National Park Service
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Rocky Mountain Network

Paleontological Resource Inventory and Monitoring
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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.

On the Cover:
A plesiosaur, *Dolichorhynchops osborni*, collected from Little Bighorn Battlefield NM in Montana, being prepared by Tobe Wilkins at Dinosaur NM during the winter of 1977-1978. The specimen is one of the more complete examples of *Dolichorhynchops* and is on display at the Smithsonian National Museum of Natural History in Washington, D.C. For more information see page 34. Photo Credit: Jim Adams, Dinosaur NM.

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Table of Contents

Introduction 1

Methods and inventory Strategies 2

Florissant Fossil Beds National Monument 6

Glacier National Park 18

Grant-Kohrs Ranch National Historic Site 28

Great Sand Dunes National Monument and Preserve… 31

Little Bighorn Battlefield National Monument 34

Rocky Mountain National Park 41

Acknowledgments 46

Appendix A: Geologic Time Scale 47

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 170 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 Inventory and Monitoring Networks, 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 Rocky Mountain Network.

The Rocky Mountain Network is comprised of 6 National Park Service areas: Florissant Fossil Beds National Monument, Glacier National Park, Grant-Kohrs Ranch National Historic Site, Great Sand Dunes National Monument and Preserve, Little Bighorn Battlefield National Monument, and Rocky Mountain National Park. These parks are located in Colorado and Montana. The Rocky Mountain Network preserves the central Rocky Mountain region's rich natural habitat. These parks share similar threats of loss of native species and habitat degradation, invasive species, pollution, urban/boundary development, and inadequate scientific data to make sound management decisions.

Fossiliferous geologic units range from the Precambrian (around 1.5 billion years ago) to the Quaternary. Significant fossils of microfossils, invertebrates, vertebrates, plants, and traces have been found in many of the parks, and the potential to discover new localities and specimens is great.

Some of the more interesting fossils in the ROMN can be found at GLAC, FLFO, and LIBI. GLAC contains some of the world's oldest fossil resources of stromatolites from the Precambrian. The paleontological material from FLFO is world renowned for the diversity and quality of preservation of fossil insects and plants. Additionally, an almost complete skeleton of a plesiosaur was discovered at LIBI.

The variety, abundance, and continuing great potential for fossils in the Rocky Mountain Network warrant the inclusion of these parks into the growing list of paleontological resource gems within the National Park Service.

ALISON L. KOCH
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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, service-wide thematic paleontological resource inventories, and Inventory & Monitoring Network based baseline paleontological resource inventories, each established with their own goals and objectives. An article outlining basic paleontological resource monitoring strategies and potential threats to fossil resources is presented by Santucci and Koch (2003).

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 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 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 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. NatureBib is a work in progress

and does not yet contain a comprehensive paleontology bibliography. The USGS Library in Reston, Virginia and Denver, Colorado 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 Additional 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 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 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 rock 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 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. 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 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 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, 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 repositories 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 (References Cited) and other associated bibliographies (Additional References). The cooperative projects section highlights projects, if any, that the park has funded or supported relating to paleontological resources. Formal datasets are established for known associated paleontological collections, research, or activities.

I&M Network reports such as this one are meant to provide network parks with sound baseline paleontological resource data. These data can then be utilized to 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 2001 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. Another legislative protection afforded to 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. That report, an "Assessment of Fossil Management on Federal & Indian Lands" summarized a number of principles relating to paleontological resources and their management from a federal government point of view. The report was also 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. 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.

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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Denver Museum of Nature and Science: http://www.dmns.org/main/en/

Montana Bureau of Mines and Geology: http://www.mbmg.mtech.edu/

NPS 2001 Management Policies (§1.4): http://www.nps.gov/refdesk/mp/chapter1.htm#ParkManagement

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.htm

Assessment of Fossil Management on Federal & Indian Lands: http://www.doi.gov/fossil/fossil.pdf

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/news/newsletter.htm

Smithsonian National Museum of Natural History Dept. of Paleobiology: http://www.nmnh.si.edu/paleo//

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/

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FLORISSANT FOSSIL BEDS NATIONAL MONUMENT

by Jason Kenworthy

Florissant Fossil Beds National Monument (FLFO) was established in 1969 to protect the abundant and diverse paleontological resources of the Florissant Formation. Fossil remains include incredibly well-preserved leaves, fruits, insects, fishes, birds, and small mammals that originally came to scientific attention in the early 1870s. Additionally, FLFO contains impressive standing stumps of petrified redwood trees.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

A comprehensive book on the fossils of FLFO was written by the park's paleontologist Herbert W. Meyer and provides an in depth look at the park's paleontology and geology (Meyer, 2003a). The FLFO paleontology database can be found at the following url: http://planning.nps.gov/flfo. This database contains a wealth of information regarding the extensive paleontological resources known from FLFO including: 559 bibliographic entries, information on more than 5,700 specimens held in over 20 museums and universities around the world, and a list of 1,994 identified fossil species. Scott et al. (2001) published a preliminary inventory of fossil resources at FLFO in an article summarizing the fossils known from National Park Service units in Colorado.

The geology of FLFO and the surrounding area is summarized in many articles and maps including: MacGinitie, 1953; Epis and Chapin, 1974; Evanoff, 1992; Evanoff, et al., 2001; Evanoff and Murphey, 1994; Murphey, 1992; Wobus, 2001; McLeroy and Anderson, 1966; and Wobus and Epis, 1978. Evanoff et al. (2001) present a stratigraphic column of the rock units found in the monument.

Fossils have been discovered in three of these units, from oldest to youngest: the Tertiary boulder conglomerate, Florissant Formation of late Eocene age, and Pleistocene gravels. The exceptionally diverse, abundant, and well-preserved fossils within FLFO are found within the Florissant Formation.

The Tertiary boulder conglomerate is an informal unit as described by Evanoff et al. (2001). Previously, Wobus and Epis (1978) mapped this conglomerate as the Eocene Echo Park Alluvium. However, the Tertiary boulder conglomerate is now thought to be equivalent to the Eocene Tallahassee Creek Conglomerate of Wobus and Epis (1978) (Evanoff, et al., 2001). Scattered silicified wood fragments are found within the boulder conglomerate (Evanoff, et al., 2001).

The late Eocene Florissant Formation has produced the extraordinary diversity and volume of fossils for which the Florissant Fossil Beds are famous. The Florissant Formation was formally named by Evanoff et al. (2001) to include all the sediments within the "Florissant Lake Beds" of many earlier authors and has been dated as 34.07 million years old (plus or minus 100,000 years) using $^{40}Ar/^{39}Ar$ (Argon isotopes) methodology (Evanoff et al. 2001). The Florissant Formation is mapped in a crescent shape in and around FLFO, with FLFO containing many of the historically important exposures of the formation. Other good exposures of the formation are in the privately-owned Clare Quarry north of FLFO and the "Florissant Road Cut" east of the town of Florissant on US Route 24. Based on the variety of lithologies, the Florissant Formation is divided into 6 informal units (from bottom to top): lower shale, lower mudstone, middle shale, caprock conglomerate, upper shale, and upper pumice conglomerate. The upper five units are exposed within FLFO. The lower shale unit is exposed in the Clare Quarry and the "Florissant Road Cut" and possibly elsewhere around the town of Florissant. The geologic history of the area is described in greater detail in a number of sources (e.g. Meyer, 2003a; Evanoff, et al., 2001; Scott, et al., 2001). Meyer (2003a) describes the processes of fossilization that likely took place preserving the fantastic Florissant Formation fossil record. In brief, lahars (volcanic mudflows and debris flow deposits) from the Thirtynine Mile volcanic complex dammed the drainages of the ancient Florissant valley forming a lake. Some of these lahars buried giant redwood trees, preserving the spectacular stumps in the petrified forest area of FLFO. Ash from subsequent eruptions settled to the bottom of the lake and began to break down, releasing silica into the lake. During times of volcanic quiescence between eruptions, diatoms found in the lake bloomed with the excess silica and formed mucus-like mats or biofilm (O'Brien et al., 2002; Harding and Chart, 2000). These mats likely trapped insects

and plants, sank to the bottom, inhibited rapid decomposition, and facilitated rapid burial, leading to the extraordinary preservation of these insects and plants. These lacustrine sediments, or "paper shales," are preserved in the shale units of the Florissant formation and account for the vast majority of fossils from the formation. The other mudstone and conglomerate units were deposited as mudflow lahars (upper part of the lower mudstone unit, and the caprock conglomerate), and stream deposits (part of the lower mudstone unit, and the upper pumice conglomerate) (Evanoff, et al., 2001). Fossil mammals are found in the lower mudstone unit.

The extraordinary fossils of the Florissant Formation have been the subject of a voluminous amount of research since they were first collected by Theodore Meade in 1871 (Meyer and Weber, 1995; Meyer, 2003a). However, it was the work during the mid-1870s of geologist A.C. Peale of the Hayden Survey and of paleontologists Samuel Scudder and Leo Lesquereux that first opened the eyes of the scientific world to the fossils, especially the plants and insects, found in and around what is now FLFO. Meyer et al. (2004) summarize the wide diversity of research during the 130 years after Peale's report, which has resulted in the collection of an estimated 50,000 museum specimens from the Florissant Formation in and around FLFO (Scott, et al., 2001). Many of the historical research papers are cited in the additional references section of this report, and a complete bibliographic listing can be found in Meyer (2003a).

The flora of the Florissant Formation has received considerable scientific attention due to the remarkable preservation of wood, leaves, flowers, fruits, pollen, and spores from at least 150 different species ranging in size from 12 foot tall (38 feet in circumference) petrified tree trunks to microscopic pollen and spores. Also like the insects, the vast majority of plant specimens have been found in the "paper shales", in particular the middle shale and lower shale unit (Evanoff, et al., 2001). While Scudder was describing some of the first insect specimens from the Florissant Formation, Leo Lesquereux described over 100 new species of plants from the formation. Lesquereux published the first scientific paper regarding Florissant in 1873 and followed with two lengthy monographs on the fossil plants in 1878 and 1883. Subsequent authors also published various publications regarding the flora of the Florissant Formation including W.F. Kirchner in 1898, T.D.A. Cockerell (e.g. 1906a,b), A. Hollick in 1907 and 1909, F.H. Knowlton in 1916, and R.W. Brown in 1937 and 1940. However the definitive work on the Florissant flora was published by MacGinitie in 1953. It is the most comprehensive systematic paleontological report yet published regarding the plants of the formation. Even after four decades, subsequent authors including MacGinitie in 1969, Manchester (1980s-1990s), Manchester and Crane in 1983 and 1987, Wolfe and Tanai in 1987 and Schorn in 1998, only made slight and taxonomic revisions to MacGinitie's original work (Manchester, 2001). The most recent taxonomic revisions and updates on the fossil flora is presented by Manchester (2001) and Meyer (2003a). The other papers within Evanoff et al. (2001b) volume on the flora and stratigraphy of the Florissant Formation also summarize the historical descriptions and modern uses of the fossil flora.

Plants known from the formation include: redwoods, white cedar, pine, spruce, hickory, redbay, elm, linden, *Conzattia*, *Thouinia*, golden-rain tree, tree of heaven, *Dipteronia*, *Eucommia*, oak, willow, poplar, rose, mountain-mahogany, currant, and maple (Meyer and Weber, 1995). Overall there are between 96 and 163 species of plants represented by megafossils such as leaves, flowers, etc. (Manchester, 2001) although the true number is probably around 120-140 (Meyer, 2003a). Manchester (2001; Table 1) recognizes 31 "reliable" families that are definitively defined in Florissant flora. There are many other families likely represented, however some of the familial associations are unclear in varying degrees. Broad-leaved hardwoods dominate the fauna while conifers account for just 11 species (Meyer, et al., 2004). The known fossils likely represent a wide variety of habitats found surrounding the ancient Lake Florissant and its evirons (MacGinitie 1953; Meyer 2003). Manchester (2001) also summarizes abundance of various megafossil taxa collected by MacGinitie (1953). *Fagopsis* (extinct member of beech family) was the most abundant at 31%. An extinct member of the elm family, *Cedrelospermum* (*Zelkova* of MacGinitie) represents another 10% with *Chamaecyparis* (white cedar), *Typha* (cattail), and *Populus* (poplar) each representing over 3% of the total flora. Taken together, these five genera accounted for approximately 60% of MacGinitie's flora. However there may be some collecting biases, as explained by Manchester (2001).

Some of the most impressive floral megafossils found within FLFO are indeed "mega" fossils. The standing stumps of petrified wood are up to 12 feet tall (3.7 meters) and 38 feet (11.6 meters) in circumference as

displayed by the specimen appropriately named "Big Stump". Most of the stumps within the petrified forest of FLFO were preserved in situ by a lahar that makes up the upper part of the lower mudstone unit and have been identified as *Sequoia affinis* (redwood). *Sequoiaoxylon pearsallii* was the original taxonomic designation, in fact "Big Stump" is the type specimen, but *S. perasallii* was placed into synonymy with *Sequoia affinis* by MacGinitie (1953), although some workers (e.g., Gregory-Wodzicki (2001)) continue to use the name *Sequoiaoxylon*. As reported by Gregory-Wodzicki (2001), the fossil redwoods at FLFO enjoyed a more favorable growing climate than their modern counterparts, the coast redwood and giant sequoia. This determination was based on tree-ring width and variability studies of fossil and modern redwoods. In addition to the common *Sequoia* wood fossils, Wheeler (2001) identifies five types of dicotyledonous wood from within FLFO. The most common of these, *Chadronoxylon florisantensis* represents a new genus and species (Wheeler, 2001). Together, these five woods double the number of late Eocene fossil woods known from North America that have been anatomically described (Wheeler, 2001). In an indication of the popular appeal of the petrified stumps, Walt Disney visited the commercial Pike Petrified Forest (now a part of FLFO) in 1956. Disney personally purchased a large (7.5 feet/2.3 meter in diameter) petrified stump for display at Disneyland's Frontierland area in Anaheim, Calif. (Meyer, 2003a; Scott, et al., 2001; Meyer, et al., 2004; Smith, written communication, 1999). The park also contains the only known "family circle" trio of redwood tree stumps in the fossil record (Meyer, et al., 2004).

The microfossil palynoflora (pollen and spores) probably represents at least 150 different taxa (Leopold and Clay-Poole, 2001; Wingate and Nichols, 2001; Manchester, 2001). About 25 plant genera, according to Leopold and Clay-Poole (2001), are known only from the microfossil record. Gymnosperm pollen typically dominates the assemblage; however, angiosperm pollen is more diverse (over 100 different species) but much less abundant (Wingate and Nichols, 2001). The Florissant Formation may contain the earliest record of the Asteraceae (sunflower) Family in the form of pollen (Wingate and Nichols, 2001).

The fossil plants have been used to estimate the paleoclimate and elevation of ancient Lake Florissant in the late Eocene. These estimates are summarized by Meyer (2001) and range from MacGinitie's original estimate of a mean annual temperature (MAT) above 64°F (18°C)and an elevation of approximately 980-3,000 feet (300-900 m) to modern estimates of 52-57°F (11-14°C) MAT at an elevation of approximately 6,200-13,500 feet (1900-4100 m). There are no close modern analogues to the floral assemblage of FLFO, however the cloud forest in the Sierra Madre Oriental of northeastern Mexico has been suggested as one modern analogue (Leopold and Clay-Poole, 2001; Meyer, 2003b). The fossil flora also displays a wide variety of insect feeding traces which provides important information regarding the coevolution of plants and insects (e.g. Labandiera, 1997; Smith, 1998, 2000).

The invertebrate fauna of the Florissant Formation is dominated by insects found in the paper shale units. Approximately 1,500 different species of insects and spiders have been described and are still valid in the taxonomic literature (Meyer, 2003a). The insect fauna was first described by Samuel Scudder in the late 1870s following expeditions to the site by himself and by the Princeton Scientific Expedition (both visited the area in 1877) (Meyer, 2003a; Meyer, et al., 2004). His work culminated with the 1890 publication *Tertiary Insects of North America*, which included many descriptions of new species of Florissant Formation insects. Subsequently, various scientists further described the insects including T.D.A. Cockerell, who published over 100 papers on the insects and plants from 1906-1941, H.F. Wickham (beetles, 1907-1908), C.T. Brues (bees, 1906-1910), M.T. James (flies, 1937-1941), A.L. Melander (flies, 1949) and F.M. Carpenter who published a monograph on the fossil ants (1930).

Known insects from the Florissant Formation include mayflies, dragonflies, cockroaches, bristletails, grasshoppers, earwigs, aphids, green lacewings, flies, bugs, beetles, wasps, ants and butterflies (Meyer, 2003a). Brief summaries are provided below, using information complied by Meyer (2003a). Complete species lists for the insects can be found in Meyer (2003a) or the FLFO Paleontology Database.

The mayflies (Order Ephemeroptera) are not common, however both adults and nymphs have been described for a total of 9 species in three families. Dragonflies and damselflies (Odonada) are represented by adults and nymphs of 21 different species in five families. The extraordinary level of preservation, including wing venation patterns on many Odonada species aids in their identification and scientific significance.

Grasshoppers, crickets, and katydids (Orthoptera) are represented by 19 different species in six families. The grasshoppers are the most common fossils of the Orthoptera. One fossil specimen even preserves the ovipositor of a female grasshopper. Mantids (Mantodea) are only represented by isolated wings, no body fossils have yet been found. However the delicate preservation typical of the Florissant Formation has aided in the identification of three different species in two families. Cockroaches (Blattaria) are known in the fossil record from the Pennsylvanian Period some 270 million years before the late Eocene Florissant Formation was deposited. Three species, representing two families have been described from the Florissant Formation. Termites (Isoptera) known from within the Florissant include five species in three families. Most of the termite fossils are of "reproductive" termites which had weak wings allowing wind to carry them over the lake. The 12 species of earwigs (Dermaptera) found within Florissant are all from the extinct genus, *Labiduromma*. Only one species of web-spinner (Embiidina), which construct silken tunnels underground or through leaf litter, is represented in the Florissant.

The true bugs (Hemiptera) are very common in the modern world and are also well-represented as Florissant fossils. Both terrestrial bugs and aquatic bugs have been discovered for a total of 17 families. The terrestrial bugs include lace bugs, leaf bugs, assassin bugs, seed bugs, squash bugs, burrower bugs, and stink bugs. The terrestrial bugs (118 species) are more common than the aquatic or semiaquatic bugs, which are represented by nine species, and occupied a wide range of habitats around Lake Florissant. Aquatic bugs are represented by waterscorpion, backswimmer, and water boatmen specimens. Semiaquatic bugs, including riffle bugs and water striders, have also been discovered.

The order Homoptera includes cicadas, hoppers, psylids, aphids, and scale insects, all of which are found in the Florissant Formation with a total of 72 different species in 12 families. Like their modern relatives, these insects were probably herbivorous and, with future research, may shed light on insect-plant coevolution. Nineteen species of the terrestrial snakeflies and lacewings (Neuroptera) have been found.

By far the most well-represented insects at Florissant are the beetles (Coleoptera). Although Coleopteran taxonomy is not well understood, about 595 different species in 55-60 families have been identified. Beetles make up about 40% of modern insect species and likewise account for 38% of the fossil assemblage at Florissant. Their hardened body parts, especially the elytra make the beetles well suited for fossilization. Beetles in the Eocene, as today, mastered many different ecological niches. Ground, diving, rove, scarab, wood-boring, click, soldier, ladybug, tumbling flower, darkling, long-horned, leaf, weevils, and snout beetles are just a small portion of the extraordinary Coleopteran diversity in the fossil record at Florissant.

The four species of scorpionflies (Mecoptera) represent omnivorous insects that likely lived in moist habitats near the lake. True files of the order Diptera are common in the fossil record of the Florissant Formation, as indicated by the 238 different species known from the formation. One of the largest families represented is the crane flies which lived near the waters of the lake. Other diverse families of flies include: robber flies, bee flies, dance flies, and syrphid flies. The Florissant Formation also contains the only known fossils of the infamous tsetse fly (Glossinidae Family).

Caddisflies of the Trichoptera order are represented by 30 different species. Caddisfly larvae pupate inside cases that they construct from sand grains, pebbles, leaves and twigs, and other materials. One unique specimen serves as a holotype for both a caddisfly larval case and the small ostracode shells the caddisfly used to construct its case.

The butterflies (Lepidoptera) found within the Florissant Formation have been assigned to 12 species in 11 genera and three families, making it the most diverse butterfly assemblage known world wide. In addition, one of the finest butterfly specimens known, *Prodryas persephone* was described from the Florissant Formation by Scudder in 1878. Moth (Lepidoptera) fossils are also known from the formation and are represented by nine different species. Curiously, modern moths outnumber modern butterflies by a 10 to 1 margin.

Sawflies, wasps, bees, and ants, all in the order Hymenoptera, are very common within the Florissant Formation. Approximately 306 different species have been discovered within the formation. Ants, like

termites, have a taphonomic bias which favors the winged reproductive caste of social species. As they were capable of limited flight, wind may have pushed them over the surface of the lake, allowing for their preservation in the lake sediments of the Florissant Formation. One specimen of the yellow jacket or hornet *Palaeovespa* serves as the logo for FLFO.

The sheer diversity of the insect fossils found within FLFO is significant in and of itself, however, it is the exceptional preservation (including, in some cases, wing venation and coloration patterns) of those insects that make them invaluable to science. For example, the FLFO Paleontology Database lists about 3,680 published museum specimens of FLFO insects. Of those, more than 1,250 have been designated as holotypes.

While insects by far dominate the invertebrate fauna, other groups are also represented. Approximately 50 species of arachnids have been discovered in the "paper shales" (FLFO Database Records, 2004). The arachnids include wolf, silk, orb web, hunting, and segestriid (tube dwelling) spiders in addition to tarantulas, many of which were described by A. Petrunkevitch in 1922 (Meyer, 2003a). Interestingly, the spiders are usually preserved with their legs extended, rather than curled under the body which is common after a spider dies. Warm or acidic water apparently prevents this curling of the legs. Thus the extended legs on the spiders may indicate that the waters of Lake Florissant were warm and/or acidic (Meyer, 2003a).

The molluscan diversity is relatively low, represented by one species of fingernail clam (*Sphaerium florissantense*) and six gastropod species, which are found in the caprock conglomerate, upper pumice conglomerate, and the shale units (Meyer, 2003a; Evanoff, et al., 2001). Ostracodes are also known from the formation and are found in the shale layers, especially the upper shale unit (Evanoff, et al., 2001).

The vertebrate fauna of the Florissant Formation is limited to fish, birds, and mammals, with fish being the most common. The fish fossils have been assigned to four genera *Amia* (bowfin), *Amyzon* (sucker), *Ictalurus* (catfish), and *Trichophanes* (pirate perch) (Meyer, 2003a). Although perhaps better known for his dinosaurian discoveries, E.D. Cope originally described all the fish from the Florissant area in the late 1870s. The bird fossils are extremely rare and include taxa of uncertain phylogenetic relationships. The five taxa include *Eocuculus* (cuckoo) and *Palaeospiza* (roller) (Chandler, 1999). *Eocuculus cherpinae* was named from a very rare nearly complete skeleton found within the Clare Ranch (Chandler, 1999). Most of the fish fossils and nearly all the bird fossils are found in the lower shale unit, not exposed within FLFO (Evanoff, et al., 2001). The mammalian fauna is more diverse than the other vertebrates, and includes the mouse opossum *Herpetotherium* (*Peratherium*), which is the only mammal yet found in the lacustrine shale layers (Meyer 2003; Evanoff and deToledo, 1999). Other mammal fossils found in the lower mudstone unit include fossils of *Mesohippus* (small horse), *Leptomeryx?* (small artiodactyl), *Merycoidodon* (oreodont), and a large brontothere (Evanoff, et al., 2001; Worley, 2004a,b). During the summer of 2003, a Geological Society of America GeoCorps intern discovered additional mammal material within the lower mudstone unit of FLFO (Worley, 2004a,b). This material included molars of a brontothere, a small artiodactyl (*Leptomeryx* cf. *L. speciosus*), and a member of the merycoidodontidae family. In addition Worley (2004a,b) discovered six lagomorph teeth marking the first discovery of rabbit fossils within FLFO. Four of these teeth are from the genus *Megalagus*, while the other two may be from the genus *Paleolagus*. Teeth and/or jaw fragments of a number of extinct rodents were also discovered by Worley (2004a,b) and include: two species of *Ischyromys* (one tentatively identified as *Ischyromys* cf. *I. douglassi*), two species of *Pelycomys* (both may be new species), *Eutypomys parvus* (extinct relative of modern beavers), *Adjidaumo minimus* (eomyid rodent), *Domnina* cf. *D. thompsoni* (earliest known shrew), *Centetodon magnus* (insectivore), and a talpid (member of the mole family) rodent. The mammalian fauna is scientifically significant as reported by Evanoff et al. (2001) and Evanoff and deToledo (1999). The mammal assemblage indicates a Chadronian age (latest Eocene) for the Florissant Formation which has been variously assigned to the late Eocene and/or early Oligocene by different authors. A Chadronian age is consistent with the isotopic age determination of the Florissant Formation (Evanoff, et al., 2001a).

The Pleistocene gravels of FLFO do not frequently produce fossils, however a fragmentary mandible and molar tooth of a mammoth, likely *Mammuthus columbi,* were discovered along the road leading to the visitor center (Meyer and Weber, 1995; Veatch, et al., 2004). Interestingly, this specimen was discovered by a park intern who was helping to park cars during activities relating to the 25th Anniversary of FLFO in 1994 (J.

Rodeck, electronic communication, 1997). The specimen has been radiocarbon dated to 49,830 years old plus or minus 3,290 years, making the specimen older than the reliable range of radiocarbon dating (Meyer, 2003a; Meyer, et al., 2004). The high elevation (8,366 feet/2,550 m) of discovery, although not unique, is significant because it indicates that mammoths were at high elevations before the last glacial maximum about 18,000 years ago (Veatch, et al., 2004).

During the 98 years following the first discovery of the fossils in 1871 to the establishment of FLFO in 1969, resource management of the fossils of the Florissant Formation underwent an interesting history which is detailed in a number of publications including Meyer and Weber (1995), Meyer (2003a), and Meyer et al. (2004). Private, amateur, and personal collecting was very popular on the site and even led to the creation of "drive-thru" commercial attractions including Coplen Petrified Forest and Pike Petrified Forest (both now a part of FLFO). The Florissant Fossil Quarry (Clare Quarry, outside of FLFO) is still operating today and has been open since 1950. Wodzicki (2001) quotes Kimmet (1986) who stated "an early photo of the forest shows such a profusion of petrified stumps, limbs, and branches that the area seemed almost impassable." Today, the only stumps left are those "too large to be moved or those still buried" (Wodzicki, 2001). In fact "Big Stump" still displays the broken saw blades of an aborted effort to ship the stump east for exhibit (Meyer 2003).

As early as 1882, 24 years before the Antiquities Act and 34 years before the creation of the National Park Service, geologists were complaining of "vandal tourists" breaking up the stumps and logs and removing them (Wodzicki, 2001 referencing Kimmet, 1986). Interestingly, owners of the Pike Petrified Forest and nearby Colorado Petrified Forest offered to sell or lease their forests to Walt Disney (who purchased a large petrified stump in 1956) stating that "the fossil beds have been worked each summer by college professors for specimens and seem to be inexhaustible. However, these beds should be closed to the public and promoted for their actual value—that is, specimens for museums in the case or rare items, and sale of lesser valued items as souvenirs." (D. Smith (Walt Disney Archives), written communication, 1999). As an indicator of the abundance of fossils, Samuel Scudder collected approximately 5,000 specimens in five days for his work on the insects of the Florissant Formation (Meyer and Weber, 1995). A proposed housing development in the late 1960s also threatened to adversely impact the paleontological resources of the Florissant area.

It wasn't until 1969, when FLFO was established, that the area was afforded legislative protection. In 1984, the monument buried an additional number of stumps apparently to prevent future vandalism (Wodzicki, 2001). Herb Meyer is the park's paleontologist, one of only 15 in the entire NPS, and has served in that role since 1994. The paleontology program at FLFO now includes a rigorous monitoring program of the monument's 59 documented fossil localities (Scott, et al., 2001). Research regarding the fossils of Florissant is continuing and encouraged by FLFO as evidenced by the nearly 50 presentations and posters regarding Florissant fossils delivered at Geological Society of America meetings since 2001. The paleontology program at FLFO has produced numerous tangible results. For example, the comprehensive Paleontology Database was made available after over seven years of research. During the summer of 2000, shelters were constructed over many of the large petrified stumps near the park's visitor center (Rodeck, et al., 2001). A project studying various conservation and stabilization techniques for the *in situ* stumps was initiated during 2004 through an Association for Women Geoscientists internship. Project P.I.C.K. (Paleontological Interns Conserving Knowledge) is part of an extensive online and on-site paleontology curriculum that involves FLFO, Woodland Park High School, Denver Museum of Nature and Science and the Florissant Fossil Quarry (Lutz-Ryan, et al., 2001a,b; National Park Service, 2004a,b).

COOPERATIVE PROJECTS:

- Florissant Paleontology Database-Compiled with the cooperation of the National Park Service and 18 museums worldwide (1994-2001).

- Geologic and Paleontologic Scoping of Florissant Fossil Beds National Monument – National Park Service Geologic Resources Division (October 1998).

- Project P.I.C.K. Online and on-site collaboration and educational program involving FLFO, Woodland Park High School, Denver Museum of Nature and Science and the Florissant Fossil Quarry (2001-2003).

- Research and Conservation of the Eocene Piedra Chamana Petrified Forest, Peru, involving collaboration of FLFO, National Science Foundation, Clark University, and San Marcos University (Peru), (2000-present and currently funded by NSF; Meyer is co-PI on NSF grant)

- Evaluation of BLM paleontological resources in South Park that relate to the resources at Florissant (2004-present)

- Preparation and publication of *Geologic Guidebook to the Gold Belt Byway, Colorado*, prepared in collaboration between FLFO, BLM, Cripple Creek and Victor Gold Mining Company, University of Colorado Museum, Front Range Community College, and the Gold Belt Tour Scenic and Historic Byway Association (publication cited in references as Henry et al., 2004) (1995-2004).

- Partner in the Colorado Digitization Project, to digitize images of fossils and historic documents (2000-2003)

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DATA SETS:

DS-FLFO-XXX Florissant Fossil Beds National Monument Files, Archive, Museum Records. 8/1969–present. (hard copy data; reports; electronic data; photographs; maps; museum collections; publications). Originated by Florissant Fossil Beds National Monument; status: Active.

DS-FLFO-XXX Florissant Fossil Beds National Monument Paleontological Archives. 5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

DS-FLFO-XXX Florissant Fossil Beds National Monument Paleontology Database. 1994-present. (electronic data; specimen photos; museum collection information; taxonomic information). Originated by Meyer, Herb; status: Active. Online: http://planning.nps.gov/flfo

GLACIER NATIONAL PARK

Glacier National Park (GLAC) was initially preserved in 1910 and has undergone multiple boundary changes and redesignations. Rugged peaks, glaciers, and glacial streams and lakes comprise the landscape. Grizzly bears, wolves and other wildlife inhabit this terrain.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The geology within and around Glacier National Park has been studied for nearly 100 years and the geological formations of GLAC, and fossils preserved within many of them, have been described in numerous publications. The basic geology and paleontology of these rocks is summarized here. National Park Service (2004) published a geologic resource evaluation report which includes basic geologic formation descriptions and summaries of paleontological resource potential within GLAC. The geologic resource evaluation report also contains a number of recommendations regarding paleontologic resources within the park and future management and interpretation potential. One of the recommendations is to perform a comprehensive study of the paleontological resources of GLAC.

Whipple (1992) provides a geologic map of the park. Ross and Rezak (1959) provide a summary non-technical publication on the geology and paleontology of Glacier National Park. Rezak (1957) and Horodyski (1993) summarized the extensive Precambrian fossils, mostly algal stromatolites, from GLAC. Many of these fossils are visible along the Going-to-the-Sun Road, as described in a number of publications describing the GLAC geology such as Mudge et al. (1977) and Raup (1983) among many others. Stromatolites within GLAC and the surrounding area have been studied since the early 1900s with C.D. Walcott's pioneering paper on the stromatolites being published in 1914. Precambrian fossils are rare worldwide, and at nearly 1 billion years old, are among the oldest recognizable fossils in the fossil record. Therefore fossils from the geological formations exposed within GLAC are especially significant. The Precambrian Belt Supergroup encompasses many of these significant Precambrian-aged formations as described by Whipple (1992).

The Precambrian Prichard Formation is composed of slate and sandstone and is the oldest formation of the Belt Supergroup. It is only mapped on the west side of GLAC. However, the Waterton and Altyn formations, found on the east side of the park, are considered stratigraphically equivalent to the Prichard Formation (Whipple, 1992). Horodyski (1981) reports poorly preserved sphaeromorphic acritarchs (enigmatic algal-like organisms of uncertain taxonomic affinity) that have undergone metamorphism associated with the high pressure of burial.

The Precambrian Waterton Formation is the oldest fossiliferous unit in GLAC and is stratigraphically equivalent to the lower part of the Prichard Formation (Whipple, 1992). This formation is primarily composed of dolomite. Whipple (1992) reports stromatolites from this unit. Stromatolites are considered "common" in the Waterton Formation by National Park Service (2004).

The Precambrian Altyn Formation is composed of limestone and dolomite and is considered equivalent to the upper part of the Prichard Formation (Whipple, 1992). The fossil crustacean, *Beltina danai*, and *Beltina* chitinous plates are found in the Altyn Formation (Willis, 1902; Daly, 1912). Fenton and Fenton (1931) report algal limestones and *Collenia columnaris* stromatolites. The first investigations of microfossils from the Altyn Formation were reported by White (1974a). White (1984) also discusses stromatolites in the Altyn Formation in conjunction with shallowing-upward cycles.

The Precambrian Appekunny Formation is primarily composed of argillite. R. J. Horodyski (1982b) discovered "problematic bedding-plane markings" from the Appekunny Formation and further investigations, including cooperative projects completed by E. L. Yochelson and M. A. Fedonkin in 2001, has resulted in reporting these markings as the newly described *Horodyski moniliformis* (Yochelson and Fedonkin, 2001; Fedonkin and Yochelson 2002). This locally abundant fossil is described as resembling a "string of beads" and Fedonkin and Yochelson (2002) suggest that they were multicellular, tissue-grade,

colonial eucaryotes. Additionally, it is suggested that they were benthonic and primarily lived in poorly oxygenated waters and probably ingested chemosynthetic bacteria as opposed to utilizing photosynthesis.

The Precambrian Grinnell Formation is composed of argillite. Rezak (1957) and Horodyski (1983) report mound-shaped dolomitic stromatolites occurring about 100 feet (30 m) from the base of the formation.

The Precambrian Empire Formation is primarily composed of shale, argillite, and quartzite. Fenton and Fenton (1937) report cryptozoan beds with *Collenia*? from this geologic unit. However, National Park Service (2004) indicates no potential paleontological resources from the Empire Formation within GLAC.

The Precambrian Helena Formation (or Siyeh Formation, nomenclature formerly used in the U. S. and still used in Canada) is composed of limestone, dolomite, and mudstone. *Collenia* (stromatolite) biostromes that range from 10 to 900 feet (3-274 m) thick occur at the base of this geologic unit (Knopf, 1950; Fenton and Fenton, 1931; Whipple, 1992; National Park Service, 2004). This significant zone of the Helena Formation also contains the stromatolites *Baicalia* and *Conophyton*, representing a moderate-energy reef front to lower-energy back-reef environments respectively (Horodyski, 1983). Mudge (1972) also reports conglomerates of stromatolites from the Helena Formation.

The Precambrian Snowslip Formation is composed of argillite, siltstone, quartzite, mudstone, and sand. Stromatolites, stromatolite zones, and stromatolitic limestones are reported from the Snowslip Formation (Childers, 1963; Whipple and Johnson, 1988). Microfossils preserved as sheaths of oscillatoriacean cyanophytes (cyanobacteria) are found in calcareous stromatolite deposits of the Snowslip Formation (Horodyski, 1979a). Horodyski (1982a; 1993) reports impressions of thin, wrinkled microbial mats from the grayish-red mudstone of the Snowslip Formation. National Park Service (2004) lists stromatolites as "common" in some beds of this unit.

The Precambrian Shepard Formation is primarily composed of quartzite. Mudge (1977) reports stromatolite beds in the lower part of the Shepard Formation. Mound-shaped dolomitic stromatolites from this formation are discussed by Horodyski (1983). National Park Service (2004) lists stromatolites as "common" in the Shepard Formation.

The Precambrian Mount Shields Formation is contains argillite, siltstone with locally present limestone beds. These limestone beds commonly contain stromatolites (National Park Service, 2004).

The Middle to Late Jurassic Ellis Group, Late Jurassic Morrison Formation, and the Early Cretaceous Mount Pablo Formation are mapped undivided in GLAC (Whipple, 1992). Limestone and sandstone deposits comprise the bulk of the sediments. All three of these geologic units are known to be fossiliferous in many areas of the Rocky Mountains. The Ellis Group is composed of four fossiliferous formations and pelecypods, *Myacites*, and other mollusks are reported from these units (Iddings and Weed, 1894; Cobban et al., 1945; Robinson and Barnett, 1963). The top (youngest) formation in the Ellis Group is the Swift Formation. Imlay (1982) reported many *Buchia concentrica* (marine bivalve) specimens in addition to the ammonite *Cardioceras* (*Scoticardioceras*) *whitfieldi* from the Swift Formation along the southern edge of the park. The Morrison Formation is well-known due to an abundance of dinosaur material. The Morrison Formation is known to be highly fossiliferous in many exposures throughout the Rocky Mountains and contains microfossils, paleobotanical material, and invertebrate, vertebrate, and trace fossils. Form more information on the Morrison Formation see Turner et al. (2004). Exposures of the Morrison within GLAC are limited (Whipple, 1992; G. Engelmann, electronic communication, 2004). The Mount Pablo Formation is nonmarine and Mudge and Rice (1982) list fossil pollen in their report.

The Early Cretaceous Kootenai Formation is primarily composed of claystone, siltstone, and conglomerate. Miller and LaPasha (1984) describe six species of conifers based on leafy twig, pollen cone, seed cone, and seed material from the Kootenai Formation of Montana. Brown (1975) reports the occurrence of ginkgophytes, *Ginkgo pluripartita* and *Stenorhachis* sp., from the Kooetanai Formation. Additional paleobotanical material includes *Sagenopteris* and a new fossil moss *Diettertia montanensis* (Brown, 1972; Brown and Robinson, 1974). Bivalves, gastropods, coiled gastropod molds, and gastropod limestones are

found in this geologic unit (Robinson and Barnett, 1963; Rice and Cobban, 1977; Witkind and Prostka, 1980; Tysdal et al., 1989a; Whipple, 1992; National Park Service, 2004). Whipple (1992) also reports that many of these fossils are found in coquina (rock type composed almost entirely of broken shell fragments) lenses near the top of the formation. *Toxolophosaurus cloudi*, a trilophosaurid reptile, was first described using two small jaws found from the Kootenai Formation in Montana (Olson, 1960).

The Early Cretaceous Blackleaf Formation is composed of shale and sandstone. The stratigraphy and paleontology of the Blackleaf Formation is described by Cobban et al. (1976). Rocks and molluscan fossils described as "Colorado Formation" along the southeast boundary of GLAC by Cobban (1951) have been assigned to the Blackleaf Formation (Cobban, et al., 1976). Cobban (1951) also presents a road log of geological exposures and fossils found along U.S. Highway 2 starting near the southeast boundary of GLAC. Stebinger (1918) reports a list of fossils from the Blackleaf Formation that includes the bivalves *Inoceramus*, *Ostrea*, the brachiopod *Lingula*, and fish vertebrae. Lang and McGugan (1988) also report agglutinate foraminifera, fragmented plant debris, mollusk fragments (especially *Inoceramus*), and fish fragments. Ballard et al. (1993) report several microfossils from the Blackleaf Formation, including the dinoflagellate genus *Ovoidinium* and the miospore genera *Cicatricosisporites*, *Corollina*, *Eucommidites*, *Lillacidites*, and *Stephanocolpites*. Tysdal et al. (1989b) recovered spores, pollen, and ferns during their investigations of assigning strata. Rice and Cobban (1977) report small horizontal burrows (*Arenicolites*) and carbonized plant fragments from the Blackleaf Formation.

Whipple (1992) includes a number of fossiliferous formations as undivided upper Cretaceous sedimentary rocks. National Park Service (2004) briefly summarizes the very diverse paleontological resources from the formations not separately mapped on Whipple's (1992) map. These upper Cretaceous formations are only found in limited exposures and include the Willow Creek Formation, St. Mary River Formation, Horsethief Sandstone, Bearpaw Shale, Two Medicine Formation, Virgelle Sandstone, and Telegraph Creek Formation.

The Willow Creek Formation contains a variety of clayey rocks, mudstone, and sandstone. Potential paleontological resources include fresh water mollusks and occasional dinosaur bones (National Park Service 2004).

The St. Mary River Formation consists of mudstone and sandstone. These sediments may produce fossils of nonmarine bivalves (e. g. *Fusconaia? stantoni*) and fossil leaves. A partial of the dinosaur *Montanaceratops* has also been discovered within the St. Mary River Formation (National Park Service, 2004).

The Horsethief Sandstone is commonly crossbedded and contains a number of molluscan fossils. These fossils include brackish water bivalves such as *Crassostrea wyomingensis* and *Veloritinia occidentalis*. The gastropod *Melania wyomingensis* and the shallow-water marine bivalve *Tancredia?* are also known from the formation (National Park Service, 2004).

The Bearpaw Shale, a marine unit, is very fossil rich. Known paleontological resources include: three species of the uncoiled ammonite *Baculites* are known from the formation as are the ammonites *Hoploscaphites* and *Placenticeras*. Marine bivalves such as *Nucula*, *Nuculana*, *Inoceramus*, *Oxytoma*, *Cymella*, and *Nymphalucina* are also reported within the Bearpaw Shale (National Park Service, 2004). A short-necked plesiosaur was discovered within the Bearpaw Shale of Little Bighorn Battlefield National Monument (see page 34 of this report).

The Two Medicine Formation, consisting primarily of mudstones, contains a variety of fossils including the herbivorous dinosaur *Brachyceratops montanensis*. A partial skeleton of *B. montanensis* is on display at the Smithsonian National Museum of Natural History, was collected in the Blackfoot Indian Reservation east of GLAC (J. Young, personal communication, 2004). Fishes, ostracodes, and fresh-water mollusks are also known from the formation (National Park Service, 2004).

The Virgelle Sandstone contains ammonite fossils including *Desmoscaphites bassleri* and *Inoceramus lundbreckensis* (National Park Service, 2004).

The shales and sandstone of the Telegraph Creek Formation contain a relatively limited fossil assemblage compared to other Cretaceous-aged formations within GLAC. Nevertheless, some mollusks, fossil wood, and burrows are noted by National Park Service (2004).

The Late Cretaceous Marias River Shale consists primarily of dark gray shale with lesser amounts of sandstone, siltstone, bentonite, and limestone. The stratigraphy and paleontology of the Marias River Shale is described by Cobban et al. (1976). The molluscan and cephalopod fossils described by Cobban et al. (1958) from near the southeast boundary of GLAC as coming from the upper part of the "Colorado Formation" are considered to be from the Marias River Shale (Cobban, et al., 1976). Lang and McGugan (1988) report agglutinate foraminifera, planktonic foraminifera, benthonic foraminifera, radiolarians, *Inoceramus* sp. fragments, fish scales, and comminuted plant debris from the Marias River Shale. Bivalves and other mollusks are found in this unit, including the ammonites *Neocardioceras juddi*, *Watinoceras reesidei*, and *W. hattini* (Obradovich and Cobban, 1975; Cobban, 1988a; Cobban, 1988b; National Park Service, 2004). Christensen (1993) studied 150 specimens, the bulk of which came from the Marias River Shale of Montana, in order to describe a new species of belemnite (*Actinocamax cobbani*). Landman (1982) described embryonic shells of *Baculites* from two horizons on the Marias River Shale in Montana. During these investigations, Landman also discovered foraminifera, scaphites, gastropods, bivalves, and fish scales.

The Eocene to Oligocene Kishenehn Formation is composed of a wide variety of lithologies with diverse and abundant paleontological resources. These lithologies include gravel, sand, mud, volcanic ash, limestone, and coal with interlayered sandstone, mudstone, and conglomerate. Ongoing multi-disciplinary studies regarding the geology and paleontology of the Kishenehn Basin within GLAC and along the park's western boundary are being performed by many researchers as part of the Kishenehn Basin Study Project (e.g. Constenius et al., 1989; Pierce and Constenius, 2001). Daly (1912) reports bivalves (*Sphaerium*) and gastropods (*Valvata, Physa, Planorbis, and Limnaea*) from a lakebed deposit in the Kishenehn Formation. Plant material, gastropods, bivalves, insects, fish, and mammal fossils occur in the Kishenehn Formation (Constenius et al., 1989; Whipple, 1992). Constenius et al. (1989) provide preliminary fossil faunal lists from the Kishenehn Formation of northwestern Montana and southeastern British Columbia that include a variety of plant microfossil and macrofossil species, 25 terrestrial gastropod species, 13 aqautic gastropod species, 5 bivalve species, 14 insect families, 4 fish families, and 24 mammal species. Pierce and Constenius (2001) update the molluscan fauna, and recognize 55 taxa (35 terrestrial and 20 aquatic). This assemblage represents one of the most prolific Tertiary snail faunas in North America (K. Constenius, personal communication, 2004). Collections of mammalian material and molluscan material have been made within GLAC along Kintla Creek and Bowman Creek, respectively (Constenius et al., 1989; Pierce and Constenius, 2001). Most of the Montana localities listed by Constenius et al. (1989) and Pierce and Constenius (2001) are along the Flathead River which forms the western and southern boundary of GLAC. Li and Wilson (1994) describe a new species of *Hiodon* (mooneye fish) from the Kishenehn Formation exposures along the Middle Fork of the Flathead River near the GLAC boundary.

A wide variety of Quaternary and recent unconsolidated glacial and alluvial deposits within GLAC are mapped by Carrara (1990). These deposits have produced various plant material samples that have been radiocarbon dated to between 780 and 11,150 years old (Carrara, 1990).

COOPERATIVE PROJECTS:

- Geologic and Paleontologic Scoping of Glacier National Park – National Park Service Geologic Resources Division (August 2002).

- Surficial and Bedrock geologic mapping of Glacier National park – Paul Carrara (USGS) and J. W. Whipple (USGS) (1980s and 1990s).

- Search for ancient metazoans – Ellis Yochelson and Robert Horodyski (1992).

- Middle Proterozoic fossils from the Appekunny Formation – Ellis Yochelson (2001).

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DS-GLAC-XXX — University of Michigan Museum of Paleontology Collections. (hard copy data; reports; electronic data; photographs; maps; museum collections; publications). Originated by university researchers; status: Active.

DS-GLAC-XXX — Smithsonian Institution National Museum of Natural History Collections. 1910s-1970s. (hard copy data; reports; electronic data; photographs; maps; museum collections; publications). Originated by various USGS researchers; status: Inactive.

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DS-GLAC-XXX	Carnegie Museum of Natural History Collections. 1980s-present. (hard copy data; reports; electronic data; photographs; maps; museum collections; publications). Originated by Kishenehn Basin Study Project Researchers; status: Active.
DS-GLAC-XXX	University of Nebraska State Museum Collections. 1980s-present. (hard copy data; reports; electronic data; photographs; maps; museum collections; publications). Originated by Kishenehn Basin Study Project Researchers; status: Active.

GRANT-KOHRS RANCH NATIONAL HISTORIC SITE

Grant-Kohrs National Historic Site (GRKO) was established in 1972 to preserve the structures and artifacts associated with the 19th century cattle ranching empire. The site continues the tradition as a working cattle ranch.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The primary geologic unit with GRKO is the late Eocene to early Miocene Renova Formation. Ages of the various beds within the Renova Formation have been determined using fossil vertebrates, and mammals in particular (Kuenzi and Fields, 1971; Fields et al., 1985). Kellogg (1995) reports twig debris in some ash beds and bone fragmens in some pebbly beds. Unique formainiferal and ostracode assemblages occur within the lacustrine deposits of the Renova Formation. Three species of the brackish-marine faraminifera genus *Elphidium* have been reported (Van Nieuwenhuise and He, 1986). Abundant fossil plant material has been discovered in localized deposits within the Renova Formation. The York Ranch flora is found in the Upper Ruby River Basin in southwestern Montana of the Dunbar Creek Member of the Renova Formation. A total of 23 families, 32 genera, 58 named species, and 11 new species were discovered from these deposits (Becker, 1973). Exceptionally preserved fossil plants and insects were found from a deposit along the Canyon Ferry Reservoir in southwestern Montana (CoBabe et al., 2002). At least 37 species of insects and 40 taxa of plants were identified. The quality of preservation allows for the study of insect color patterns, feeding, and reproductive structures. Monroe and Wicander (1979) report an additional fossil insect deposit called the Sweetwater Creek fossils. Beetles and mosquitoes are described and the report also indicates that fossil plant impressions have been found in association with the insect beds. Pierce and Rasmussen (1992) report nonmarine mollusks, and the gastropod family Pupillidae in particular, within the Cabbage Patch beds of the Renova Formation. Fresh water and terrestrial mollusk specimens have aided in extending the range of various genera and provided scientists with new climatic indicators. The Cabbage Patch beds have been identified in numerous isolated strata of Blackfoot, Flint Creek, Deer Lodge, and Divide basins in Montana. Henrici (1994) describes a new amphibian genus and species, *Tephrodytes brassicarvalis*, using the remains of a nearly complete specimen from the Cabbage Patch beds. Many significant vertebrate mammals fossils have been reported from the Renova Formation and continue to be described ranging from rodents to rhinoceros (D. Rasmussen, personal communication, 2004). Lillegraven and Tabrum (1983) report a new species of geolabidid insectivore, *Centetodon kuenzii*, from fine-grained tuffaceous sediments referable to the Renova Formation. The new primitive genus of fossil squirrel *Douglassia* is named and investigated for early evolutionary implications of the family Sciuridae from jaw and teeth material found in the Renova Formation (Emry and Korth, 1996). Lastly, two specimens of the rare amphicyonid carnivore *Daphoenictis* were discovered from the Renova Formation and provided an extension of the known geographic range for the genus (Emry and Hunt, Jr., 1980). Fossils from the Renova Formation are not yet known from within GRKO. However, future investigations may reveal their presence within the park.

Other deposits within the boundaries of GRKO include Quaternary sediments. These deposits are composed of alluvium, fan and terrace gravel, gravel deposits on pediment surfaces, glacial till, and outwash deposits (Lewis, 1998). No paleontological discoveries from these sediments have been reported.

COOPERATIVE PROJECTS:

- Contract with the National Park Service to produce both digital and paper 7' quadrangle maps for the Geologic Resources Division of Grant-Kohrs Ranch National Historic Site – Senior Research Geologist Dick Berg, Montana Bureau of Mines and Geology (2004).

- Geologic and Paleontologic Scoping of Grant-Kohrs Ranch National Historic Site – National Park Service Geologic Resources Division (August 2002).

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GREAT SAND DUNES NATIONAL MONUMENT AND PRESERVE

Great Sand Dunes National Monument and Preserve (GRSA) was proclaimed in 1932 to protect the largest and highest dune deposit in the United States. The dunes are nestled at the base of the rugged Sangre de Cristo Mountains.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The oldest fossiliferous unit exposed within GRSA is the Middle Pennsylvanian Minturn Formation. This geologic strata contains a biohermal limestone unit that produces abundant marine invertebrate fossils. Although there are no reports of fossils found within this unit from GRSA, fossil localities have been noted just outside the park boundary. Walker (1972) specifically reports on the bioherms found within the Minturn Formation and indicates that most colonies are composed of blue-green algae with foraminifera, brachiopods, and crinoids. Ten crinoid species and six cromyocrinids species from the Minturn Formation are reported by (Webster and Houck, 1998). Rigby and Church (1993) report the first occurrence of the calcareous sponge *Wewokella solida* from Colorado. The authors also describe an unnamed demosponge and fragments of root tufts found with *Wewokella*. Stevens (1965a) reports two specimens of the brachiopod *Chonetinella jeffordsi* from the Minturn Formation that retained their original color markings and the author states that these "may be the most spectacularly colored fossil brachiopods so far discovered…". At a locality in northwestern Colorado, conodonts, foraminifera, fish or shark teeth, and vertebrate scales or plates were found within the Minturn Formation (Murray and Chronic, 1965). Distribution and diversity of fossil foraminifera, algae, and brachiopods relative to water depth and distance to shore was investigated using specimens from the Minturn Formation of central Colorado (Stevens, 1971). Fusulinids were cited by Lindsey et al. (1983) to indicate changes in tectonic activity. The Minturn Formation near McCoy, Colorado has produced marine body (including rugose corals, fenestrate bryozoans, brachiopods, pelecypods, gastropods, and crinoids) and trace (including *Planolites* and *Curvolithus*) fossils, fossil leaves, and fossil wood (Houck, 1997; Stevens, 1965b). Souilliere et al. (1984) report fossil land plants from this formation in Custer and Saguache counties, Colorado.

The other strata exposed within the boundaries of GRSA are Quaternary deposits. These sediments composed of dune fields, sandsheets, alluvium, and alluvial fan deposits. Quaternary deposits within the park have produced a mammoth femur and bison phalange and are housed in the park museum collections (Scott et al., 2001).

COOPERATIVE PROJECTS:

- Geologic and Paleontologic Scoping of Great Sand Dunes National Monument and Preserve – National Park Service Geologic Resources Division (August 1998).

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LITTLE BIGHORN BATTLEFIELD NATIONAL MONUMENT

Little Bighorn Battlefield National Monument (LIBI) was initially protected in 1879 and memorializes the battle between the Northern Plains Indians and the U.S. Army. Lakota, Arapaho, and Cheyenne warriors defeated the U.S. Army led by Lt. Col. George A. Custer on June 25-26, 1876.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The oldest fossiliferous formation exposed in LIBI is the Upper Cretaceous Judith River Formation. This geologic unit is composed of cross-bedded sandstone with lesser amounts of yellowish-gray silty shale (Vuke et al., 2000). Bony fish and shark remains have been discovered from the Judith River Formation in Montana and new taxa have been described or revised using this material (Case, 1978; Wilson et al., 1992; Siverson, 1995). Dinosaur fossils occur in this geologic unit including pachycephalosaurids and the following genera: *Daspletosaurus*, *Diclonius*, *Dysganus*, *Hadrosaurus*, *Lambeosaurus*, and *Stegoceras* (Coombs, 1988; Coombs and Galton, 1988; Galton and Sues, 1983; Horner et al., 1992; Ostrom, 1964; Wall and Galton, 1979). Soft-shelled turtles have been recovered from the Judith River Formation. Blob (1997) reports the occurrence of *Aspideretoides* remains from south-central Montana and Gardner et al. (1995) report four species of trionychine trionychid turtles from multiple sites in western North America. Montellano (1992) summarizes the mammalian fauna of the Judith River Formation, which includes the following genera: *Mesodma*, *Cimexomys*, *Paracimexomys*, *Meniscoessus*, *Cimolodon*, *Alphadon*, *Pediomys*, *Eodelphis*, *Gypsonictops*, *Paranyctoides*, and *Falepetrus*. Rogers and Kidwell (2000) investigated associations of vertebrate skeletal concentrations and discontinuity surfaces in terrestrial and shallow marine records utilizing both the Judith River and Two Medicine formations of Montana for analysis. From this research they report the occurrence of carbonaceous plant debris, wood fragments, shell debris, freshwater clams, gastropods, shark teeth, fish bones, marine reptile bones, and dinosaur remains. Blob and Fiorillo (1996) analyzed the faunal abundance and fossil size and shape from microvertebrate localities of the Judith River Formation.

The other fossiliferous unit within LIBI is the Upper Cretaceous Bearpaw Shale. Primarily composed of dark-gray fissile shale with interbedded siltstone and fine-grained shale, this unit also contains numerous calcareous concretions and bentonite beds (Vuke et al., 2000). Within the calcareous concretions, a rich marine fauna exists. Reiskind (1975) reports three distinct biofacies from the concretionary layers that include the following fossils: *Protocardia subquadrata*, *Inocermaus typicus*, *Lingula nitida*, *Dosiniopsis deweyi*, *Ostrea translucida*, *Oxytoma nebrascana*, *Malletia evansi*, *Anomia* sp., *Chlamys nebrascensis*, *Pteria notukeuensis*, *Nymphalucina occidentalis*, *Nucula* spp., and *Nuculana scitula* (bivalves); *Euspira obliquata* and *Drepanochilus evansi* (gastropods); *Dentalium gracile* (scaphopod); *Hoploscaphites* sp. (ammonite); and *Baculites* sp. (ammonite). Fossil lobsters have also been discovered within the concretions of the Bearpaw Shale (*Palaeonephrops browni*, *Hoploparia bearpawensis*, and *Linuparus pustulosus*) (Feldmann et al., 1977; Kammer and Raff, 1978). Two new species of crabs, *Notopocorystes* (*Eucorystes*) *eichhorni* and *Zygastrocarcinus griesi*, were described using specimens from the Bearpaw Shale in Valley County, Montana (Bishop, 1983). Cobban (1962) researched and named new *Baculites* species from many Bearpaw Shale localities in Montana. Horner (1979) reports four dinosaur specimens recovered from south-central Montana and represent the first dinosaur material to be reported from the Bearpaw Shale. There are two specimens of *Hadrosaurus* ("*Kritosaurus*") *notabilis*, and one specimen of cf. *Lambeosaurus magnicristatus* and *Panoplosaurus* sp.

A short-necked plesiosaur (extinct group of marine reptile) specimen from the Bearpaw Shale was discovered within LIBI in November of 1977. Tabrum (1978) summarizes the discovery of this scientifically significant specimen. During routine excavation of a grave in section "H" of the Custer National Cemetery, an NPS employee encountered the specimen (Tabrum, 1978; J. Doerner, electronic communication, 2004). The specimen, which contained a complete pectoral and pelvic girdles, numerous ribs, and a nearly complete vertebral column was identified by Tabrum as *Dolichorhynchops osborni* Williston, a short-necked plesiosaur. The bone was generally well-preserved, although some of the larger bones were fractured (Tabrum, 1978). The LIBI specimen is significant in that short-necked plesiosaurs are poorly understood, and well-preserved specimens such as the one found at LIBI are rare. In fact, the LIBI specimen was probably the first short-

necked plesiosaur collected in Montana, one of the more complete specimens known of *Dolichorhynchops osborni*, and may represent the first known occurrence of *Dolichorhynchops* in Campanian (Late Cretaceous) time (Tabrum, 1978). The specimen was prepared by Dinosaur National Monument (DINO) preparator Tobe Wilkins during the winter of 1977-1978 and is figured on the cover of this report (A. Elder, electronic communication, 2004). After preparation, the specimen was sent to the Smithsonian National Museum of Natural History in Washington, D.C. It was cataloged in 1987 as USNM Specimen 419645 and is currently on display in the museum's Ancient Seas exhibit (J. Young, personal communication, 2004).

COOPERATIVE PROJECTS:

- Plesiosaur excavation; Many Custer Battlefield National Monument (LIBI) staff members assisted with the excavation and administrative aspects regarding the plesiosaur discovery. Paleontologists and preparators from Dinosaur National Monument assisted with the excavation and preparation of the specimen. Alan Tabrum, then of the University of Montana (Missoula) Dept. of Geology, oversaw the excavation and reported to the Rocky Mountain Regional Office. (November 1977-winter 1978).

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ROCKY MOUNTAIN NATIONAL PARK

Rocky Mountain National Park (ROMO) was established in 1915 and captures the grandeur of the Rocky Mountain peaks, wildflowers, and wildlife. ROMO preserves 415 square miles of the Rocky Mountain range including many spectacular glacial features.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES:

The oldest fossiliferous unit exposed within ROMO is the Upper Cretaceous Pierre Shale. Although there have been no reports of fossil discoveries from within the park, this formation has produced paleontological resources outside the park. The Pierre Shale is a marine unit primarily composed of silty shale and sandstone. Bergstresser and Krebs (1983) report diatoms from Pierre Shale localities in Colorado, Kansas, South Dakota, and Wyoming. Griffitts (1949) lists 48 species of mollusks from the Pierre Shale of northern Colorado. A new species of crab (*Eomunidopsis cobbani*) from Larimer County, Colorado was described by Bishop (1985) and extended the known stratigraphic range of that genus. This distinction was made using a few dozen specimens and they were found in conjunction with a diverse molluscan fauna and fossil wood fragments. Heteromorphic ammonites of the Pierre Shale were investigated by Cobban et al. (1993). Ten ammonite localities within Grand County, Colorado are referenced in this report. Powell et al. (1998) used fossil mollusks from the Pierre Shale of Colorado to investigate community structures and taphonomic relationships. Three species of radiolaria were reported by Bergstresser (1983) from specimens recovered in Colorado, Kansas, and Wyoming and *Dictyomitra multicostata* is the most abundant. Additionally, dinosaur, crocodile, and mosasaur remains were reported from the Pierre Shale in Natrona County, Wyoming (Wegemann, 1911).

Upper Oligocene to Lower Miocene Troublesome Formation is composed of siltstone, limestone, ash, sand, and clay. Izett (1968) compiled a fossil mammal list, in addition recorded the occurrences of fresh-water clams, snails, pollen, and spores that were collected from the Troublesome Formation of Grand County, Colorado. Lewis (1969) describes diagnostic vertebrate fauna of the Troublesome Formation. Specimens of rodents, horses, large rhinoceros, camels, and oreodonts are cited.

The known paleontological resources within the boundaries of ROMO are found in Holocene and Pleistocene deposits. ROMO's museum collections houses 99 paleontological specimens. This collection includes plant fossils, petrified wood, molluscan specimens including *Stylommatophora*, insects, and teeth from *Ursus americanus*, *Equidae* sp., and *Bovidae* sp. (Scott et al., 2001). Between 1991 and 1999 Elias has conducted extensive research on Holocene paleoecology of ROMO with particular interest in evaluating pollen, plant, and insect remains (Elias et al., 1986).

COOPERATIVE PROJECTS:

- Study of the vegetational history of the glacial-interglacial (Holocene) transition; Holocene Environments; Late Quaternary Paleoecology; Quaternary insect fossils – Scott Elias, University of Colorado (1991-1999).

- Geologic and Paleontologic Scoping of Rocky Mountain National Park – National Park Service Geologic Resources Division (August 1998).

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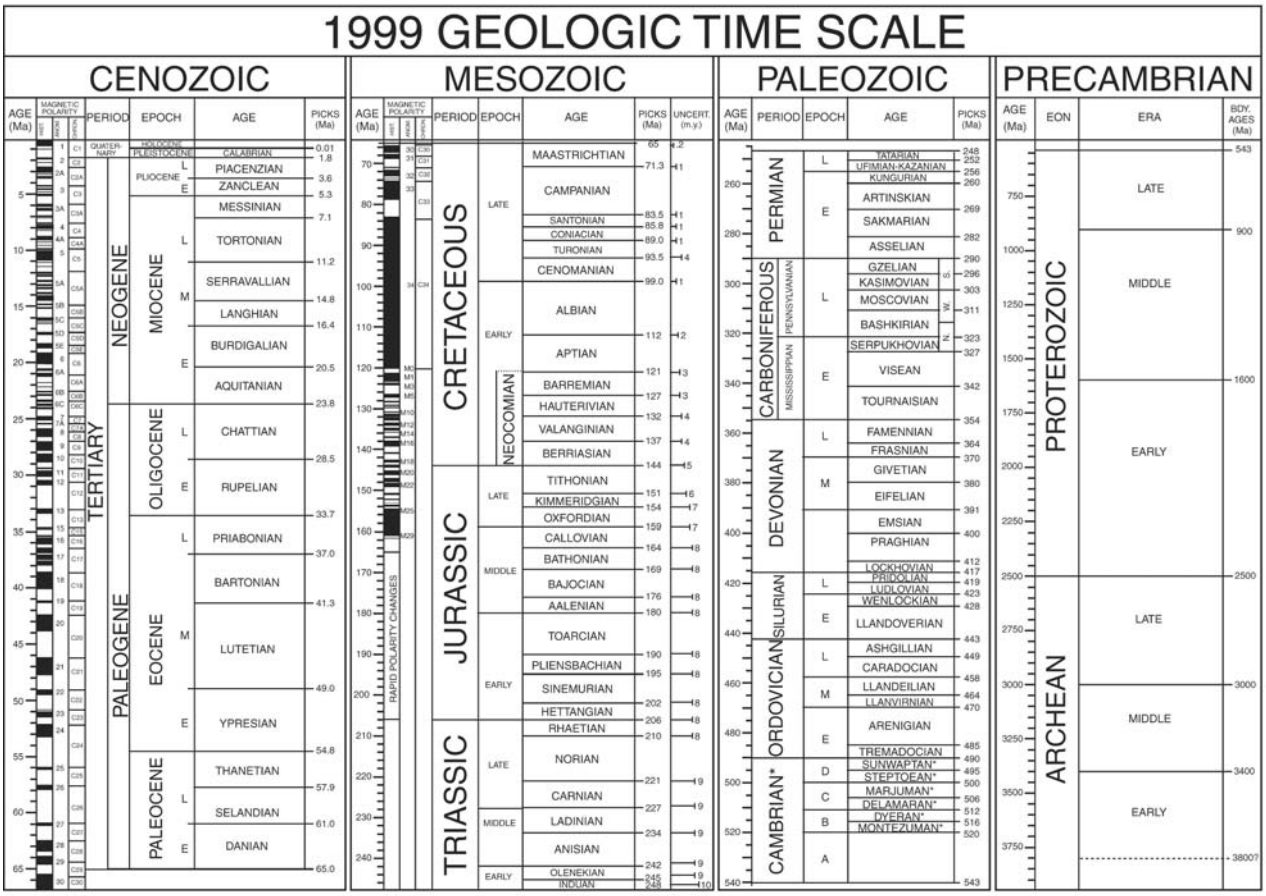
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APPENDIX A: GEOLOGIC TIME SCALE



Note: Picks (Ma) = age of the geologic time unit boundary in millions of years (Ma).

This timescale is available online as a PDF: http://www.geosociety.org/science/timescale/timescl.pdf