vertebrate cave faunas from the southeastern Mojave Desert region. There are 45 known caves within MOJA proper. A recently initiated survey of the caves will attempt to identify caves within MOJA that may contain paleontological resources (T. Weasma, personal communication, 2001).

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DATA SETS:

DS- MOJA-XXX	Mojave National Preserve Paleontological Archives. 5/1985 – present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.
DS- MOJA-XXX	Mojave National Preserve Files, Archive, Museum Records. 10/1994 – present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Mojave National Preserve; status: Active.
DS- MOJA-XXX	Inventory of Paleontological Resources Associated with National Park Service Caves. 1997- 2001. (field notes; photographs; publication). Originated by Santucci, Kenworthy, and Kerbo; status: Inactive.
DS- MOJA-XXX	Mojave National Preserve Paleontological Archives. 1999 – present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Weasma, Ted; status: Active.
DS- MOJA-XXX	San Bernardino County Museum Collection. 1980 – present. (field notes, photographs, maps, specimens). Originated by Reynolds, Robert; status: Inactive.
DS- MOJA-XXX	Department of Geology, University of Arizona, Tucson. 1972. (field notes, photographs, maps, specimens). Originated by Everett Lindsay; status: Inactive.
DS- MOJA-XXX	University of California, Riverside, Geology Collections. 1980 – present. (field notes, photographs, maps, specimens). status: Active.

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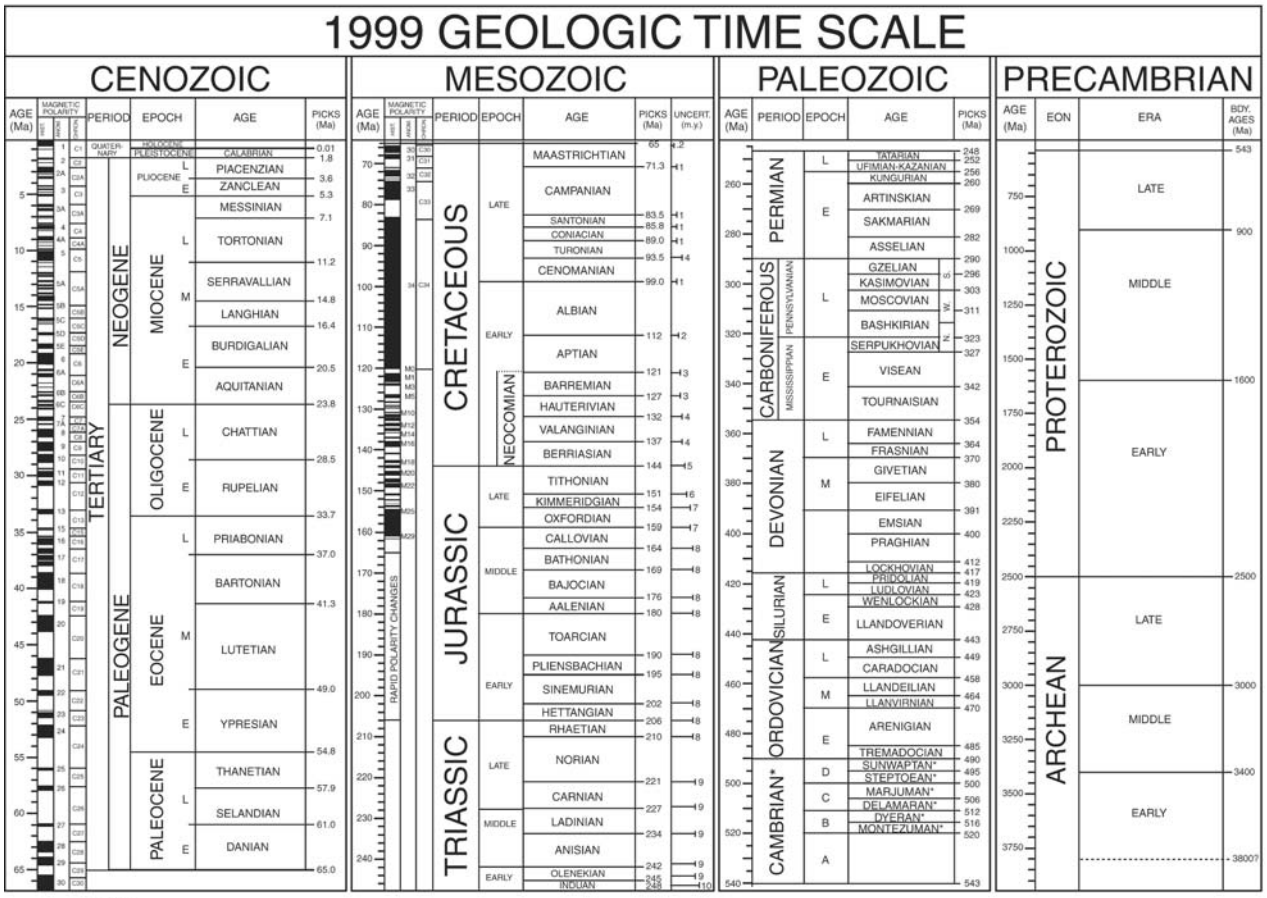
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APPENDIX A: GEOLOGIC TIME SCALE



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*International ages have not been established. These are regional (Laurentian) only. Boundary Picks were based on dating techniques and fossil records as of 1999. Paleomagnetic attributions have errors, Please ignore the paleomagnetic scale.

Sources for nomenclature and ages: Primarily from Gradstein, F., and Ogg, J., 1996, *Episodes*, v. 19, nos. 1 & 2; Gradstein, F., et al., 1995, SEPM Special Pub. 54, p. 95–128; Berggren, W. A., et al., 1995, SEPM Special Pub. 54, p. 129–212; Cambrian and basal Ordovician ages adapted from Landing, E., 1998, *Canadian Journal of Earth Sciences*, v. 35, p. 329–338; and Davidek, K., et al., 1998, *Geological Magazine*, v. 135, p. 305–309. Cambrian age names from Palmer, A. R., 1998, *Canadian Journal of Earth Sciences*, v. 35, p. 323–328.

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