



Paleontological Resource Inventory and Monitoring *Sierra Nevada Network*

Natural Resource Technical Report NPS/NRPC/NRTR—2007/053



ON THE COVER

Large mammalian bone from Bear Den Cave at Sequoia-Kings Canyon National Parks, California.
NPS Photograph courtesy: Joel Despain (SEKI).

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Natural Resource Technical Report NPS/NRPC/NRTR—2007/053

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NOTE:

This report provides baseline paleontological resource data to National Park Service administration and resource management staff. The report contains information regarding the location of non-renewable paleontological resources within NPS units.

It is *not* intended for distribution to the general public.

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National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Abstract

Paleontological resources (fossils) are any remains of past life preserved in a geologic context. Paleontological resources are non-renewable resources found in more than 180 National Park Service units. Despite the abundance and diversity of these resources throughout the NPS, few parks have adequate baseline paleontological resource data.

The NPS National Inventory and Monitoring Program and the NPS Geologic Resources Division have developed various strategies to provide parks with the baseline paleontological resource data necessary for appropriate management of these resources. This report presents a paleontological resource summary for the parks of the Sierra Nevada Network. The summary was compiled through extensive literature review and interviews with park staff and professional geologists and paleontologists. Preliminary paleontological resource management recommendations are also included for each park. Similar summaries have already been prepared for 16 other NPS Inventory and Monitoring Networks. The National Inventory and Monitoring Program provided funding to complete these paleontological resource summaries for each of the remaining networks.

Despite the primarily igneous and metamorphic geology of the Sierra Nevada Network, fossils are known from Sequoia and Kings Canyon National Parks and Yosemite National Park. These fossils occur both *in situ* within the parks and as part of parks' museum collections. The more than 225 caves within Sequoia and Kings Canyon National Parks are the source of the parks' paleontological resources. Highly deformed Triassic-Jurassic marine invertebrates are known from the metamorphosed limestones making up the bedrock where the caves are located. Two of these marine invertebrates (ammonites) are within Sequoia-Kings Canyon museum collections. The caves themselves preserve a rich assemblage of Pleistocene-Holocene fauna and flora. Packrat middens and lake sediment cores within Sequoia-Kings Canyon provided the basis for paleoecological reconstruction of the Sierra Nevada area dating back to the Pleistocene. A number of researchers from NPS, U.S. Geological Survey, Northern Arizona University and other institutions have studied the fossil resources from Sequoia-Kings Canyon. Paleontological resources are rare in Yosemite National Park. The park's collections include some fossil material from outside of the park in addition to rare marine invertebrate fossils found in metamorphosed sediments within the park. Fossil flora and pollen recovered within lake sediment cores in the park (along with similar data from Sequoia and Kings Canyon National Parks) contribute to a greater understanding of the post-glacial vegetation throughout the Sierra Nevada.

Acknowledgements

The authors graciously thank all those individuals, both within and outside of the National Park Service who have contributed valuable information, comments, and suggestions for this report. Reports such as this are impossible without extensive input from those people who know the resources the best.

Special thanks to NPS park staff who provided information, comments, suggestions, and/or reviewed their park's section: Linda Mutch (SIEN), Ward Eldredge (DEPO and SEKI), Joel Despain (SEKI), Greg Stock, Miriam Luchans, and Chris Schierup (YOSE), and Erik Oberg (GWMP—formerly SEKI).

Thomas McGinnis (USGS) has been incredibly helpful from the initiation of this project and provided copies of hard to find publications which directly related to this inventory.

The continued valuable support and information provided by the NPS Geologic Resources Division (GRD), in particular Tim Connors, Bruce Heise, Bob Higgins, Jim F. Wood, Lindsay McClelland, and Jim C. Woods is greatly appreciated. Additionally, we extend our thanks to NPS Librarian David Nathanson at the Harpers Ferry Center Library and the staff at the U.S. Geological Survey Library in Reston, Virginia, for their continued assistance with our use of National Park Service archives.

Special thanks to SIEN Network Coordinator Linda Mutch for her support and enthusiasm for this project.

Finally, this report would not have been possible without the support of Bert Frost (Assistant Director for Natural Resources) and Gary Williams (NPS Inventory and Monitoring Program). A sincere thanks is extended to Bert and Gary for providing the means upon which this work, and similar work, can be accomplished.

Introduction

Paleontological resources, or fossils, are any remains of past life preserved in a geologic context. There are two main types of fossils: body fossils and trace fossils. Body fossils are the physical remains of an actual organism (shells, bones, teeth, plant leaves, etc.) while trace fossils (burrows, coprolites, footprints, trackways, etc.) preserve evidence of an organism's activity or behavior. Fossils are non-renewable natural resources that possess great scientific, educational, and interpretive value.

The establishment of baseline paleontological resource data is essential for the appropriate management of fossils found within National Park Service (NPS) areas. Although more than 180 NPS areas have been identified with paleontological resources, few parks have adequate baseline paleontological resource data.

In conjunction with the NPS Geologic Resources Division and the NPS Inventory and Monitoring (I&M) Program, paleontological resource inventories have been initiated in dozens of parks Servicewide and are further described in this report's Methodology and Inventory Strategies section. This report presents paleontological resource inventory and monitoring data for the parks of the Sierra Nevada I&M Network (SIEN).

The Sierra Nevada Network (SIEN) includes three NPS areas in California (Figure 1): Devils Postpile National Monument (DEPO), Sequoia and Kings Canyon National Parks (SEKI) and Yosemite National Park (YOSE). The Sierra Nevada Network parks range in size from 323 ha (798 acres) at DEPO to 350,438 (865,952 acres) at SEKI. Yosemite National Park and Devils Postpile National Monument are located in the central Sierra Nevada; Sequoia and Kings Canyon National Parks is situated in the southern Sierra Nevada.

The Sierra Nevada is the highest and longest mountain range in the continental United States. Mount Whitney, its highest point at 4418 m (14,496 ft), is situated along SEKI's eastern boundary. The Sierra Nevada Range is bounded by the Great Basin to the east, Mojave Desert to the south, California's Central Valley to the west, and the Cascade Range to the north.

Many spectacular canyons have developed along the 644 km (400 miles) of the Sierra Nevada Range. Most extend perpendicular to the axis of the range and form a rugged topography. King's Canyon is approximately 2400 m (8000 ft) deep, greater than the Grand Canyon of the Colorado River in Arizona.

The Sierra Nevada Network parks share a common geologic history of mountain building (orogeny), volcanism, and glaciation. Some of the oldest rocks in the Sierra Nevada extend back to the early Paleozoic, approximately 540 million years ago during the Cambrian Period. These Paleozoic rocks were primarily marine deposits formed on the seafloor. The remains of ancient organisms were presumably preserved in these marine sediments, but folding and metamorphism associated with the development of the Sierra Nevada range and other tectonic activity contributed to the alteration or destruction of fossils originally preserved in the Paleozoic sedimentary rocks. Thus, the scarcity of fossils in the SIEN parks is directly related to the post-depositional history of mountain building and metamorphism.

A rich human history is associated with the Sierra Nevada Mountains. Native American archeological sites are preserved in the canyons and within mountain passes. Some of the notables who have traversed the Sierra Nevada include mountain man Jedediah Smith, explorer John C. Fremont, geologist Clarence King, members of the Donner Party, and a large number of individuals hoping to discover gold. Today the parks of the Sierra Nevada Network host a combined total of more than 4.5 million visitors annually.

Collectively, the paleontological resources of the Sierra Nevada Network parks are relatively rare, with the exception of Pleistocene-Holocene fossils associated with park caves. Continued paleontological resource inventories will expand an ever-widening base of paleontological knowledge throughout the

National Park Service. Although more than 180 NPS sites preserve fossils much of the history of life on earth remains to be discovered.

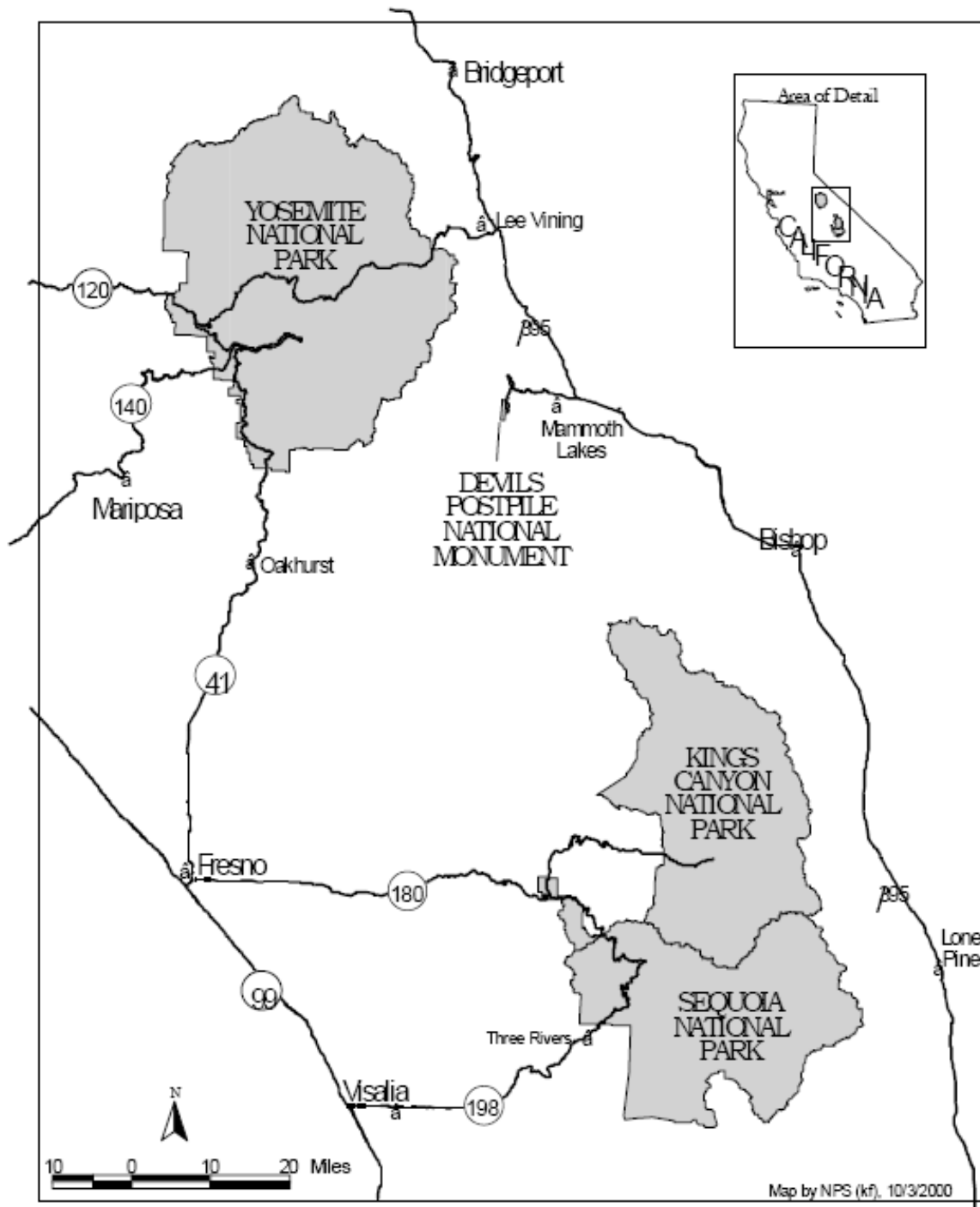


Figure 1. Map of the Sierra Nevada Inventory & Monitoring Network. Map courtesy SIEN staff.

Paleontological Resource Inventory Strategies and Methodology

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, each with its own goals and objectives. These strategies include: comprehensive park-specific paleontological resource inventories, Servicewide thematic paleontological resource inventories, and Inventory & Monitoring Network-based baseline paleontological resource inventories. Santucci and Koch (2003) outline basic paleontological resource monitoring strategies and potential threats to fossil resources.

Comprehensive Park-Specific Paleontological Resource Inventories

Comprehensive park inventories are designed to identify all known paleontological resources within a single park unit. A team of specialists from within the NPS and from educational institutions and cooperators work with the targeted park to identify and address all aspects of its paleontological resources, including resource management, museum curation, law enforcement, and interpretation. Paleontology-specific training for park staff is an important component of many comprehensive paleontological inventories. Park-specific comprehensive paleontological resource inventories have been completed at Yellowstone NP (first park to have inventory completed), Arches NP, Bighorn Canyon NRA, Death Valley NP, Grand Teton NP, Santa Monica NRA, Walnut Canyon NM, and Zion NP.

Servicewide Thematic Paleontological Resource Inventories

Servicewide thematic paleontological resource inventories compile data regarding specific types of paleontological resources that occur in parks throughout the NPS. The first thematic paleontological resource inventory was an inventory of fossil vertebrate tracks from NPS areas (Santucci et al. 1998). This thematic inventory identified nineteen NPS units that preserve fossil vertebrate tracks. Subsequent discoveries have increased the number of parks identified with fossil vertebrate tracks to twenty-five and warranted an updated publication (Santucci et al. 2006). Another thematic paleontological resource inventory identified paleontological resources associated with NPS caves in thirty-five parks (Santucci et al. 2001). Cave fossils occur in two contexts: First, fossils can be preserved in the marine limestones in which caves develop; second, the remains of Pleistocene / Holocene animals and plants that lived, died or were transported into caves after death are common types of cave fossils. Servicewide thematic inventories have also been initiated for fossil fish (Hunt et al. 2006) and fossils found in cultural resource contexts (Kenworthy and Santucci 2006).

Inventory and Monitoring Network Paleontological Resource Inventories

Network-based paleontological resource inventories compile baseline paleontological resource data for each of the parks within a particular network. Network-based inventories have been completed for 16 of the 32 I&M Networks including: the Chihuahuan Desert, Eastern Rivers and Mountains, Greater Yellowstone, Gulf Coast, Mediterranean Coast, Mid-Atlantic, Mojave Desert, National Capital Region, Northeast Coastal and Barrier, Northern Colorado Plateau, Pacific Island, Rocky Mountain, Sierra Nevada (this report), Southern Plains, Southwestern Alaska, and Upper Columbia Basin networks. The summary for the San Francisco Bay Area Network, by Elder et al., is currently (September 2007) in review. Research for summaries of the Appalachian Highlands, Arctic, Great Lakes, Northern Plains, and South Florida/Caribbean networks are currently underway (September 2007). NPS I&M Program funding is targeted to complete paleontological resource summaries for the remaining networks by FY2009. Citations for the completed reports are in the Additional References section.

I&M Network Paleontological Resource Inventory Methodology

Network-based paleontological inventories were funded directly by the individual networks from 2002-2006. In FY2006, the National I&M Program provided funds to complete reports for the remaining networks between FY2006-2009. 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 assemble 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. The American Geological Institute's GeoRef is the primary database for geology references and contains millions of references from the middle 1700s through today. GeoRef, available in both online or CD-ROM versions, is accessible at many major university libraries. The NPS NatureBib (which supersedes PaleoBib) is an internet-based database for scientific citations presented as bibliographic references but 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 at 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, field notes, 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 might otherwise be undocumented and potentially lost or unrecognized. Bibliographic searches include a search for geologic maps associated with each park. The NPS Geologic Resources Division maintains a database of geological map coverage for many parks (current contact is Tim Connors). In addition, the USGS National Geologic Map Database (NGMDB; see citation below in Additional References section) lists maps for a given geographic area or place name and provides information on where to obtain maps. Geologic maps show the types of rocks and the associated geological formations within a park area. These maps, alone, will often indicate the potential for paleontological resources to occur within a park.

Fossils are most commonly found in sedimentary rocks such as sandstones, shales, and limestones. Fossils, with few exceptions, are not found within igneous rocks (volcanic or intrusive origin) or metamorphic rocks (altered by heat, pressure, and/or chemical change) due to the extreme heat and/or pressure associated with their origin and history. The nomenclature for geologic formations can be confusing, but the NGMDB includes a searchable lexicon of valid geologic formation names that can be very useful in clearing up nomenclatural confusion. This lexicon provides a basic summary for each formation, summarizes current and past usage of the various formation names found in the literature, and provides an annotated bibliography for each formation.

The information from these various sources for each park is then compiled and summarized in a written report and 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. These reports are 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 addition 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. Paleontological resources can be divided into four taxonomic groups: paleobotany (fossil plants), invertebrates (animals without backbones), vertebrates (animals with backbones), and trace fossils (evidence of biological activity such as tracks, traces, burrows, etc.). Fossils typically have a finite stratigraphic range and occurrence in geologic time (a geologic time scale is included in Appendix A). The period between the first and final occurrences 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. Likewise, 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 these data may indicate the potential for fossils in similar stratigraphic units exposed within park boundaries.

Given the tremendous diversity of past life, the existence of life for over a billion years, and the range of environments to which life has adapted, there is 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, more than 180 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 museums or universities serving as repositories for park fossils, and a comprehensive list of publications related to paleontological research associated with the park. The reports include all bibliographies that may be associated with a park's paleontological resources. However, bibliographic data are subdivided in the report into those cited in the narrative (References Cited) and other associated bibliographies (Additional References). The cooperative projects section highlights paleontological resources projects, if any, that the park has funded or supported. Formal datasets are established for known associated paleontological collections, research, or activities.

Paleontological Resource Management Legislation and Guidance

I&M Network reports such as this one are meant to provide network parks with sound baseline paleontological resource data that can stimulate future research, interpretation, education, or resource management projects. The proper management of resources identified through these inventories is mandated by many NPS policies. For example, the 2006 National Park Service Management Policies (§1.4.6) stipulates that paleontological resources are considered park resources and values that are subject to the “no impairment” standard set forth by the NPS Organic Act in 1916. Basic guidelines for management of paleontological resources are found in sections 4.8.2 and 4.8.2.1 of the 2006 NPS Management Policies. Another legislative protection for paleontological resources is found in the NPS Omnibus Management Act of 1998. Section 207, with the following statement, “Information concerning the nature and specific location of . . . paleontological objects within the units of the National Park System . . . may be withheld from the public source,” safeguards paleontological locality information from requests under the Freedom of Information Act.

Paleontological resource management issues were the subject of a Report of the Secretary of the Interior in May 2000, prepared in response to a Congressional request for an assessment of the need for a unified federal policy on the collection, storage and preservation of fossils and for standards that would maximize the availability of fossils for scientific study. That report, an “Assessment of Fossil Management on Federal & Indian Lands” summarized a number of principles relating to paleontological resources and their management. The Paleontological Resources Management section of Natural Resource Management Reference Manual 77 provides guidance and additional information regarding the implementation and continuation of paleontological resource management programs. Links to the above

documents are listed in the Additional References section. The Geologic Resources Division is assembling a geologic resource monitoring manual that includes chapters on various geologic resources, including in situ paleontological resources, and a set of monitoring vital signs that may be applicable to a variety of parks. Monitoring represents the next phase in paleontological resource management, following the initial research inventory (represented by this report) of potential fossils and any subsequent field work to identify fossils within a park. Publication is expected by early 2008. Contact the Geologic Resources Division for more information or to obtain a copy of the report when it is available.

Our knowledge of the fossil record is only as 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.

Additional References and Websites of Interest

Website addresses are current as of 13 September 2007.

- Elder, W. P., T. Nyborg, J. P. Kenworthy, and V. L. Santucci. In review. Paleontological Resource Inventory and Monitoring—San Francisco Bay Area Network. Natural Resource Technical Report NPS/NRPC/NRTR—2007/xxx. National Park Service, Fort Collins, Colorado.
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General SIEN Information

SIEN I&M Network: <http://www.nature.nps.gov/im/units/sien/index.cfm>

Geological Survey Websites

California Geological Survey: <http://www.consrv.ca.gov/cgs/>

U.S. Geological Survey: <http://www.usgs.gov>

Geological Society of America: <http://www.geosociety.org>

American Geological Institute: <http://www.agiweb.org>

Library catalogs

U.S. Geological Survey Library Catalog: <http://igsrilib03.er.usgs.gov:8080/#focus>

Smithsonian Institution Libraries Catalog: <http://www.siris.si.edu/>

Museums

University of California Museum of Paleontology, Berkeley: www.ucmp.berkeley.edu/

California Academy of Science: www.calacademy.org

Natural History Museum of Los Angeles County: www.nhm.org/

Smithsonian National Museum of Natural History Dept. of Paleobiology: <http://paleobiology.si.edu/>

Resource Management/Legislation Documents

NPS 2006 Management Policies (§1.4; Park Management): <http://www.nps.gov/policy/mp/chapter1.htm>

NPS 2006 Management Policies (§4.8.2.1; Paleontological Resources):

<http://www.nps.gov/policy/mp/chapter4.htm>

NPS 1998 Omnibus Management Act (paleontological resource summary):

http://www2.nature.nps.gov/geology/paleontology/paleo_5_1/index.htm

NPS Natural Resource Management Reference Manual #77 (paleontology section):

<http://www.nature.nps.gov/rm77/paleo.cfm>

Assessment of Fossil Management on Federal & Indian Lands: <http://www.fs.fed.us/geology/fossil.pdf>

National Park Service Paleontology Program sites

NPS Geologic Resources Division: <http://www2.nature.nps.gov/geology/>

NPS Paleontology Program: <http://www2.nature.nps.gov/geology/paleontology/>

NPS Park Paleontology Newsletter: <http://www2.nature.nps.gov/geology/paleontology/newsletter.cfm>

I&M Network paleontological resource summary project website and PDFs of all reports (InsideNPS):

<http://inside.nps.gov/waso/custommenu.cfm?lv=4&prg=753&id=4518>

NPS Technical Information Center (Denver, repository for technical (TIC) documents):

<http://etic.nps.gov/>

Other geology/paleontology tools

Bates, R. L. and J. A. Jackson (editors). American Geological Institute dictionary of geological terms (3rd Edition). Bantam Doubleday Dell Publishing Group, New York.

U.S. Geological Survey Geologic Terms Glossary:

<http://wrgis.wr.usgs.gov/docs/parks/misc/glossary.html>

Topozone (interactive access to all USGS topographic maps): <http://www.topozone.com>

U.S. Geological Survey National Geologic Map Database (NGMDB): <http://ngmdb.usgs.gov/>

U.S. Geological Survey Geologic Names Lexicon (GEOLEX; geologic unit nomenclature and summary):

http://ngmdb.usgs.gov/Geolex/geolex_home.html

U.S. Geological Survey Geographic Names Information System (GNIS; search for place names and geographic features): <http://gnis.usgs.gov/>

Paleobiology Database (search for fossil taxonomy, localities, or geologic formations):

<http://paleodb.org/cgi-bin/bridge.pl>

Paleontology Portal (general fossil info based on geographic location or geologic time):

<http://www.paleoportal.org/>

University of California-Berkeley Museum of Paleontology online paleontology exhibits:

<http://www.ucmp.berkeley.edu/>

U.S. Geological Survey, description of physiographic provinces: <http://tapestry.usgs.gov/Default.html>

Devils Postpile National Monument

Devils Postpile National Monument (DEPO) is a 323 ha (798 acre) site within the Sierra Nevada Range which preserves an outstanding exposure of polygonal columns or pillars of basalt. Devils Postpile was originally included within the eastern boundary of Yosemite National Park when it was established in 1890. However, the boundary of Yosemite was later reduced and land including Devils Postpile was withdrawn from the park in 1905. President William Howard Taft eventually designated the area as Devils Postpile National Monument on July 6, 1911.

Baseline Paleontological Resource Inventories

Geologic scoping sessions, coordinated by the NPS Geologic Resources Division, were conducted for Devils Postpile National Monument and the other SIEN parks in September 2002. Paleontological scoping sessions or inventories have not been planned based on the low potential for paleontological resources at the monument. The geologic formations within the park are basalt flows and are not known to preserve paleontological resources

Geologic Background

Devils Postpile National Monument is located on the western slope of the Sierra Nevada Mountains. The monument lies between 2,200 m (7,218 ft) and 2,500 m (8,202 ft) in elevation within the Sierra Nevada granite batholith. Volcanism occurred along active faults in the eastern Sierra Nevada beginning approximately 3 million years ago. The oldest volcanic rocks in or near Devils Postpile are Quaternary basalt flows which date to about 100,000 years ago. The proposed source of the lava is near the Upper Soda Springs Campground, at the north end of Pumice Flat on the floor of the Middle Fork of the San Joaquin River. The lava flow appears to have been impounded by moraine and accumulated to a thickness of approximately 122 m (400 ft).

Basalt flows at DEPO exhibit specialized fracturing (columnar joints) which occurred during the cooling and crystallization of the lava and divided it into tall polygonal columns or pillars. The great thickness of the lava contributed to a slower cooling, influencing the development of long, symmetrical columns.

Individual columns reach lengths up to 18.3 m (60 ft) and diameters up to 1.1 m (3.5 ft). The approximately 400 individual columns identified at DEPO are primarily five-sided or six-sided, but a few seven-sided and very few three-sided columns have been documented at the monument. Several columns from Devils Postpile National Monument are on display at the entrance to the U.S. Geological Survey headquarters in Reston, Virginia. A spectacular waterfall named Rainbow Falls drops 31 m (102 ft) over a volcanic cliff.

During the Pleistocene, ending nearly 10,000 years ago, glaciation was extensive in the Sierra Nevada. Evidence of past glacial activity at Devils Postpile includes abrasions, striations, and polishing on the top surfaces of the polygonal columns. An excellent website on the geology of DEPO has been developed through a partnership between the National Park Service and the U.S. Geological Survey (<http://www2.nature.nps.gov/geology/usgsnps/depo/dpgeol1.html>). Huber and Rinehart (1965) developed a geologic map for Devils Postpile National Monument.

Park Collections

There are no reported fossils either documented from DEPO or cataloged within the park collections (NPS, W. Eldredge, SEKI/DEPO Museum Technician, pers. comm., 2007).

Paleontological Resource Management, Preliminary Recommendations

- The occurrence or discovery of fossils from within the boundaries of DEPO is unlikely. However, park staff should consult with professional geologists or paleontologists if a potential fossil discovery would occur in the future.

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Data Sets

Devils Postpile National Monument Paleontological Archives

5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

Sequoia and Kings Canyon National Parks

Sequoia and Kings Canyon National Parks (SEKI) are two jointly administered National Park Service units. Sequoia National Park was established to preserve groves of giant sequoia trees and Mount Whitney, the highest mountain in the contiguous United States. Kings Canyon National Park consists of two large canyons of the Kings River and the summit peaks of the High Sierra. Collectively the two parks comprise 350,438 ha (865,952 acres) on the western slope of the south-central Sierra Nevada. The parks represent areas of exceptional topographic relief contributing to the abundance and diversity of vegetation types. SEKI ranges in elevation from the low western foothills at 400 m (1312 ft) to the crest of the Sierra at 4418 m (14,495 ft). Vegetation types in the rugged and mountainous terrain vary from chaparral, oak woodland, savanna, and upland hardwood forest, to conifer forest, with woodland, meadow, and alpine plant communities.

Three major river systems drain the park including: the Kaweah, Kern and Kings rivers. The climate is Mediterranean, with hot, dry summers and cool winters. An extensive network of caves, with more than 225 identified, is formed within metamorphosed Mesozoic limestones and is home for nearly 20 endemic species of invertebrates. Approximately 85% of SEKI (292,588 ha or 723,000 acres) is designated wilderness and the park has been designated as an International Biosphere Reserve.

Baseline Paleontological Resource Inventories

Geologic scoping sessions, coordinated by the NPS Geologic Resources Division, were conducted for SEKI and other SIEN parks in September 2002. Paleontological scoping for SEKI was conducted in March 2007 during the initial work for this inventory report. Fossils are found within park collections and *in situ*. The *in situ* fossils within SEKI are found in two settings: within the Mesozoic bedrock of park caves and Pleistocene-Holocene fossils discovered within SEKI caves as described below. Santucci et al. (2001) included SEKI cave fossils as part of a Servicewide summary of fossils found in NPS caves.

Geologic Background

Sequoia and Kings Canyon National Parks lie along the crest and western slope of the Sierra Nevada and therefore share a similar geologic history with Yosemite National Park (see YOSE section in this report). Knopf and Thelen (1905), MacDonald (1941), Ross (1958), and Moore et al. (1979) provide an overview for the geology of SEKI. The Paleozoic history of the park is not well understood, although isolated Paleozoic strata occur east and north of the park. Moore and Foster (1980) provide an overview of Paleozoic metasedimentary rocks in the Sierra Nevada.

Triassic and Jurassic metasedimentary and metavolcanic rocks are preserved as roof pendants upon the Sierra Nevada batholith. The Mesozoic metamorphic rocks are well exposed in the canyons of Kings River and Kaweah River, as well as in the Mineral King portion of the park. These rock units consist of marbles, schists, and cherts, which are found in association with metavolcanics. Many of the SEKI caves are formed within the marbles exposed in the park.

During the Cretaceous, plutonic activity was widespread in the Sierra Nevada. The Sierra Nevada batholith plutons were emplaced in a series of episodic events (Bateman 1974). The older granites have been dated from the western portion of the park and the younger granites were determined to be near the crest of the Sierra Nevada. The older intrusives have a more mafic composition such as quartz diorite. The younger intrusives have a more felsic composition and are represented by the granodiorites and quartz monzonites.

Uplift and westward tilting of the batholith began sometime during the early Cenozoic. Originally the pluton was formed at considerable depth and was covered by the older Paleozoic and Mesozoic rock sequences. Today nearly all of the Paleozoic and Mesozoic metamorphic rocks have been removed

through erosion, leaving only some isolated roof pendants. Uplift and tilting has continued episodically to the present. Today the eastern Sierra Nevada is extremely tall and steep and includes the tallest point in the continental United States at Mt. Whitney, California. No evidence of late Cenozoic volcanism within the southern Sierra Nevada is found within the park, only occurring outside the SEKI boundary.

The effects of glaciation on SEKI were not as extensive as at YOSE. However, the landscape has been influenced and shaped by the action of alpine glaciers. The development of glaciers in the southern Sierra began early, perhaps during the Late Pliocene. The river valleys on the western slope were transformed through glacier scouring to form typical U-shaped topography. The impacts of glaciation are more evident in Kings Canyon National Park than in Sequoia National Park. A period of renewed glacial development is documented at Kings Canyon National Park during the Little Ice Age (1450-1850 A.D.), when glaciers were reestablished in Pleistocene cirques. Small valley glaciers also advanced near Mount Goddard and in the Palisades region along the northeast boundary of the park.

Park Collections

Only two fossil specimens are currently in SEKI museum collections. These are metasedimentary rock units with invertebrates collected from the park's Mineral King area. More current collections of cave fossils have not yet been curated into the park collections.

Cave Fossils (Mesozoic Limestone Bedrock)

The largest limestone caves in California occur along the western boundary of Sequoia and Kings Canyon National Parks. There are approximately 225 caves within SEKI boundaries, the vast majority of which formed in metamorphosed limestones (NPS, J. Despain, SEKI Cave Specialist, pers. comm., 2001). Geologic features in the park are dominated by the emplacement of Late Cretaceous granitic batholiths. Due to the intrusion of these batholiths, sedimentary rocks do not exist in their original state and are confined to metamorphosed roof pendants (Harris and Tuttle 1983). These pendants have undergone complex deformation and their stratigraphy is debated. Marble in the pendants has been partially dissolved by groundwater, forming caverns such as Crystal, Clough, Palmer, Paradise, Hurricane Crawl, Lange, and Bear Den caves (NPS, J. Despain, SEKI Cave Specialist, pers. comm., 2001; Despain 1995, 2003), and the recently discovered Ursa Minor Cave.

Most of the fossil remains preserved within the limestones were destroyed during metamorphism. However, two heavily deformed fossils, including an ammonite, indicate that the limestones were deposited sometime between the Late Triassic and Early Jurassic (NPS, J. Despain, SEKI Cave Specialist, pers. comm., 2001). Jones and Moore (1973) report that the ammonite is Early Jurassic in age and was discovered in a fragment of slate below the trail to Boyden Cave in Kings Canyon. The source is believed to be the Boyden Cave Marble.

Busby-Spera (1982) reports the occurrence of Late Triassic (Norian) marine invertebrates within metasediments intercalated with meta-rhyolite ashflow tuffs, found in roof pendants in the Mineral King portion of SEKI. Fossils collected from the Franklin Unit were pelecypods and those from the Crystal Creek Unit were brachiopods, pelecypods, and crinoids (Christensen 1959; Busby-Spera 1982).

Cave Fossils (Pleistocene-Holocene Cave Dwelling Organisms)

Bear Den Cave is developed within a marble formation exposed in Yucca Creek at SEKI. This cave is quite dry and holds potential for fossil specimens of relatively good preservation. A black bear jaw and packrat middens were some of the first paleontological resources discovered in Bear Den Cave. Additional material from Bear Den includes extensive deposits of long and short bones, vertebrae, and a skull (see cover illustration). Mead et al. (2006) sampled floor-fill deposits to 40 cm (15.8 in) depth in Bear Den Cave. Radiocarbon dating of charcoal in the test pit yielded an early-middle Holocene age (7220 years before present (b.p.)) for the deposit. A diverse vertebrate and microvertebrate fauna recovered in the excavation included amphibians, reptiles, and mammals. A taphonomic assessment of the skeletal assemblage suggests that the remains were accumulations of prey from within ringtail dung (Mead and Van Devender

1981; Mead et al. 2006). Two salamander taxa were found in the cave and tentatively identified as either clouded or wandering salamander (*Aneides ferreus* or *A. vagrans*) and lungless salamander (*Plethodon*). None are currently extant in the Sierra Nevada.

Palmer Cave is a large collapsed pit with a debris pile nearly 25 m (75 ft) high. The cave is rather wet, which quickly degrades resources, but extensive bone material is reported from the cave. Fossilized *Sequoia* has been discovered in a number of the caves. The distribution of the fossil *Sequoia* suggests that these trees previously existed in some areas of the park where they are not found today (NPS, J. Despain, SEKI Cave Specialist, pers. comm., 2001).

During the 1950s, the remains of a Harlan's ground sloth were discovered in Lange Cave and subsequently excavated. Unfortunately the current location of the specimen is unknown. Small rodent bones, some with "chew" marks on them, and a few long bones were found in Crystal Cave. Inside Hurricane Crawl Cave, a number of small skeletons and bones have been discovered, some contained within the cave's flowstone. Carmoe Crevice discoveries include a few small bones and a skeleton also preserved in flowstone. Small bones have been found in Lilburn Cave. In addition, an apparent deer skeleton was recovered in an area referred to as Pet Cemetery. The ages of the cave passages are not well established. However, passages in Crystal Cave and Soldier's Cave have been dated to 172,000 and 71,000 years b.p., respectively, using Uranium-series dating from speleothems (NPS, J. Despain, SEKI Cave Specialist, pers. comm., 2001).

Within the SEKI park files is an August 1983 letter from USGS Research Geologist, John Tinsley, referencing vertebrate skeletal remains from Crystal Cave. The specimens were identified by Charles Repenning (USGS) as the jaw of a Belding ground squirrel (*Citellus beldingi*) and two incisors from a marmot (*Marmota* sp.). Tinsley suggested possible paleoclimatic interpretations based upon the occurrence of these taxa at lower elevations than normal. Specifically Tinsley stated, "During the Tioga stage, the ground squirrels and marmots presumably were distributed at lower elevations and across more southerly latitudes relative to their present geographic range."

Cole (1983) produced the first report of late Pleistocene packrat middens from the western side of the Sierra Nevada. Plant remains and dung pellets were collected from seven middens. One midden, King's Canyon No. 8, produced identifiable vertebrate skeletal remains of web-toed salamander (*Hydromantes* sp.), southern alligator lizard (*Gerrhonotus* cf. *multicarinatus*), western fenced lizard (*Sceloporous* cf. *occidentalis*), garter snake (*Thamnophis* sp.), pocket gopher (*Thomomys* sp.) and bushytailed woodrat (*Neotoma* cf. *cinerea*) (Mead and Mead 1985). This assemblage indicates an early or middle Wisconsin-age record (late Pleistocene).

Paleontology graduate student Lisa Schaaf visited four park caves as part of a partial cave paleontological resources inventory in the summer of 2007. Caves visited were Bear Den, Crystal, Kaweah and Ursa Minor, which was examined twice. Sediment and bone samples from all of the caves were collected. Preliminary "picking" of the samples showed a wide variety of vertebrate remains include the bones of deer, salamanders, mustelids, rabbits, rodents, large carnivores and more. Schaaf also found obsidian from Native Americans in two of the caves. Schaaf will use this research for her M.S. thesis work at Northern Arizona State and will supply SEKI with a preliminary report on her findings by the end of calendar year 2007.

Paleoecological Reconstructions (Pleistocene-Holocene)

An extensive literature base reports paleoclimatic interpretations based upon plant macrofossils, pollen and microscopic charcoal collected and analyzed from lake core sediments from the Sierra Nevada. Some of the initial research into Pleistocene-Holocene paleoecology in the Sierra Nevada was undertaken by Adam (1967, 1985), Batchelder (1980), Cole (1983), and Wood (1975). Detailed palynological data has been established by Davis et al. (1985), Mackey and Sullivan (1986), Byrne (1988), Davis and Moratto (1988), and Anderson (1990).

Anderson et al. (1997) evaluated 234 radiocarbon dates, representing 72 localities in the Sierra Nevada with paleoecological data. The work looked at extensive data that had not been previously published and recommended future work based on gaps in current research. The analyses enable biogeographic, climatic and temporal interpretations based on changes and distribution of vegetation (Anderson et al. 1997).

The paleobiogeography of the giant sequoia (*Sequoiadendron giganteum*) has been studied for more than a century (Muir 1876; Axelrod 1959, 1986; Hartesveldt et al. 1975; Anderson 1992). The largest concentrations of giant sequoia occur within the southern Sierra Nevada range. The sequoia groves become smaller and more isolated further north in the Sierra (Hartesveldt et al. 1975). Various climatic hypotheses have been raised to explain the reduction of the sequoia's range. Muir (1876) and Axelrod (1959) suggest that reduction of the sequoia is associated with cooler Pleistocene temperatures. Axelrod (1986) also proposed that the reduction of the sequoia's range may be related to the Holocene's warming climate.

Paleontological Resource Management, Preliminary Recommendations

- Paleontological studies within SEKI yielded significant information over the last few decades. Continuing to support paleontological studies within the park will continue to provide information regarding the past life preserved within SEKI.
- The NPS Geologic Resources Division can help advertise, recruit, and provide technical assistance for these efforts.
- Results of cave paleontological resources inventory can be used to create paleontological resource monitoring prescriptions, should the park establish a program of paleontological resource monitoring.

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Sequoia and Kings Canyon National Parks Museum Collections and Park Files.

1982–present. (museum specimens; associated specimen notes; collection records; maps; correspondence; etc.). Originated by SEKI staff; status: Active.

Northern Arizona University (Flagstaff) Research Collections.

1980s–present. (fossil specimens; associated specimen notes; collection records; maps; correspondence; etc.) Originated by NAU staff; status: Active.

Yosemite National Park

Yosemite National Park (YOSE) is a scenic wildland established as a national park on October 1, 1890 to preserve a portion of the central west slope of the Sierra Nevada. Yosemite was previously set aside on June 30, 1864 by Abraham Lincoln when he signed a bill granting Yosemite Valley and the Mariposa Grove of Giant Sequoias to the State of California as an inalienable public trust. This was the first time in history that a federal government set aside scenic lands simply to protect them and to allow for their enjoyment by all people. Today the 308,073 ha (761,266 acre) park ranges from 607 m (1991 ft) to nearly 4000 m (13,123 ft) in elevation. The most well known features of YOSE include alpine wilderness, three groves of Giant Sequoias, and the glacially carved Yosemite Valley with impressive waterfalls, cliffs and unusual rock formations. Approximately 94% of Yosemite's acreage is legally designated Wilderness. Yosemite is designated a World Heritage Site as part of a system of sites set aside to preserve internationally significant natural and cultural resources. The California Wilderness Act of 1984 established portions of the Tuolumne River (including the Dana and Lyell Forks) as part of the Wild and Scenic Rivers System. In 1987, Congress also designated the main stem and the South Fork of the Merced River as part of the Wild and Scenic Rivers System.

Baseline Paleontological Resource Inventories

Geologic scoping sessions, coordinated by the NPS Geologic Resources Division, were conducted for Yosemite National Park and other SIEN parks in September 2002. Paleontological scoping sessions or inventories have not been planned based on the low potential for paleontological resources at the park. Nevertheless there are fossils within YOSE museum collections. Fossils were also obtained from lake sediment cores within the park. These occurrences are described below.

Geologic Background

The oldest rocks in Yosemite National Park are Paleozoic metasediments and metavolcanics – cherts, greenstones, quartzites, and siltstones -- preserved in roof pendants on top of the batholith. Near the crest of the Sierra Nevada, on the eastern boundary of YOSE, is a contact between the eastern metamorphic belt and the granitic batholith. A similar western metamorphic belt occurs just outside of the park's western boundary. The metamorphic, sedimentary, and volcanic rocks which flank the granitic batholith are referred to as the Calaveras Assemblage.

West of the Calaveras sequence are some Jurassic-age metamorphic rocks, mapped as the Mariposa Slates outside of the park, that consist primarily of metavolcanics. Similar metavolcanics are also found in the eastern metamorphic belt just out of the eastern boundary of YOSE. These rocks have generally undergone less intense metamorphism than the older Paleozoic rocks. Long periods of erosion have removed much of these Paleozoic and Jurassic rocks directly above the batholith.

During the Early Cretaceous a series of widespread and complex igneous intrusion events occurred throughout the region. Calkins (1930), Matthes (1930), Smith (1962), Hill (1975), Huber (1987) and many others have attempted to interpret this Cretaceous plutonic activity. Within what is now Yosemite Valley, a series of magmas intruded the older Paleozoic and Mesozoic sequences. These magmas have been referred to as the Western Intrusive Series and represent the major intrusive event and the emplacement of the composite batholith.

The Western Intrusive Series consists of the following units from youngest to oldest: Diorite of the Rockslides; Arch Rock Granite; Granodiorite of the Gateway; El Capitan Granite; and Taft Granite. A younger series of Cretaceous intrusives were later emplaced and are referred to as the Minor Intrusive Series, consisting of the following units from youngest to oldest: Leaning Tower Quartz Monzonite; Bridalveil Granite; Quartz-mica Diorite; and Diorite of "Map of North America". The "Map of America" is a large diorite dike which has intruded into the El Capitan Granite and is visible on the face of El Capitan from the floor of Yosemite Valley. The youngest of the Cretaceous intrusive events are

represented by the Tuolumne Intrusive Series which consists of the following units from youngest to oldest: Sentinel Granodiorite; Half Dome Quartz Monzonite; Cathedral Peak Granite; and Johnson Granite Porphyry. The Sentinel Granodiorite and Half Dome Quartz Monzonite are visible within Yosemite Valley. The Cathedral Peak Granite and Johnson Granite Porphyry are exposed at the surface in Tuolumne Meadows, east of Yosemite Valley.

Uplift and westward tilting of the batholith began sometime during the early Cenozoic. Originally the pluton was formed at considerable depth and was covered by the older Paleozoic and Mesozoic rock sequences. Today the eastern and western metamorphic belts are all that remain of these rocks which covered the batholith. The uplift and tilting has continued episodically to the present. Today the eastern portion of the Sierra Nevada is extremely tall and steep, with elevations of more than 3353 m (11,000 ft) in many areas.

Regionally there was volcanic activity during the Late Cenozoic. Most of the volcanic rocks of this period occur outside of the park boundaries except for some within the park north of the Grand Canyon of the Tuolumne River. These units are largely andesitic along with some lahars (volcanic mudflows).

As the Sierra Nevada mountains were uplifted, a western and southwestern drainage pattern developed. The Merced River and other rivers incised into the western slopes of the mountains and eventually developed into broad river valleys. The drainage of tributaries to the Merced River proceeded at different rates and traversed rocks of varying hardness and resistance to erosion. As a result, waterfalls began to develop in the tributaries, such as Bridalveil Creek, which crossed more resistant rock. The results of this differential downcutting by tributary drainages were the development of waterfalls emerging from the hanging valleys.

By the Pleistocene, Yosemite Valley was a deep and V-shaped river valley with steep ridges dividing the tributary drainages. Pleistocene glacial activity dramatically altered its surface features and topography. Severe erosion occurred during advances within each of the four stages of glacial activity identified in YOSE: Sherwin, Tahoe, Graveyard, and Tioga from youngest to oldest. The earlier stages were longer and resulted in greater amounts of erosion. Curry (1969), Burke and Birkeland (1983), and Porter and others (1983) present detailed glacial histories for the central Sierra Nevada.

Most of the evidence of the Sherwin Glacial Stage was destroyed by subsequent (younger) stages. Tahoe Glacial Stage moraines indicate that glaciation extended a few kilometers west of El Portal near the park entrance. The Graveyard Glacial Stage advanced to the base of Bridalveil Falls. The Tioga Glacial Stage is the most recent of the glacial advances and is represented by the most extensive and undissected moraines.

Yosemite's Pleistocene glaciers were extremely thick and largely reshaped Yosemite Valley. They rounded the V-shaped river valley to a classic U-shaped glacial valley floor. Glaciers further excavated and sculptured the area to form giant staircases and hanging valleys within the tributary valleys. Many of the famous waterfalls cascade over the staircases or dramatically drop, sometimes several hundred feet, from the locations where the hanging valleys open into Yosemite Valley.

Glacial deposits and other evidence of the glacial activity can be found throughout the park. The last glacier retreated from Yosemite Valley approximately 15,000 years ago, depositing significant amounts of alluvial outwash, glacial debris and moraine material. Lake Yosemite temporarily developed behind the glacial deposits (Huber 1987). The floor of Yosemite Valley is blanketed with approximately 610 m (2000 ft) of alluvium. Glacial deposits and other evidence of the glacial activity can be found throughout the park. Today nearly 25 small glaciers occur within the park.

During the last 3000 to 4000 years groves of the giant sequoia trees have been reestablished in isolated areas along the western slopes of the Sierra Nevada, after being nearly extirpated by the widespread and

successive Pleistocene glaciations. The giant sequoias have an affinity for sandy loam soils derived from granitic rock.

Park Collections

A number of fossil specimens are cataloged into the YOSE collections (NPS, M. Luchans YOSE Museum Registrar and C. Schierup YOSE Museum Technician, pers. comm., 2007). Two pieces of petrified wood (YOSE 982 and 15000) were collected from the Canyon of Piute Creek near Pate Valley within the park during 1922. The pieces may be part of the same specimen (C. Schierup, pers. comm., 2007). The stratigraphic occurrence of these specimens of petrified wood is unknown. There are several possible explanations for the occurrence of the petrified wood in the central part of the park. YOSE Museum Technician Chris Schierup suggests that its source may be from a local mud-lava flow containing fossil wood. Old museum documents (September 1936) include a reference to fossil wood from a mud-lava flow on the south side of Rancheria Mountain. Schierup pointed out that the 1989 geologic map for Yosemite National Park (Huber et al. 1989) shows some Miocene (20–5 million years in age) volcanic deposits in the area where the wood was collected.

The absence of an identified local source for the petrified wood raises the possibility that these fossils may have been transported either by natural processes such as glaciation or by humans. Archeological resources documented from Pate Valley support the possibility that the petrified wood in that area may be related to some cultural context such as human transport or trade.

There are also a few pieces of petrified wood, leaf impressions, and a dinosaur vertebrae (from Dinosaur National Monument) in the YOSE museum collection which are clearly not from the park. These appear to have been items obtained to support the interpretation of earth history by past rangers (NPS, C. Schierup YOSE Museum Technician, pers. comm., 2007).

There are three specimens of sedimentary rocks containing fossils. The first (YOSE 15289) is described as a fossiliferous limestone with invertebrate shells collected in 1936. Its referenced locality is inside the park on the west slope of Mt. Dana at 3444 m (11,300 ft) elevation. The other two specimens (YOSE 15499 and 15500) are referred to as “fossil-bearing sedimentary” rocks with crinoid stems and colonial coral impressions, collected in 1934. The locality is listed as Parker Pass, just outside of the park boundary. Schierup (pers. comm., 2007) points out that Huber (1987) describes isolated occurrences of Paleozoic-Triassic sedimentary beds (metasediments) within and around the park.

A specimen (YOSE 15201) identified as radiolarian chert has been cataloged into the park’s older collections database. The specimen collection locality is listed as Merced Canyon below El Portal outside of the park boundary.

Paleoecological Data from Lake Sediment Cores (Pleistocene-Holocene)

Although paleontological resources are relatively rare at YOSE, the remains of macrofossils, pollen and microscopic charcoal have been collected and analyzed from core samples of lake sediments within YOSE. Some of the initial research into Pleistocene-Holocene paleoecology in the Sierra Nevada was undertaken by Adam (1967, 1985), Wood (1975), Batchelder (1980), and Cole (1983). Detailed palynological data has been established by Davis et al. (1985), Mackey and Sullivan (1986), Byrne (1988), Davis and Moratto (1988), Anderson (1990a), and Anderson et al. (1997). Anderson and Smith (1991) provide a summary for paleoecological research conducted in both Sequoia and Kings Canyon and Yosemite National Parks. In general, the post-glacial record is better known from Yosemite than from the Sequoia and Kings Canyon area.

Adam (1964, 1967) provided an early, but comprehensive assessment of the central Sierra Nevada paleoclimate using pollen analyses. Adam collected three cores from Yosemite National Park: the Hodgdon Ranch with valley alluvium, Crane Flat from an archeological midden, and Soda Springs from a spring mound. Analyses of radiocarbon dates demonstrated a transition from glacial to modern vegetation

around 10,000 years b.p. based upon radiocarbon dates. This period was followed by a postglacial climatic optimum in the Sierra, during which two warm periods are documented. The climatic optimum terminated about 2900 years b.p. (Adam 1967).

The palynological data obtained from the lake cores indicates broadly synchronous environmental changes in the Sierra Nevada over the last 12,000 years (Smith and Anderson 1992). The climatic interpretation supports: a cooler late Pleistocene; warmer and drier early Holocene; cooler middle Holocene; and a warming during the late Holocene.

Smith and Anderson (1992) extend this climatic record back further to 16,000 years b.p. based on a core from Swamp Lake in Yosemite National Park. Their data support the occurrence of Tioga Stage deglaciation between 16,000 and 13,700 years b.p. and the appearance of a late glacial mixed conifer forest by 12,000 years b.p. Further, the record indicates that the modern Sierra Nevada montane forest became established during the early Holocene. This period is interpreted as warmer and drier than present. The mid-Holocene record indicates a cooling trend between 6500 and 3700 years b.p. (Smith and Anderson 1992).

Anderson and Carpenter (1991) undertook the first research to evaluate long-term vegetation changes within Yosemite Valley. A sediment core was taken from Woski Pond, a small oxbow depression or cut-off meander on the Merced River floodplain, in Slaughter House Meadow near the base of El Capitan. The core yielded paleoenvironmental change data spanning the last 1550 years, a period of considerable climatic change and expansion of human populations in the area. Palynological analysis indicated a rapid decline in conifers at around 650 years b.p., followed by evidence for the establishment of more open canopy vegetation types such as oaks, sage, and shrubs.

Today Yosemite National Park is one of the largest and least fragmented habitat blocks in the Sierra Nevada and supports a diverse and abundant assemblage of plants and animals. The major vegetation zones in Yosemite have developed into large north-south trending bands along the axis of the Sierra Nevada. The deep canyons dissected by the major east-west watersheds form secondary vegetation patterns. YOSE is rich in plant diversity and supports five major vegetation zones including: chaparral/oak woodland; lower montane; upper montane; subalpine; and alpine. Ensembles of rare plant species are found locally where unique soils are derived from underlying geologic formations. State-listed rare species of plants are mapped in the El Portal area, associated with soils developed from the local metamorphic rock and granite contact zone. These plant-bedrock associations were probably present in the past at YOSE.

Paleontological Resource Management, Preliminary Recommendations

- Paleontological studies within YOSE yielded significant information over the last few decades. Continuing to support paleontological studies within the park will continue to provide information regarding the paleoecology of the park.
- The NPS Geologic Resources Division can help advertise, recruit, and provide technical assistance for these efforts.

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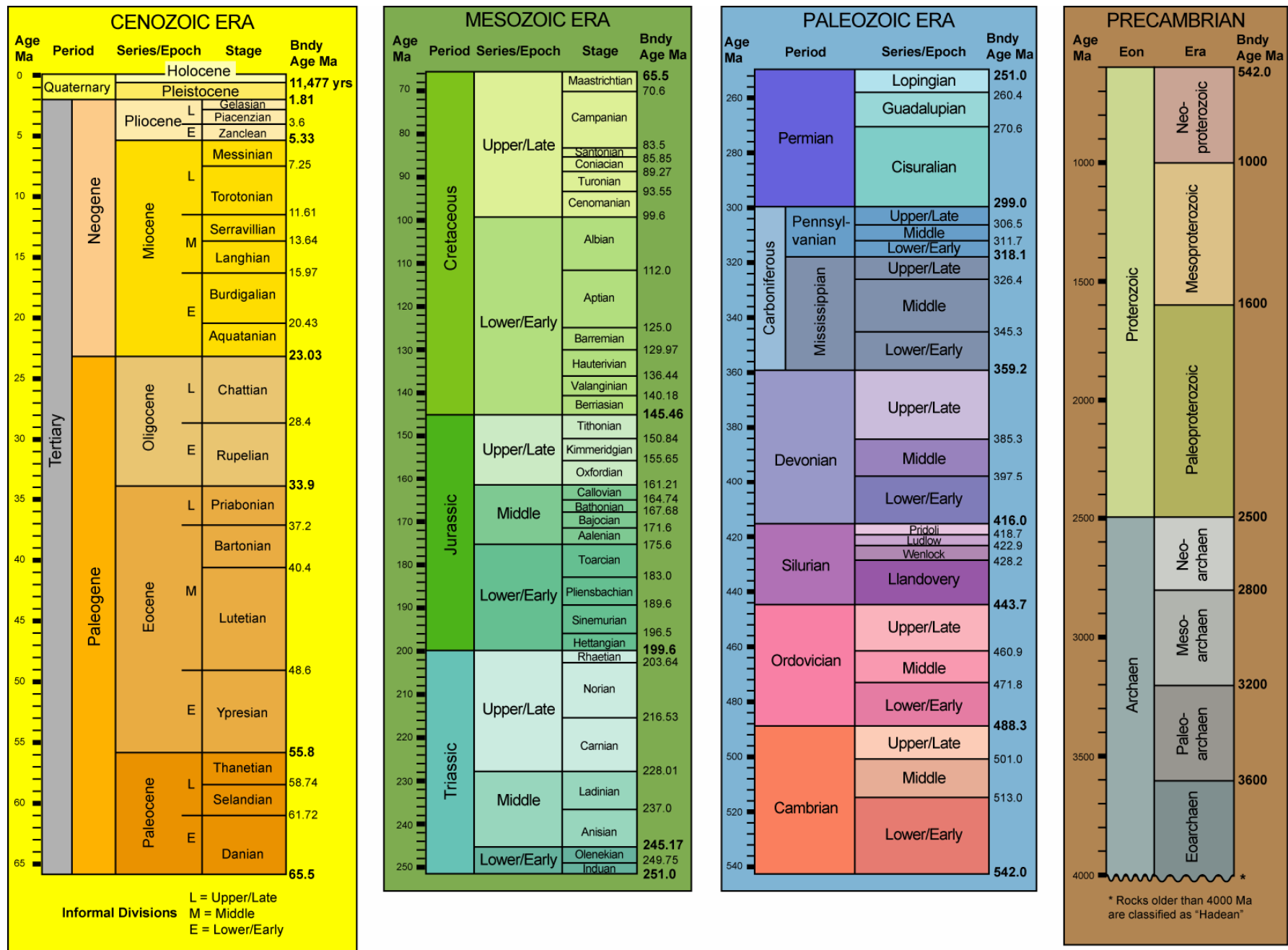


Figure 2. Geologic Time Scale. Ma = Millions of year old. Bndy Age = Boundary Age. Colors are USGS standard colors found on geologic maps. Modified from 1999 Geological Society of America Time scale (www.geosociety.org/science/timescale/timescl.pdf). Boundary dates and additional information from 2004 International Commission on Stratigraphy (www.stratigraphy.org/gssp.htm) and U.S. Geological Survey Fact Sheet 2007-3015 (<http://pubs.usgs.gov/fs/2007/3015/>).

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