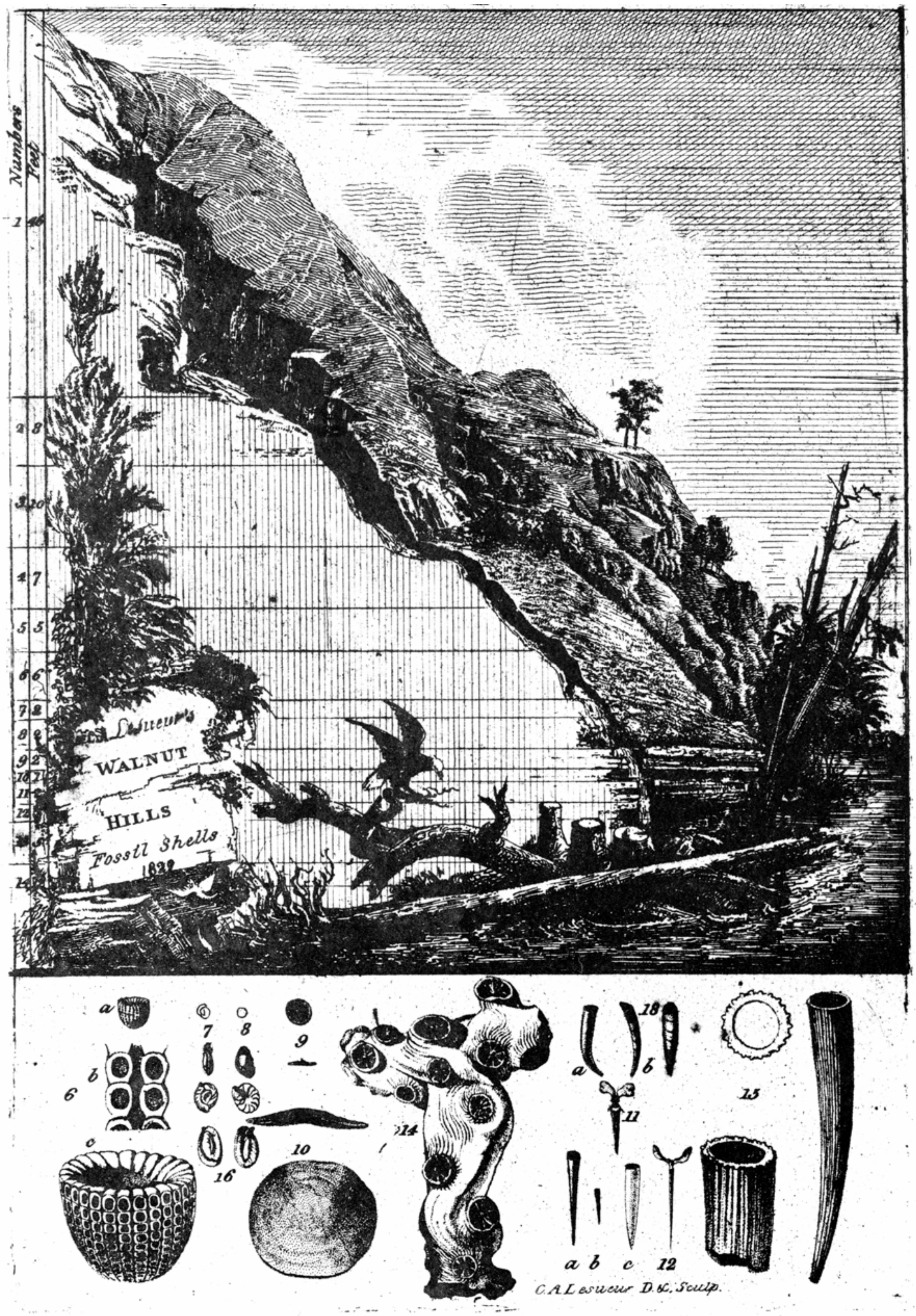
National Park Service
U.S. Department of the Interior

Gulf Coast Network

Paleontological Resource Inventory and Monitoring
Gulf Coast Network



Paleontological Resource Inventory and Monitoring
Gulf Coast Network

Jason P. Kenworthy
Paleontology Technician
Geologic Resources Division

Vincent L. Santucci
Chief Ranger
George Washington Memorial Parkway

Christy C. Visaggi
Paleontological Intern
University of North Carolina-Wilmington

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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:
French naturalist Charles A. Lesueur collected and illustrated numerous fossils from the base of "Walnut Hills" near Vicksburg, Mississippi in 1829. His "Walnut Hills" locality is within or immediately adjacent to what is now Vicksburg National Military Park. The cover illustration is the first of 12 such plates from "Walnut Hills" and includes the first measured section and detailed geological study within Mississippi. The fossils are identified by Lesueur as: bryozoan (fig. 6); foraminifera (figs. 7-10, 16); coral (fig. 14); and scaphopods (straight shelled mollusks, figs. 13,18). Dockery (1982) reproduced all of Lesueur's plates. The original plates are housed in the Academy of Natural Sciences in Philadelphia. For more information, see the Vicksburg National Military Park chapter of this report.

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INTRODUCTION

Paleontological resources, or fossils, are any remains of past life preserved within 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 the Methodology and Inventory Strategies section of this report. This report presents paleontological resource inventory and monitoring data compiled for the parks of the Gulf Coast I&M Network (GULN).

The Gulf Coast Network includes eight National Park Service areas in Florida, Alabama, Mississippi, Tennessee, Louisiana, and Texas as shown in Figure 1: Big Thicket National Preserve (Texas; BITH) Gulf Islands National Seashore (Florida, Mississippi; GUIS), Jean Lafitte National Historical Park and Preserve (Louisiana; JELA), Natchez Trace Parkway (Mississippi, Alabama, Tennessee; NATR), Padre Island National Seashore (Texas; PAIS), Palo Alto Battlefield National Historic Site (Texas; PAAL), San Antonio Missions National Historical Park (Texas; SAAN), and Vicksburg National Military Park (Mississippi; VICK). All together, the parks of the GULN encompass over 444,000 acres and hosted more than 10.6 million visitors in FY2006.

Four GULN parks were established primarily to preserve and interpret natural resources (BITH, GUIS, and PAIS). Three GULN parks were established primarily for cultural and historical resources related to the Spanish Colonial Period (SAAN), United States-Mexico War (PAAL), and the American Civil War (VICK). JELA was established to preserve and interpret both the natural history of the Mississippi Delta area and Acadian cultural history. The 715 km (444 miles) of NATR commemorate the Natchez Trace, a historic trail utilized by American Indians and early European settlers between what is now Mississippi and central Tennessee.

While none of the parks were established specifically for paleontological resource stewardship, fossils are known from a number of GULN parks including Big Thicket National Preserve, Gulf Islands National Seashore, Natchez Trace Parkway, Padre Island National Seashore, and Vicksburg National Military Park. Building stones within San Antonio Missions National Military Park also display fossils. Palo Alto Battlefield National Historic Site and Jean Lafitte National Historical Park and Preserve contain younger (few hundred-few thousand years old) deposits preserving important paleoenvironmental data.

The paleontological resources found within GULN parks are quite diverse, span more than 460 million years, and in some cases are nationally, or even globally significant. For example, NATR crosses nearly 460 million years of geologic time represented by some four dozen fossiliferous formations in three states and two physiographic provinces. These formations have yielded globally significant specimens near and within NATR boundaries illustrating the evolution of the southern Appalachian Mountains and the Gulf Coast region. The cliffs surrounding Vicksburg National Military Park ("Walnut Hills") were the site of the first geologic investigation in Mississippi in 1829 as figured on the cover of this report. Mint Springs Bayou, also within Vicksburg National Military Park, is a classic Oligocene marine invertebrate collecting locality from the late 1800s through today. John Wesley Powell collected fossil snail shells from the Pleistocene loess deposits at Vicksburg while serving during the Civil War. Rhinoceros and mammoth material were recovered from Miocene and Pleistocene river deposits near or within Big Thicket National

Preserve. Pleistocene fossils wash up on the beaches of Padre Island National Seashore from now offshore lake sediments.

Collectively, the paleontological resources of the Gulf Coast Network contribute much to a greater understanding of the history of life on earth. Continued paleontological resource inventories will serve to expand this ever-widening base of paleontological knowledge represented throughout the National Park Service. Although more than 180 parks have already been identified as containing paleontological resources, much of what is to be known about the history of life on earth remains to be discovered.

Jason P. Kenworthy, Vincent L. Santucci, and Christy Visaggi—February 2007

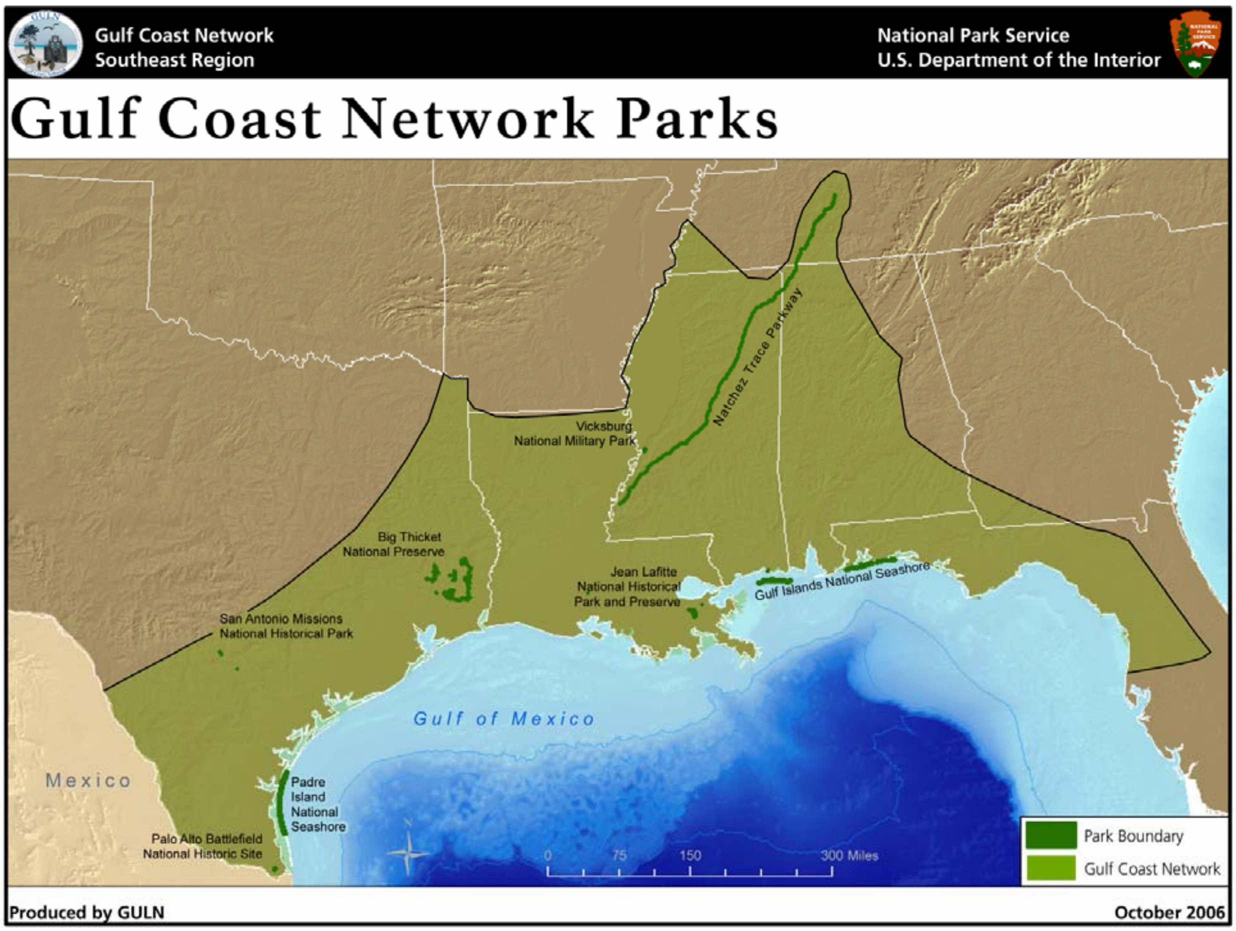

Figure 1. Map of Gulf Coast I&M Network parks. Map produced by GULN staff.

PALEONTOLOGICAL RESOURCE INVENTORY STRATEGIES AND METHODOLOGY

In order to better document fossil occurrences and to provide baseline paleontological resource data in National Park Service areas, the NPS Geologic Resources Division (GRD) and the NPS Inventory and Monitoring Program (I&M) have established three paleontological resource inventory strategies. These strategies include: comprehensive park-specific paleontological resource inventories, Servicewide thematic paleontological resource inventories, and Inventory & Monitoring Network-based baseline paleontological resource inventories, each established with their own goals and objectives. An article outlining basic paleontological resource monitoring strategies and potential threats to fossil resources is presented by Santucci and Koch (2003).

Comprehensive Park Paleontological Resource Inventories

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.

Servicewide Thematic Paleontological Resource Inventories

Servicewide 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 and warranted an updated publication (Santucci et al. 2006). 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 Pleistocene / Holocene 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. 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

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 nearly half of the 32 I&M Networks including: the Eastern Rivers and Mountains, Greater Yellowstone, Mediterranean Coast, Mid-Atlantic, Mojave Desert, National Capital Region, Northeast Coastal and Barrier, Northern Colorado Plateau, Rocky Mountain, Southern Plains, Southwestern Alaska, and Upper Columbia Basin networks. The NPS I&M Program will be providing funding to complete paleontological resource summaries for the remaining networks by FY2009. Summaries for the Appalachian Highlands, Chihuahuan Desert, Pacific Islands, San Francisco Bay Area, and Southern Colorado Plateau are currently underway (January 2007). Citations for the completed reports are in the Additional References section.

Inventory and Monitoring Network Paleontological Resource Inventory Methodology
Network-based paleontological inventories, including the Gulf Coast Network, have been 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. GeoRef, established by the American Geological Institute, 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. NatureBib is a work in progress and does not yet contain a comprehensive paleontology bibliography. The USGS Library in Reston, Virginia is a premier repository for geologic publications, and houses most of the publications obtained for the network-based paleontological resource inventories. Additionally, museum libraries such as the Smithsonian Institution's National Museum of Natural History, and university libraries provide access to a wide range of geological and paleontological publications. Individual state geological surveys are also excellent sources of information and geologists familiar with local geology and paleontology.

The literature search also includes gray (unpublished) literature searches of individual park files, museum archives, local newspapers, 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. 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 types 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 range 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 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 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.

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. 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 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 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. The Geologic Resources Division is coordinating the assembly of a geologic resource monitoring manual. This manual 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. It 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. Currently the draft monitoring manual is undergoing peer review. 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

Hunt, R. K., V. L. Santucci and J. P. Kenworthy. 2006. A preliminary inventory of fossil fish from NPS units. Pages 63-69 in Lucas, S. G., et al. America's Antiquities (Proceedings of the 7th Federal Fossil Conference). New Mexico Museum of Natural History & Science, Albuquerque, NM. Bulletin 34.

Kenworthy, J. P. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring, Southwestern Alaska Network. National Park Service TIC# D-93. 27 pages.

Kenworthy, J. P. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring, Northeast Coastal and Barrier Network. National Park Service TIC# D-340. 28 pages.

Kenworthy, J. P. and V. L. Santucci. 2004. Paleontological Resource Inventory and Monitoring, National Capital Region. National Park Service TIC# D-289. 97 pages.

Kenworthy, J. P. and V. L. Santucci. 2006. A preliminary inventory of NPS paleontological resources found in cultural resource contexts, Part 1: General Overview. Pages 70-76 in Lucas, S. G., et al. America's Antiquities (Proceedings of the 7th Federal Fossil Conference). New Mexico Museum of Natural History & Science, Albuquerque, NM. Bulletin 34.

Kenworthy, J. P., C. C. Visaggi, and V. L. Santucci. 2006. Paleontological Resource Inventory and Monitoring, Mid-Atlantic Network. National Park Service TIC# D-800. 85 pages.

Kenworthy, J.P., V. L. Santucci, M. McNerney, and K. Snell. 2005. Paleontological Resource Inventory and Monitoring, Upper Columbia Basin Network. National Park Service TIC# D-259. 71 pages.

Koch, A. L. and V. L. Santucci. 2002. Paleontological Resource Inventory and Monitoring, Northern Colorado Plateau Network. National Park Service TIC# D-206. 44 pages.

Koch, A. L. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring, Southern Plains Network. National Park Service TIC# D-107. 34 pages.

Koch, A. L. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring, Greater Yellowstone Network. National Park Service TIC# D-1025. 20 pages.

Koch, A. L. and V. L. Santucci. 2003. Paleontological Resource Inventory and Monitoring, Mediterranean Coast Network. National Park Service TIC# D-177. 27 pages. 27 pages.

Koch, A.L. and V. L. Santucci. 2004. Paleontological Resource Inventory and Monitoring, Eastern Rivers and Mountains Network. National Park Service TIC# D-265. 50 pages.

Koch, A. L., J. P. Kenworthy, and V. L. Santucci. 2004. Paleontological Resource Inventory and Monitoring, Rocky Mountain Network. National Park Service TIC# D-436. 47 pages.

Santucci, V. L. 1998. The Yellowstone Paleontological Survey. Yellowstone Center for Resources, Yellowstone NP, WY. YCR-NR-98-1. 54 pages.

Santucci, V. L. 2000. What constitutes a comprehensive National Park Service paleo survey? Online information: (http://www2.nature.nps.gov/geology/paleontology/surveys/survey_outline.htm)

Santucci, V. L. and A. L. Koch. 2003. Paleontological resource monitoring strategies for the National Park Service. Park Science 22(1): 22-25.

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

Santucci, V. L., J. Kenworthy, and R. Kerbo. 2001. An inventory of paleontological resources associated with National Park Service Caves. NPS Geological Resources Division, Denver. Technical Report NPS/NRGRD/GRDTR-01/02. (TIC# D-2231). 50 pages.

Santucci, V. L., J. P. Kenworthy, and C. C. Visaggi. 2006. Paleontological Resource Inventory and Monitoring, Chihuahuan Desert Network. National Park Service TIC# D-500.

Santucci, V. L., A. L. Koch, and J. P. Kenworthy. 2004. Paleontological Resource Inventory and Monitoring, Mojave Desert Network. National Park Service TIC# D-305. 50 pages.

Santucci, V. L., A. P. Hunt, T. Nyborg, and J. P. Kenworthy. 2006. Additional fossil vertebrate tracks in National Park Service areas. Pages 152-158 in Lucas, S. G., J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci. America's Antiquities: 100 Years of Managing Fossils on Federal Lands. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 34.

General GULN Information

Gulf Coast I&M Network: http://www.nature.nps.gov/im/units/guln/index.cfm

Geological Survey Websites

Geological Survey of Alabama (University of Alabama, Tuscaloosa): http://www.gsa.state.al.us/

Florida Geological Survey (Tallahassee): http://www.dep.state.fl.us/geology/

Louisiana Geological Survey (Louisiana State University, Baton Rouge): http://www.lgs.lsu.edu/

Mississippi Office of Geology (Jackson): http://www.deq.state.ms.us/MDEQ.nsf/page/Geology_home?OpenDocument

Tennessee Division of Geology (Nashville): http://www.state.tn.us/environment/tdg/

Texas Bureau of Economic Geology (University of Texas, Austin): http://www.beg.utexas.edu/

Gulf Coast Association of Geological Societies (Corpus Christi): http://www.gcags.org/

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://igsrglib03.er.usgs.gov:8080/#focus

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

Museums

Texas Memorial Museum (Austin): http://www.utexas.edu/tmm/exhibits/index.html

Mississippi Museum of Natural Science (Jackson): http://www.msnaturalscience.org/

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

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/news/newsletter.htm

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/glossarya.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://geonames.usgs.gov/pls/gnispublic/

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

BIG THICKET NATIONAL PRESERVE

Nine land units and six water corridors, together totaling over 97,000 acres in east Texas, make up Big Thicket National Preserve (BITH). The park was authorized on October 11, 1974 as the first preserve in the National Park System. The many varied habitats such as floodplain forest and swamp, flatlands palmetto hardwood, savannah, and upland hardwood/pine forest found in the park contribute to a great ecological diversity. As a testament to this diversity, BITH was designated an International Biosphere Reserve by the United Nations in 1981.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geologic scoping sessions, coordinated by the NPS Geologic Resources Division, have not yet been held for Big Thicket National Preserve. Paleontological scoping sessions have likewise not been held for the park and there have been no formal paleontological resource surveys or inventories. Nevertheless, paleontological resources are known from within BITH and there is good potential for continued discovery. One paleontology specimen is curated within BITH museum collections (L. Jameson, personal communication, 2006).

Big Thicket National Preserve is located near Beaumont, Texas within the Coastal Prairies region of the Gulf Coastal Plain physiographic province. According to Wermund (1996), at the surface this region is characterized by nearly flat sedimentary strata representing Pleistocene-Holocene deltaic sands and muds which are underlain by Miocene sediments. These deposits record sea level change and river system evolution association with the Miocene-Holocene evolution and sea level change of the Gulf of Mexico. The Beaumont area geologic map produced by Shelby et al. (1992) lists a number of such gravels, sands, silts, and clays within the various units of BITH. In stratigraphic order from lower to upper (oldest to youngest), these geologic units are the Miocene Fleming Formation, Pleistocene Willis Formation, undivided Pleistocene fluvial terrace deposits, Pleistocene Bentley Formation, Pleistocene Montgomery Formation, Pleistocene Beaumont Formation, the Late? Pleistocene-Recent "Deweyville" Formation, and Recent alluvium. The Pleistocene and underlying Miocene and Pliocene deposits of the Texas Gulf Coast are well known for producing paleontological resources and there are numerous collecting localities known from the region surrounding BITH. The Pleistocene of Texas has yielded innumerable fossil finds, and is particularly well studied in southern Texas (e.g. Baskin, n.d.). The Pleistocene deposits in some areas have complex interrelationships as they are entrenched within each other and can overlap. The Recent alluvium unit consists of modern river deposits and therefore does not contain paleontological resources. Most of the park is heavily vegetated and exposures of the underlying geology (and associated paleontological resources) are only likely to be found in river cutbanks, gullies, or other erosional features.

Park Collections

Within the museum collections of Big Thicket National Preserve, there is one paleontological specimen, a mammoth tooth and associated partial lower left jaw (mandible) fragment. The fragment was discovered in the banks of the Trinity River in the park's Menard Creek Unit and assigned BITH Accession 006. Geraldine Watson (personal communication, 2006), at the time a plant ecologist and park ranger at BITH, discovered the tooth in fall of 1981. According to correspondence between BITH and the Texas Memorial Museum (TMM) in Austin, Dr. Margaret Skeels Stevens, then of Lamar University and now retired, assisted with collection of the specimen. The specimen originated in Pleistocene sediments, but may have been washed out and redeposited lower in the creek, perhaps mixed with sediments of Miocene (Fleming Formation) age (G. Watson, personal communication, 2006). The mandible was curated at the Texas Memorial Museum in Austin where it was assigned the number TMM-42283-1 (locality TMM 42283). The tooth was returned to the park in April 1986, where it now resides in the collections (L. Jameson, personal communication, 2006).

Doug Neighbor, former chief of resources at BITH (personal communication, 2001), noted the tooth was identified as "*Mammuthus imperator,*" however documentation from TMM does not include any identification more specific than "mammoth." Indeed, TMM collections manager Lyndon Murray (personal communication, 2006) noted the difficulties associated with species level identification of mammoth material. George McDaniel and George Jefferson, both of Anza-Borrego State Park in California, have worked extensively with mammoth material from California and Texas. They may be able to provide a more thorough identification or additional information regarding the specimen, depending on preservation (L. Murray, personal communication, 2006). Larry Agenbroad of the Mammoth Site in South Dakota is another contact regarding mammoth identification and information.

Fleming Formation (lower-middle Miocene)
The lower (early)-middle Miocene Fleming Formation in the Beaumont and BITH area is characterized by light gray to yellowish gray clay, silt, and sand. According to Shelby et al. (1992), the silt and sand of the Fleming is locally well indurated (cemented) and the formation can be red in color where it underlies the Willis Formation. The Miocene Fleming Formation is exposed in some of the deep gullies within BITH (G. Watson, personal communication, 2006). However these exposures, due to their small horizontal area, are not mapped within the park on the 1:250,000 scale map produced by Shelby et al. (1992). The depositional environments of the Fleming are variously interpreted by authors, but are generally thought of as fluvio-deltaic (river delta) deposits near marine waters.

The Fleming Formation of east Texas yields locally abundant and diverse vertebrate fossils from the Texas Coastal Plain. While these discoveries tend to be fragmentary and poorly preserved (e.g. Wilson 1956), they have played a very important role in paleoenvironmental and stratigraphic reconstruction of the east Texas Miocene. Numerous authors documented Fleming Formation fossils over the last 150 years, and a brief summary is here presented. Many discoveries have occurred near (within approximately 32 km or 20 miles) of BITH, and are indicative of the breadth of local paleontological resources. The locally terrestrial, fluvial, brackish, or marine (closer to the Gulf of Mexico), sediments yielded specimens of fish, crocodiles, frogs, salamanders, snakes, lizards (Slaughter 1965; Holman 1977) and mammalian fossils. The mammalian material is the most abundant and as such is utilized for regional, continental (especially with the High Plains), and even global correlation. Plants (petrified wood) and invertebrates are also noted occasionally (e.g. Stenzel and Turner 1944).

The mammalian fossils of the Fleming Formation have been the subject of numerous research papers (see the Additional References section) mostly from the early-middle 1900s. Hay (1924) and Hesse (1943) produced some of the first vertebrate faunal descriptions. A later series of papers described Miocene fossils, including many new taxa, from several of the major mammalian orders and families including artiodactyls (Patton 1969), carnivores (Wilson 1960), equids (Quinn 1952, 1955), rhinoceroses (Prothero and Manning 1987), and entelodonts (extinct group of pig-like mammals; Wilson 1957). Wilson (1956) produced one of the first attempts to correlate and stratigraphically define "local faunas" based primarily on Miocene mammalian fossils from the Texas Gulf Coast. Local faunas are assemblages of animals typical of a local area or region within a widespread geologic formation such as the Fleming. Field collections by these and other authors included many towns and localities near BITH including: near Moscow, around Livingston Dam, near Goodrich, west of Doucette, near Woodville, at Saratoga Field, along Push Creek, and near Town Bluff. Some of these same sites have also yielded microvertebrate and rodent material (e.g. Slaughter 1965, 1981; Schiebout 1997; Schiebout and Ting 1998). As one example of abundant paleontological resources from the Fleming Formation, the extensive fauna from Burkeville, in Newton County (easternmost Texas), contains a diverse assemblage of terrestrial and aquatic mollusks, fish, reptiles, birds, and mammals (Stenzel and Turner 1944; Stenzel et al. 1944).

Slaughter (1965), in a study funded by the National Park Service, collected garfish scales, a rhinoceros tooth, small mammal bone fragments and significant microvertebrate fossils of fish, crocodiles, frog, salamander, in addition to a new rodent species from exposures now inundated by Livingston Reservoir. Holman (1977) also collected a snake from the Boidae family from the Livingston Dam site.

The Town Bluff site (Texas Memorial Museum localities TMM-31087 and 43316) is located immediately to the southwest of the Army Corps of Engineers dam on the Neches River forming B.A. Steinhagen Lake, just outside of BITH. The site is referenced in some comparative mammal fauna studies (e.g. Quinn 1955, Patton 1969). From Town Bluff Holman (1977) collected vertebrae from a new species of *Siren* salamander, anurid (*Hyla* and *Rana* genera) bones, and vertebrae from colubrid snakes (*Salvadora*, *Elaphe*, and *Neonatrix* genera). Holman (1977) also named a new colubrid snake genus and species (*Texasophis fossilis*) from Town Bluff material. Schiebout and Ting (1998) and Schiebout (1997) compared microvertebrate fossils from Town Bluff to Miocene sites in east Texas near Burkeville and western Louisiana (Fort Polk). Rodent teeth from Town Bluff were referred to a new taxon of geomyid rodent (*Texomys ritchiei*, Slaughter 1981). Slaughter's (1978) description of the Town Bluff locality places it immediately outside the northern boundary of the Upper Neches River Corridor Unit of BITH. Schiebout (personal communication, 2006) recently revisited Wilson's 1950s collection sites along Town Bluff. She noted that dense vegetation and passage of 50 or more years made locating the original sites difficult. The Army Corps of Engineers (ACOE) cultural resources manager reported that paleontological resources are not commonly found during cultural resource reports surrounding the lake (S. Austin, personal communication, 2006). However, most of the ACOE cultural resource studies take place closer to the northern reaches of the lake, while Town Bluff is to the south.

Fleming Formation (Miocene)—Rhinoceros discovery within/near BITH

Lisa Jameson (BITH Biologist) and Dr. James Westgate (Lamar University paleontologist) both reported (personal communication, 2006) that Miocene rhinoceros material was collected near, probably within BITH along the Neches River in the Town Bluff area. Dwyer (2005) reported the discovery was made in 2002 along the Neches River below Dam B of the B.A. Steinhagen Lake. According to the park map, BITH land begins at the dam and follows the Neches River (on both banks) down to Beaumont. The high, especially for east Texas, relief in the Neches River-Town Bluff area provides good opportunity for exposure of the Miocene (and Pleistocene) geology of the area. This find, by a local resident, was reported in the Beaumont Enterprise (Dwyer 2005). Currently, the fossils are now on display at the Icehouse Museum in Silsbee (J. Westgate, personal communication, 2006). According to Westgate (cited in Dwyer 2005), the material included jawbones and teeth likely from the Miocene rhinoceros *Aphelops* or *Teloceras*.

While this fossil rhinoceros does illustrate the potential for discovery of paleontological resources within the park, it also illustrates the potential for unauthorized collection of such non-renewable resources. Dwyer (2005) noted that the landowner was informed by Lamar University that he "could not keep artifacts found on federal land" and subsequently donated them to the Icehouse Museum. The article also mentioned the potential for large pieces of petrified wood to be found in the area. Westgate (personal communication, 2006) indicated that some fossils from the local Town Bluff area may have been on display at the Army Corps of Engineers (ACOE) office there. ACOE archeologist Stephen Austin (personal communication, 2006) did not report the discovery of fossil material during archeological research in the area, nor during the recent drawdown of the lake.

Fleming Formation (Miocene)—Reworked/Mixed sediments

Pleistocene fossils, including the mammoth material now in park collections, have been noted within BITH mixed with sediments from the Miocene Fleming Formation (G. Watson, personal communication, 2006). The Pleistocene fossils were likely eroded out of overlying Pleistocene deposits during flood events and subsequently mixed with sediments of the underlying Fleming Formation and redeposited. Such "reworking" of sediments is to be expected in a region where stream gradients and deposits are controlled by changes in sea level and depositional environments cycling between deposition, erosion, and redeposition. Baskin (1991), Cornish and Baskin (1995), and Morton et al. (1996) comment on this phenomenon in south and southeastern Texas.

Willis Formation (Pliocene-Pleistocene)

In the Beaumont area, the Willis Formation is characterized by red clay, silt, sand, and siliceous (silica/quartz-rich) gravel and represents the oldest Pleistocene, maybe upper Pliocene, geologic unit

(Shelby et al. 1992). The unit unconformably (non-continuous sedimentation) overlies (is younger than) the Miocene Fleming Formation. The unit is considered fluviatile (river) in origin and contains many cross-bedded channel and point bar deposits (Rigsby 1980). Shelby et al. (1992) map the Willis Formation within the Big Sandy Creek Unit of BITH.

While fossils are not common within the Willis Formation, the basal gravels of the formation yield petrified wood fragments (Rigsby 1980; Shelby et al. 1992). While many of the Pleistocene fluvial deposits may yield fossil wood, this resource was specifically mentioned by Shelby et al. (1992) and Rigsby (1980) in the Willis Formation.

As another indication of the abundance of petrified wood in the Big Thicket area, Sloat (1977) writes of the Johnson Museum and Petrified Forest located in Indian Springs, Texas, immediately adjacent to the Big Sandy Creek unit of BITH. This enormous private collection of petrified wood, apparently containing some 500 tons (one million pounds!) of material, was entirely collected within 121 km (75 miles) of Livingston, Texas (Sloat 1977). Most of the wood was found in erosional features such as stream or river beds. The area surrounding BITH Big Sandy Creek is mapped primarily as Willis Formation, and may have yielded some of the specimens within the collection. Sloat (1977) also remarks on the diversity of wood in the Johnson collection which includes specimens of cottonwood, palm, ash, oak, grapevine, pine, cypress, Hercules club, willow, and ironwood among some unidentified specimens. Given that most of the geologic units in the area (Miocene and Pleistocene) have petrified wood potential, the finds probably came from a variety of geologic formations and ages.

Undivided fluviatile terrace deposits (Pleistocene)
Shelby et al. (1992) utilize the “undivided fluviatile terrace deposits” map unit to indicate an area of gravel sand and silt deposits found in valley walls that are likely correlative to the Beaumont, Montgomery, and Bentley deposits. However, differentiating between them was difficult at the map scale and they are grouped together. The paleontological resources of the Beaumont, Montgomery and Bentley deposits are addressed in their own separate paragraphs. Thus areas where the “undivided” unit are mapped by Shelby et al. (1992), only found within the Big Sandy Creek Unit, may yield fossils typical of the aforementioned formations. None have yet been officially documented within the park.

Bentley (Lower Lissie) Formation (Pleistocene)
The Bentley Formation has also been mapped as the lower part of the Lissie Formation (Rigsby 1980; Shelby et al. 1992). Characterized by generally brown fluviatile clay, silt, sand, and a minor gravel component, the Bentley Formation is mapped in the Beech Creek Unit, Turkey Creek Unit, Menard Creek Unit, and the Hickory Creek Savannah Unit of BITH. The Bentley is interpreted as a coastal deltaic facies (finer material) and an inland fluvial facies (coarser material) (Rigsby 1980). The unit unconformably overlies the Willis Formation.

There are no reports of well preserved macrofossils within the Bentley. However, Meyer (1939) reports the presence of foraminifera and invertebrate shell fragments in some of the isolated marine deposits of the Bentley Formation. Fossils are “rare” in the undivided Lissie Formation (now divided between the Bentley and Montgomery formations) of Sellards et al. (1932). Nevertheless, Sellards et al. (1932) reported fragmentary plant leaves, land snails, and a vertebrate fauna from the Lissie Formation. Deussen (1914) briefly noted vertebrate fossils of *Equus* (horse), *Elephas* (mastodon), and *Megalonyx* (ground sloth) occur in the Lissie Formation “at a number of places.” Lundelius and Stevens (1970) reported on the skull, mandible, and partial skeleton which formed the type specimen of a small stilt-legged horse *Equus francisci* discovered in the Lissie Formation of Wharton County, Texas. The area around Sour Lake, located approximately 6 km (4 miles) south of the Pine Island-Little Pine Island Bayou Corridor Unit of BITH, yielded a number of Pleistocene vertebrates near the boundary between Deussen’s (1914) Lissie Formation and Beaumont Clay. Leidy (1873) and Hay (1924) reported bones and teeth from the Sour Lake area including the genera *Trachemys* (turtle), *Testudo* (turtle), *Megalonyx* (ground sloth), *Equus* (horse), *Mammut* (mastodon), and *Trucifelis* [*Smilodon*] (sabre-tooth cat). The collections records of the Texas Memorial Museum (accessed 2/16/06) list a holotype (original described specimen) of *Smilodon* *fatalis* from the Pleistocene deposits of Sour Lake. While similar fossils have not been officially documented within BITH, such occurrences outside of the park indicate the potential for future discovery in the park.

Montgomery (Upper Lissie) Formation (Pleistocene)
The Montgomery Formation was previously mapped as the upper part of the Lissie Formation (Rigsby 1980; Shelby et al. 1992). The Montgomery Formation is mapped within the Lance Rosier Unit and is characterized by locally calcareous clay, silt, sand, with very minor gravel (no larger than small pebbles) component. Similar to the Bentley Formation, the Montgomery preserves both a fluvial and deltaic facies.

There is no mention of fossils within the Montgomery Formation by Rigsby (1980) or Shelby et al. (1992). The undivided Lissie Formation has yielded fossils, however, as described in the Bentley Formation paragraph above. Fossils have not yet been officially documented from within the Montgomery Formation of BITH.

Beaumont Formation (Pleistocene)
The Beaumont Formation is also known as the Prairie Formation in Louisiana. Within BITH and the surrounding area, clay, silt, and some sand characterize the Beaumont Formation (Shelby et al. 1992). The Beaumont's clay content is generally much higher than the other Pleistocene deposits and ranges in color from blue-gray to yellow-gray, to purple and various shades of red (Rigsby 1980). The Beaumont Formation, also known as the "Beaumont Clay" because of its clay content, is mapped in extensive areas surrounding the eponymous city of Beaumont by Shelby et al. (1992). As such is it mapped in or adjacent to a number of BITH units, including Menard Creek Unit, Loblolly Unit, Lance Rosier Unit, Pine Island-Little Pine Island Bayou Corridor Unit, Neches Bottom and Jack Gore Baygall Unit, and the Upper Neches River Corridor Unit. The Beaumont is one of the most widespread of all the Pleistocene fluvial deposits on the Texas Gulf Coastal Plain.

The Beaumont is also paleontologically productive, especially near the Texas coastline. Numerous authors have studied the fossil invertebrate and vertebrate fauna and flora from the formation, which can include older (Miocene-Pliocene) reworked specimens (e.g. Baskin 1991). Sellards et al. (1932) listed the fossils known from the Beaumont close to the Gulf of Mexico, which are primarily brackish-water or even marine mollusks, the most common being *Rangia cuneata* (an estuarine clam) and *Ostrea virginica* (common oyster). Sellards et al. (1932) and Price (1934) also noted the occasional discovery of a vertebrate bone or tooth of possible mastodons, mammoths, and horses within the Beaumont. Cypress logs are common in the Beaumont Formation, in addition to other organic material and peat in some places (Deussen 1914; Sellards et al. 1932). Within Houston, the Beaumont formation yielded freshwater snails, freshwater mussels, a suckerfish and a pit viper in the "Caroline Street Local Fauna" (e.g. Aronow et al. 1991). Fossils have not yet been officially documented within BITH from the Beaumont Formation, but there is some potential for future discovery.

Trinity River Terraces (late Pleistocene)
The well developed river terrace deposits along the banks of the Trinity River (frequently referred to as "T-1" or "T-2") yielded abundant paleontological resources, primarily near Dallas. For example, Slaughter et al. (1962) described the fossil-rich terrace deposits of the upper Trinity River which yielded at least 63 vertebrate species, 32 mollusk species, and several insects and plants. Quinn (1957) noted the equid fossils found in this region. Uyeno and Miller (1962) described as many as seven species of freshwater fish from one locality. There are numerous other articles detailing fossil specimens from this region, some are listed in the additional references section.

Closer to the Big Thicket area, the terraces of the Trinity River (which forms the western boundary of the Menard Creek Unit, and may have been the source of the BITH mammoth material) are also fossiliferous. For example, Pleistocene gravels now submerged under the Livingston Lake, yielded exceptionally well-preserved skulls of *Megalonyx jeffersonii* (ground sloth) and a species of *Tapirus* (tapir), good skulls of which are very rare (Lundelius and Slaughter 1976). Lundelius and Slaughter (1976) also reported abundant fossil oak logs and limbs from the gravel deposit, which were radiocarbon dated to approximately 21,590 years b.p.

Deweyville Formation (Late? Pleistocene-Recent)
The Deweyville Formation is characterized by sands, silts, clay, and some gravel found in natural levee, stream channel, and backswamp deposits (Shelby et al. 1992). The Deweyville is the youngest of the Pleistocene deposits in the BITH area and may straddle the boundary between Recent and late Pleistocene. Shelby et al. (1992) map gravels of the Deweyville along the Trinity River in the Menard Creek unit area, they also map the Deweyville Formation immediately west of the Neches River between Beaumont and the Silsbee area. As reported by Baskin (1991), there is some dispute regarding the age of the Deweyville, but it is at least 13,000 and perhaps as many as 50,000 years old. Blum et al. (1995) describe the stratigraphic relationships of the Deweyville terraces within the Texas Gulf Coastal Plain.

The Deweyville Formation does not contain abundant paleontological resources, but petrified wood is occasionally found. For example, Aronow (1966) reports a radiocarbon date of 19,900 years b.p. for a log found in the Livingston-Trinity area, northwest of BITH. Fossils are not yet known from this formation within the park.

Alluvial Deposits (Recent)
As described by Shelby et al. (1992), the alluvial deposits in the BITH region are characterized by clay, silt, and sand sediments associated with modern streams. Alluvial deposits are mapped within BITH by Shelby et al. (1992) along the larger water bodies in the area, primarily the Neches River and Big Sandy Creek.

The alluvial deposits contain abundant organic material in localized areas. Also, as mentioned above, older fossils may be reworked with younger sediments during storm events. Shelby et al. (1992) indicate that some areas mapped as Recent Alluvium include many small “inliers” of underlying Miocene (Tertiary) formations and small outcrops of the Deweyville or Pleistocene formations, all of which may be fossiliferous.

Paleontological Resource Management, Preliminary Recommendations

- Given the diversity of paleontological resources from the Miocene and Pleistocene formations throughout the BITH area, as well as the potential for unauthorized collection, a field-based inventory of paleontological resources might be beneficial. As reported above, Geraldine Watson (personal communication, 2006) noted the presence of uncollected and undocumented fossil material within the park in addition to the mammoth tooth she collected in 1981. This field work could be performed by seasonal employees, interns, or outside specialists. The NPS Geologic Resources Division can help advertise, recruit, and provide technical assistance for these positions.
- The mammoth material in BITH collections (Accession 006) might be further identifiable as per discussions with Lyndon Murray (Texas Memorial Museum). Murray indicated (personal communication, 2006) that both Dr. George Jefferson and Dr. George McDaniel of Anza-Borrego State Desert Park in California may be able to assist with identification. Dr. Larry Agenbroad (Mammoth Site, South Dakota) might also be able to provide assistance.
- Jim Westgate (Lamar University), Jon Baskin (Texas A&M University-Kingsville) and Judith Schiebout (Louisiana State University) all noted (personal communication, 2006) that the dense vegetation that gives Big Thicket its name, does preclude extensive exposures of fossil-bearing deposits. Nevertheless, as described above, the river banks, bluffs, and gullies of the park afford some access to these layers.
- Unauthorized collection of paleontological resources from the Fleming Formation (rhino material) or Pleistocene deposits (petrified wood) either immediately adjacent to or perhaps within BITH, might be occurring (L. Jameson, J. Westgate, personal communication, 2006). The large collection of fossil wood at the Johnson Museum and Petrified Forest speaks to the

paleontological resources in the area, and the high level of public interest in those resources. Public education and interpretation regarding fossils, the stewardship mission of the NPS, and the boundaries of BITH may minimize unauthorized collecting and increase the collective knowledge and awareness of local paleontological resources. Such education and interpretation may also bring locally collected specimens to light.

- There is potential potential for discovery of fossil material by park staff during other field work, particularly along streams, creeks, gullies, and erosional features of the park.
- The establishment of a study collection of fossils from the local area could be beneficial. A field-based inventory could provide specimens for such an endeavor.
- Interpretively, the abundance of fossil wood in south east Texas, demonstrated by the Johnson Museum and Petrified Forest, provides a connection to the modern "thicket" environment. Similarities and differences between modern and fossil floras (and faunas) allow for paleoecosystem-modern ecosystem comparison.
- Results of field inventory can be used to create paleontological resource monitoring prescriptions, should the park decide to establish a program of paleontological resource monitoring.

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DS-BITH-XXX Big Thicket National Preserve Museum Collections. 1982-present. (museum specimen; associated specimen notes; collection records; maps; etc.). Originated by BITH staff; status: Active.

DS-BITH-XXX Texas Memorial Museum (Austin) Collections. (museum specimens collected throughout southern and eastern Texas; associated specimen notes; collection records; field notes; publications; historical photos and documents; maps; etc.). Originated by museum staff and other researchers; status: Active.

GULF ISLANDS NATIONAL SEASHORE

At more than 258 km (160 miles) in length, Gulf Islands National Seashore (GUIS) is the longest national seashore in the United States. The park, with units in Mississippi and Florida, preserves and interprets a large diversity of both natural and cultural resources. Natural resources include the barrier islands Santa Rosa and Perdido Key (Florida) and Petit Bois, Horn, and Ship islands (Mississippi) and their surrounding waters and associated ecosystems. The park also preserves extensive cultural resources including a system of coastal fortifications dating back to the late 18th century. The white sand beaches of the park provide recreational access to the Gulf of Mexico. The park was authorized on January 8, 1971.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geologic scoping sessions, sponsored by the NPS Geologic Resources Division, were conducted in September of 2006. Formal paleontological resource surveys have not yet been completed for the park. There is one potentially paleontological specimen within the park's museum collections. Unlike Padre Island National Seashore, fossils are not known to wash up on the beaches of GUIS in any great quantity. There is limited potential for future discovery of fossils within GUIS, although subsurface cores of some islands yielded fossils.

Barrier islands such as those within GUIS are very transient geological features, created and destroyed through continuous wave action and erosion. These islands also are usually very young, geologically speaking, with ages ranging from recent to tens of thousands of years old. The white sands making up much of the GUIS beaches however, are much older quartz grains eroded from the Appalachian Mountains. Barrier islands, by definition, represent the seamost extension of the Coastal Plain physiographic province.

The modern emerged Gulf Islands are approximately 4000 years old (Nummedal 1982, 1983 as reported by Cooper et al. 2005). There are many papers summarizing the local and regional geology and geologic history of the Gulf Islands area also described in Cooper et al. (2005) and referenced here in the additional references section. The general geologic stratigraphy of the area is summarized in many articles including Otvos (1994) and Otvos and Howett (1992). Dauphin Island, adjacent to GUIS in Alabama also has an extensive literature base.

Unlike Padre Island National Seashore which has an offshore source of paleontological material, there is no such source off the coast of Gulf Islands National Seashore. Hence very few fossils wash up on the shore of the park. In addition, the geologically very young barrier island sediments exposed on the surface of GUIS are not known to contain fossils. Hence, the main sources of paleontological resources are subsurface wells. Wells yielded paleontological material, as described below in Mississippi's Horn Island, near Santa Rosa Island (Florida), and near the Naval Live Oaks area (Florida).

Gulf Coast Network parks such as Padre Island National Seashore, Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve and Palo Alto Battlefield National Historic Site are geologically very young making it difficult to determine what material is a "fossil" what would be considered "modern." The National Park Service defines a fossil as any remains of life preserved in a geologic context. This definition does not include an arbitrary date where older specimens are considered fossils, and younger specimens are not. The "geologic context" phrase is intended to imply some level of antiquity, however. Generally, specimens dating back to the late Pleistocene are considered fossils. Late Holocene (last few hundred or thousand years, "Recent") specimens are usually considered modern and not fossils. Subsurface specimens collected at GUIS span this range between Pleistocene and Holocene. Regardless of what label is assigned to them, these specimens are important natural resources and valuable pieces of the history of life on earth.

Park Collections
With no offshore source of abundant paleontological specimens, there is only one potential paleontological specimen in the park's collection. Housed at the NPS Southeast Archeology Center (SEAC), the specimen is described only as a mineralized fossil and may be a mollusk shell (R. Sellers, personal communication, 2006). The material apparently was found in association with an archeological site. The actual age and identification of the specimen is still unknown. Further research into the specimen's provenance may yield additional information.

Subsurface sediments (Pliocene-Pleistocene-Holocene)-Horn Island
During 1991, the U.S. Geological Survey drilled a stratigraphic test hole on Horn Island within GUIS as described by Gohn et al. (1994, 1996). These cores were informally divided into three separate lithologic units, the first unit was described as Pliocene in age, the second Pliocene(?) and the third Holocene.

"Unit 1" was the oldest (lowest) unit and its fine grained sediments yielded a rich fossil record of foraminifera, ostracoda, mollusca (pelecypods or bivalves), and an extensive dinoflaggelate and pollen record. Collectively the sediments and fossils of "Unit 1" represent a Pliocene-aged estuarine paleoenvironment. The middle "Unit 2" is characterized by cyclic fining-upward sections of noncalcareous sands and clays, devoid of calcareous fossils. However some minor pulverized plant material and small burrows were noted. The unit was assigned a tentative "Pliocene?" age based upon the lithologic characteristics and observed similarity to Pliocene units in nearby Jackson County, Mississippi (Gohn et al. 1996, referencing Otvos 1994). Gohn et al. (1996) suggest that this unit was deposited in a fluvial or upper estuarine paleoenvironment. The youngest (top) unit of Gohn et al. (1996) was "Unit 3." This unit was further redefined into three subunits based on lithology and fossils. Fossils such as echinoid spines, fragmented mollusks and microfossils, are found as high in the core as 4.4 m (14.5 ft) below the surface. Overall, the fossil assemblage includes diverse foraminifers, ostracodes, mollusks, dinoflagellates and pollen. A radiocarbon age of approximately 9470 years before present (b.p.) was determined for the unit. All of the molluscan species discovered in "Unit 3" are extant, aiding in the Holocene age determination. As the youngest unit, "Unit 3" provides a sedimentary and fossil record of sea level rise and island migration during the Holocene to present day. The foraminifera specimens from the core hole were further described with paleoenvironmental interpretation by Gibson (1994). Gohn et al. (1996) also note that the Gulfport and Biloxi formations, prevalent along the coast of Mississippi, are not present on Horn Island, at least not at the core site.

Gohn et al. (1996) also correlated their results to those of previous wells drilled by the U.S. Army in the 1940s (see Brown et al. 1944). Walton (1960) studied the modern subsurface faunal characteristics along Horn Island to identify barrier island trends. Otvos (1988) indicates that a number of cores have been collected from Ship Island, but does not provide additional information. Rainwater (1964) described a series of core samples taken across Mississippi Sound from Beauvoir to Ship Island. These cores yielded Pleistocene and Recent fossiliferous material from the bottom of the sound including foraminifera, ostracods, bryozoan, mollusks, echinoids, and barnacles. Rainwater (1964) utilized these cores to illustrate the sea level and associated shoreline changes associated with melting of ice sheets responsible for the early formation of many of the Gulf barrier islands, including those within GUIS.

Subsurface sediments (Pleistocene)-Santa Rosa Island
As described by Otvos (1982, and references therein), Santa Rosa Island is a composite (secondary) barrier island. Such islands are characterized by a subsurface Pleistocene barrier island core surrounded by and topped with Holocene and modern island progradational, aeolian, etc. sediments. The Pleistocene core yielded fossils, primarily foraminifera. Foraminifera are generally marine, single celled protozoans characterized by a test of one or more chambers that are composed of calcite or agglutinated ("glued" together into a mass) particles. NPS-administered lands on Santa Rosa Island are generally westward of the Pleistocene core. Drill cores near the west end of the island yielded Pleistocene sands, but they were nonfossiliferous (Otvos 1982).

The fossils studied in the Santa Rosa Island cores were primarily foraminifera, as stated above and were preserved in the subsurface nearshore marine sands and estuarine sands-clayey sands of the Pleistocene Biloxi Formation and the sandy barrier sediments of the late Pleistocene Gulfport Formation. Fossils in these cores provide information regarding the formation of barrier islands, their history and continuing evolution from the Pleistocene through today. Within Pensacola Beach, east of GUIS, another core hole described by Marsh (1966) yielded microfossils and fossil mollusca from Pleistocene and Recent sediments, including the Citronelle Formation and undifferentiated Miocene-aged sediments, Miocene-Pliocene Pensacola Clay and the Oligocene-Miocene Tampa Formation and Oligocene Chickasawhay Limestone.

Undifferentiated Sediments (Pleistocene-Holocene)-Naval Live Oaks Area and Fort Barrancas Area
As mapped by Scott et al. (2001), the Naval Live Oaks and Fort Barrancas areas are underlain by siliciclastic deposits. These deposits may date back to the Pleistocene, but also include more modern deposits. They are characterized by unconsolidated to poorly consolidated light gray, tan, brown to black, clean to clayey, variably organic-bearing sands and blue green to olive green poorly to moderately consolidated sandy, silty, clays. Near Fort Barrancas, these deposits display a surface expression of beach ridges and dunes. These sediments in the Florida Panhandle are “unfossiliferous” (Scott et al. 2001).

While no fossils have yet been found exposed at the surface near Naval Live Oaks and Fort Barrancas, and there is very little potential for discovery based on the underlying geology, a paleontologically important well was drilled west of Naval Live Oaks Area near Fair Point. Described by Marsh (1966), a large assemblage of fossil mollusks was recovered from a depth of approximately 7.6 m (25 ft) in a water well located on “Fairpoint Peninsula.” It is believed that the fossils were located within the Pleistocene Citronelle Formation, which adds to their significance. According to Marsh (1966), identifiable fossils are extraordinarily rare in the Citronelle Formation of Santa Rosa or Escambia counties.

Undifferentiated Coastal Sediments (Pleistocene-Holocene)-Davis Bayou Area
The Davis Bayou (Mississippi) area is primarily modern brackish muddy sands. Pleistocene sediments typical of the Mississippi coastal area such as the Gulfport, Prairie, and/or Biloxi formations may also be present in the subsurface. Fossils are uncommon if present at all in the Gulfport and Prairie formations (Brown et al. 1944). However the Biloxi Formation is known to be abundantly fossiliferous including stratigraphically significant fossil foraminifers, mollusks, and ostracodes (e.g. Otvos 1982). Such fossils are not yet known from within GUIS.

Paleontological Resource Management, Preliminary Recommendations
As fossils do not commonly wash up on the beaches of GUIS, and fossils are generally only found in subsurface research wells, there are few opportunities for active paleontological resource management. Nevertheless, there is one potential fossil in the park’s collection, which may indicate the presence of similar material in other archeological areas. In addition, the subsurface fossils found within and near GUIS offer educational and interpretive opportunities and scientific research potential related to barrier island formation and the evolution of the Gulf of Mexico.

COOPERATIVE PROJECTS

- Geologic Resources Division: Geologic Resource Evaluation Scoping Session (September 2006). Participants from GRD, GUIS, and other agencies and local institutions met to discuss geologic issues pertaining to GUIS.

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DS-GUIS-XXX Gulf Islands National Seashore Museum Collections. 5/1985–present. (museum specimen, associated notes, etc.). Originated by park staff, housed at Southeastern Archeological Center; status: Active.

JEAN LAFITTE NATIONAL HISTORICAL PARK AND PRESERVE

Jean Lafitte National Historical Park and Preserve (JELA) preserves the significant natural and cultural resources of Louisiana's Mississippi Delta region. The park consists of six administrative units. Three interpret the Acadian culture of the area. Barataria Preserve interprets the natural and cultural history of the uplands, swamps, and marshlands of the region. Chalmette Battlefield and National Cemetery preserve the site of the 1815 Battle of New Orleans. The park also has a visitor center in the French Quarter of New Orleans interpreting the diverse culture and history of the city and region. The park's namesake Jean Lafitte gained notoriety leading smugglers and privateers who, while betraying the British, supported Gen. Andrew Jackson during the Battle of New Orleans. The Chalmette unit was originally established as Chalmette Monument and Grounds in 1907 and subsequently transferred to the NPS in 1933. The park was reestablished as Chalmette National Historical Park in 1939 and incorporated into the new Jean Lafitte National Historical Park and Preserve established on November 10, 1978.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

There have been neither geological nor paleontological resource scoping sessions held for Jean Lafitte National Historical Park and Preserve. Formal paleontological resource inventories have likewise not been completed for the park. There are no paleontological specimens in the park's museum collection (D. Muth, personal communication, 2006). The underlying geology of the park holds little potential for future discovery of paleontological resources.

Jean Lafitte National Historical Park is located in the Mississippi Alluvial Plain region of the Coastal Plain Province. The Mississippi Alluvial Plain, as its name suggests, is a broad flat alluvial plain of the Mississippi River. The sediments of the plain are primarily Holocene age river deposits associated with the ancestral and present day Mississippi River. Pleistocene age fluvial sediments and loess are mapped at JELA units in Eunice and Lafayette, respectively.

Regional or parish-based geologic maps for the Chalmette Battlefield and Barataria Preserve units (both part of I&M program) of JELA have not yet been prepared, however both are immediately south of the Ponchataula (McCulloh et al. 2003) and Gulfport (Heinrich et al. 2004) 1:100,000 scale geologic maps. Nevertheless this area is part of the St. Bernard Delta lobe, mapped by McCulloh et al. (2003) and Heinrich et al. (2004). Likewise, regional or parish-based geologic maps are not yet available for the Thibodeaux (Wetlands Acadian Cultural Center) area. Geologic maps have been produced for the areas surrounding the other Acadian Cultural Centers in Lafayette (Heinrich and Autin 2000) and Eunice (Heinrich et al. 2003).

Gulf Coast Network parks such as Padre Island National Seashore, Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve and Palo Alto Battlefield National Historic Site are geologically very young making it difficult to determine what material is a "fossil" what would be considered "modern." The National Park Service defines a fossil as any remains of life preserved in a geologic context. This definition does not include a hard and arbitrary date where older specimens are considered fossils, and younger specimens are not. The "geologic context" phrase is intended to imply some level of antiquity, however. Generally, specimens dating back to the late Pleistocene are considered fossils. Late Holocene (last few hundred or thousand years, "Recent") specimens are usually considered modern and not fossils. Material from the JELA area is typically Recent in age, while subsurface material may date back to the Pleistocene or later. Regardless of what label is attached to them, these specimens are important natural resources and valuable pieces of the history of life on earth.

River terraces and loess (middle-upper Pleistocene)
While not technically a part of the I&M program, the Acadian Cultural Centers at Eunice and Lafayette, are situated atop Pleistocene river terraces and loess older than the Mississippi River Delta complex deposits of the other JELA units. Within Eunice, Heinrich et al. (2003) map the coastal plain deposits

(clay, sandy clay loam, silty clay loam, some sand and gravel) of middle-upper (late) Pleistocene streams of the Beaumont Alloformation. An alloformation is a geologic unit bounded by unconformities, which are breaks or gaps in the geologic record. Alloformations are not usually well defined lithologically, but can be correlated on the basis of morphologies as per Johnston et al. (2000). This is useful in areas like much of Louisiana where similar fluvial sediments deposited over large areas that are difficult to differentiate. The Lafayette unit of JELA is underlain by the Avoyelles Alloformation (sand to clay deposited as meander belts of the late Pleistocene Mississippi River) and modern Vermilion River alluvium (Heinrich and Autin 2000). At Lafayette, these geologic deposits are blanketed by upper (late) Pleistocene Peorian loess.

Like many of the other units of JELA described below, the Eunice and Lafayette units are in developed areas with no subsurface exposures. However, the Pleistocene age of the river terraces increases the potential for paleontological resources within the local areas. The Beaumont Alloformation generally correlates with the Beaumont Formation of Texas, and is described further in the Big Thicket National Preserve section of this report. The Beaumont yields fossils in Texas. Fossils are not yet reported from the Avoyelles Alloformation.

Fossils from the Peorian loess are well known, including abundant terrestrial gastropods and even mammoth material, particularly in Mississippi (Snowden and Priddy 1968). For more information on Pleistocene loess fossils, see the Vicksburg National Military Park section of this report. Although road cuts and excavations in both Mississippi and Louisiana yielded fossils, none are yet reported near Lafayette. There are limited, if any, exposures near the Acadian Cultural Center, and therefore little opportunity for paleontological material.

Mississippi River Delta Complexes (Holocene)

The Holocene evolution of the Mississippi River Alluvial plain and delta complexes has resulted in a complex record of deposition and erosion as new delta lobes and complexes form as the river's course migrated over the last 6,000 years. Frazier (1967) published one of the earliest papers detailing this complex chronology. Although located just south of the mapped areas of McCulloh et al. (2003) and Heinrich et al. (2004), the French Quarter, Chalmette and Barataria units are located within lobes of the St. Bernard Delta Complex. Frazier (1967) considers these natural levee, deltaic plain, and coastal marsh deposits to be no older than approximately 2,000-5,000 years before present.

In part, Frazier (1967) utilized various macroinvertebrate shells and plant material to date the various delta lobes. However, there is little chance for observable paleontological material within the Barataria, Chalmette, French Quarter and Thibodeaux units due to the young age of the sedimentary deposits and lack of exposures. Like the barrier island parks of the Gulf Coast Network, the subsurface may be the only source of paleontological material in the area surrounding the park. Because of important oil and gas deposits in the area, there is an extensive library of geologic cores and well logs housed at the Louisiana Geological Survey in Baton Rouge (D. Muth, R. McCulloh, personal communication, 2006). Some of these subsurface samples include fossils which are used as stratigraphic indicators, although none are yet known from within the park.

As one historic example of local subsurface fossils, Hilgard (1870) studied the cores of an artesian well sunk in New Orleans in 1856. Hilgard does not provide any additional information regarding the well's exact location, but documents the 41 species of foraminifera and mollusks discovered in the well cores. He also notes the presence of wood in many of the samples. Based on similarities to modern faunas, Hilgard (1870) thought the age of the material to be "post-pleiocene [sic]" or younger. Otvos (1978, 1982) also describedforaminifera and mollusks collected form subsurface late Holocene barrier ridges below New Orleans.

Even though the floral and faunal material within the Holocene River sediments are considered modern, they provide important information for paleoenvironmental reconstruction and the rise of subsistence agriculture over the last few hundred to few thousand years (P. Heinrich, personal communication, 2006).

In this light, Holmes (1986), Speaker et al. (1986), and Giardino (n.d.) describe the formation of the St. Bernard Delta Complex in the context of cultural resource potential ("geoarcheology") within Barataria unit of JELA. Ryan (1982) produced a field trip guidebook for the cultural changes of the Barataria basin from 900-1700 AD.

Paleontological Resource Management, Preliminary Recommendations
As fossils are not known from JELA, there are few opportunities for active paleontological resource management. Nevertheless, the subsurface (wells) fossils found near JELA offer educational and interpretive opportunities and scientific research potential related to the history and evolution of the Mississippi River. The geoarcheology of many sites in the Mississippi delta, including those near JELA (Barataria in particular) may provide interesting interpretive and resource management opportunities. In addition Paul Heinrich of the Louisiana Geological Survey (Baton Rouge) has experience in geoarcheology and is interested in creating a natural history (modern flora and fauna, geology, geoarcheology, etc.) guide to various parks in Louisiana, including JELA.

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DATA SETS

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NATCHEZ TRACE PARKWAY

The Natchez Trace Parkway (NATR) commemorates the Natchez Trace, a historic trail that connected southern portions of the Mississippi River to the salt licks in what is now central Tennessee. From about 1785-1830, the trail was utilized by American Indians and early settlers. Today the parkway stretches 715 km (444 miles) from Natchez, Mississippi to near Nashville, Tennessee and interprets a rich cultural history. Funds for the parkway were first authorized in 1934 and NATR was transferred to the National Park Service in 1938. The parkway was completed in 2005 and is a National Scenic Byway and All-American Road.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Neither geological nor paleontological resource scoping sessions have yet been held for Natchez Trace Parkway. Likewise formal paleontological resource inventories have not yet been completed. Nevertheless, Natchez Trace Parkway and the surrounding area, contains significant and abundant paleontological resources. Park collections include more than 151 paleontological specimens curated at NATR with an additional 1,781 primarily archeological specimens housed at the Southeast Archeological Center as described in the park collections section.

Geologically the park is very significant. Through its 715 km (444 mile) length NATR traverses two main physiographic provinces, the Interior Low Plateaus and the East Gulf Coastal Plain. Nearly every geologic formation crossed by the parkway in Tennessee, Alabama, and Mississippi preserves fossils, some within the park. A linear park such as NATR offers few opportunities for large areal exposures of geology. Thus road cuts or erosional features may provide access to the underlying geology. However road cuts along the parkway are mostly found north of Tupelo (C. Stubblefield, personal communication, 2006). Most of the parkway is vegetated, but exposures are frequently visible just outside of the parkway (D. Dockery, personal communication, 2006). Road cuts would be more likely in Tennessee where well-cemented limestones hold up steeper slopes than the less consolidated Coastal Plain deposits of Mississippi.

Construction efforts revealed fossils along the parkway, for example near Twentymile Creek (Mississippi; see Coffee Sand paragraph). Other sites known to yield fossils within the parkway include Garrison Creek (Tennessee; see Catheys Formation paragraph) and Choctaw Agency (Mississippi; see Yazoo Clay paragraph). The Prairie Bluff Formation (Mississippi) was the source of most of the fossils in the park's collections and has yielded fossils very close to NATR boundaries (see Prairie Bluff paragraph). A fossil display used to be located along NATR near milepost 235 (see park collections and Prairie Bluff paragraph). Fossils may also have been collected within or near the parkway in the Pride Mountain Formation (Mississippi; see Pride Mountain paragraph). Black (1962) also described some fossil occurrences along the parkway in a preliminary inventory of geological features of the Natchez Trace Parkway (see Hermitage Formation, Bigby and Cannon limestones, Leipers Formation, Brassfield Limestone, Hartselle Sandstone, and Meridian Sand paragraphs). The summaries below also describe many formations that preserve fossils near the parkway, some at very significant localities, indicating potential for similar finds within the park.

Paleontological resources from NPS sites administered by or located near NATR (Brices Cross Roads National Battlefield Site, Tupelo National Battlefield, and Natchez National Historical Park) are also summarized at the end of the NATR summary. For ease of organization, this report is divided by state and then by physiographic province and finally by geologic age with the oldest units summarized first.

Park Collections
According to ANCS+ records, there are 151 paleontology specimens in NATR museum collections (C. Miller, personal communication, 2006). The great majority of specimens were apparently collected in Chickasaw County, Mississippi from the Prairie Bluff Formation. The Prairie Bluff fossils include serpulid worm tubes, bivalves (pelecypods), gastropods, cephalopods (straight and coiled ammonites and

nautiloids), echinoids, a piece of petrified wood, shark teeth (Chondrichthyes), and three specimens labeled "feces," may be fish coprolites. There are also five specimens (all oysters) from the "Selma Chalk" and one specimen from the Leipers Formation, an Ordovician formation exposed in Tennessee (see Leipers Formation section below). As the locality information for most of the fossils is "Chickasaw County," they might have been part of a fossil display that used to be located near MP235. This display has since been taken down and removed (C. Miller, personal communication, 2006). The Prairie Bluff Chalk paragraph has more information regarding this display.

The NPS Southeast Archeological Center (Tallahassee, Florida) also maintains records of 1,781 specimens from NATR with the word "fossil" in their description (B. Carter, personal communication, 2006). Nearly all of these specimens are curated at the Cobb Institute of Archeology (Mississippi State University). Most of the specimens are pottery fragments that utilized "fossil shell" tempering, where chalky sediments (e.g. Selma Group) were employed as a tempering agent (B. Carter, personal communication, 2006). There are many actual fossils in the collections as well including marine invertebrates from Tennessee. Depending on their source, some fossils in the collection might have been used as trade or funerary items given the many Native American burial mounds along NATR. Fossils (crinoid stems, sharks teeth, etc.) have been found as funerary items in American Indian mounds in various Midwestern sites such as near Effigy Mounds National Monument (Iowa) and Hopewell Culture National Historical Park (Ohio) are just two examples (Kenworthy and Santucci 2006). Further investigation into these collections and their geological provenance would be beneficial and allow "official documentation" of fossils from formations where there is good potential for fossils but none are formally documented yet. Kenworthy and Santucci (2006) presented an introduction to NPS fossils found in cultural contexts (building stones, archeological resources, ethnographic stories and legends, and historical occurrences). There might be many examples from NATR that could be further described.

TENNESSEE

Within Tennessee, Natchez Trace Parkway passes through Wayne, Lawrence, Lewis, Maury, Hickman, Williamson, and Davidson counties in southern and west-central Tennessee from milepost (MP) 341.8 (Tennessee-Alabama state line) to the parkway's terminus at MP444 at Tennessee Route 100 and McCrory Lane, 27 km (17 miles) southwest of Nashville. Throughout these 100 miles, the parkway crosses a number of fossiliferous formations from the Ordovician, Mississippian, and Cretaceous periods with an extensive literature base. The Middle Ordovician-aged rocks in Tennessee, at approximately 460-470 million years old (see Appendix A) are by far the oldest rocks not only along NATR, but within the entire Gulf Coast Network.

NATR crosses rocks of the Nashville Basin (primarily Ordovician limestones), and Highland Rim Section (primarily Mississippian sediments) of the Interior Low Plateaus physiographic province. Near the Alabama border in Wayne County, the parkway crosses the East Gulf Coastal Plain Region (Cretaceous sediments) of the Coastal Plain physiographic province. An introduction to the geologic history of Tennessee is presented by Miller (1974). The Ordovician limestones were primarily deposited in a shallow marine sea in what is now central Tennessee. These limestones, as described below, are abundantly fossiliferous. However, their stratigraphic interrelationships have been difficult to unravel (Miller 1974). The Mississippian rocks were likewise deposited in shallow marine environments with more siliciclastic (silica-rich) terrestrial sediments being washed in, as evidenced by the large amounts of chert present in some formations. Following deposition of the marine sediments, this basin was tectonically raised to form the "Nashville Dome" and subsequently eroded to form the Nashville Basin (also known as Central Basin) region of Tennessee. The Cretaceous sediments crossed by the parkway in Wayne County are much younger, primarily terrestrial sediments deposited less than 100 million years ago during the Cretaceous in streams eroding what were then the highlands of northwest Tennessee.

Geologic Maps
Large scale (1:24,000) geologic maps have been published by the Tennessee Division of Geology for 15 of the 16 USGS 7.5 minute quadrangles crossed by NATR in Tennessee. The lone exception is the Cypress Inn Quadrangle, where the parkway crosses the Alabama-Tennessee state line. These maps were published in the 1960s and 1970s and would be excellent components of the park's resource management library. Published geologic quadrangle maps include (from southwest to northeast): Three Churches (Wilson and Marcher 1972), Collinwood (Marcher and Barnes 1963), Negro Hollow (Marcher and Wilson 1963), Ovilla (Marcher 1963a), Riverside (Wilson and Marcher 1962), Henryville (Marcher and Lounsbury 1965), Gordonsburg (Colvin and Marcher 1964), Sunrise (Colvin 1970), Greenfield Bend (Wilson and Miller 1964), Williamsport (Wilson et al. 1964), Primm Springs (Wilson and Colvin 1965), Theta (Wilson and Colvin 1964), Fairview (Wilson 1972), Leipers Fork (Morrow and Wilson 1963), and Bellevue (Wilson and Miller 1979). Most of these maps were created before completion of the parkway, hence NATR does not appear on many of the maps. However, the "Natchez Trace" is indicated on most. More recent editions of topographic maps for these quadrangles have the NATR boundaries indicated, and can be used in conjunction with the older geologic maps. Sources of smaller (regional) scale geologic information include the 1966 geologic map of Tennessee (Miller et al. 1966). Also, because of the recent completion of the parkway, many of the paleontological studies of the region in the late 1800s through mid 1900s do not reference the parkway and were not able to utilize/study the road cuts created along the parkway in any paleontological investigations.

<u>Tennessee—Interior Lowlands Province—Nashville Basin</u>

The rocks of the Nashville Basin exposed near the parkway are middle and upper (late) Ordovician limestones from the Stones River Group, Nashville Group, and a variety of upper Ordovician limestones. Nearly all of the Ordovician Limestones are fossiliferous, in some cases quite abundantly. Marine invertebrates dominate the faunas. These very fossiliferous Ordovician limestones are some of the best studied rocks in central Tennessee as evidenced by their lengthy literature base and their application to understanding the evolution of the southern Appalachians. At least one fossil locality is known within NATR in rocks of the Catheys and Leipers Formations, at the Garrison Creek picnic area, see the formation descriptions below. There are a number of good websites that describe the Ordovician fossils around Nashville. Dr. Steven Holland (University of Georgia) maintains a comprehensive website (http://www.uga.edu/~strata/nashville/index.html, Accessed 21 November 2006) with photos and bibliographies related to Ordovician fossils and stratigraphy near Nashville. The Nashville Group rocks in particular are also important sources of phosphate (Smith and Whitlatch 1940; Cathcart 1989).

Donald Black served as a naturalist at the NATR in the early 1960s. His background in geology fueled his interest in the subject as it related to NATR. Black (1961) summarized the extensive Ordovician exposures and fossils from the Stones River Group, Nashville Group, upper Ordovician Formations near NATR area and identified areas where such formations may be exposed near the parkway. Black (1962) collected marine invertebrate fossils from the Carters, Hermitage, Bigby, Cannon, Leipers, and Brassfield (Silurian) formations. Bassler (1932) and Wilson (1949; second edition 1990) produced the first monographs to comprehensively describe to abundant paleontological resources from the Ordovician formations in the Nashville Basin. These reports formed the basis for Black's (1961) summary. Unless otherwise cited, the information below was obtained from these main sources.

Stones River Group (Middle Ordovician)-Carters Limestone
Rocks of the Carters Limestone represent the oldest rocks exposed along NATR. The Carters Limestone is the youngest formation in the Stones River Group of central Tennessee. It was originally named the "Upper Lebanon Limestone" (Safford 1851) and later the "Carter's Creek Limestone" (Safford 1869). The Carters Limestone is divided into two members, the upper and lower members generally characterized by light gray to dove or even blue colored limestones. Both are known to be fossiliferous, and the lower member contains fossiliferous coquina beds. As mapped by Black (1961, 1962), the Carters Limestone is exposed along the Natchez Trace region on both sides of Duck River near Gordon House and Ferry Site (MP407.7).

The abundant Carters Limestone fossils are described in much greater detail in Bassler (1932), Wilson (1990), and summarized by Black (1961). Within the lower member of the Carters Limestone, fossils include reef forming rugosan corals, tabulate coral, sponges, gastropods and plant material. The corals and sponges form local reefs up to 1 m (3 ft) thick. The upper member contains a variety of bryozoans, stromatoporoid sponges, brachiopods, gastropods, bivalves, cephalopods, ostracodes, and trilobites. Siesser et al. (1998) described marine microfossils (chitinozoans) from the Carters Formation and their utility for regional and global correlation. These faunas are indicative of a clear, shallow marine sea. Black (1962) discovered bryozoans, cephalopods, sponges, gastropods, and crinoids near the parkway right-of-way in the Carters, Hermitage, Bigby, Cannon, Leipers, and/or Brassfield formations.

Nashville Group (Middle Ordovician)

The Middle Ordovician Nashville Group is stratigraphically divided into four marine formations in ascending (oldest to youngest order), they are the Hermitage Formation (or Limestone), Bigby Limestone, Cannon Limestone, and Catheys Formation (or Limestone). As described by Black (1961), exposures of all four formations are mapped near the parkway, and as such characteristic fossils may be found along or near the parkway, especially near the Duck River Crossing, along the Harpeth River (near Bradley Bend and Brown Creek), West Harpeth River, and southwest of Leipers Fork. Ordovician formations tend to be exposed lower in creek valleys below the Mississippian-aged formations described in the Highland Rim Section. Bassler (1932) correlated rocks now assigned to the Nashville Group with the now-defunct (in Tennessee) "Trenton Group" nomenclature.

Nashville Group (Middle Ordovician)—Hermitage Formation

The Hermitage Formation, named for exposures near the home of President Andrew Jackson east of Nashville, overlies the Carters Limestone. The Hermitage is divided into four to six informal members by various authors (e.g. Wilson 1990; Wahlman 1992). Overall the Hermitage Formation members are characterized by light gray limestone (Curdsville Limestone), a silty nodular blue limestone, a laminated argillaceous (containing clay) blue or yellowish brown (weathered) limestone, a brachiopod (*Reserella* (*Dalmanella) fertilis*)-dominated coquina layer, a bivalve (*Ctenodonta*)-dominated layer, and a phosphatic member (the last two are included within Wilson's (1962) laminated argillaceous member). As mapped by Black (1961), exposures of the Hermitage Formation are found stratigraphically above the Carters Limestone at the Duck River crossing (MP407.7) and near the Bradley Bend on the Harpeth River near Nashville east of the parkway's terminus. The Hermitage is mapped near NATR on the Williamsport quadrangle (Wilson et al. 1964). Wahlman (1992) summarized the various marine depositional settings of the Hermitage Formation's members from shallow subtidal marine to deep stagnant water to shoal areas subjected to intensive waves and currents.

The limestone and coquina layers and members of the Hermitage are abundantly fossiliferous including characteristic brachiopods (especially "*Dalmanella*," now *Reserella*), tabulate corals, bryozoans, bivalves (particularly *Ctenodonta hermitagensis*) ostracodes and trilobites (Bassler 1932; Wilson 1962; Wilson 1990; Wahlman 1992). Fossils are rare in the argillaceous and silty layers. Marintsch (1998) described in great detail the bryozoan fauna of the Hermitage Formation exposed in east-central Tennessee and its biostratigraphic applications. Holland and Patzkowsky (1997, 1998) and Patzkowsky and Holland (1999) described paleoenvironmental, fossil "biofacies," and sequence stratigraphy changes through middle-upper Ordovician time utilizing fossils from the Hermitage Formation. Siesser et al. (1998) described nine species of marine microfossils (chitinozoans) from the Hermitage Formation and their utility for regional and global correlation. Black (1962) discovered bryozoans, cephalopods, sponges, gastropods, and crinoids near the parkway right-of-way in the Carters, Hermitage, Bigby, Cannon, Leipers, and/or Brassfield formations.

Nashville Group (Middle Ordovician)—Bigby and Cannon Limestones

The Bigby Limestone is frequently mapped together with the Cannon Limestone as the informal "Bigby-Cannon Limestone" since the formations are generally contemporaneous. The formations grade into each other with a "dove-colored" facies along the transition between the two (e.g. Wilson 1990; Wahlman

1992). The Bigby and Cannon limestones unconformably overly the Hermitage Formation. The Bigby and Cannon limestones are characterized by limestone in various shades of blue to bluish gray, typically weathering to a brown color. Chert is found in abundance in some layers. The Bigby Limestone is a common building stone in Tennessee and was selected for construction of the Tennessee state Capitol building, earning it the nickname "Capitol Limestone" in the late 1800s (Bassler 1932). Black (1961) identified a number of areas along and near the parkway mapped as Bigby, Cannon, or "dove-colored" facies including along Harpeth and Duck rivers and near Gordon House. The fragmentary fossils of the Bigby indicate a high energy-wave impacted marine environment with the dove-colored facies representing shelf-lagoon, and the Cannon representing relatively quiet shallow marine deposition (Wilson 1990; Wahlman 1992).

Fossils are found throughout the Bigby Limestone but are most common in the middle and upper layers. Many of the layers are composed of "ground fragments of the hard parts of a wide variety of marine organisms" (Wilson 1962). Fossils include an assortment of bryozoans, articulate brachiopods, bivalves, gastropods, and straight nautiloids. Sponges and rugosan corals are common in the upper layers of the Bigby Formation (Bassler 1932; Wilson 1962, 1990; Wahlman 1992). Fossils from the "dove-colored facies" are rare but include sponges, tabulate corals, brachiopods, bivalves, gastropods, monoplacaphoran (univalve mollusk), ostracodes and the worm burrow trace fossil *Skolithos*. Wilson (1990) interpreted some of these remains as washed-in detritus (Wahlman 1992). The Cannon Limestone fossils include sponges, tabulate corals, bryozoans, brachiopods, bivalves, and ostracodes (Alberstadt 1973; Wilson 1990; Wahlman 1992). Holland and Patzkowsky (1997, 1998) and Patzkowsky and Holland (1999) described paleoenvironmental, fossil "biofacies," and sequence stratigraphy changes through middle-upper Ordovician time utilizing fossils from the Bigby and Cannon formations. Siesser et al. (1998) described three species of marine microfossils (chitinozoans) from the "Bigby-Cannon Formation" and their utility for regional and global correlation. Black (1962) discovered bryozoans, cephalopods, sponges, gastropods, and crinoids near the parkway right-of-way in the Carters, Hermitage, Bigby, Cannon, Leipers, and/or Brassfield formations.

Nashville Group (middle-upper Ordovician)—Catheys Formation

The middle-upper Ordovician Catheys Formation is the uppermost (youngest) formation in the Nashville Group as defined by Wilson (1949). The Catheys Formation is frequently mapped together with the overlying (younger) Leipers Formation. Fossils from the Catheys-Leipers Formation were discovered along the parkway near Garrison Creek, as described below. This Catheys and Leipers formations unit is mapped in a number of places along NATR. For instance, Black (1961) noted "about a dozen different places" where the parkway would cross rocks mapped as the Catheys Formation between Duck River and the parkway terminus.

There is one important Catheys Formation locality ("Garrison Creek Locality") located within NATR at a road cut between MP427-428 near the Garrison Creek Picnic Area (Holland and Patzkowsky 1998, 1999). This road cut exposes both Catheys Formation and Leipers Formation (see below) limestones. The fossils collected by Holland and Patzkowsky (1999) include a biostrome (blanket-like mass of rock built by and composed of sedentary organisms) consisting almost entirely of the sponge *Pattersonia*. The biostrome is 40-50 cm (16-20 in) thick and extends for some 100 meters (328 ft) laterally. Holland and Patzkowsky (1999) note the significance of this discovery along NATR as it is very rare to find biostromes of sponges in upper Ordovician rocks. In fact the NATR discovery was the first such example in their field work. In addition to the rare *Pattersonia* biostrome, Holland and Patzkowsky (1999) also noted other marine invertebrates above and below the biostrome including *Platystrophia*, *Hebertella*, *Orthorhynchula*, and *Rafininesquina* brachiopods, *Constellaria* and *Parvohallopora* bryozoans, *Tetradium* coral, *Isotelus* and *Flexicalymene* trilobites, the nautiloid *Cyrtoceras*, *Sinuites* gastropod, *Caritodens* bivalve, and the edrioasteroid (sessile, stalked, starfish-like echinoderm) *Streptaster*. Holland and Patzkowsky (1997, 1998) and Patzkowsky and Holland (1999) described paleoenvironmental, fossil "biofacies," and sequence stratigraphy changes through middle-upper Ordovician time utilizing fossils from the Catheys Formation including those exposed at Garrison Creek ("C-1" sequence). Siesser et al. (1998) described seven species of marine microfossils (chitinozoans) from the Catheys Formation and their utility for regional and global correlation. Other marine invertebrates are detailed by Black (1961), Wilson (1990), and Wahlman (1992) for the Catheys Formation in central Tennessee. Such fossils, particularly the *Constellaria* bryozoan beds of the shaly facies, might be found in other outcrops along NATR, although none are yet documented outside the Garrison Creek area road cut.

Inman Formation (Upper Ordovician)

The upper (late) Ordovician Inman Formation was originally named by Wilson (1949) and is characterized by greenish-gray calcareous shale with interbeds of red shale and zones of limestone. This formation was included as part of the "Eden Group," a now informal name. As noted by Black (1961), exposures of this formation are not likely to be found along NATR, they are included here for completeness. They are present along Tennessee Route 100 near Percy Warner Park, approximately 6 km (4 miles) east of the NATR terminus. The marine fossils fauna of the Inman Formation include brachiopods, bryozoans and a straight nautiloid (Wilson 1990; Wahlman 1992).

Leipers Formation (Upper Ordovician)

The upper (late) Ordovician Leipers Formation, or Leipers Limestone, was originally named by Hayes and Ulrich (1903) and assigned to the now informal "Maysville Group" (Wilson 1949). Wilson (1990) divided the Leipers Formation into three informal facies: an argillaceous facies (variable clay and limestone lithologies), granular facies (dark-blue limestone), and pale-colored facies (pale blue limestone). The Leipers Formation is frequently mapped together with the underlying (older) Catheys Formation on the geologic quadrangle maps covering NATR. This combined Leipers and Catheys formations map unit is mapped in many areas crossed by the parkway on the Bellevue (Wilson et al. 1979), Leipers Fork (Morrow and Wilson 1963), Fairview (Wilson 1972), and Williamsport (Wilson et al. 1964) quadrangles between the Little Harpeth River, Gordonsburg, and the parkway terminus (Black 1961).

The Leipers Formation, as with most of the Ordovician formations, is fossiliferous. One important fossil locality was described from a road cut within NATR near the Garrison Creek picnic area (MP427-428; Patzkowsky and Holland 1999). This locality also included fossils from the underlying Catheys Formation, and is described in the Catheys Formation summary above. Fossils are known from all three Leipers Formation facies and include abundant brachiopod and bryozoan assemblage from the argillaceous facies and abundant broken and abraded marine invertebrates from the granular facies (Wilson 1990; Wahlman 1992). While not as abundant as fossils in the previous two facies, the pale colored facies preserves a fossil fauna characterized by *Platystrophia* brachiopods and various gastropod species (Wahlman 1992). Holland and Patzkowsky (1997, 1998) and Patzkowsky and Holland (1999) described paleoenvironmental, fossil "biofacies," and sequence stratigraphy changes through middle-upper Ordovician time utilizing fossils from the Leipers Formation including those exposed at Garrison Creek within NATR. Additional Leipers Formation fossils are possible within NATR if good exposures (road cuts) exist within the formation. Black (1962) discovered bryozoans, cephalopods, sponges, gastropods, and crinoids near the parkway right-of-way in the Carters, Hermitage, Bigby, Cannon, Leipers, and/or Brassfield formations.

A small slab of limestone with "an abundant fossil fauna" (trilobites and brachiopods according to Black 1962) is figured by Black (1961) as was collected "in an outcrop at the junction of Tennessee Highway 99 and the Parkway." This location is near Gordonsburg, on the Gordonsburg quadrangle. Colvin and Marcher (1964) mapped the area as Leipers or Fernvale Formations (see "Richmond Group" section below). As both formations preserve marine invertebrates, the slab could have come either formation.

There is one specimen within NATR collections (NATR420) listed as "Leipers Formation," although the ANCS records also list the collecting location as Chickasaw County, Mississippi (Prairie Bluff Formation). The specimen is described as limestone, which indicates it is likely from the Leipers, not the Prairie Bluff. The Leipers is not mapped along the parkway in Mississippi. Likewise, the Prairie Bluff is not mapped along the parkway in Tennessee. The "Chickasaw County" locality might reference the fossil display that used to be present along the parkway near MP235 in Chickasaw County. This specimen may have been a part of that display. The specimen is labeled as a cast of an impression of the fins of "large marine animal."

Such large vertebrate fossils are not known from the Leipers Formation. The fossil might be a bryozoan frond (M. Hoyal, personal communication, 2006) as bryozoan fronds can superficially resemble fins. Further investigation is needed to definitively identify this fossil.

"Richmond Group" formations (upper Ordovician)
The youngest Ordovician formations exposed in the Natchez Trace region were originally assigned to the "Richmond Group" and included the Arnheim Formation, Sequatchie Formation, Fernvale Limestone, and Mannie Shale (e.g. Wilson 1949). The "Richmond Group" nomenclature has now been abandoned, but the individual formations are still recognized, and grouped together here. The Arnheim Formation and the Fernvale Limestone are frequently mapped together (e.g. Bassler 1932; Howe 1969, 1973, 1988). All of these upper Ordovician formations, as their names suggest are predominantly limestone and shale deposits which can intertongue laterally and/or vertically. These formations may be exposed along the parkway as described by Black (1961). However only a very small area of Sequatchie Formation is definitively crossed by the parkway as mapped on the Bellevue quadrangle (Wilson et al. 1979) near its terminus.

Marine invertebrate fossils are known from all of the "Richmond Group" formations and are listed by Bassler (1932) and Wilson (1990). The Sequatchie Formation of the Bellevue quadrangle is not noted to contain fossils (Wilson et al. 1979). However, Black (1961) noted *Reserella* (*Dalmanella)* brachiopods from the "relatively unfossiliferous" Sequatchie Formation. Abundant brachiopods are noted from the Arnheim Formation and Fernvale Limestone (Howe 1969, 1973, 1988; Wahlman 1992). The Mannie Shale (part of the Fernvale Formation of Bassler 1932) preserves abundant and diverse brachiopods, bryozoans, gastropods, and crinoids. Holland and Patzkowsky (1997, 1998) and Patzkowsky and Holland (1999) described paleoenvironmental, fossil "biofacies," and sequence stratigraphy changes through middle-upper Ordovician time utilizing fossils from the Arnheim and Sequatchie Formation-Fernvale Limestones. If the parkway actually crosses these formations, and if good exposures are present, similar fossils may be exposed within NATR, although none are yet documented.

Brassfield Limestone and Wayne Group (lower-middle Silurian)
Natchez Trace Parkway may cross very small map areas of Silurian-aged formations including the lower (early) Silurian Brassfield Limestone and lower (early)-middle Silurian Wayne Group particularly on the Leipers Fork quadrangle (Morrow and Wilson 1963). These Silurian formations might be exposed immediately beneath the Devonian Chattanooga Shale (see below). The Brassfield Limestone is an olive-gray very fine to medium grained limestone. The Wayne Group is divided by Morrow and Wilson (1963) into the lower (older) Osgood Formation which is a calcium rich shale and argillaceous (containing clay) limestone and an upper (younger) Laurel Limestone, a medium gray to light brownish gray fine grained limestone.

Both the Brassfield Limestone and Wayne Group rocks can be fossiliferous. Wilson (1990) reported that fossils are locally abundant, but can also be absent or rare in various exposures of the Brassfield Limestone. A variety of marine invertebrate fossils are known from the Brassfield (Wilson 1990), with corals being the most common. Wayne Group fossils include typical marine invertebrates such as ostracods, brachiopods, trilobites, bryozoans, corals, bivalves, and echinoderms which are documented in north-central Tennessee (Lumsden and Haw 1975). Black (1962) discovered bryozoans, cephalopods, sponges, gastropods, and crinoids near the parkway right-of-way in the Carters, Hermitage, Bigby, Cannon, Leipers, and/or Brassfield formations.

<u>Tennessee—Interior Lowlands Province—Highland Rim</u>

On geologic maps (Miller et al. 1966), marine rocks of the Highland Rim section of the Interior Lowlands Province encircle the older Nashville Basin rocks and cap the highlands over much of west central and east central Tennessee. Most of NATR's miles in Tennessee pass over the Highland Rim geologic formations, primarily the Fort Payne Formation. As with the Ordovician marine limestones of the Nashville Basin, the Devonian through Mississippian marine shales and limestones described below are frequently fossiliferous and essentially any of the units could display fossils in road cuts along the parkway.

Chattanooga Shale (upper Devonian-lower Mississippian)
The upper (late) Devonian through lower (early) Mississippian Chattanooga Shale was first named for exposures near Chattanooga by Hays (1891). Conant and Swanson (1961) describe the stratigraphic and nomenclatural history of the formation in their monograph on the Chattanooga Shale. In south central Tennessee, the Chattanooga Shale lies unconformably on various Ordovician Formations and was deposited in a shallow sea (Conant and Swanson 1961). The Chattanooga is an important stratigraphic maker because it is easy to recognize and is exposed over a large area. Lithologically, the Chattanooga Shale is characterized by dark black shale with some gray claystone, and a basal sandstone ("Hardin Sandstone") and abundant organic material and coal (Conant and Swanson 1961). A "blue phosphate" layer near the base is frequently noted on the geologic maps along NATR. A number of Conant and Swanson's (1961) outcrops were near present day NATR boundaries. The Chattanooga Shale is frequently mapped together with the overlying Fort Payne Chert, see below.

There are abundant fossils in the Chattanooga Shale. Plant remains are the most common, giving the shale its dark coloring. Most of the plant fossils however, are not well preserved. Conant and Swanson (1961) did report *Callixylon* (conifer) material, probably fossil wood. Various other "free-floating marine algae" were also noted by Conant and Swanson (1961). Brachiopod shells and molds are very common in many exposures (Conant and Swanson 1961). Conodonts are also known from the Chattanooga Shale as described by Hass (1956) who utilized them as correlative tools and to divide the Chattanooga Shale into various members (Conant and Swanson 1961). Occasional and isolated fish bones and shark teeth have also been found in the Chattanooga Shale of Jackson County, Tennessee (Maher and Dunkle 1955; Conant and Swanson 1961). Many of the geologic maps note the "blue phosphate" layer is "fossiliferous," likely referring to conodonts or other age-descriptive fossils. Fossils of this formation have not yet been documented along the parkway. However, it is mapped (along with the Fort Payne Chert) over much of the parkway's extent in Tennessee.

Fort Payne Formation (lower Mississippian)
The lower (early) Mississippian Fort Payne Formation, also known as Fort Payne Chert, is extensively mapped throughout the Highland Rim of central Tennessee. Between the Cretaceous rocks near the Alabama border (see Tuscaloosa Group, below) and the Ordovician rocks mentioned above, the parkway traverses many miles of rocks mapped as the Fort Payne Formation. The Fort Payne Formation caps most of the high hills of the Highland Rim (e.g. Miller et al. 1966). Many of the geologic maps along the parkway further subdivide the Fort Payne Formation into various cherty (upper) and silty (lower) facies. In the Theta and Leiper's Fork quadrangle, Wilson and Colvin (1964) and Morrow and Wilson (1963) also include a middle silicastone or limestone facies, respectively. The basal beds of the Fort Payne Formation are occasionally referred to or mapped as the Maury Shale. The Maury Shale is a thin green claying shale with abundant phosphatic concretions (Conant and Swanson 1961). The Fort Payne Formation is frequently weathered to a rubble of chert creating sometimes poor exposures (e.g. Bassler 1932; Wilson and Miller 1964; Colvin 1970). The Fort Payne Formation is also mapped along the parkway in Alabama (see Alabama section). It is an important oil and gas producing unit (e.g. Lumsden 1988). Lumsden (1988) presented a paleoenvironmental history of the Fort Payne Formation in Tennessee as a broad marine "ramp" with water depths of 10 to 100 meters (33-330 ft).

The Fort Payne Formation is abundantly fossiliferous. Despite the weathered exposures of the Fort Payne, silicified (organic calcite replaced by silica) crinoid stems and other marine invertebrates are common in some weathered exposures (e.g. Bassler 1932; Morrow and Wilson 1963). In some areas of central Tennessee, the extraordinary masses of crinoid stems formed large mounds, or "bioherms" (Marcher 1963b; Miller 1974). The lower Maury Shale beds contain a marine fauna frequently found only in the phosphate nodules. This fauna includes brachiopods, cephalopods, crustaceans, conodonts, various fish bone fragments and plant remains (Conant and Swanson 1961). In beds thought to be between the Maury Shale and lowest Fort Payne Formation beds, Kogovsek et al. (2002) described abundant bryozoans from green carbonate "mud-mounds" in north-central Tennessee. Eastburn and Knox (1992) also described conodonts near the Maury Shale-Fort Payne Formation contact in south-central Tennessee. The lower silty facies also yielded crinoids in some areas (e.g. Collinwood Quadrangle, Marcher and Barnes 1963). The "middle" limestone facies on the Leiper's Fork Quadrangle (Morrow and Wilson 1963) is noted to be fossiliferous (crinoids). Lumsden (1988) noted crinoids, bryozoans, brachiopods, and ostracodes in the siliceous beds. Most of the geologic quadrangle maps in Tennessee along the parkway indicated the upper cherty facies is fossiliferous. Needle-like sponge spicules are abundant in the cherty layers (Lumsden 1988). Interestingly, the upper cherty facies is also a source of geodes which can be locally abundant. Unweathered exposures of the Fort Payne Formation are rare, but nevertheless may yield fossil material. Such material is not yet documented within NATR.

Warsaw and St. Louis limestones (upper Mississippian)
The Tuscumbia Formation mapped along the parkway in Alabama (see Alabama section) is equivalent to the Warsaw (lower/older) and St. Louis (upper/younger) limestones mapped in Tennessee. Both the Warsaw and St. Louis limestones are frequently mapped together over large areas, as on the Tennessee state geologic map (Miller et al. 1966). Many of the geologic quadrangle maps traversed by NATR only map the Warsaw Limestone atop hills, indicating that the St. Louis has weathered away in many areas surrounding the parkway. In Tennessee, the Warsaw and St. Louis limestones are characterized by gray coarse-grained limestone and fine grained brownish-gray limestone, respectively (Miller et al. 1966). These limestones unconformably overlie the Fort Payne Formation. As with the underlying Fort Payne Formation, exposures of the Warsaw and St. Louis limestones are highly weathered. The parkway crosses Warsaw and St. Louis limestones in the Ovilla (Marcher 1963a), Riverside (Wilson and Marcher 1962), Henryville (Marcher and Lounsbury 1965), and Gordonsburg (Colvin and Marcher 1964) quadrangles. Within these quadrangles the formations (primarily the Warsaw) are described as blocks of chert in a red, yellow, brown or gray sandy clay soil resulting from weathering.

The Warsaw and St. Louis limestones both form karstic features, however there are few solution enlarged cavities in the Warsaw, while the St. Louis has many solutions enlarged cavities, caves, and sinkholes (Wolfe et al. 1997). Caves in the Tuscumbia Formation in Alabama are further described in the Alabama section.

Even though the exposures of the Warsaw and St. Louis are highly weathered, the cherty blocks are frequently fossiliferous in all of the quadrangles listed above. For example, Colvin and Marcher (1964) describe abundant bryozoans and horn corals within chert of the Warsaw Limestone in the Gordonsburg Quadrangle. Some exposures of the Warsaw Limestone in central Tennessee are "crowded" with fragments of fossil marine invertebrates, primarily bryozoans, but also crinoids and brachiopods (Bassler 1932). Trilobites are also reported from the Warsaw Limestone in Dickson County, Tennessee (Bradley and Corgan 1991). Blocks of chert from the St. Louis limestone, within the Gordonsburg Quadrangle (Colvin and Marcher 1964) and other areas of central Tennessee (Bassler 1932), yielded "*Lithostrotion*" or *Syringopora* corals. Due to the weathered nature of the Fort Payne Formation, Warsaw, and St. Louis Limestones, these formations are frequently differentiated by their associated fossils, soil, chert, and topography. Fossils are not yet officially documented from this formation within NATR, however if similar blocks of chert are present within the park, they might yield a similar fossil fauna as summarized here.

<u>Tennessee—Gulf Coastal Plain Province</u>

Tuscaloosa Formation (Upper Cretaceous)
The Tuscaloosa Formation represents the youngest rocks traversed by the parkway within Tennessee except for Quaternary gravels and modern alluvium. The Tuscaloosa Formation in Tennessee is characterized by poorly sorted, light-grey chert gravel in a matrix of silt and sand (Miller et al. 1966). The sands and gravels of the Tuscaloosa are primarily nonmarine, likely deposited in littoral, lagoonal, or fluviatile environments (Marcher and Stearns 1962; Russell 1975). In Tennessee, NATR crosses sediments mapped as the Tuscaloosa Formation between the Alabama-Tennessee line (MP341.8) and approximately

MP357 in south-central Wayne County. The Tuscaloosa Formation is also mapped along the parkway in northeast Mississippi and northwest Alabama (Gordo Formation) as described in those states' respective sections.

Fossils are not common in the Tuscaloosa Formation in Tennessee and are limited to plant impressions and occasionally petrified logs. Berry (1913, 1919) described a fossil flora from Tishomingo County Mississippi, near Iuka. In Wayne County, Tennessee, east of NATR, Tuscaloosa gravels are exposed along Middle Cypress Creek and a fragment of fossil wood was discovered in a road cut near Friendship Cemetery approximately 10 km (6 miles) east of NATR (Russell 1975). In southeastern Wayne County, "questionable borings," possibly created by marine crustaceans, were reported by Russell (1975). Fossils are not likely to be found in the Tuscaloosa Formation along NATR.

Alluvial deposits (Quaternary)
Particularly along major streams or rivers (e.g. Harpeth, Duck, etc.) the parkway may cross Quaternary alluvial deposits, although these deposits are not typically mapped on the geologic quadrangle maps unless they are of significant thickness. Miller et al. (1966) mapped alluvial deposits near NATR in Wayne County along Cypress Creek, just north of the Mississippi-Tennessee state line.

Fossils are not preserved in modern (Holocene) alluvial deposits, however Corgan and Breitburg (1996) describe a diverse assemblage of fossils from Pleistocene deposits throughout Tennessee. None of these localities are within current NATR boundaries, although some are nearby. For instance, *Mammut americanum* (mastodon) material was collected in 1879 from Hicks Bend on the Harpeth River, approximately 3 km (2 miles) east of the parkway's terminus. There is a Pleistocene or Holocene "peccary tooth" in SEAC's NATR collections, found in Tennessee. Additional investigation may further identify this tooth and its provenance.

ALABAMA

Natchez Trace Parkway crosses the Mississippi-Alabama state line at MP308.9 and traverses Colbert and Lauderdale counties before entering Tennessee at MP341.8. These 33 miles cross the East Gulf Coastal Plain section of the Coastal Plain physiographic province and the Interior Low Plateaus province. Every major geologic formation that the parkway traverses in Alabama preserves fossils, some of which might be found within the park. Geologic maps are published for Colbert (Harris et al. 1963a) and Lauderdale (Harris et al. 1963b) counties; however they do not show NATR as construction was not yet completed. The Szabo et al. (1988) geologic map of Alabama does show the parkway, but at a smaller (1:250,000) scale than the county maps. An interactive digital geologic map of the state is hosted by the Geological Survey of Alabama website (http://portal.gsa.state.al.us/Portal/index.jsp; Accessed 12 November 2006). Shapefiles for use in ArcView are also available for download at this site.

In addition, the Mississippian-aged limestones contain many caves and karst features. As described throughout the National Park Service by Santucci et al. (2001), karst features (caves, sinkholes, etc.) display fossils in one of two ways. First, karst features provide exposures of fossiliferous Paleozoic limestones, some of which contain abundant large invertebrate remains. Secondly, karst features can also preserve fossil remains of Pleistocene or Holocene animals that utilized and/or died, or were transported into the cave. See the Tuscumbia Formation section below.

Alabama—Interior Low Plateaus Province

Fort Payne Chert (Lower Mississippian)
The Lower (Early) Mississippian Fort Payne Chert was originally named by Smith (1890) for exposures in northeastern Alabama. In Colbert and Lauderdale counties, the Fort Payne Chert is characterized by gray, light-gray, and white hard limestone containing large quantities of chert (Harris et al. 1963a, 1963b). Chert is a hard, dense sedimentary rock made up of microcrystalline silica occurring commonly as nodules in

limestones. Where fresh, its density and conchoidal (smoothly curved) breakage planes make it an excellent choice for projectile points. The Fort Payne Chert is mapped along NATR in Alabama where the parkway enters Lauderdale County opposite Colbert Ferry at MP328.7 (Harris et al. 1983b). The Fort Payne Chert is more extensively mapped along the parkway in Tennessee (see Tennessee section of NATR report).

As with most Paleozoic limestones, fossils are abundant in the Fort Payne Chert and consist primarily of stem or columnal plates of pelmatozoans (echinoderms attached to a substrate; e.g. crinoids and blastoids) (Harris et al. 1963a; Szabo et al. 1988). Fossils of the Fort Payne Chert have been described throughout northern Alabama. Harris et al. (1963b) also reported a coral and identified *Platycrinus* (now *Platycrinites*) as a common crinoid. At least eight species of brachiopods were described from the Fort Payne along Cedar Fork in extreme western Lauderdale County (Butts 1926). Road cuts through the Fort Payne Chert, if any along the parkway, might display similar fossils.

Tuscumbia Limestone (Upper Mississippian)
The Upper (Late) Mississippian Tuscumbia Limestone was named by Smith (1894) for exposures near Tuscumbia in Colbert County. The Tuscumbia Limestone is characterized by a hard, coarse-grained light gray limestone with light-gray chert nodules throughout (Harris et al. 1963a; Szabo et al. 1988). The Tuscumbia Limestone is equivalent to the St. Louis and Warsaw limestones in Tennessee as described in the Tennessee section (Butts 1926). In Alabama, the parkway crosses the Tuscumbia Limestone on both sides of the Tennessee River (Pickwick Lake) in addition to a narrow area mapped in southwestern Colbert County (Harris et al. 1963a, 1963b; Szabo et al. 1988). The exposures along the Tennessee River are some of the areas of greatest relief near or within NATR (Morse 1930; A. K. Rindsberg, personal communication, 2006). Pashin et al. (1993) noted exposures of the Tuscumbia Limestone along NATR approaching Colbert Ferry and just past the gate for the Colbert Ferry picnic area.

Fossils are common in the Tuscumbia Limestone as described by Butts (1926) for the St. Louis and Warsaw limestones. Crinoid fragments are the primary component of some beds of the Tuscumbia (Szabo et al. 1988). Waters et al. (1993) summarize the extensive and significant echinoderm (crinoid and blastoid) faunas from Mississippian rocks in Alabama. The echinoderms of the Tuscumbia Limestone are generally poorly preserved and not well understood (Waters et al. 1993). Harris et al. (1963a) noted common fragments of crinoid stem plates, bryozoans, corals, and brachiopods at many Tuscumbia Limestone exposures in Colbert County. However, Harris et al. (1963b) stated "no fossils were found in the Tuscumbia Limestone in Lauderdale County, where the formation is deeply weathered" into a reddish cherty clay. Hassler and Stock (1993) utilized conodonts (tooth-like structures from a group of enigmatic marine animals) from a quarry in Allsboro and along Pennywinkle Creek in Allsboro to provide relative age dating (biostratigraphy) of the Tuscumbia. The historic Natchez Trace passes through Allsboro; NATR was constructed east of Allsboro. Fossils have not yet been officially documented from the Tuscumbia along NATR, but any exposure of the formation has potential to display fossils. As such, those exposures mentioned above near Colbert Ferry likely preserve fossils.

Caves are well known in the Tuscumbia Limestone in Colbert County and elsewhere in Alabama. For example, Georgetown Cave is located along NATR near Georgetown (Colbert Ferry; MP327.3). The site has been closed to the public since 1969 (Santucci et al. 2001). As stated above, fossils can be preserved in the limestone of the cave's walls or as Pleistocene animals inside the cave itself. Fossils have not yet been officially documented from any karstic features along NATR. Archeological surveys were completed for Georgetown Cave (C. Miller, personal communication, 2006). Little Bear Cave, Little Bear Cave #2, Bell Cave, and Winston Cave are all located near the city of Tuscumbia within its eponymous limestone (G. Bell, personal communication, 2006). All four of these caves have yielded Pleistocene fossil vertebrates including fish, amphibians and mammals. Mammal material is the most common and includes: ground sloths, the first record of *Smilodon* (saber-tooth cat) in Alabama, to giant beaver, bear, peccary, tapir, armadillo, horses, deer, bats, rodents, and rabbits (Womochel and Barnett 1980; Womochel 1982; Bell 1985; Lively et al. 1992). Joseph Leidy's 1855 description of *Megalonyx jeffersoni* (ground sloth) as the first fossil mammal known from Alabama, was based on material likely collected from Little Bear Cave #2, although the exact locality is not known (Bell 1985). See the Mississippi-Pleistocene Loess section for more information about Leidy's paleontological research near Natchez.

Pride Mountain Formation (Upper Mississippian)
The Upper (Late) Mississippian Pride Mountain Formation was named by Welch (1958) for exposures on Hawk Pride Mountain near Pride in Colbert County. Lithologically, the formation is characterized by medium to dark gray shale with sandstones and limestones in the lower beds of the Pride Mountain (Szabo et al. 1988). Merrill et al. (1988) describe the Pride Mountain Formation and long nomenclatural history in greater detail for exposures in Tishomingo County, Mississippi (see Mississippi section). The maps of Colbert and Lauderdale counties, Alabama (Harris et al. 1963a, 1963b), do not map the Pride Mountain Formation as such, instead using the now locally abandoned stratigraphic names "Gasper Formation," "Bethel Sandstone," and "Ste. Genevieve Limestone" for rocks now assigned to the Pride Mountain Formation. In Alabama, the Pride Mountain Formation is mapped along NATR in Colbert County.

The paleontological resources of the Pride Mountain Formation are described in depth in the Mississippi section of the NATR summary. Harris et al. (1963a) noted abundant fossil brachiopods, dominated by *Productus inflatus* in the Pride Mountain Formation ("Ste. Genevieve Limestone") of Colbert County. The shales of the Pride Mountain Formation ("Gasper Formation") also yielded coral, crinoids, and brachiopods (Harris et al. 1963a). Waters et al. (1993) summarize the extensive and significant echinoderm (crinoid and blastoid) faunas from Mississippian rocks in Alabama, including the Pride Mountain Formation. The formation is particularly fossiliferous near Allsboro (Morse 1930) near the historic Natchez Trace, but outside of NATR boundaries. For example, Morse (1930) collected blastoids (*Pentremites*) and brachiopods (*Composita*) "by the hundreds" from the Wagnon Member ("Southward Pond Formation") of the Pride Mountain Formation in Colbert County at the mouth of Pennywinkle Creek, about 5.6 km (3.5 miles) west of NATR below U.S. Route 72. The locality near "Bishop Bridge" over Bear Creek locality referenced by Morse (1930) and Burdick and Strimple (1982) yielded fossils in the Pride Mountain Formation including two genera of crinoids. The Bishop Bridge locality is less than 1.6 km (1 mile) north of NATR, just east of the Alabama-Mississippi state line in Colbert County. Ostracodes are also common in the Pride Mountain Formation and were used by Dewey and Puckett (1993) for paleoenvironmental reconstruction near the edges of carbonate shelf preserved as part of the Pride Mountain Formation.

Alabama—Gulf Coastal Plain Province

Tuscaloosa Group (Upper Cretaceous)—Gordo Formation
The Upper (Late) Cretaceous Gordo Formation is the upper formation of the Tuscaloosa Group in Alabama as mapped by Szabo et al. (1988). The Tuscaloosa Group is undivided in many older publications (e.g. Harris et al. 1963a, 1963b). Sediments of the Tuscaloosa Group are also exposed along the parkway in Mississippi and Tennessee as described in the summaries for those states. In Colbert and Lauderdale counties, Alabama, the Gordo Formation is characterized by mottled red and pale red-purple, massive beds of nonmarine sand, gravelly sand and locally carbonaceous clay (Szabo et al. 1988). It is one of the few nonmarine geological units along the parkway, and the only nonmarine unit on the Alabama segment. The Gordo Formation caps the highlands traversed by the parkway in Alabama. Harris et al. (1963b) noted a particularly good exposure of basal Tuscaloosa Group sands in a road cut at the intersection of NATR with the Florence-Waterloo Road (Alabama Route 14). This road cut may no longer be exposed (A. K. Rindsberg, personal communication, 2006).

Given the coarse-grained character of the Gordo Formation, and the Tuscaloosa Group as a whole, fossils are not common. Nevertheless leaf impressions and lignitized logs were reported from clay beds within the Tuscaloosa Group in Alabama, but not in Colbert or Lauderdale counties, by Smith and Johnson (1887) and Stephenson (1926). Berry (1919) described a fossil flora southeast of Iuka (Tishomingo County, Mississippi). Stephenson and Monroe (1940) also reported poorly preserved fossil leaves and mollusks (*Ostrea* and *Volsella*) near Maplesville in central Alabama. These fossils were discovered in the

Eoline Member of the Tuscaloosa, which is not exposed in northwest Alabama (A. K. Rindsberg, personal communication, 2006). There is minimal potential for discovery of fossils within this unit along the parkway.

MISSISSIPPI

Nearly 309 miles of the Natchez Trace Parkway are in Mississippi. The parkway crosses almost all of Mississippi's stratigraphic units in its southwest/northeast traverse from Natchez (MP0) to the Alabama-Mississippi state line (MP308.9). As the mileage increases to the northeast, so to does the geologic age of the units. The youngest deposits along the parkway (Pleistocene loess) are thus found near Natchez, while the oldest deposits in Mississippi are found along the parkway near Tishomingo (MP304.5) and the state line area. Fossils are known from nearly every stratigraphic unit mapped along the parkway. Some exposures along NATR may even preserve such fossils within the park. The fossil record provides exceptional research and interpretive opportunities. Many of the fossils discovered along the Natchez Trace region are significant. This is a unique cross section not only of Mississippi's geology but a fantastic history of the evolution of the entire Gulf Coast Region. Just as the rocks of Chesapeake and Ohio Canal National Historical Park (Kenworthy and Santucci 2004) tell the story of the evolution of the central Appalachian Mountains, the rocks along NATR highlight the evolution of the southern Appalachians and the Gulf Coast region of the United States. The Paleozoic (Mississippian) rocks along the parkway are part of the Highland Rim Section of the Interior Low Plateaus physiographic province (see Tennessee section of NATR report). The Cretaceous and younger rocks are part of the East Gulf Coastal Plain Section of the Coastal Plain Province.

Geologic Maps
Geologic maps were published by the Mississippi Office of Geology (Jackson) for most of the counties the parkway crosses including Adams (Vestal 1942), Claiborne (Bicker 1966), Hinds (Moore 1965), Madison (Priddy 1960), Attala (Parks 1963), Choctaw (Vestal 1943), Webster (Vestal 1952), Clay (Bergquist 1943), Pontotoc (Priddy 1943), Lee (Vestal 1946), Itawamba (Vestal 1947), Prentiss (Parks 1960), and Tishomingo (Merrill et al. 1988). County maps have not yet been created for Jefferson, Leake, and Chickasaw counties. Regional geologic maps are included in the studies of the Upper Cretaceous rocks of Mississippi (Stephenson and Monroe 1940) and the Claiborne Group exposures in Mississippi (Thomas 1942). Because most of these maps were published long before the completion of the parkway, only the Tishomingo County map shows the parkway right of way. In addition, many authors use now outdated stratigraphic nomenclature as described below. The Mississippi Office of Geology is currently mapping the geology of 1:24,000 scale USGS 7.5 minute quadrangles throughout the state with current, updated nomenclature and geologic interpretations. As of October 2006, geologic quadrangle maps have been published or are in progress for 18 quadrangles along NATR. These quadrangle maps are Mississippi Office of Geology Open-File Reports for the following quadrangles in Claiborne County: Willows, Carlisle, Port Gibson, and Hermanville (Starnes and Davis 2004a, 2004b, 2004c, 2004d). In Attala County, maps are published for the Kosciusko and Ethel South quadrangles (Thompson 2006a, 2006b). In Choctaw and Webster counties, maps are published for the Tomnolen, Sapa, and Reform quadrangles (Thompson 1998a, 1998b, 2003). In Tishomingo County, maps are published for the Belmont, Tishomingo, Paden SE, Fulton NE and Red Bay quadrangles (Merrill 1998a, 1998b, 1998c, 1998d). Geologic maps are also in progress (October 2006) for a number of quadrangles along the parkway including Big Black and Cayuga in Hinds County, Ridgeland and Madison in Madison County, French Camp and Weir in Attala and Choctaw counties, and Maben and Mantee in Choctaw, Clay, and Webster counties. Dr. David Dockery is the Mississippi Office of Geology contact for geologic mapping efforts.

<u>Mississippi—Interior Low Plateaus Province—Highland Rim</u>

The oldest rocks along the parkway in Mississippi are from the Pride Mountain Formation and the Hartselle Formation in northeastern Tishomingo County. These formations are part of the Highland Rim

Section of the Interior Low Plateaus physiographic province. Formations of similar age are found along the NATR in greater abundance within Alabama and Tennessee.

Pride Mountain Formation (upper Mississippian)
The upper (late) Mississippian Pride Mountain Formation is mapped in short stretches along the last 5 miles of the parkway in Mississippi and is best exposed in Tishomingo County in the Bear and Cedar creek valleys immediately to the north and west of NATR (Merrill et al. 1988). There are also excellent exposures of the formation in the Tishomingo State Park area (MP304.5). It is the oldest geologic unit the parkway crosses within the state of Mississippi. The Pride Mountain Formation has been divided into members by many previous authors (Butts 1926; Morse 1928; Welch 1958, 1959; summarized by Merrill et al. 1988). Merrill et al. (1988) do not differentiate these members on their geologic map and they characterize the Pride Mountain Formation by olive- to dark-gray shale, light to brownish gray fossiliferous limestone and very light to brownish gray sparingly fossiliferous sandstone.

While Merrill et al. (1998) provide an in depth description of the geology and depositional environments of the Pride Mountain Formation, Morse (1930) describes the fossils of the formation as part of his monograph on the Paleozoic rocks of Mississippi. Since the 1920s-1930s, the local stratigraphic nomenclature has been updated as described in Merrill et al. (1998), with Morse's (1930) equivalents of the Pride Mountain Formation following in parentheses: Alsobrook Member ("Alsobrook Formation"), Tanyard Branch Member ("Allsboro Sandstone"), Wagnon Member ("Southward Pond Formation"), Southward Spring Sandstone Member, ("Southward Spring Sandstone"), Sandfall Member and Mynot Sandstone Member ("Southward Bridge Sandstone") and Green Hill Member (equivalent to the upper shales of the "Forest Hill Formation"). Marine invertebrate fossils including bryozoans, crinoids, blastoids, brachiopods, were collected from limestones in nearly all of these members and can be very abundant and well preserved. Brachiopods are the most diverse and abundant fossils.

A number of Morse's localities are within or adjacent to present day NATR boundaries. Morse (1930) collected throughout the NATR region including near Mingo ("Southward Bridge"), Forest Grove, and within NATR at Cave Spring (MP 308.4; "Southward Pond and Spring"). Today, his Southward Pond appears on USGS topographic maps as Cypress Pond Ditch and Southward Spring is Cave Spring. While fossils are not specifically mentioned from Cave Spring, Morse's sections throughout the area, especially "Southward Pond" and "Southward Bridge" near Mingo yielded abundant marine invertebrates. Exposures of the same layers may be within the park and would likely also yield fossils. Farther to the southwest, Morse (1930) collected fossils specifically the blastoid *Pentremites* along MacDougal Creek approximately 3.2 km (2 miles) west of Neil at "Underwood Bridge." The parkway passes just north of Neil and crosses the old railroad bed Morse references. He does not mention fossils near Neil. Morse (1936) includes measured sections and eloquent geologic descriptions of rocks along Bear Creek within Tishomingo State Park. His sections mention abundant bivalve and gastropod fossils near the northern border of Tishomingo State Park. NATR bisects the state park and exposures of the Pride Mountain Formation might produce fossils in the park.

Hartselle Formation (upper Mississippian)
Merrill et al. (1988) characterize the Hartselle Formation (or Hartselle Sandstone) as a light gray to brownish gray pure (minimal mud or silt) sandstone, generally forming small cliffs, ledges, and overhangs. The Hartselle was originally deposited as beach, back-barrier, or shelf sediments (Rindsberg 1994). Merrill et al. (1988) also describe the nomenclatural history of the Hartselle Formation dating back to Smith (1894). For instance, Morse (1928, 1930) named these sandstone beds the "Highland Church Member" of the "Forest Grove Formation." The Hartselle Formation's well cemented nature and purity make it an excellent building stone. Many buildings in Tishomingo County, including the main office and museum of Tishomingo State Park are constructed with Hartselle Formation blocks.

Both Merrill et al. (1988) and Morse (1930) described marine invertebrate fossils (crinoid stems, bryozoans, brachiopods, bivalves, and gastropods) from the Hartselle Formation. As described by Morse (1930) these sandstones display a "mass" of bivalve and gastropod molds and casts in some localities.

However, these impressions are faint and poorly preserved, unlike fossils from the limestones of the Pride Mountain Formation (Merrill et al. 1988). Merrill et al. (1988) illustrated a typical fossiliferous zone of the Hartselle on the north side of Bear Creek Valley near Horseshoe Bend within Tishomingo State Park. This locality is approximately 0.8 km (0.5 mile) south of NATR as it passes through the state park. Also in the vicinity of NATR, along Rock Creek, near the Tishomingo-Prentiss County line and present day Tennessee-Tombigbee Waterway, Morse (1930) measured sections of the Hartselle Formation ("Highland Church Member"). These sites may now be under water (Merrill et al. 1988). While he does not specifically mention fossils from these localities near the parkway, he includes a general description that the sandstones of the "Forest Grove Formation" including what is now referred to as the Hartselle Sandstone, are fossiliferous. If good exposures of these rocks exist within NATR, they might yield fossils. Likewise, Morse (1930) measured a section at the railroad bed near Neil, likely immediately adjacent to current NATR boundaries describing the Hartselle ("Highland Church Member"). Again no fossils were listed, but the MacDougal Creek exposures near the parkway yielded fossils.

In addition to the marine invertebrates, trace fossils and plant impressions are preserved in some exposures of the Hartselle Formation. The trace fossils, including worm burrows, are quite diverse, with over 23 different morphologies or "ichnospecies" described from the Hartselle Formation in northern Alabama (Rindsberg 1994). These fossils can be important paleoenvironmental indicators. "Indistinct" leaf impressions and tree trunk molds are sometimes found in the Hartselle Formation (Merrill et al. 1988). Interestingly, a well-preserved partial *Lepidodendron* (scale tree) trunk was discovered in a small sandstone quarry about 1.6 km (1 mile) south of NATR. Black (1962) also reported a "large log of fossil wood with well preserved bark patterns" was collected from a stone quarry in the "Highland Church Sandstone" (Hartselle Sandstone) near the parkway's right-of-way. The geology department of Mississippi State University (Starkville, Miss.) collected and housed the specimen referenced by Black (1962). Both Merrill et al. (1988) and Black (1962) may be referencing the same specimen.

<u>Mississippi—Gulf Coastal Plain Province</u>

The Upper (Late) Cretaceous and younger rocks of the Coastal Plain Province lie unconformably above the Mississippian rocks of the Hartselle Sandstone. The erosional unconformity indicates a period of nondeposition (erosion) during the Permian through Jurassic periods, coinciding with the uplift of the Appalachian Mountains. Following the formation of the Appalachians, they subsequently began to erode in the Cretaceous. These terrestrial sediments are deposited in some of the marine units described below, including the Coffee Sand. Nearly all of the Upper Cretaceous formations were deposited in various shallow marine environments, relatively nearshore. The marine deposits formed as part of the Mississippi Embayment during the much higher global sea levels during the Upper Cretaceous. Stephenson and Monroe (1940) describe in detail the Upper Cretaceous deposits and very abundant and diverse fossils of Mississippi. Draining of this embayment as sea level lowered during the Cenozoic (including present-day) lead to the formation of the Mississippi River and the associated Mississippi River Valley. Major geologic formations or groups from the Tertiary include the Midway Group, Wilcox Group, Claiborne Group, Jackson Group, Vicksburg Group, Neogene sediments, Pre-loess sand and gravel. Extensive Pleistocene loess deposits blanket older formations in the western and west central regions of Mississippi. Fossils are known from all of these formations in Mississippi, some within or near the parkway.

Tuscaloosa Group (Upper Cretaceous)
The Tuscaloosa Group (or Formation) is a heterogeneous lithologic unit characterized by variously colored sediments including well rounded chert gravel, frequent silt and clay matrix, sands, clays, chert pebble conglomerates, and lignite (coal) (Merrill et al. 1988; Parks 1960; Stephenson and Monroe 1940). The Tuscaloosa was originally described near Tuscaloosa, Alabama by Smith and Johnson (1887) and has had a complex nomenclatural history since then as described in Stephenson and Monroe (1940) and Merrill et al. (1988). Russell and Keady (1990) proposed differentiating the Tuscaloosa Group in the NATR region into the lower Gordo Formation and placing the upper gravels in the McShan Formation of the Eutaw Group (see below). Clays of the Tuscaloosa Group are important sources of pottery clay

(Logan 1909). The Natchez Trace Parkway crosses Tuscaloosa Group sediments in a number of locations in southern and eastern Tishomingo County and extreme southeastern Prentiss County. The parkway also crosses Tuscaloosa Group sediments in Alabama and Tennessee, as described in the section for those states.

Given the generally coarse-grained nature of the Tuscaloosa Group, fossils are not common. Nevertheless, fossil leaves and logs were recovered in Alabama and in Mississippi near Fulton (Itawamba County) and east of Iuka (Tishomingo County) (Berry 1913, 1919; Stephenson and Monroe 1940). Neither of these localities is within or near NATR, and fossils are not yet documented within the park from the Tuscaloosa Group.

Eutaw Group (Upper Cretaceous)—McShan Formation
The McShan Formation is considered by Merrill et al. (1988) as the basal member of the Eutaw Group. Stephenson and Monroe (1940) do not differentiate the McShan Formation, mapping only the "Eutaw Formation." Regardless of its map label and lithologic name, the marine unit is characterized by pale yellowish-brown to light-gray fine to fine-grained well sorted, frequently crossbedded sand (Merrill et al. 1988). The parkway crosses McShan Formation sediments in southwestern Tishomingo County south and east of the Bay Springs Lake Dam.

According to Merrill et al. (1988), marine invertebrates are not present in the McShan. However, they describe abundant petrified wood fossils, especially in the upper beds of the formation, near the contact with the overlying Eutaw Group (Formation) (Merrill et al. 1988). Apparently a number of large petrified logs were discovered in McShan Formation sediments during construction of the Tennessee-Tombigbee Waterway (Merrill et al. 1988). In addition, Berry (1919) reported leaf impressions from the McShan Formation (Merrill et al. 1988) near Iuka. Trace fossils from the McShan include *Callianassa* (shrimp) burrows which can be occasionally found (Merrill et al. 1988). Vertebrate fossils from the McShan Formation are summarized by Daly (1992) and include hadrosaurian dinosaurs and possibly the geologically oldest (stratigraphically lowest) hadrosaur material in North America (Carpenter 1982; see also Eutaw Group-Tombigbee Sand Member, below). The dinosaurs were collected in Monroe County, some 32 km (20 miles) east of NATR. Fossils are not yet known from the McShan Formation within NATR.

Eutaw Group (Upper Cretaceous)—"typical Eutaw Group" and Tombigbee Sand Member
The Eutaw Group, as with most of the Upper Cretaceous lithologic units in Mississippi, Alabama, and Tennessee had undergone considerable nomenclatural changes as described in Stephenson and Monroe (1940), Merrill et al. (1988). Above the McShan Formation, the Eutaw Group consists of an unnamed unit of lower ("typical") Eutaw Group sediments and an upper Tombigbee Sand Member. The parkway crosses sediments of the Eutaw Group in southeastern Prentiss and northwestern Itawamba counties (Stephenson and Monroe 1940; Parks 1960; Vestal 1947). Vestal (1947) maps recent floodplain deposits over those of the Eutaw Group, which may obscure the underlying Cretaceous rocks. The Tombigbee Sand Member is mapped in a narrow band along NATR near Kirkville by the above authors.

The lower Eutaw Group sediments of southeastern Prentiss are not as fossiliferous as those of the Tombigbee Sand, described below. However, Park (1960) reports some sharks teeth and bone fragments found in Prentiss County, none within or near NATR. *Callianassa* sp. burrows (ghost shrimp) are common in Tishomingo County exposures of the lower Eutaw Group (Merrill et al. 1988), but are not specifically mentioned in Prentiss (Park 1960) or Itawamba County (Vestal 1947).

The Tombigbee Sand Member is locally fossiliferous as described by Stephenson and Monroe (1940) and repeated by Parks (1960) with stemless crinoids, 14 species of bivalve mollusks characterized by *Exogyra ponderosa*, nine species of cephalopods (mostly ammonites), and at least two types of sharks teeth. In Prentiss County, the Tombigbee Sand Member yielded five species of bivalves. The decapod crustacean burrow *Halymenites major*, and shrimp burrow *Callianassa sp.* are very common in the Tombigbee Sand (Stephenson and Monroe 1940; Merrill et al. 1988). Kennedy et al. (1997) summarized the rich ammonite fauna (at least 10 common species) from the Tombigbee Sand Member exposed along the Tombigbee River in Mississippi and Alabama. While none of the collecting localities cited by Stephenson and Monroe (1940), Parks (1960), or Kennedy et al. (1997) are within current NATR boundaries, Parks (1960) described a fossil locality that yielded a large silicified log east of Hazeldell and USGS Locality 9517 west of Marietta which yielded abundant bivalve fossils. Exposures of the Tombigbee outside of NATR near Booneville in Prentiss County yielded most of the fossil material from the formation in Mississippi (Stephenson and Monroe 1940; Parks 1960).

There are extensive vertebrate fossils known from the Tombigbee Sand Member summarized by Daly (1992). Vertebrate fossils include numerous shark teeth and fish vertebrae in Clay (Bergquist 1943) and Lee (Vestal 1946) counties. Emry et al. (1981) discovered a eutherian mammal molar, a mosasaur tooth, elasmobranch (sharks, skates, rays) and fish teeth near Vinton in Clay County, some 48 km (30 miles) east of NATR. They determined the mammal tooth was the geologically oldest (stratigraphically lowest) mammal molar in North America at the time. Mosasaur material was collected from the Tombigbee Sand in Lowndes County (Daly 1992). A hadrosaur ("duck-billed") dinosaur limb discovered near Columbus, 64 km (40 miles) east of the parkway, represented the geologically oldest (stratigraphically lowest) record of hadrosaur dinosaurs in North America at the time (Kaye and Russell 1973). Fossils are not yet known from the "typical Eutaw" or Tombigbee Sand within NATR.

Selma Group (Upper Cretaceous)
The Selma Group was originally named the Selma Chalk in 1894 for exposures near the Alabama town of the same name. Rocks now included in the Selma Group were previously known by the descriptive name "Rotten limestone" (Stephenson and Monroe 1940). The USGS recognizes a six-fold division of the Selma Group in Mississippi, from oldest (lowest) to youngest (highest), Mooreville Chalk/Formation, Coffee Sand, Demopolis Chalk/Formation, Ripley Formation, Prairie Bluff Formation, and Owl Creek Formation. These formations have complex interrelationships and can grade into one another based on geographic location, see Dockery (1993) for one stratigraphic interpretation of the Selma Group. The Coffee Sand, Demopolis Formation, Ripley Formation, and Prairie Bluff Formation are mapped along the parkway and summarized in the paragraphs below. The Owl Creek Formation is not mapped near NATR. Stephenson and Monroe (1940) only map the Coffee sand, Ripley Formation, Prairie Bluff Formation, and Owl Creek Formation separately. The remaining units were mapped together by Stephenson and Monroe (1940) as "Selma chalk" and likely correlate to the Demopolis Chalk. Geologically, the Selma Group is primarily composed of chalk, which in turn is made up of the calcareous structures of coccolithophores, microscopic marine planktonic organisms. There are also beds of limestone and chalky clays and sands. Chalk deposits along NATR were used extensively as a tempering agent for American Indian pottery (B. Carter, personal communication, 2006).

Selma Group (Upper Cretaceous)—Coffee Sand (Tupelo Tongue)
Dockery (1993) presented a detailed description of the Coffee Sand's nomenclatural history and its geology. The Coffee Sand represents a terrigenous marine unit in that it contains material eroded from land and deposited in shallow nearshore marine environments. These sediments are primarily crossbedded sands. In Lee County, the sands were supplied by eroding Appalachian Mountains. The Coffee Sand is the lowest (oldest) member of the Selma Group. NATR crosses the Coffee Sand near the formation's southernmost map area in Lee County. These exposures, as described below and by Dockery (1993) are more marine in nature and hence are more fossiliferous. These marine sediments are named the Tupelo Tongue for exposures near the eponymous town.

The fossils of the marine sands of Tupelo Tongue of the Coffee Sand include diverse marine invertebrates (nearly 40 species of bivalves, two species of scaphopods, at least 14 species of gastropods, four species of cephalopods) and isolated sharks teeth (Stephenson and Monroe 1940). Dockery (1993) published an extensive monograph on the exceptionally well preserved gastropods of the Coffee Sand in Lee County, with 100 recognized species. Localities within or near NATR yielded much of this material.

Dockery (1993) described a significant Coffee Sand (Tupelo Tongue) locality near Twentymile Creek along NATR. In 1976, excavation of the parkway uncovered numerous ammonite-bearing concretions. David Dockery and Wilbur Braughman of the Mississippi Office of Geology visited the construction site in May of that year and found the concretions to be "moderately to sparsely" fossiliferous. A more significant locality was then discovered opposite and north of the NATR Twentymile Bottom Overlook (MP278.4) and designated Mississippi Geological Survey (MGS) Locality 128 (Dockery 1993). This locality yielded large *Exogyra ponderosa* and *Cucullaea (Idonearca) grandis* bivalves in addition to concretions containing *Placenticeras*, *Menabites (Delawarella),* and *Baculites* ammonites. Gastropods included *Calliomphalus paucispirilus*, *C. tuberculosus*, *Tympanotonus (Exechocirsus) cowickeensis*, *Turritella trilia*, *T. quadrilira*, *Laxispira lumbricalis*, *Gymnentome unicarinata*, *Perissoptera prolabiata mississippiensis* (new subspecies), *Latiala? sp.*, *Graciliala johnsoni*, *Thylacus cretaceus*, *Cerithioderma nodosa*, *Amaurellina stephensoni*, *Pseudamaura lepta*, *Gyrodes (Gyrodes) major*, *G. (Sohlella) spillmani*, and *Euspira rectilabrum*. According to Dockery (1993) the locality sporadically yielded material over a 14 year period, but was mostly overgrown by 1993. George Phillips of Mississippi Museum of Natural Science in Jackson (personal communication, 2006) also collected bivalves from near Twentymile Creek and noted *Crassatella* bivalves eroding out of some of the clay along the access road in that area.

MGS Locality 129 is located at the same stratigraphic level (i.e., same sedimentary layers are exposed) as MGS 128 in the Chapelville horizon of the Tupelo Tongue of the Coffee Sand. Locality 129 is approximately 3.2 km (2 miles) northwest of the Twentymile Bottom Overlook. Locality 129 was discovered in 1982 and extensively collected by Dockery (1993). In fact the vast majority of described specimens in his monograph were collected at this locality. The Chapelville horizon contains abundant large well preserved bivalves (*"Ostrea" falcata*) and *Exogyra* in addition to the vast majority of the more than 100 species of gastropods described by Dockery (1993).

Sohl (1960, 1964a, 1964b) collected 63 species (53 genera) of gastropods from the Coffee Sand in northeastern Mississippi. However, as Dockery (1993) reports, most of the species were from a single locality 3.2 km (2 miles) due west of Ratliff, Mississippi and within a few kilometers of present-day NATR. This locality yielded well preserved and diverse but not necessarily abundant specimens. Dockery (1993) revisited the locality in 1989 and found that it was unfossiliferous.

The vertebrate fossil fauna of the Coffee Sand is summarized by Daly (1992). Fish otoliths (ear bones) are important indicators of fish fauna and can be used for paleoenvironmental reconstruction. An abundant otolith fauna is reported from the Coffee Sand at Locality 129 by Nolf and Dockery (1990) and summarized by Daly (1992). This was the first reported otolith fauna from the Campanian (Late Cretaceous) and included 21 taxa. Nolf and Dockery's (1990) summary also greatly increased the age range for several groups of fish (Daly 1992). Case (1991) described eleven taxa, one potentially new, of elasmobranchs (sharks, rays, skates) from the Coffee Sand also within or near Locality 129. Other shark teeth are known from the Coffee Sand near Tupelo (Vestal 1946).

Overall, the fossils of the Coffee Sand, especially the Tupelo Tongue material from Locality 129 are globally significant in that they are likely the "best preserved Campanian [Late Cretaceous; see appendix A] fauna known anywhere" (letter of transmittal in Dockery 1993; Dockery 1990). The preservation of these specimens is more remarkable in that most of the listed gastropods are a few millimeters to centimeters in size. They are also very important biostratigraphic indicators and can be used to correlate the Mississippi fauna to others of similar age in the United States and Europe (Sohl 1964b, Dockery 1993). The specimens referenced by Dockery are housed in either the collections of the Mississippi Office of Geology (Jackson, MS) or the Smithsonian National Museum of Natural History (Washington, DC; type specimens only).

Selma Group (Upper Cretaceous)—Demopolis Formation

Stephenson and Monroe's (1940) "Selma chalk" unit is mapped in a wide swath in northeastern Mississippi and roughly correlates to the Demopolis Formation (or Demopolis Chalk). The parkway passes through this unit in south and western Lee County, near Tupelo, and southeastern Pontotoc County. As with other Late Cretaceous-aged units in Mississippi, the Selma preserves an abundant marine fauna from dozens of localities in Mississippi (e.g. Stephenson and Monroe 1940). This marine fauna is characterized by one crinoid species ("Echinodermata"), three species of annelid worms, one brachiopod species ("Molluscoidea" of Stephenson and Monroe), 35 bivalve species, at least two gastropod species, three ammonites, and occasional vertebrate remains. The bivalves are the most abundant and diverse fossils, dominated by *Exogyra* and *Ostrea* (oysters). Kennedy et al. (1997) described the abundant ammonite fauna (mostly *Baculites taylorensis*) from the Demopolis Formation exposed along the Tombigbee River. The U.S. Geological Survey made paleontological collections in a number of localities near NATR in the Tupelo area. Stephenson and Monroe (1940) list the fossils and localities, many along Mississippi Route 6, near its intersection with what is now NATR.

Daly (1992) summarized the vertebrate fossils from the Selma Group. The Demopolis Formation in Mississippi and Alabama, for example, contains a vertebrate fauna dominated by reptiles including shark teeth, mosasaurs, sea turtles, plesiosaur, a crocodile and a possible ornithiscian and hadrosaurine dinosaur in addition to less common fish (e.g. Derstler 1988; Russell 1988). Within Lee County specifically, Gidley (1913) named a new species of *Anomodeodus* fish from material found about 14.5 km (9 miles) west of Tupelo in the Demopolis Chalk. Gilmore (1927) reported mosasaur material "near Saltillo." Saltillo is approximately 1.6 km (1 mile) west of NATR. A hadrosaurian dinosaur tooth crown was also found near Saltillo (Carpenter 1982). Vestal (1946) reported shark teeth near both Saltillo and Tupelo from the Demopolis Formation. Lougee (1940, referenced by Daly 1992) noted mosasaur material including a jaw with teeth in the "chalk deposits near Tupelo." Lull and Wright (1942) discovered hadrosaur dinosaur hind limb material "near Tupelo" from the Demopolis Formation. While none of these localities are within NATR, their presence indicates the potential for future discovery within the park.

Selma Group (Upper Cretaceous)—Ripley Formation

The Ripley Formation is the second youngest (uppermost) unit of the Selma Group. The Ripley is characterized by gray to greenish gray glauconitic (containing mineral glauconite) fine-grained sandstones and sandy limestones, all of marine origin. Calcareous sands and sandstones are particularly well developed in Pontotoc and Chickasaw counties. The parkway crosses sediments mapped as the Ripley Formation in a thin band in south central Pontotoc and the middle third of Chickasaw counties (Stephenson and Monroe 1940). The exposures of the Ripley Formation in the Tallabinnela Creek Valley (between Troy and NATR) are considered typical of the formation (Priddy 1943).

Marine fossils of the Ripley Formation are common, and in some localities abundant. Stephenson and Monroe (1940) presented an extensive list of fossils from the Ripley Formation which includes coral, three species of crinoids, two serpulid worms (see Padre Island National Seashore section of this report), two annelid worms, 59 species of bivalves, two species of scaphopods ("tusk shells"), 48 species of gastropods, six ammonite and nautiloid species, a "muffin crab," ghost shrimp, and sharks teeth from two dozen USGS localities in northeastern Mississippi, many near the city of Pontotoc (see also Priddy 1943). One of these localities (USGS 6471/17259) is located within 1.6 km (1 mile) west of NATR along an abandoned railroad cut east of Troy. This locality primarily yielded bivalves and straight nautiloids (Stephenson and Monroe 1940). Another locality immediately east of Troy is described by Priddy (1943) and yielded a similar invertebrate assemblage in addition to shark teeth. In Chickasaw County, along Mississippi Route 8, in a cut in the Houlka Creek Valley, approximately 2.4 km (1.5 miles) east of NATR, Stephenson and Monroe (1940) map a USGS locality (6473) that yielded *Exogyra* and *Gryphaea* bivalves and shark teeth. The vertebrate fauna of the Ripley Formation is summarized by Daly (1992) and includes sharks teeth, fish bones and otoliths, and the Cretaceous crocodile *Thoracosaurus*, collected in Oktibbeha County outside of NATR. This specimen reported by Carpenter (1983) represents the most complete North American skeleton of the poorly understood genus *Thoracosaurus* (Daly 1992). If similar rocks are exposed within NATR they might yield similar fossils, although none have yet been reported.

Selma Group (Upper Cretaceous)—Prairie Bluff Formation
The Prairie Bluff Formation of the Selma Group is the uppermost (youngest) Upper Cretaceous formation mapped along NATR (Stephenson and Monroe 1940). The name "Prairie Bluff limestone" was first applied to the uppermost Cretaceous rocks in Alabama at Prairie Bluff by Winchell (1857). The Prairie Bluff Formation interfingers with the Owl Creek Formation of the Selma Group in Union County, well north of NATR (Dockery 1993). NATR crosses sediments of the Prairie Bluff Formation in the vicinity of Houston (Chickasaw County), and the junction of Mississippi Route 8 (Stephenson and Monroe 1940). The Prairie Bluff Formation is a hard, brittle chalk and limestone marine unit. Carbonate "skeletons" of microscopic planktonic organisms called coccolithophorids compose chalk.

The Prairie Bluff Formation is abundantly fossiliferous in places, especially exposures in its southern map area. These exposures display copius internal phosphatic molds of bivalves. More northern exposures lack the macrofossils but contain a microfossil invertebrate assemblage (Stephenson and Monroe 1940). Stephenson and Monroe (1940) consider the Prairie Bluff the uppermost formation in their *Exogyra costata* zone in Mississippi. Like the underlying Ripley Formation, summarized above, the Prairie Bluff has an abundant invertebrate fauna, although most bivalve specimens are preserved as molds. Stephenson and Monroe's (1940) fossil list from the Prairie Bluff includes corals (five species), crinoids (six species), serpulid and annelid worms, bryozoans and brachiopods (one species each), bivalves (42 species), gastropods (11 species), various shrimp and crab specimens in addition to fish vertebrae and bone fragments and shark teeth. Cobban and Kennedy (1995) described Prairie Bluff Formation ammonites (28 species) from Mississippi and Alabama including localities in Pontotoc and Chickasaw counties. A few of the USGS localities listed by Stephenson and Monroe (1940) and Cobban and Kennedy (1995) within Chickasaw County are near NATR particularly in road and abandoned railroad cuts around Houston and Sparta. For example, USGS locality 17231 is located along the banks of Chewawah Creek immediately west of NATR and yielded *Pecten* (scallop) molds and crab claws. USGS 17230 is located along "Houston-Van Vleet Road" approximately 1.6 km (1 mile) west of NATR and yielded a crinoid, bivalves, and an ammonite.

The vertebrates are summarized by Daly (1992) and include sharks teeth found approximately 6.4 km (4 miles) east of NATR near Montpelier (Bergquist et al. 1943) and in Kemper County well east of NATR (Hughes 1958). Priddy (1943) reported mosasaur bone fragments and shark teeth in Pontotoc County, outside of NATR.

Fossils have been found within Prairie Bluff Formation in or very near NATR boundaries, and were likely included in a "Fossil Display" at MP235. Black (1962) described an "on-site exhibit being constructed near Houston to feature a section of the sea floor." *In situ* fossils might have been a part of this display. The original fossil display consisted of an exposed portion of the Prairie Bluff Formation, enclosed in a glass case. (D. Dockery, personal communication, 2007). According to NATR Historian Chris Miller (personal communication, 2006), the display was removed many years ago. The fossil display was replaced by a wayside panel showing the extent of the Upper Cretaceous sea across Mississippi and North America (D. Dockery, personal communication, 2007). Most of fossils in the NATR park collection listed as "Chickasaw County" therefore might have originally been part of this display. These fossils include dozens of mollusks (gastropods, bivalves, and cephalopods-ammonites and nautiloids), serpulid worm burrows, sand dollars, and shark teeth from the Prairie Bluff Formation.

George Phillips of the Mississippi Museum of Natural Science in Jackson reported the discovery of a remarkably well preserved, nearly complete *Dakotacancer australis* (crab) within 480 m (one-third of a mile) of the parkway. Phillips (personal communication, 2006) discovered the specimen in May 2000 in the gravel roadbed of Chickasaw County Road 118 a few hundred meters from its intersection with NATR in Tombigbee National Forest. Heavy rains gouged the roadbed down to "marl," most likely the Prairie Bluff Formation. This specimen (MMNS IP-19) is now in the collections of the Mississippi Museum of Natural Science.

Upper Cretaceous-Paleocene Transition ("K-T Boundary")
The transition from Upper Cretaceous ("K") to Paleocene (Tertiary, "T") is a major transition in geologic time. It marks the end of the Mesozoic Era and a major mass extinction event leading to the demise of the terrestrial dinosaurs, marine mosasaurs (giant carnivorous marine reptiles), ammonites, and most coccolithophores, the main component of chalk, just to name a few found as fossils along/near NATR. It also marks the beginning of the Cenozoic Era (Tertiary) during which time mammals rapidly radiate and diversify, taking over from reptiles (and dinosaurs) as the dominant terrestrial vertebrates. The following formations all postdate this important transition. While there are likely no exposures of the actual K-T boundary along the parkway, changes in modern vegetation assemblages signal this geological transition (D. Dockery personal communication, 2006).

Midway Group (Paleocene)—Clayton Formation
The Paleocene Clayton Formation is the oldest tertiary unit crossed by the parkway and is the basal formation of the Midway Group. The Clayton Formation generally consists of fine sands that are calcareous near the base of the formation. Fossiliferous limestones and siltstones are found in some exposures in the lower (limestone) and upper (siltstone) layers (Priddy 1943). The parkway crosses Clayton Formation sediments (and the K-T Boundary) in southern Chickasaw County, where the Clayton Formation might be exposed as sand, calcareous sandstone, or a limestone (D. Dockery, personal communication, 2006). Black (1962) noted that the parkway would only traverse approximately 1.6 km (1 mile) of Clayton Formation sediments south of Houston in Chickasaw County. The "Arnold Sand Pit" locality in southern Pontotoc County, along U.S. Route 15, is a good exposure of the Clayton Formation that also yields fossils (D. Dockery, personal communication, 2006).

The Clayton Formation preserves a locally abundant marine fauna in Mississippi. Invertebrates include molds and casts of bivalves, gastropods. Interestingly, in Pontotoc County at the Arnold Sand Pit, the fossil shell material has been replaced by the clay mineral beidellite (Stephenson 1939; D. Dockery, personal communication, 2006). This is a very unusual occurrence and certainly noteworthy. Vertebrates from the Clayton Formation are summarized by Daly (1992) and include shark teeth from Tippah County (Lowe 1933; Conant 1939), although they may be reworked from the underlying Upper Cretaceous formations (Toulmin 1977). Black (1962) noted that marine invertebrates were abundant in the Clayton Formation. Further investigation is needed to determine if Clayton Formation fossils are exposed along or near NATR.

Midway Group (Paleocene)—Porters Creek Clay
According to Vestal (1952), the largest Porters Creek exposure in Webster County, and one of the largest in Mississippi, is located along a branch of Prairie Creek within 0.8 km (0.5 mile) southeast of the present-day NATR Dancy ranger station. This exposure is dark gray to bluish-black or black very fine grained clay. The Porters Creek Clay is also mapped along NATR in northwestern Clay County (Bergquist 1943) and northeastern Choctaw County (Vestal 1943). Sediments of the Midway Group in Texas are exposed near San Antonio Missions National Historical Park (see SAAN section of this report).

As is typical of such clay deposits, fossils are not extensive and in Webster County are primarily "comminuted" (pulverized) plant remains which were found at the above locality near NATR (Vestal 1952). Black (1962) noted that marine invertebrates were abundant in the Clayton Formation. Further investigation is needed to determine if Clayton Formation fossils are exposed along or near NATR. Marine microfossils (foraminifera) are also found in the Porters Creek Clay of Webster (Vestal 1952) and Clay (Bergquist 1943) counties. Kline (1943) lists more than 100 species foraminifera and ostracods from the Porters Creek Clay in Clay County. Some of the foraminifera are large and abundant enough to be seen with the naked eye and are well exposed at a locality along Little Cane Creek, northwest of Montpelier, approximately 6.4 km (4 miles) east of the parkway in Clay County (Bergquist 1943). Foraminifera and a solitary coral were found along the canal of Old Field Creek about 4.8 km (3 miles) east of NATR in Clay County (Bergquist 1943). Such fossils have not yet been documented within the park.

Midway Group (Paleocene)—Naheola Formation
The Naheola Formation overlies (is younger than) the Porters Creek Clay with a continuous gradational contact between the two. The Naheola is the uppermost formation of the Midway Group exposed in Mississippi and along the parkway. It is characterized by fine sand and thin layers of dark-gray to light gray silty shale with interbeds of sand (Vestal 1952). Good exposures of the formation are located in Webster County immediately east of NATR along the Big Black River Valley northwest of Mathiston and southwest of Cumberland described by Vestal (1952). Sediments of the Midway Group in Texas are exposed near San Antonio Missions National Historical Park (see SAAN section of this report).

Vestal's (1952) descriptions of the sections near NATR do not include specific mention of fossils. However abundant and diverse molds of macroscopic marine invertebrate (bivalves and gastropods) fossils are known from the Naheola Formation in Kemper County, Mississippi (Vestal 1952) and in Alabama (Toulmin 1977). Similar fossils are not yet known from NATR.

Wilcox Group (upper Paleocene-lower Eocene)
The Wilcox Group is divided into four main formations in Mississippi, from lowest (oldest) to highest (youngest), The Nanafalia Formation, the Tuscahoma Formation, the Bashi Formation, and the Hatchetigbee Formation. The globally important Paleocene-Eocene transition is located within the Wilcox Group between the Tuscahoma and Bashi formations, as described in those formations' paragraphs. Fossils are known from all four formations, and are particularly well exposed in Alabama, where the formation is primarily marine in origin. In Mississippi, the Wilcox sediments and fossils are more fluvial and deltaic in nature.

Wilcox Group (upper Paleocene)—Nanafalia Formation
The Nanafalia Formation is mapped as the "Ackerman Formation" in Choctaw and Webster counties (Vestal 1952, 1943). It is extensively exposed and described in numerous road cuts, ravines, and gullies within Webster County by Vestal (1943). Along NATR, the Nanafalia ("Ackerman") is mapped between Mathiston and Cumberland in Webster County and northeastern Choctaw County. The Nanafalia is characterized by a basal brown and red-brown coarse to medium grained sand, a middle silt, clay, and fine sand interval with iron ore, and an upper thin bedded silt, find sand, and light-gray clay (Vestal 1952). The Nanafalia has been divided into three members based on the above lithologies, from lowest (oldest) to highest (youngest), Gravel Creek Sand Member, *Ostrea thirsae* beds, and Grampian Hills Member. The Nanafalia is a transgressive (rising sea level) marine unit.

Fossils, particularly marine mollusks, are known from the Nanafalia Formation, although poorly preserved (Dockery 1998). The *Ostrea thirsae* beds are named for an oyster abundant in those layers, especially in Alabama. Overall, Dockery (1998) lists 64 species of bivalves and gastropods from the Nanafalia Formation, mostly in Alabama. None are yet reported from within or near NATR.

Wilcox Group (upper Paleocene)—Tuscahoma Formation
The contact between the upper Paleocene Tuscahoma Formation and the lower Eocene Bashi Formation (see below and Appendix A) marks an important transition between the Paleocene and Eocene epochs as noted in the Bashi Formation paragraph below. Most of the "Holly Springs Formation" (now-abandoned nomenclature) of Vestal (1943) in Choctaw County is probably equivalent to the Tuscahoma Formation (D. Dockery, personal communication, 2006). Vestal characterized these primarily marine sediments as coarse-grained white, yellow, red, and purple sands (bluish-greenish unweathered) and dark or light gray, pink, or white clays in Choctaw County. The parkway crosses the Tuscahoma Formation in central and southwestern Choctaw County (Vestal 1943).

Fossils are well known from the Tuscahoma Formation, and are frequently collected in Mississippi near the town of Meridian (Lauderdale County). The diverse molluscan fauna is limited to a few beds of the Greggs Landing Marl Member (111 taxa) and Balls Landing Marl Member (77 taxa) in Alabama (Dockery 1998). These fossiliferous sands are not found north of Kemper County, Mississippi (along the Alabama state line) where the Tuscahoma sediments become more deltaic in origin (Dockery 1998). Many vertebrate fossils are from the informally named "T4 sand," which is an upper marine sand. Daly (1992) and Dockery (1998) summarized these occurrences including sea snake (*Palaeophis*) vertebrae, turtle bones, rare lizard and bird remains, abundant shark teeth, fish teeth, and mammal teeth. Case (1994a, 1994b) described the abundant fish fauna from the Tuscahoma and Bashi formations in Lauderdale County, Mississippi and compared it to faunas in Europe and Africa. The land mammal fossils are primarily isolated teeth and include at least 23 different taxa (Beard et al. 1995). Fossil leaf impressions were noted by Vestal (1943) in Choctaw County. Fossils, although well known from the Tuscahoma, are not yet reported within or near NATR.

Wilcox Group (lower Eocene)—Bashi Formation

The Bashi Formation of the Wilcox Group is sometimes mapped as a member of the Hatchetigbee Formation. Vestal (1943) may have included sediments of the Bashi Formation in his "Holly Springs Formation." Vestal used "Holly Springs" nomenclature for all Wilcox Group sediments above the Nanafalia ("Ackerman") Formation in Choctaw County. The contact between the underlying Tuscahoma Formation and the Bashi Formation marks the important transition between the Paleocene and Eocene (see Appendix A), which involved world-wide faunal turnover in response to global tectonics and changes in deep-sea currents (Dockery 1998 and other papers in Aubry et al. 1998). Like the other Wilcox Group sediments, the marine sands of the Bashi Formation were well exposed in Alabama; many localities are now covered by waters of the Tombigbee or Alabama River waterways (Dockery 1998).

Fossils of the Bashi Formation are diverse. Dockery (1998) utilized the 218 molluscan taxa from Bashi Formation exposures in Alabama to describe faunal turnover across the Paleocene-Eocene boundary. The Wilcox Group exposures in Alabama probably contain the best Paleocene-Eocene molluscan record in the western hemisphere (Dockery 1998). Fossiliferous Bashi Formation exposures are also found in Mississippi with classic collecting localities near Meridian, in Lauderdale County. Dockery (1980) listed mollusk and vertebrate fossils from the Bashi Formation in Clarke County. The vertebrate fauna of the Bashi Formation, mostly discovered near Meridian, was summarized by Daly (1992) and included dozens of species of fish otoliths (ear bones), fish bones and teeth, shark, skate, sawfish, and ray teeth, alligator teeth, sea snake vertebrae, and whale vertebrae. Case (1994a, 1994b) described the abundant fish fauna from the Tuscahoma and Bashi formations in Lauderdale County, Mississippi and compared it to faunas in Europe and Africa. The Bashi Formation also contains an important land mammal record in the form of small teeth (Dockery et al. 1991). For example, the first early Eocene mammal, an omomyid (tarsier monkey-like) primate, from eastern North America was discovered in the Bashi Formation at Meridian (Beard and Tabrum 1991). *Hyracotherium* (early horse) and creodont (extinct group of carnivorous mammals) jaw and teeth have also been found in the Bashi Formation (Beard and Tabrum 1991; Dockery 1998). Fossils of the Bashi Formation have not yet been described within or near NATR.

Wilcox Group (lower Eocene)—Hatchetigbee Formation

The Hatchetigbee Formation is the uppermost (youngest) formation in the Wilcox Group within Mississippi. The underlying Bashi Formation is sometimes referred as a member of the Hatchetigbee. Vestal (1943) may have included sediments of the Hatchetigbee Formation in his "Holly Springs Formation." Vestal used "Holly Springs" nomenclature for all Wilcox Group sediments above the Nanafalia ("Ackerman") Formation in Choctaw County. Parks (1963) characterized the Hatchetigbee Formation as a heterogeneous body of alternating clay, silt, sand and lignite ("brown coal") with clays and silts predominate. Parks mapped the formation near NATR in the northeast corner of Attala County, but noted that most of the few Hatchetigbee Formation exposures are poor with a well developed soil layer.

Parks (1963) did not mention any fossils from the Hatchetigbee Formation in Choctaw County. Ingram (1991) also described Hatchetigbee exposures near Meridian (Lauderdale County) as "unfossiliferous." However, 78 marine mollusks (mostly venericardid bivalves) are known from the Hatchetigbee Formation, most from Hatchetigbee Bluff in southwestern Alabama (Dockery 1998). Dockery (1980) noted a "dwarf gastropod fauna" from the Hatchetigbee in Clarke County, Mississippi. Fossils are not known from this formation along or near NATR, providing little potential for future discovery of fossils in the Hatchetigbee Formation.

Claiborne Group (lower-middle Eocene)
The lower (early)-middle Eocene Claiborne Group is divided into seven formations from lowest to highest, the Meridian Sand, Tallahatta Formation, Winona Formation, Zilpha Shale, Kosciusko Formation, Cook Mountain Formation, and the Cockfield Formation. The Claiborne Group was originally described in Alabama and contains abundant and well preserved marine fossils which have been studied since the mid1800s (Charles Lyell and Timothy Abbot Conrad). In Mississippi, the Claiborne is alternatingly marine and deltaic (Dockery 1980), with less common fossils. Thomas (1942) produced a monograph detailing the Claiborne Group sediments in Mississippi.

Claiborne Group (lower-middle Eocene)—Meridian Sand
In the past, the lower (early)-middle Eocene Meridian Sand of the Claiborne Group was sometimes mapped with and considered a member of the Tallahatta Formation (see below; e.g. Parks 1963). Thomas (1942) placed the Meridian Sand in the underlying Wilcox Group. The Meridian Sand is now considered the basal (oldest) member of the Claiborne Group (e.g. Dockery 1986; personal communication, 2006). Geologically the unit is characterized by fine to medium grained gray to light-gray nonmarine sands that weather to a buff, yellow, tan, or red-brown color (Parks 1963). The parkway crosses Tallahatta Formation sediments (including the Meridian Sand Member as mapped by Parks 1963) in northeast and east-central Attala County. Some Meridian Sand exposures in southwestern Choctaw County are near NATR. As described by Vestal (1943), these exposures are along NATR near the town of French Camp (MP181), just north of the Attala-Choctaw county line, and approximately 6.4 km (4 miles) northeast of French Camp 223 m (250 yards) east of NATR.

Fossils from the Meridian Sand are not well documented and include fragments of fossil wood in some localities within Attala County, one within or near NATR. Park Ranger Guy Taylor, who like Donald Black was a geologist working at NATR in the early 1960s, discovered fossil logs "adjacent to the Parkway's Right of Way" near Little Mountain (Black 1962). Little Mountain is located within the Jeff Busby Site (MP193.1) in Choctaw County and is mapped as Meridian Sand (Vestal 1943). Vestal (1943) also noted fossil wood within a few hundred meters of the parkway 6.4 km (4 miles) north of French Camp in Choctaw County. Taylor also found "apparently Eocene" fossil leaves in the "Little Mountain recreation area near Mathiston, Mississippi." (Black 1962). Well preserved fossil leaves are known from the Eocene Tallahatta Formation (see below) and might have been the source of Taylor's discovery. Mathiston is located approximately 19 km (12 miles) northeast of the Jeff Busby site in Webster County. Vestal mapped Paleocene marine formations including Porters Creek, Naheola, and Nanafalia ("Ackerman") near Mathiston.

Claiborne Group (lower-middle Eocene)—Tallahatta Formation
The lower (early)-middle Eocene Tallahatta Formation is divided into members by some authors, some of which included the Meridian Sand (see above) as a member of the Tallahatta (Thomas 1942; Parks 1963). The Tallahatta Formation is characterized by silica-rich claystone, siltstone and sandstone, with beds of shale, clay, greensand, glauconitic and non-glauconitic sand, all of which are of marine or coastal marsh origin (Thomas 1942). The Tallahatta Formation is mapped along NATR in northeastern and east-central Attala County (Parks 1963).

Fossils are common in some exposures of the Tallahatta Formation. For example, molds of "thin-shelled mollusks" were found in most of the fine grained sediments of the Tallahatta Formation (Basic City Shale Member) (Parks 1963). Similar fossils are reported in Clarke County (Dockery 1980) in addition to well preserved plant fossils in some exposures. Plant fossils from the Tallahatta might have been found at the Jeff Busby site, as described above in the Meridian Sand paragraph. The sands of the Tallahatta Formation (Nebosha Shale Member) are non fossiliferous (Thomas 1942). Aside from the potential discovery near Jeff Busby site, fossils have not yet been discovered from this formation within or near NATR.

Claiborne Group (middle Eocene)—Winona Formation
The middle Eocene Winona Formation of the Claiborne Group is characterized by fossiliferous medium to coarse grained greensand (contains the mineral glauconite) (Thomas 1942). Parks (1963) mapped the Winona Formation along NATR in a very thin band south of east of Kosciusko in Attala County.

The Winona Formation is abundantly fossiliferous in some exposures, of which there are many in Attala County, but most of the fossils are poorly preserved (Parks 1963). The fossil fauna is quite diverse and included bivalves, gastropods, echinoids, crabs, shark and fish teeth (Lowe 1915, 1923; Dockery 1980), and microfossils (foraminifera and ostracodes) (Thomas 1942). However, there are not many localities were good material can be collected with the exception of exposures near Enterprise in Clarke County (Thomas 1942; Dockery 1980). "Typical" Eocene mollusk fossils including the guide fossil *Cubitostrea lisbonensis* (oyster) were found at a pond excavation approximately 2.4 km (1.5 miles) east of NATR, due east of Kosciusko in Attala County (D. Dockery, personal communication, 2006). Fossils of the Winona are not yet known from within NATR.

Claiborne Group (Eocene)—Zilpha Clay
The Eocene Zilpha Clay of the Claiborne Group is described by Thomas (1942) as a carbonaceous shale with blocky clay with silt, sand, glauconite, and greensand. The Zilpha Clay is mapped along NATR south and southeast of Kosciusko in Attala County (Parks 1963). Parks (1963) further divided the Zilpha into three units, which are summarized together here.

Fossils from the Zilpha Clay are predominately plant fragments, giving the clay its distinctive carbonaceous character (Thomas 1942). Molds of mollusks including (*Ostrea*) and echinoids (*Proscutella*) were noted by Thomas (1942). Parks (1963) also noted "abundant," albeit poorly preserved, fossils from the Zilpha Clay in many localities in Attala County. Fossils from the Zilpha are not yet reported within or near NATR.

Claiborne Group (Eocene)—Kosciusko Sand
Thomas (1942) characterized the Eocene Kosciusko Sand of the Claiborne Group as a thick heterogeneous deposit of non-marine sands, silts, and clays with quartz rich siltstones. Unlike the relatively small areal extent of the Winona Sand and Zilpha Clay, the Kosciusko Sand is mapped over a wide swath of Attala and Leake counties. NATR crosses Kosciusko sediments through these counties along the Yockahockany River south of Kosciusko.

Plant fragments are abundant in the silty shales of the Kosciusko, with some exposures producing well preserved fossil leaves, especially in Carroll County (Thomas 1942). Dockery (1980) reported a fragmented fossil rib tentatively identified as a small rhinoceros or whale (Daly 1992) from the Kosciusko along the Chickasawhay River in Clarke County in addition to venericardid bivalves. No fossils are yet known within or near NATR.

Claiborne Group (middle Eocene)—Cook Mountain Formation
Sediments of the Cook Mountain Formation are mapped by Thomas (1942) as the "Wautubbee Formation," a now abandoned stratigraphic name. Some historical literature also used the stratigraphic name "Lisbon" (currently used in Alabama) to describe beds of the "Wautubbee," now the Cook Mountain Formation. Thomas (1942) characterized these sediments as fossiliferous marls, greensands, glauconitic sand and limestones with associated carbon-rich shales, non-glauconitic sands, and bentonite (clay). Thomas (1942) also noted the formation becomes non-marine northwest of the Yockahockany River. The Cook Mountain Formation disconformably overlies the Kosciusko Formation. NATR was constructed immediately to the west of the Yockahockany River and crosses Cook Mountain Formation sediments ("Wautubbee") in a narrow band within Leake County (Thomas 1942). Thomas (1942) also discusses the three members of the Cook Mountain Formation: the Archusa Marl Member (lowest/oldest), the Potterchitto Member, and the Gordon Creek Shale Member (highest/youngest). In Leake County, these members are not differentiated.

Fossils are well known from the Cook Mountain Formation ("Wautubbee") and were first described by Lowe (1919). Lowe (1919) reported the marls now called the Cook Mountain Formation are locally rich in marine fossils with the saddle-shaped oyster "*Ostrea sellaeformis*" (now *Cubitostrea sellaeformis*) being particularly abundant. Clarke County contains many good examples of Cook Mountain marine invertebrates (Dockery 1980). Thomas (1942) further discussed the marine fossils from each member of the formation. Vertebrate fossils from the Cook Mountain Formation were summarized by Daly (1992) and include a new species of rhino-like brontothere (extinct group of perissodactyls) discovered in Clarke County. The undifferentiated "Wautubbee" sediments of Thomas (1942) in central Mississippi are also described as fossiliferous, with bivalve fossils found in the marine facies of the formation. The Shipps Creek Shale is considered contemporaneous (deposited at the same time) as the Cook Mountain Formation, but is mapped northwest of NATR in Holmes and Attala counties. Leaf fossils are known from the Shipps Creek Shale (Thomas 1942), but not near NATR. Because NATR traverses the non-marine sediments of the Cook Mountain Formation, discovery of abundant marine fossils within or near the parkway is unlikely. Exposures of the marine sediments (and fossils) are present in Newton and Clarke counties, southeast of NATR near the Alabama state line.

Claiborne Group (Eocene)—Cockfield Formation
The Cockfield Formation is the uppermost (youngest) formation assigned to the Claiborne Group in Mississippi. Thomas (1942) described the nomenclatural history of the Cockfield ("Yegua") Formation, and characterized the formation as a heterogeneous geologic unit with non-marine (fluvial and deltaic) sands, silts, shales, and clays with lignite ("brown coal"), siderite (iron ore), and bentonite (clay). The Cockfield Formation is mapped along NATR in southwestern Leake and eastern Madison counties (Thomas 1942). Modern alluvium from the Peal River probably obscures the Cockfield Formation in Madison County, as the parkway was constructed along or near the transition between the Cockfield and alluvium (Priddy 1960).

Fossils in the Cockfield Formation are limited. Thomas (1942) only noted occasional fossil leaves from the formation and indicated the badly weathered nature of most Cockfield Formation exposures, thus limiting fossil preservation. Priddy (1960) did not mention fossils from the Cockfield Formation in Madison County. Dockery (1986) mentioned only abundant burrows at the top of the Cockfield Formation at Riverside Park in Jackson. Engelhardt (1964) described 56 species of pollen dominated by the Juglandaceous (walnut-like) grain *Momipites coryloides* from Riverside Park in Jackson. This assemblage indicated a subtropical coastal climate. Dockery (1980) noted the transitional nature of fossil pollen in the Cockfield Formation between the Claiborne Group and the Jackson Group (see below).

Jackson Group (upper Eocene)
The Jackson Group is a very fossiliferous marine unit of upper (late Eocene) age. There are two formations within the Jackson Group, the lower (older) Moodys Branch Formation and the upper (younger) Yazoo Clay. Both are known to be fossiliferous, and the Moodys Branch has been collected since the nineteenth century, and ranks second only to the bluffs at Claiborne, Alabama (see Claiborne Group, above) in diversity and preservation of marine fossils (Monroe 1954). Monroe (1954) summarized some of the early collecting efforts and stratigraphic interpretation and regional and global correlation by Charles Lyell (1849) and Timothy Abbott Conrad (1856) at the type localities in and near Jackson. The parkway does not cross sediments mapped as the Moodys Branch Formation, but it does cross the fossiliferous Yazoo Clay.

Jackson Group (upper Eocene)—Moodys Branch Formation
The Moodys Branch Formation is the lowest (oldest) formation in the Jackson Group. The formation is exposed only in a narrow band within and just north of Jackson in Hinds County. Monroe (1954) characterized the Moodys Branch Formation as a fossiliferous blue-gray glauconite-rich clayey sand or sandy clay. Exposures of the Moodys Branch in and near Jackson (i.e. Riverside Park and Fossil Gulch, Dockery 1989, 1996) form the type locality for the formation. The parkway does not currently cross sediments of the Moodys Branch Formation, as the parkway skirts to the north and west of Jackson, but they are included here due to their regional and global significance. Exposures of the Moodys Branch

Formation used to be visible along the Natchez Trace at the bottom of a bluff at the River Bend stop. This locality was submerged under the waters of Ross Barnett Reservoir (D. Dockery, personal communication, 2007).

The fossils of the Moodys Branch Formation are primarily molluscan, although microfossils (foraminifers), bryozoans, corals, and echinoderms are also abundant (Monroe 1954). The extraordinary mollusks (some preserving original coloration) of the Moodys Branch Formation were systematically described by Dockery (1977) and include 182 gastropod, nine cephalopod, and 74 bivalve species, subspecies, and varieties. Many of these genera indicate a tropical paleoclimate (Dockery 1989). Dockery's collecting localities were primarily in and near Jackson but also included Yazoo and Clarke counties. Dockery (1977) summarized not only the mollusks of the Moodys Branch, but also the extensive literature base and historical research performed with Moodys Branch material. Dockery (1977) divided the Moodys Branch into terrigenous (shallow marine sediment consisting of material eroded from land surface) facies based on fossil assemblages and lithology.

Jackson Group (upper Eocene)—Yazoo Clay
The upper (late) Eocene Yazoo Clay is the uppermost formation of the Jackson Group and was first described by Lowe (1915). The Yazoo Clay is extensively exposed in Hinds County within and surrounding Jackson. NATR crosses these sediments west of Jackson in Hinds County, but also north of Jackson in Madison County (Priddy 1960). The Yazoo Clay in Hinds County is generally characterized by blue-green to blue-gray (weathering to yellowish or greenish yellow) calcareous and fossiliferous deepwater marine clay (Moore 1965). In Hinds County, there are "numerous" exposures but they are frequently badly weathered and slumped (Moore 1965). Unfossiliferous, and noncalcareous beds of the Yazoo are also known. Some of these noncalcareous beds contain expansive clays (montmorillonite and bentonite), which creates many civil engineering challenges, cracked foundations, and undulating roadways (e.g. Moore 1965, Stover et al. 1988; Pitalo et al. 2004). In the area around Jackson, the Yazoo Clay (and most other Cenozoic formations) is draped by Pleistocene loess deposits (Monroe 1954).

The best exposure of the typical Yazoo Clay was located approximately 1.6 km (1 mile) north of NATR in Cynthia near the southwest corner junction of Madison (Priddy 1960) and Hinds County (Moore 1965). This locality is within the clay pit of the Jackson Ready-Mix Concrete (Miss-Lite Clay Pit) plant in Cynthia, Mississippi and yielded an important fossil fauna described below. The locality was a field trip stop in a number of guidebooks including Kolb et al. (1976) and Dockery (1989). The quarry, however, is now closed (Dockery 1992). Riverside Park, in Jackson, is another collecting locality for fossils of the Yazoo Clay (Dockery 1986). Stratigraphically, the Yazoo Clay is also very important in that its upper limit is also the boundary between the upper Eocene (Jackson Group sediments) and lower Oligocene Vicksburg Group sediments (see VICK section, and Eocene-Oligocene transition paragraph, below).

The important paleontological record of the Yazoo Clay includes both microfossils (foraminifera) and mega-macrofossils including primitive whales. The microfossil record includes abundant and diverse microfossils, particularly foraminifera, ostracodes, and a nannoflora (Obradovich et al. 1993; Dockery 1996; Oboh et al. 1996). These microfossils have been used to biostratigraphically place and date the important global transition and rapid paleoclimate change referenced above between the Eocene and Oligocene. Unlike the Moodys Branch Formation, there is a limited mollusk fossil fauna from the Yazoo Clay. Monroe (1954) only noted three bivalve genera from a well in Rankin County east of Jackson. A few kilometers east of NATR, on the east side of Pearl River, in northern Rankin County, the Yazoo Clay preserves abundant *Ostrea trigonalis*, bryozoans, and calcareous algae (stromatolites) (Monroe 1954). These fossils have weathered out of the clay and are found there on the surface. While most of the fossils are indicative of a deepwater marine environment, some shallow water mollusks are noted in the upper part of the Yazoo Clay (Dockery 1996) as they probably were washed into the deeper water sediments.

The most well-known vertebrate from the Yazoo is the state co-fossil *Basilosaurus cetoides*. *Basilosaurus* is paleontologically significant as a very primitive whale (vestigial rear limbs are preserved on some specimens), the oldest in North America. The other state fossil is another primitive whale, *Zygorhiza* *kochii* also known from upper Eocene deposits in Mississippi. Bones, particularly vertebrae, and teeth of *Basilosaurus* are common in Yazoo Clay deposits throughout Mississippi (Daly 1992) and near Jackson (e.g. Lowe 1925; Sullivan 1948). *Basilosaurus* bones have been found within the Cynthia ready-mix plant (Miss-Lite) exposures near NATR (Priddy 1960; Moore 1965; Daly 1992). A new genus and species of whale (*Cynthiacetus maxwelli*) was recently described utilizing material from the Miss-Lite pit (Uhen 2005). *Basilosaurus* bones were also found Dockery and Johnston (1986) near Madison, approximately 4.0 km (2.5 miles) north of the parkway north of Jackson. The vertebrate fauna of the Yazoo Clay is not limited to whales however. Dockery and Manning (1986) noted large (~7 cm or 2.75 in high) *Charcharodon auriculatus* shark teeth from the Miss-Lite locality. Fossil vertebrae of the large marine snake *Pterosphenus* were also discovered at the Miss-Lite locality (Daly 1992). Fish and rays are also known in other localities within Mississippi (Daly 1992).

There is an interesting historical occurrence of fossils from the Yazoo Clay within or immediately adjacent to what is now NATR. Silas Dinsmoor served as the Choctaw Agent for Mississippi during the early 1800s (Dockery, in press) and constructed a large agency house near Ridgeland along the old Natchez Trace. While digging a well in an unsuccessful bid to find water in 1811 (Elliot 1998), he discovered a number of fossils (oyster shells) from the Yazoo Clay. He displayed these fossils inside the house, and they were noted by some of the early nineteenth century travelers along the Trace (D. Dockery, personal communication, 2006). Two unidentified fossils are in the collections of the Southeast Archeological Center (NATR Accession 00226) with a collection locality listed as "Choctaw Agency." Further investigation may reveal if these fossils were part of Silas Dinsmoor's collection.

Eocene-Oligocene Transition

Prothero et al. (2003) and papers therein present global discussion of the paleoclimate transition from the warm Eocene ("greenhouse") to the global cooling ("icehouse") of the Oligocene. This important geological transition has been dated to 34.3 Ma (million years ago) utilizing Yazoo Clay exposures in Mississippi, including Society Ridge, 4.8 km (3 miles) north of the parkway, north of Cynthia (Obradovich et al. 1993). Mollusk fossils from the Cynthia Miss-Lite pit, just north of the parkway, also illustrate this transition (Hansen et al. 2004). The Vicksburg National Military Park section of this report also summarizes this transition.

Vicksburg Group (Lower Oligocene)

As described in much greater detail in the VICK section of this report, the lower (early) Oligocene Vicksburg Group is a globally significant assemblage of highly fossiliferous marine sand, clay, and limestone units that record the paleoecological, spatial, and faunal evolution of the Gulf of Mexico as sea levels transgressed (rose) and regressed (fell). The current stratigraphic interpretation of the Vicksburg Group involves its separation into seven formations as redefined by Dockery (1982a) and MacNeil and Dockery (1984). In ascending order (oldest to youngest), the Vicksburg Group contains the Red Bluff Formation, Forest Hill Formation, Mint Spring Formation, Marianna Limestone, Glendon Limestone, Byram Formation, and Bucatunna Formation. The Red Bluff Formation is not exposed along NATR. Moore (1965) maps the Forest Hill Formation separately from the remainder of the Vicksburg Group. NATR crosses sediments of the Vicksburg Group south and west of Jackson in Hinds County (Moore 1965). In Hinds County, the Forest Hill Formation is primarily deltaic deposits of silty sands and clays while the other formations of the Vicksburg Group are associated marine limestones, marls, and clays. The Vicksburg Group in Hinds County is only exposed in creek beds, gullies, and road cuts (Moore 1965). Nevertheless the type sections for the Byram Formation (Casey 1902; banks of Pearl River at Byram, south of Jackson) and Forest Hill Formation (Cooke 1918; along Mississippi Route 18 near Forest Hill School, southwest of Jackson) were described within Hinds County.

Fossils including marine invertebrates and vertebrates are well known from the Vicksburg Group, and are globally significant. The VICK section of this report describes these important fossils in much greater detail. The Forest Hill Formation at Flora, Mississippi (Madison County) 11 km (7 miles) north of NATR north of Jackson preserves a large quantity and diversity of petrified wood. This locality, the Mississippi Petrified Forest, was designated a National Natural Landmark. Petrified wood is the official state "stone" of Mississippi. Monroe (1954) and Moore (1965) mention plant fossils in and around Jackson from the Forest Hill Formation. Blackwell (1983) described fossil wood, both angiosperm (new species) and conifer, from "Sand Hill," approximately 13 km (8 miles) east of NATR, in Rankin County east of the Pearl River/Ross Barnett Reservoir. The marine microfossils and invertebrates of the Vicksburg Group in Hinds County are primarily preserved in exposures along the Pearl and Big Black rivers and along Interstate 55 (Moore 1965) Fossils have not yet been officially described from the Vicksburg Group within NATR. Future discovery within the park may be hampered by the limited exposures of the Vicksburg Group near NATR in Hinds County.

Catahoula Formation (Oligocene-Miocene)
In counties traversed by NATR, the Catahoula Formation is mapped by Moore (1965) over the vast majority of southern and western Hinds County, nearly all of Claiborne County (Bicker 1966), and the northern and western reaches of Jefferson County. The Catahoula is widespread throughout south-central Mississippi. Pleistocene loess (described below), however, blankets nearly all of the Catahoula sediments traversed by the parkway in Hinds, Claiborne, and Jefferson counties. Thus there is limited potential for significant exposures of the Catahoula along the parkway. The sediments of the Catahoula are primarily nonmarine silts, sands, and clays in colors ranging from gray to purple. The sands can be well indurated (cemented) and were used in construction of the Old State House building in Jackson. The sediments now assigned to the Catahoula Formation were originally named as part of the "Grand Gulf Group," a stratigraphic term now obsolete. Interestingly, Wailes (1854) utilized exposures at Grindstone Ford along the historic Natchez Trace, and now part of NATR (MP45.7) as part of his original description of the "Grand Gulf Group."

There are limited paleontological resources within the Catahoula Formation, and little chance for their discovery along the parkway. Moore (1965) did not observe any fossils in the Catahoula Formation within Hinds County, but noted "obscure [animal] prints" were discovered in the Catahoula of Simpson County, Mississippi in 1931. Bicker (1966) presented a measured section and photograph of the Catahoula at two exposures near NATR including one "on the Natchez Trace" approximately 4.8 km (3 miles) along the parkway north of the parkway's crossing of Bayou Pierre. He indicated typical Catahoula clay and sandstone were exposed there, but no fossils were mentioned by Bicker (1966). Berry (1917b) described the fossil flora of the Catahoula Formation which includes a specimen of *Palmoxylon cellulosum* (petrified palm wood) discovered within Bayou Pierre in Claiborne County. However, Bicker (1966) believed that the specimen referenced by Berry (1917b) originated within the Quaternary terrace deposits rather than the Catahoula. As reported by Bicker (1966), no Catahoula fossils were known in Claiborne County, but the terrace deposits were known to preserve petrified wood. No marine fossils have been found in the Catahoula within Mississippi, but petrified palm wood is common (Matson 1917).

Neogene Deposits (Miocene-Pliocene)
Stratigraphic relationships between the Neogene deposits (Miocene-Pliocene age), the underlying Oligocene-Miocene Catahoula Formation, and the overlying Pleistocene deposits are not well defined and have undergone considerable stratigraphic and nomenclatural changes (e.g. Otvos 1994; Otvos in press). The current stratigraphic column for Mississippi (D. Dockery, personal communication, 2006) lists these formations in ascending (oldest to youngest) order as the middle-upper Miocene Hattiesburg Formation, the upper Miocene Pascagoula Formation, the lower Pliocene Graham Ferry Formation and the upper Pliocene Citronelle Formation. These formations are generally sandy to muddy siliciclastic (quartz rich) sediments with varying gray, blue, and green color (e.g. Otvos and Howat 1992; Otvos 1994; Otvos 1998). They are more marine in nature closer to the modern coast and become more brackish and alluvial farther inland (i.e. closer to NATR). As such, these formations are better studied along the coast of Mississippi (generally from cores and wells) and are poorly, if at all, exposed along the parkway as loess blankets nearly their entire mapped area along NATR.

Microfossils, particularly foraminifera, have been used by many authors (e.g. Otvos 1994) to date and attempt to place these formations in proper stratigraphic sequence. Otvos and Howat (1992) advocated use of the term "undifferentiated Neogene deposits" in southern Mississippi because of the difficulties associated with defining these very similar deposits. The Neogene deposits farther inland have limited marine macrofossils due to their more brackish/alluvial depositional environment. Fossil leaves and "lignitized wood" have been found within the Hattiesburg Formation in Adams County (Vestal 1942). Leaf "impressions" are found in some Adams County exposures of the Pascagoula Formation in Adams County (Vestal 1942). Silicified logs and other plant material (at least 18 species in an assemblage similar to modern day Gulf Coast) were collected from the Citronelle Formation by Berry (1917a). Similar fossil wood material was noted by Vestal (1942). Due to their poor (if any) exposure along the parkway, fossils are not yet known from Neogene deposits within or near NATR.

Pre-loess Sand and Gravel and Natchez Formation (Pleistocene)
Below the loess deposits at the eastern extent of the Mississippi's alluvial plain are alluvial deposits, primarily sands and gravels whose age has been debated, but are considered Pleistocene (pre-loess) (Dockery 1996). Bicker (1966) described the Pre-loess terrace deposits in Claiborne County and noted that most of the deposits are blanketed by loess and only deep ravines and other erosional features display these underlying pre-loess gravels. Deposits assigned to the early Pleistocene Natchez Formation by Vestal (1942) overlie (are younger than) the pre-loess sand and gravel. The pre-loess sand and gravel is approximately 600,000 years old (D. Dockery, personal communication, 2006). The pre-loess sand and gravel can be distinguished from the Natchez Formation based on the percentage of igneous (previously molten) rock cobbles in the gravel (D. Dockery, personal communication, 2006). The pre-loess deposits contain very rare igneous cobbles while the Natchez contains approximately 10%, similar to the modern Mississippi River gravels. The Natchez Formation also contains agates from the Lake Superior area (D. Dockery, personal communication, 2006).

As with the older Neogene deposits, macrofossils in the pre-loess gravels are apparently limited to silicified wood, which is found in abundance with sizes ranging from small fragments to complete logs (Dockery 1996). Bicker (1966) figures one such log from northeastern Claiborne County, south of NATR. Such fossils are not yet reported along NATR. The vertebrate fossils assigned by many authors to the "pre-loess blue clay" are likely contemporaneous with the loess rather than the pre-loess gravel fossils described in this paragraph. See the "blue clay" paragraph below for more information.

Loess Deposits (Pleistocene)
The loess deposits of Mississippi are well documented and described in greater detail in the Vicksburg National Military Park (VICK) section of this report. Snowden and Priddy (1968) describe the loess of Mississippi which is of a "glacio-fluvial-aeolian" origin consisting mostly of tan or yellowish-buff silt-size grains, primarily composed of quartz. NATR traverses extensive loess deposits in Hinds (Moore 1965), Claiborne (Bicker 1966), Jefferson, and Adams (Vestal 1942) counties, Mississippi. "Loess Bluff" at MP12.4 along NATR is an exposure of Pleistocene loess typical of the area. The loess unconformably blankets the underlying (older) geologic formations where it is found. As such it obscures much of the Neogene-aged geologic formations crossed by the parkway. There is an extensive bibliography regarding the geology and paleontology of the loess, starting with Charles Lyell's (a British geologist and one of the founding fathers of modern geology) description of Mississippi loess in the mid-1800s. Many papers are cited in the VICK section of this report. Those specific to areas near NATR are mentioned here.

The loess is paleontologically very productive. Shells of land snails are ubiquitous in many exposures of the loess throughout Mississippi (e.g. Hubricht 1963a, 1963b; Snowden and Priddy 1968). There is also a vertebrate fauna, described below and in the following "blue clay" section. The Loess Bluff along NATR (MP12.4) may display these characteristic snail shells within with the park. Indeed, nearly any exposure of the loess has great potential to preserve such fossil material.

Shimek (1902) wrote extensively of the loess found in and around Natchez. He also visited Vicksburg (see VICK section). Shimek summarized, and commented on, many of the geological and paleontological observations of Charles Lyell, who visited Natchez in 1847 and described the loess (Lyell 1849). Lyell also mentioned the loess and its fossils in his nineteenth century geology text "Principles of Geology" and compared them to loess deposits in Europe (Snowden and Priddy 1968).

Shimek (1902) visited more than 50 loess localities in and around Natchez and collected fossils from 26 of them. Four of these fossiliferous localities were located along Liberty Road east of Natchez. Liberty Road forms the southern terminus (MP0) of NATR indicating the paleontological potential near the terminus. Shimek (1902) did not discover any vertebrate remains (he was primarily concerned with the gastropods) near Natchez, but emphasized that most vertebrate discoveries from the "blue clay" (see below). Shimek's (1902) "abundant" gastropod fauna from around Natchez included some 40 species with the most abundant specimens in the genera *Helicina*, *Polygyra*, and *Zonitoides*. Vestal (1942) noted that in Adams County, by far the most abundant snail is *Polygyra elevata*. The overall Pleistocene assemblage is similar to the extant gastropod assemblage. Shimek's (1902) most productive locality (11) in terms of both number of specimens and diversity was located in loess bluffs southwest of Natchez below the Natchez-Vidalia bridge. None of Snowden and Priddy's (1968) collecting localities were near Natchez, but they present an extensive review of historical literature related to Mississippi loess. Moore (1965) and Bicker (1966) both report abundant land snails in the loess of Hinds and Claiborne counties respectively. Hubricht (1963a, 1963b) collected land snails fossils from 40 localities in De Soto, Tate, Panola, Tallahatchie, Grenada, Carroll, Yazoo, Hinds, Warren, Claiborne, Jefferson, Adams, and Wilkinson counties. Many of Hubricht's Claiborne, Jefferson, and Adams county localities are very near or within a few kilometers of NATR. For example, Hubricht collected 22 species of snails "two miles south of Port Gibson" in Claiborne County. Without further locality data, this is very close to current NATR boundaries. Likewise, Hubricht (1963b) collected seven species of snail "two miles northwest of Lorman." Lorman (Jefferson County) is approximately 1.5 miles east of NATR. Hubricht's (1963b) "Selma" and "one mile northeast of Washington" (Adams County) localities are very near the old terminus of NATR at US Route 61 north of Natchez while his "two miles west of Fenwick" is near the parkway's intersection with US Route 84/98.

Vertebrate fossils are well known from the loess of Mississippi and are summarized by Daly (1992). Many of the vertebrate fossil finds reported by Lowe (1915, 1919), including lion, bear, ground sloth, tapirs, horse, deer, bison, mammoth and some mastodon may have been from the "blue clay" at the base of the loess, described below. This "blue clay" has an extensive vertebrate fauna and may have been aqueously deposited loess (D. Dockery, personal communication, 2006). Mastodons are known from the loess proper near Natchez and can be "abundant" (Lowe 1915, 1919; Hay 1923; Daly 1992). Dockery (personal communication, 2006) indicates that most Pleistocene bones in Mississippi could be attributed to the loess. Bicker (1966) did not report any vertebrates from the loess in Claiborne County, but noted their occurrence in Warren (see VICK section) and Adams counties. Likewise Moore (1965) did not report any vertebrates from the loess in Hinds County. No vertebrate fossils have yet been discovered within the loess along NATR.

Loess Deposits (Pleistocene)—Natchez Man

Another famous discovery near Natchez is that of "Natchez Man." As reported by Lyell (1849) and summarized in numerous articles such as Lyell (1863), Stewart (1951), Richards (1951), Quinby (1956), Hamilton (1990), and Cotter (1991) a human pelvis was found allegedly below (hence, older than) Pleistocene sloth and other vertebrate bones in present day Mammoth Bayou. Understandably this discovery in the 1830s created quite a sensation. Charles Lyell and other paleontologists including Joseph Leidy questioned the actual antiquity of the pelvis. Radiocarbon dating finally settled the issue in the early 1990s. Hamilton (1990) and Cotter (1991) reported the human bones had been dated to 5580±80 years before present (Holocene) while the "associated" sloth bones were dated to 17,840±125 b.p. (Pleistocene). As the bayous are active erosional features, sloth material and human pelvis were likely eroded from Pleistocene and recent sediments respectively and were redeposited lower in the stream bed.

Loess deposits (Pleistocene)—"blue clay" (Natchez Lion)

The "blue clay" referenced by many authors since the mid-1800s preserves an exceptional vertebrate fossil record near Natchez, with most discoveries coming from the Mammoth Bayou area. Mammoth Bayou (or Mammoth Ravine), named for its paleontological resources, is located immediately north of Natchez, west Mississippi Route 555, northeast of NATR. Lyell (1849) also noted similar fossil vertebrate assemblage near Washington, Mississippi northeast of Natchez. Washington is just north of NATR along

US 61-84. Dockery (personal communication, 2006), noted that unweatherd loess can fit the "blue clay" description, and that most Pleistocene vertebrate finds should be attributed to the loess deposits.

Lyell (1849), Gidley (1901), Shimek (1902), Lowe (1925), Hay (1923, 1928, 1930), and Daly (1992) summarize the diverse Pleistocene vertebrate fossil record from the Natchez area, which they primarily assign to the "blue clay" immediately below the "true" loess. This fauna includes *Megalonyx jeffersonii* (ground sloth), *Paramylodon (Glossotherium) harlani* (ground sloth), *Ursus americanus* (black bear), *Panthera atrox* (American lion, see "Natchez Lion" below), *Castoroides ohioensis* (giant beaver), *Tapirus haysii (copei)* (tapir), *T. veroensis* (tapir), *Equus complicatus* (horse), *Odocoileus virginianus* (white tail deer), *Bootherium bombifrons* (musx-ox), *Bison latifrons* (bison), *Mammut americanum* (mastodon), and *Mammuthus* sp. (mammoth).

The American lion (*Panthera atrox*) was originally described by Joseph Leidy (1853), one of the founding fathers of American paleontology, as *Felis atrox* from a specimen collected near Natchez. Some taxonomists consider the American lion a subspecies of African lion (*Panthera leo atrox*). The specimen was likely collected from the Mammoth Bayou area outside of NATR. William Henry Huntington of Natchez discovered the lion's lower left jaw fragment with three teeth along with other vertebrate fossils in 1836. Huntington subsequently donated the material to Leidy. This specimen served as the type specimen of the American lion. *Panthera atrox* is now well known from the Pleistocene in North America, particularly from the LaBrea Tar Pits in California. Interestingly, the statue of Leidy in front of the Academy of Natural Sciences building in Philadelphia, where Leidy worked, shows him holding the Natchez lion jaw (G. Phillips, personal communication, 2006). Casts of the Natchez lion are in the collections of the Mississippi Museum of Natural Science in Jackson.

Alluvial Deposits (Holocene)

Natchez Trace Parkway crosses numerous Holocene (modern) alluvial deposits near large streams and rivers throughout Mississippi. Alluvial deposits include various silts, sands, and gravels. Some authors reported high levels of organic or carbonaceous material within alluvial deposits (e.g. Monroe, 1954; Merrill et al. 1988). Fossils are not typically documented in such young (few hundred or few thousand years old) deposits. However, other Gulf Coast Network parks, Gulf Islands National Seashore, Jean Lafitte National Historical Park &Preserve, Padre Island National Seashore, and Palo Alto Battlefield National Historic Site contain Holocene faunal and floral remains, allowing for paleoenvironmental reconstruction over the last few hundred or thousand years. See those parks' sections in this report for more information.

NATIONAL PARK SERVICE AREAS NEAR NATCHEZ TRACE PARKWAY

There are three NPS areas located near NATR that are not part of the Gulf Coast Network: Natchez National Historical Park (Natchez, MS), Brices Cross Roads National Battlefield Site (west of Baldwyn, MS), and Tupelo National Battlefield (Tupelo, MS). Brices Cross Roads NBS (BRCR) and Tupelo NB (TUPE) are administered by Natchez Trace Parkway. Natchez National Historical Park (NATC) is located in Natchez, south of Natchez Trace Parkway terminus. Although not part of the network, these areas have potential to preserve paleontological resources, and in the case of BRCR, fossils have been documented within the park. They are therefore mentioned briefly here. Shilo National Military Park (SHIL) and Stones River National Battlefield (STRI), both in Tennessee, are located in the Cumberland Piedmont I&M Network and will be addressed in that network's forthcoming summary.

Brices Cross Roads National Battlefield Site

Brices Cross Roads National Battlefield Site (BRCR) is located west of Baldwyn, Mississippi in Lee County. The primary geologic formation mapped near the park is the Demopolis Chalk of the Upper Cretaceous Selma Group (see detailed description above) as reported by Dockery (personal communication, 2005). Fossiliferous exposures of the Demopolis Chalk surround the park (D. Dockery, personal communication, 2005). The oysters *Exogyra* and *Pycnodonte* are the most common large fossils.

Examples of these fossils are known within the Brices Cross Roads National Battlefield Site and were discovered during archeological excavations within the park. NATR Historian Chris Miller (personal communication, 2005) confirmed that there are two drawers of fossils from BRCR within NATR collections. The vast majority of the specimens are bivalves, although some gastropods are also included. According to ANCS collections information, the fossils were discovered in the Upper Cretaceous Prairie Bluff Formation. However, Dockery (personal communication, 2005), believes that the fossils are more likely from the Demopolis Chalk, the unit stratigraphically above (younger than) the Prairie Bluff. There are no exposures of the Prairie Bluff near BRCR. As both formations contain some characteristic fossils, Dockery would be able to identify which formations the fossils came from by viewing a suite of specimens in the park collections. This could be accomplished via digital photos and email.

Tupelo National Battlefield

Tupelo National Battlefield is located in downtown Tupelo, Mississippi (Lee County). The park is primarily underlain by the Coffee Sand of the Upper Cretaceous Selma Group as mapped by Stephenson and Monroe (1940). This Coffee Sand geology and paleontology is discussed in greater detail above. While no paleontological resources are known from the park, and there are limited (if any) subsurface exposures in the park, the underlying geology is known to yield fossils outside of TUPE along the Natchez Trace Parkway.

Natchez National Historical Park

Natchez National Historical Park (NATC) is located in southern Natchez, Mississippi (Adams County). The extensive loess deposits typical of Natchez underlie the park. The well known geology and paleontology of the Mississippi loess is described above. Many important paleontological finds have occurred in stream beds of bayous (e.g. Mammoth Bayou) eroded into the loess north of Natchez. The natural areas within and surrounding NATC may include exposures of the underlying loess, and therefore have good potential to display fossils, particularly land snails.

Paleontological Resource Management, Preliminary Recommendations

- A field-based inventory (focus on road cuts and other exposures) of paleontological resources to investigate known fossil localities along parkway (e.g. Garrison Creek, Twentymile Creek, old Fossil Display, etc.) and determine if fossils are still visible at those and other localities may be recommended. This field work could be performed by seasonal employees, interns, or outside institutions. The NPS Geologic Resources Division can help advertise, recruit, and provide technical assistance for these positions.
- David Dockery (Mississippi Office of Geology) is interested in producing and publishing a geologic road guide to Natchez Trace Parkway. Dockery would be willing to work with NPS and cooperating associations to develop and print the book.
- Significant paleontological resource localities should be officially documented utilizing NPS Paleontological Resource Locality and Condition Assessment forms. These forms are currently being revised (Fall 2006); however the Geologic Resources Division will be able to provide support and additional recommendations for their utilization. Use of the forms satisfies GPRA goal Ia9: Paleontological Resources and provides baseline data for future resource management and monitoring, field studies, or interpretation.
- Geologic maps and publications (particularly Mississippi Office of Geology Bulletins) related to the parkway could be a valuable addition to resource management library.
- The park may encourage, and when possible, support scientific research (including academic thesis work) utilizing the significant fossil resources present in the park. David Dockery of the Mississippi Office of Geology is a primary contact for the paleontology of the area. Other contacts include Mike Hoyal (Tennessee Division of Geology), Andrew Rindsberg (University of Western Alabama), and George Phillips (Mississippi Museum of Natural Sciences).

- Further investigation into fossils as cultural resources (e.g. Kenworthy and Santucci 2006) might reveal additional information regarding fossils along the historic trace (funerary items, trade items, discoveries, etc.).
- A study collection of typical fossils along the parkway might be beneficial for park staff. The current park collections include many examples of Upper Cretaceous fossils from Mississippi. Collections from Tennessee limestones (marine invertebrates) and Pleistocene loess (snails) would broaden the scope of the paleontological specimens.

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DATA SETS

DS-NATR-XXX Natchez Trace Parkway Paleontological Archives. 5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

DS-NATR-XXX Natchez Trace Parkway Natural Resource Files. 6/1934–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by NATR Staff; status: Active.

DS-NATR-XXX Mississippi Museum of Natural Science. 1900s. (museum specimens; hard copy data; reports; electronic data; photographs; maps; publications). Originated by George Phillips and museum staff; status: Active. Some specimens collected very near NATR boundaries.

DS-NATR-XXX Mississippi Office of Geology Collections. 1976–present. (fossil specimens; hard copy data; reports; electronic data; photographs; maps; publications). Originated by Dockery, David and other MOG staff; status: Active. Includes fossil material collected along parkway during construction and other research (e.g. Coffee Sand).

DS-NATR-XXX Smithsonian National Museum of Natural History. 1900s. (museum specimens; field notes; hard copy data; reports; electronic data; photographs; maps; publications). Originated by USGS and other researchers; status: Active. Many collections made near NPS boundaries before NATR was established. Dockery's type specimens are housed at Smithsonian.

Padre Island National Seashore

At 105.4 km (65.5 miles) in length, Padre Island National Seashore (PAIS) preserves the longest undeveloped stretch of barrier island in the United States. Located along the Gulf Coast of Texas, Padre Island is one of two barrier island systems within the Gulf Coast I&M Network, the other being Gulf Islands National Seashore (Alabama and Mississippi). Padre Island's undeveloped character provides exceptional habitat for numerous plants and animals inhabiting its beaches, dunes, grasslands, and flats. Natural resource management and research are a primary focus of the park, as evidenced by PAIS sea turtle research programs and the designation of the park as a globally important bird area. The park was authorized on September 28, 1962 and established on April 6, 1968.

Baseline Paleontological Resource Inventories

Geologic scoping sessions for Padre Island National Seashore, sponsored by the NPS Geologic Resources Division, were held in May of 2003. Formal paleontological resource surveys have not yet been completed for the park. Nevertheless, PAIS has at least 13 paleontological specimens within the parks' museum collection. These fossils were all found within the park, most having been washed ashore. There is a very high probability that fossils will continue to be discovered on the shoreline of Padre Island.

Barrier islands such as Padre Island are very transient geological features, created and destroyed through relentless wave action and erosion. These islands also are usually very young, geologically speaking, with ages ranging from recent to tens of thousands of years old. Padre Island, in its modern, emerged form has existed for approximately 3000 years, although it may be as much as 5000 years old (Weise and White 1980). The detailed natural history of the island are presented by Hunter et al. (1972) and Weise and White (1980). Geologic maps of the region were produced by Aronow and Barnes (1975) and Brewton et al. (1976). Quaternary (Recent) alluvium and barrier island deposits were the primary units identified in those maps. Weise and Ward (1980) further described 23 different environments thought the park. These environments include 11 barrier island units, 8 lagoon units, and 4 man-made or modified units. While the island itself is not a major source of paleontological resources, fossils from the Pleistocene Seven and One Half Fathom Reef have been washed ashore at PAIS. Pleistocene shells have been recovered from subsurface lagoonal deposits within PAIS. Also the Pleistocene Ingleside Fauna was described from a locality outside of the park near Corpus Christi (Lundelius 1972). Spoil piles associated with dredging of local waterways may also bring Pleistocene fossils, coquina, or serpulid reef material to the surface. The paragraphs below highlight these various occurrences.

Gulf Coast Network parks such as Padre Island National Seashore, Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve and Palo Alto Battlefield National Historic Site are geologically very young making it difficult to determine what material is a "fossil" what would be considered "modern." The National Park Service Paleontology Program defines a fossil as any remains of life preserved in a geologic context. This definition does not include an arbitrary date where older specimens are considered fossils, and specimens younger are not. The "geologic context" phrase is intended to imply some level of antiquity, however. Generally, specimens dating back to the late Pleistocene are considered fossils. Late Holocene (last few hundred or thousand years, "Recent") specimens are usually considered modern and not fossils. Material within the aforementioned GULN parks spans this area between the late Pleistocene and early Holocene. Regardless of what label is attached to them, these specimens are important natural resources and valuable pieces of the history of life on earth.

Park Collections

The park's museum collections contain at least 13 paleontological specimens, most are fragments of bone or teeth. Dr. Jon Baskin (Texas A&M University-Kingsville) identified a number of specimens in 2005 (P. Slattery, personal communication, 2005). Likewise Dr. Ernest Lundelius, Professor Emeritus at the University of Texas Vertebrate Paleontology Laboratory (Austin), provided tentative identifications of a number of specimens, based on photographs in 2006. All together the collection includes mammalian limb bone fragments, a mammalian acetabulum, lower molars of a bison and horse, mammoth teeth or tooth plates, what may represent part of a giant tortoise, and a number of other unidentifiable bone fragments. The age of the specimens likely ranges from late Pleistocene to Holocene. The mammoth material is definitely Pleistocene in age, as mammoth went extinct at the end of the Pleistocene. According to PAIS Education Technician Phil Slattery (personal communication, 2005, 2006) and PAIS Chief of Science and Resource Management Darrel Echols (personal communication, 2006) most of these specimens were discovered by park staff or visitors having washed ashore along the beaches of the park.

Subsurface lagoonal deposits of PAIS (late Pleistocene)
Miller and Hunter (1979) reported the results of a study of subsurface Pleistocene lagoonal deposits within PAIS. Their report indicated that a shell layer is present from about 8-15 m below modern sea level in the central part of Padre Island, and about 19 m below sea level in the northern reaches of Padre Island. Miller and Hunter (1979) reported the presence or absence of more than 90 species of marine invertebrates and one terrestrial snail within these subsurface deposits. Radiocarbon dates of *Mulinia lateralis* (dwarf surf clam) from two wells, approximately 21 m below sea level, ranged in age from approximately 27,380 to 29,980 years before present (Miller and Hunter 1979).

Seven and One-Half Fathom Reef (late Pleistocene)
Seven and One-Half Fathom Reef is a submerged ridge located in approximately 14 m (46 ft) of water, 3.2 km (2 miles) off the shoreline of PAIS, 74 km (46 miles) south of the park's northern entrance (Thayer et al. 1974). Thayer et al. (1974) also report that the ridge is approximately 50 m (164 ft) wide, 350 m (383 yards) long, with a maximum relief of 5.4 m (18 ft). The ridge is primarily a pale yellowish brown fine moderately well cemented sandy marl (mixture of clay and calcium carbonate) interpreted as a late Pleistocene intermittent lake deposit (Thayer et al. 1974). These lake sediments were submerged as sea level rose during the Holocene as continental ice sheets melted. Due to their relative hardness, they now form an underwater ridge. There were many different interpretations and descriptions of the deposit as presented by a number of authors including Mattison (1948), Williams (1951), Curray (1960), Rusnak (1960), Hayes (1965), Tunnell and Causey (1969), and Thayer et al. (1974). Full citations for these reports can be found in the additional references section.

Although the Seven and One-Half Fathom Reef is submerged outside of PAIS boundaries, it is likely the source of most of the park's paleontological resources. Wave action erodes the ridge and transports the fossils to the shores of PAIS. Gateway National Recreation Area in New York City experiences a similar phenomenon. The Pleistocene Gardiner Clay is located just off shore and yields paleontological material which frequently washes up on the shore of the park's beaches (Kenworthy and Santucci 2003). Mollusk fossils found *in situ* within rock samples collected from Seven and One-Half Fathom Reef included freshwater (*Helisoma trivolvis*, *Physa* sp.) and terrestrial (*Polygyra septemvolva febiferis* and *Helicina orbiculata tropica*) snails (Thayer et al. 1974). Tunnell and Causey (1969) discovered four *Mammuthus columbi* (mammoth) teeth and a number of bone fragments that likely originated from crevices in the ridge. These bone fragments consist of a mandibular symphsis ("chin" bone) from *Mammut americanum* (American mastodon), proximal end of a *Bison* sp. scapula, large whale vertebra, and a variety of partial long bones and other unidentifiable bone fragments of a mammoth or mastodon (Tunnell and Causey 1969). Hayes (1967) discovered a single mammoth tooth on Padre Island during his study of the geological affects of Hurricane Carla. Phil Slattery (personal communication, 2005), PAIS education technician and acting curator, also reported discovering a mammoth tooth plate on the beach within PAIS. The Texas State Aquarium in Corpus Christi has a diorama and exhibit space dedicated to the modern environments created by the Seven and One Half Fathom Reef (J. Tunnell, personal communication, 2006). Comprehensive documentation of fossils from the continental shelf area is a valuable research endeavor (Tunnell 1993).

Ingleside Fauna and Barrier beach rock (late Pleistocene)
Lundelius (1972) describes an extensive late Pleistocene fauna discovered outside of PAIS near Ingleside, Texas, north of Corpus Christi Bay. This fauna is one of the largest and most diverse known from a single

locality in Texas and contains some 42 vertebrate taxa including mammals, birds, reptiles, amphibians, and fish (Lundelius 1972). Whereas the now offshore Seven and One Half Fathom Reef yielded fossils from a time when sea level was lower than present day, the Ingleside Fauna represents a time when sea level was higher than today and hence the deposit is landward of PAIS. Similar deposits are not mapped within PAIS, but mention of the Ingleside Fauna is included here to illustrate the diversity of paleontological resources in the Corpus Christi/PAIS area.

Beaches that were deposited more or less contemporaneously with the Ingleside Fauna are known as the Ingleside Barrier (Behrens 1964; Prouty and Lovejoy 1992; McBride and Honda 1994). Exposures of these beach sandstone contain fossils in the form of a shell coquina are found along the western margin of Laguna Madre, 8 km (13 miles) south of Baffin Bay as described by McBride and Honda (1994). The coquina is made up primarily of shell material and may date back to 120,000-140,000 years ago, the supposed age of Ingleside Barrier. The dates provided by McBride and Honda (1994; 23,800-32,400 b.p.) are noted to be erroneously low, which is apparently a common error in Carbon-14 dating of upper Pleistocene coastal deposits. Watson (1971) studied these ancient shell beaches along the western shore of Laguna Madre, comparing them to the modern shell beaches of Padre Island and postulating a similar depositional environment. Prouty and Lovejoy (1992) also report on the coquina along the western shore of Laguna Madre, noting the almost identical faunal assemblages between the shells of the Pleistocene coquina and the modern shell beaches within the park. Schideler (1981) notes some of the controversy regarding the Ingleside Barrier origin, and reports a radiocarbon date of approximately 29,260 years before present (b.p.), within the supposed erroneous range of McBride and Honda (1994). Interestingly, Wick (1987) evaluated the potential fossil record accumulating in modern day southern Laguna Madre. Wick noted that understanding the potential fossil record in modern lagoons can provide insight into paleoecological interpretations of ancient coastal lagoons.

Spoil Piles (late Pleistocene?-Recent)
Weise and White (1980) include a detailed description and map of the numerous spoil piles found throughout PAIS and the surrounding Laguna Madre waterways. The spoil piles represent sediment dredged primarily during construction and maintenance of the Intracoastal Waterway, Mansfield Channel, and Yarborogh Pass. Some of the spoil piles are quite large, and may contain sediments ranging back to the Pleistocene for some of the deeper channels (Weise and White 1980).

The piles provide an opportunity to view the subsurface sediments and paleontological resources of the Laguna Madre and PAIS area. Pleistocene sediments are generally more compacted than their recent counterparts (Weise and White 1980). Coquina, a geologic term for a limestone composed of cemented shell fragments, may be found on the spoil piles within such Pleistocene sediments in the park (Weise and White 1980). Additionally, Pleistocene serpulid reef material may potentially be found in the spoil piles.

Serpulid worms are sessile, tube forming polychaete worms. Large assemblages of these tubes and associated shell and mud material form “reefs.” Such serpulid reefs are common in Laguna Madre and Baffin Bay and are mapped by Weise and White (1980) and described by Andrews (1964). The serpulid reefs are no longer active, but may have formed as early as the late Pleistocene or early Holocene (J. Tunnell, personal communication, 2006). Cole (1981) reported an age of approximately 3,000 b.p for the reefs of Baffin Bay. As described by Hardegree (1997) the reefs may also serve as important modern ecosystems.

Alluvial deposits (Recent)
The alluvial deposits mapped by Aronow and Barnes (1975) and Brewton et al. (1976) are catch-all units for a variety of recent geologic sediments including clay, silt, sand, and gravel deposited in point bars, natural levees, stream channels, backswamps, coastal marshes, mud flats, clay and sand dunes and oyster reefs. The alluvial deposits on are the landward (western) side of the island. Similar environments are mapped by Weise and White (1980). As explained above, paleontological resources are not known from the alluvial deposits

Barrier island deposits (Recent)
The barrier island deposits of Aronow and Barnes (1975) and Brewton et al. (1976) are primarily well sorted fine grained sand with abundant recent shells and shell fragments. The barrier island deposits are mapped on the seaward (eastern) side of Padre Island. More landward deposits contain a higher clay and silt component and interfinger with the alluvial deposits. The shells are particularly abundant along the aptly named Small Shell Beach (dominated by the small clam *Donax*) and Big Shell Beach (dominated by larger clams) within the park. Andrews (1972) provides an in depth discussion of the different types of modern shells that can be collected in the park while Weise and White (1980) describe the ecological characteristics of the beaches. Hunter et al. (1972) indicate radiocarbon ages for 10 *Mercenaria* (clam) shells have been obtained and range from 1,240-7,180 years old. These shells are generally not considered fossils, however fossils may wash up onto the beaches from off shore deposits such as Seven and One Half Fathom Reef.

Paleontological Resource Management, Preliminary Recommendations
Because of the float nature of paleontological resources within PAIS, a monitoring program for specific localities would be difficult to implement. However, recommendations would include continuing to maintain the park's museum collection of material and increasing staff awareness of material that may wash ashore. Potentially identifiable material should be collected. Local paleontologists and researchers (Dr. Jon Baskin, Dr. Ernest Lundelius, Dr. Wes Tunnell, etc.) may be able to assist in identifying specimens or other inquiries. While shell collecting is permitted within the park, collecting paleontological or any other natural or cultural resources is prohibited. This dichotomy might cause some comfusion among the visiting public. Continued interpretation and education may not only lessen the effects of any illegal collecting, but may bring new specimens to light.

COOPERATIVE PROJECTS

- Geologic Resources Division: Geologic Resource Evaluation Scoping Session (May 2003). Participants from GRD, PAIS, and other agencies and local institutions met to discuss geologic issues pertaining to PAIS.

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DS-PAIS-XXX	Padre Island National Seashore Museum Collections. 1968-present. (museum specimens; associated specimen notes; ANCS+ collection records; publications; etc.). Originated by PAIS staff; status: Active.

PALO ALTO BATTLEFIELD NATIONAL HISTORIC SITE

Palo Alto Battlefield National Historic Site (PAAL) preserves the site of the first battle of the United States-Mexican War. The battle at Palo Alto (May 8, 1846) marked the beginning of two years of conflict between the nations. Palo Alto Battlefield National Historic Site was authorized on November 10, 1978, but not fully established until June 23, 1992. National Park Service facilities are currently being developed for the park, which will focus interpretation on both nations' perspectives of the war and its implications.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Neither geological nor paleontological scoping sessions have been held for Palo Alto Battlefield National Historic Site. There are no paleontological specimens in the park's museum collection. There is limited potential for future fossil discovery due to the vegetated prairie landscape and underlying geology of the park.

Pala Alto Battlefield National Historic Site is located within the Coastal Prairies region of the Gulf Coastal Plain physiographic province (Wermund 1996). This region of the Gulf Coastal Plain is characterized by nearly flat prairie (and nearly flat underlying strata) consisting primarily of deltaic sands and muds (Wermund 1996).

Gulf Coast Network parks such as Padre Island National Seashore, Gulf Islands National Seashore, Jean Lafitte National Historical Park and Preserve and Palo Alto Battlefield National Historic Site are geologically very young, making it difficult to determine what material is a "fossil" what would be considered "modern." The National Park Service defines a fossil as any remains of life preserved in a geologic context. This definition does not include an arbitrary date where older specimens are considered fossils, and younger specimens are not. The "geologic context" phrase is intended to imply some level of antiquity, however. Generally, specimens dating back to the late Pleistocene are considered fossils. Late Holocene (last few hundred or thousand years, "Recent") specimens are sometimes considered modern and not fossils. Regardless of what label is attached to them, these specimens are important natural resources and valuable pieces of the history of life on earth.

Late Holocene sediments
Brewton et al. (1976) map two Quaternary alluvium geologic units within the park, one dominated by mud, the other by silt and sand. These units are floodplain deposits from the lower course of the Rio Grande River, and are primarily recent (Holocene, less than 10,000 years old) deposits. Modern alluvial deposits do not generally contain paleontological resources and none are reported from the park.

Caran et al. (2005) detail a geoarcheological survey within PAAL, which included creating a Late Holocene stratigraphic profile across the Resaca de Palo Alto. This profile allows paleoenvironmental and geomorphic reconstruction within the park over the last few thousand years. This study was conducted to define the environmental conditions of the battlefield and their influence on the military engagements. See also Haecker and Mauck (1997). Faunal material within the backhoe trenches of Caran et al. (2005) included burrows of fiddler crabs (*Uca subcylindrica*), and occasionally snail shells (*Rabdotus* sp. and cf. *Gyranulus* sp.). An extensive floral (pollen) record was also recovered and described. Radiocarbon analysis yielded calibrated ages ranging from approximately 300-5300 years before present for the material studied within Resaca de Palo Alto.

A more diverse assemblage of late Holocene material was discovered approximately 3.2 km (2 miles) southeast of PAAL in a mixed clay and silt layer of the intermittent Resaca del Rancho Viejo in Cameron County (Neck 1985). This assemblage is overwhelmingly dominated by a freshwater hydrobiid snail, *Pyrgophorus coronatus*. The other large component of the assemblage is the pond snail *Physella virgata*. Other fossils discovered within the fossiliferous layers include the Florida marsh clam *Cyrenoida floridana*, a variety of terrestrial gastropods, a water scavenger beetle, a fiddler crab, and non-diagnostic fish scales. Except for *C. floridana*, all identifiable species are found in the area today (Neck 1985; Cooper et al. 2004). Neck and Heber (1981) suggest that the age of the Resaca del Rancho Viejo fossil assemblage is no older than 3000 years, a similar age reported for Resaca de Palo Alto by Caran et al. (2005). Neck (1985) also presents a detailed paleoenvironmental reconstruction and comments on the implications of the site.

Although there are no Pleistocene (Ice Age) exposures within or adjacent to PAAL, southern Texas is well known for its abundant Pleistocene fossils as described in the PAIS and BITH sections of this report. Closer to PAAL, Hay (1924) mentioned an "elephant [mammoth or mastodon] molar which had been found near Brownsville." Hay provided no additional information, but Brewton et al. (1976) mapped the Pleistocene Beaumont Formation (see BITH section) some 24 km (15 miles) north of PAAL, which may be the source of the tooth. Discoveries such as this illustrate the rich paleontology of south Texas, albeit preserved outside of PAAL.

Paleontological Resource Management, Preliminary Recommendations
As fossils are not known from PAAL, there are few opportunities for active paleontological resource management. Nevertheless, the geoarcheological specimens found within PAAL offer continued educational and interpretive opportunities and scientific research potential related to the history and cultural resources of the park. An initial field investigation of any deep ravines or gullies might expose Pleistocene sediments, however, most are probably Holocene in age.

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DS-PAAL-XXX Palo Alto Battlefield National Historic Site Natural Resource Files. 6/1992–present. (geoarcheology reports). Originated by PAAL staff; status: Active.

SAN ANTONIO MISSIONS NATIONAL HISTORICAL PARK

A number of colonial Spanish missions including Concepcion, San Jose, San Juan, and Espada, flourished in the mid to late 18th century along the San Antonio River within and near San Antonio, Texas. Today the four missions, an associated ranch, and Acequia (irrigation ditch) system, are preserved as part of San Antonio Missions National Historical Park (SAAN). The four missions are part of a widespread network of frontier missions and presidios (forts) and attest to Spain's successful attempts at colonization north of present-day Mexico during the 17th, 18th, and 19th centuries. Mission San Antonio de Valero (the Alamo) is another colonial Spanish mission and is managed by the Daughters of the Republic of Texas. SAAN was authorized on November 10, 1978 and fully established on April 1, 1983.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geological or paleontological scoping sessions have not yet been held for the park. There are no paleontological specimens in the park's museum collections. However, geologic formations mapped within or near the park yielded paleontological resources in areas outside of the park. Therefore there is some potential for future fossil discovery, although rock exposures are limited within SAAN. In addition, some of the stones used in the construction of Mission San Juan are known to display fossils.

Physiographically, the city of San Antonio is located on the boundary between the Interior Coastal Plains section of the Gulf Coastal Plain Province (to the south and east) and the curved Balcones Escarpment section of the Edwards Plateau Province (to the north and west) (Wermund 1996, Ewing 1996a). The coastal plain sediments are characterized by Upper Cretaceous and Tertiary mudstone and sandstone. The Balcones Escarpment is capped by harder (and older) Lower Cretaceous limestones which are extensively faulted and display many karstic features such as sinkholes and caves (Veni 1988). One such cave is the well-known Friesenhahn Cave, which is located approximately 32 km (20 miles) north of San Antonio and contains extensive paleontological resources (e.g. Evans 1961). As the park is situated along the San Antonio River, the primary geologic formations of the park are Recent river alluvium and Pleistocene river terrace deposits (Brown et al. 1974; Ewing 1996a, 1999). Bedrock formations mapped within or near the park include Upper Cretaceous, Paleocene, and Eocene coastal plain formations (Navarro Group, Midway Group, and Wilcox Group). A Cretaceous limestone (Austin Limestone) was quarried north of San Antonio for some decorative stones. All of these formations and the Pleistocene terrace deposits yielded fossils outside of the park as summarized below. A section on the missions' building stones is also included.

Navarro Group (Late Cretaceous)
In Bexar County, the Navarro Group is characterized by marine limestones, sandstones, siltstones and large sandstone and limestone concretions. The sandstones, particularly in the upper layers of the Navarro are tinged green by the mineral glauconite (Sellards 1919; Brown et al. 1974; Ewing 1996a). The Navarro is stratigraphically equivalent to the Escondido Sandstone west of Bexar County (Brown et al. 1974). The Navarro Group is mapped north of an inferred fault running near Mission Concepcion within SAAN (Ewing 1999). However, Ewing (personal communication, 2006) noted that no definitive Navarro Group exposures have been noted along the San Antonio River near SAAN.

Fossils, primarily marine invertebrates are known from the Navarro Group and can be locally abundant. The large oyster *Exogyra costata* is particularly common (Sellards 1919; Ewing 1996). *Gryphaea vesicularis* and *Alectryonia larva* (both oysters) were discovered by Sellards (1919) at various localities north and west of San Antonio. Exposures of the Navarro Group along Leon Creek (southwest of San Antonio) yielded sharks teeth (Sellards 1919). Fossils from the Navarro Group are not yet known within SAAN, and there is little potential for future discovery due to minimal exposures.

Midway Group (Paleocene)
The Paleocene Midway Group in Bexar County is characterized by gray, greenish or yellowish brown arenaceous (sand-like texture) clays with brown sandstone or limestone concretions and phosphate pebbles. Silty and sandy lithologies are also components of the Midway Group (Sellards 1919; Brown et al. 1974; Ewing 1996a). Sellards (1919) labeled these beds "Lower Eocene", as the term Paleocene had not yet been accepted. See Appendix A for a geologic time scale. The Midway Group was exposed within SAAN along the San Antonio River near the Espada Dam. This locality is now at least partially obscured by erosion control materials such as riprap and regrading (Ewing 1996b).

Marine fossils can be found in the Midway Group but are rarely abundant (Sellards 1919). The basal beds of the formation yielded shark's teeth and bivalve shell molds (Ewing 1996a). The bivalves *Venericardia* and *Exogyra* are the most common (Sellards 1919; Ewing 1996a). Similar fossils are not yet known from within the park. Some of the exposures near Espada Dam, mentioned by Ewing (1996b), might yield fossils if they are not totally obscured. However Ewing did not indicate their presence. In addition to marine invertebrates, a limited collection of fossil plant material is also known from the Midway Group near the town of Earle, about 6.4 km (4 miles) southwest of SAAN, indicating a near shore depositional environment. Berry (1916) described the "scanty" floral assemblage from a gully just south of the Medina River near Earle which includes 10 species of *Pourouma* (tree-grape), *Ficus*, *Platanus* (sycamore), *Cinnamomum* (cinnamon), *Laurus* (laurel), *Asimina* (pawpaw), *Dolichites* (member of pea or bean family Fabaceae/Papilionaceae), and *Terminalia* (almond).

Wilcox Group (Eocene)
The Eocene Wilcox Group is characterized by a variety of lithologies, primarily brown or yellowish brown to gray mudstone (Sellards 1919, Brown et al. 1974, Ewing 1996a). Sandstones and calcareous or arenaceous (sandstone like texture) concretions are also present in the Wilcox Group sediments (Ewing 1996a). Extensive lignite and coal deposits are also known from the group. Ewing (1996b) mentions two exposures of the Wilcox Group within SAAN. One is along the San Antonio River at Espada Dam (same locality as the Midway Group, described above). Ewing (personal communication, 2006) indicated the river bed was almost completely obscured near Espada Dam, but that the Army Corps of Engineers restoration and regarding projects along the San Antonio River may create new exposures. A much better exposure is found beneath the Espada Aqueduct where it crosses Sixmile Creek (historic Piedras Creek) and near the Graf Road Crossing north of Mission San Juan. The sandstones are thicker than the typical exposures of the Wilcox, making the exposure one of the best and most accessible (T. Ewing, personal communication, 2006). According to Ewing (1996b), the name Piedras Creek comes from the blocks of Wilcox Group sandstones that have slumped into the creek. "Piedras" is the Spanish word for "stones" or "rocks." Sandstones of the Wilcox Group were utilized in the construction of some of the mission buildings, see below.

Like the Paleocene Midway Group, rocks of the Wilcox Group yield both marine invertebrates and plants. The marine invertebrates are not common and not listed specifically by Sellards (1919), although a reference to the clam *Venericardia* was included. Plants in the Wilcox Group are not well preserved in Bexar County although Sellards (1919) and Ewing (1996a) reference plant or leaf impressions within exposures of the Wilcox Group. None of these fossils were described from exposures within or near SAAN, although there is limited potential that future field work will reveal their presence within the park.

Terrace gravels (Pliocene-Pleistocene-Recent)
There are three general levels of gravel terraces in Bexar County near San Antonio. The highest terraces are the oldest terrace deposits. These deposits include the Pliocene-Pleistocene Uvalde Gravel of Sellards (also mapped as "High Terrace", 1919) and Brown et al. (1974). They are exposed primarily to the west of San Antonio. The gravels are likely equivalent to the high gravels found east of downtown, beneath Fort San Houston and south to Southside Lions Park (T. Ewing, personal communication, 2006) Fossils are very rare in the older terrace deposits (Sellards 1919) and none are mentioned by Ewing (1996a).

The Fluviatile terrace deposits of Brown et al. (1974) (middle or "Leona?" terrace of Sellards 1919) are mapped within SAAN and are exposed along the San Antonio River south of Mission Concepcion. These deposits are dominantly carbonate pisolithic gravels (pea-sized carbonate accretions), fluvial oolites (0.25-2mm accretionary bodies consisting of a sand grain nucleus surrounded by concentric layers of calcium carbonate), and carbonate tufa (chemical sedimentary rock formed by evaporation or algal precipitation) (Ewing 1996a). McGammon (1975) reported that shells are quite common within the oolites found in now-covered historic quarries near the San Antonio River. The shells include whole and fragmented shells of *Goniobasis* and *Polygyra* gastropods in addition to charophytes ("green algae") and blue-green algae (McGammon 1975; T. Ewing, personal communication, 2006). The tufa may represent deposits from a Pleistocene spring, and their relative hardness provided a firm substrate for construction of the missions, perhaps fostering their longevity (T. Ewing, personal communication, 2006). Sellards (1919) commented on the distinctiveness of the pisolithic gravels and included a figure of them from a location along Mission Loop Road, perhaps the same "Ashby" [Ashley] Road location described by Ewing (1996b). A number of other small quarries were nearby. Some of the quarries date from the Mission period, others are more recent, however most have since been filled (T. Ewing, personal communication, 2006). Mammoth, or "proboscidian," remains are known from the gravels within San Antonio, although Sellards (1919) doesn't provide additional locality or identification information.

The Low terrace deposits of Brown et al. (1974) ("Late Pleistocene" terrace of Sellards 1919 and Ewing 1996a) are the youngest terrace deposits, and are therefore found stratigraphically lower, closer to the present San Antonio River flood plain. They are late Pleistocene in age and primarily composed of loess and silt, with gravels near the base (Ewing 1996a). Fossils are well known from the Low terrace deposits in the San Antonio area, however, none have yet been found within SAAN. Sellards (1919) reported an "abundance" of the land snail *Bulimulus dealbatus mooreanus*. Sellards (1919) also noted that *B. dealbatus* was still extant in the area, while absent from the older gravels. This indicates a similar environment continuing from the late Pleistocene until today. Some other fossils found in the gravels are no longer extant however. Sellards (1919) also reported a mammoth tooth and bones from localities on the east side of Salado Creek and near the Frio Road (approximate route of present-day Route 2536) crossing over the Medina River. Salado Creek converges with the San Antonio River approximately 4.8 km (3 miles) south of Mission Espada. Sellards (1919) assigned the modern elephant genus *Elephas* to one of the mammoth teeth from the Salado Creek locality. Most mammoth material is now referred to the *Mammuthus* genus. Additional mammoth material was discovered at two archeological sites near San Antonio. The first site, the Richard Beene Site, has undergone extensive archeological excavations, at was active primarily during the Holocene (~8,800-750 years before present (b.p)). It is located on the Medina River about 15.3 km (9.5 miles) south of San Antonio and produced *Mammuthus columbi* long bones in late Pleistocene deposits (Thoms et al. 2005). The San Antonio River Site is located on the east side of Interstate 37 near the San Antonio River and yielded mammoth tusk, molar, mandible, vertebra, rib, and long bones (Thoms 2001; Thoms et al. 2005). Based on fauna from a similar stratigraphic position at the Richard Beene Site, Thoms et al. (2005) extrapolated a date of approximately 12,745 b.p. for the San Antonio River Site mammoth material. Interestingly, evidence from both sites suggests human modification ("bone quarrying") of the mammoth bones (Thoms et al. 2005).

Mission Building Stones (Late Cretaceous-Pleistocene-Recent)
The four missions preserved within SAAN were constructed with a variety of building stones found locally along the San Antonio River, including the Late Cretaceous Austin Chalk which displays fossils at Mission San Jose. Unless otherwise cited, the following information is from Ewing (1996b, 1997, 1999).

Mission Nuestra Señora de la Purisma Concepcion (completed in 1755) was primarily constructed of adobe with small stones, faced with dressed tufa (perhaps from the Fluviatile terrace deposits), and finally plastered and painted. Pits that likely provided the tufa can be found in Concepcion Park. While fossils are not likely to be found in the tufa, there are "distinctive tubular structures" and large voids in the tufa as described by Ewing (1996b) which may represent root casts.

The various buildings of Mission San Jose y San Miguel de Aguayo (completed in 1782) were constructed with a number of local building stones. Most of the current compound walls were built with sandstone from the Wilcox Group (see above) as reconstructions by the Works Progress Administration in the 1930s. The church itself was constructed primarily of tufa from the same quarries near Mission Concepcion, although about 20-30% of the blocks are Wilcox Group sandstones. Fossils are not yet known from either the tufa or Wilcox sandstones at Mission San Jose. However, "numerous fossils" (Roemer 1849, quoted in Ewing 1999) and "characteristic shells" (Ewing 1996b) are visible in the intricate carvings of the Rose Window and the front door frame of the mission. The Rose Window and door frame were sculpted from Late Cretaceous Austin Limestone, the same stone used in the construction of the Alamo (Ewing 1999). The Austin Limestone was obtained from quarries near the San Antonio Springs (T. Ewing, personal communication, 2006). Austin Limestone contains abundant marine invertebrates such as the oysters *Phrygia* (*Gryphaea*) *aucella* and *Exogyra laeviscula* (Sellards 1919).

Mission San Juan Capistrano (completed in 1756) was primarily constructed of tufas and conglomerates including the conspicuous pisolithic pebble conglomerate, likely from the Fluviatile terraces. Approximately 30-40% of the building stones are Wilcox Group sandstones. Fossils are not yet known from these building stones.

Mission San Francisco de la Espada (completed in 1756), unlike the other missions, was constructed primarily (80-85%) of Wilcox Group sandstones. The remaining stones are from the tufa and conglomeratic rocks listed above. Some bricks, including those used in archways, were made from the Midway Group claystone. Interestingly, the flat bricks of the Midway Group claystone were a local specialty, unique to the Espada Mission. Currently there are no documented fossils within these building stones.

Paleontological Resource Management, Preliminary Recommendations
As fossils are not abundant in the bedrock and terraces of SAAN, there is limited opportunity for active management. However, all of the units, particularly the terrace gravels are fossiliferous outside of the park, so there is potential that field investigations may yield fossil material within SAAN. Additionally, the Army Corps of Engineers regrading and restoration work along the San Antonio River may expose fossiliferous sediments (T. Ewing, personal communication, 2006). The fossils visible in the Rose Window offer interpretive opportunities to discuss origins of regional building stones and why particular stones are chosen. Ewing (personal communication, 2006) notes a few topics for potential geological research in the park including geophysical studies of an inferred paleo-spring deposit responsible for the tufa near Mission Concepcion. Tom Ewing (Frontera Exploration Consultants, San Antonio) has studied the geology along the San Antonio River and is influence on the missions and cultural history of the area and would be a good contact for additional information.

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DATA SETS

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VICKSBURG NATIONAL MILITARY PARK

During the American Civil War, the city of Vicksburg, Mississippi, with its high bluffs overlooking the Mississippi River, was known as the "Gibraltar of the Confederacy." Battles in west central Mississippi and Louisiana coupled with a 47-day siege by Union forces in 1863 led to the surrender of the town on July 4. The surrender of Vicksburg together with the Fall of Port Hudson (Louisiana) divided the South and gave the North undisputed control of the Mississippi River. Vicksburg National Military Park (VICK) was established February 21, 1899 to commemorate this decisive campaign. The park was transferred from the War Department to the NPS in 1933. Today, 32 km (20 miles) of reconstructed trenches and earthworks and more than 1300 historic monuments and markers related to the campaign are preserved within the park.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geologic scoping sessions, sponsored by the NPS Geologic Resources Division have not yet been completed for Vicksburg National Military Park. There have been no formal paleontological resource inventories for VICK and no paleontological material is currently curated into VICK museum collections (E. Joyner, personal communication, 2006). Nevertheless, VICK and the surrounding area contain a rich diversity of incredibly abundant paleontological resources including globally significant specimens and a history of fossil study extending back to the 1820s. Fossils are well known from the area and many museums have collections of Vicksburg-area fossils. Future discoveries within the park itself are highly likely. Morse (1935) wrote a brief summary of the geology of VICK. Ron Kerbo and Greg McDonald of the NPS Geologic Resources Division visited VICK in September of 2005 during a Technical Assistance Request to study paleontological and travertine resources (Kerbo and McDonald 2005).

Situated on bluffs overlooking the Mississippi River, Vicksburg National Military Park is located near the boundary of the Mississippi Alluvial region and Gulf Coastal Plain region of the Coastal Plain physiographic province. The park's geology is characterized by Oligocene-aged bedrock with a thick veneer of Pleistocene loess resting on an erosional surface of the upper Vicksburg Group (D. Dockery, personal communication, 2005); both of which are fossiliferous. As detailed below, the Oligocene deposits (Vicksburg Group) and Pleistocene loess within and around what is now VICK have long been known to yield well-preserved fossils. In fact Mint Spring Bayou serves as a type locality (place of original description) for the eponymous Mint Spring Formation of the Vicksburg Group and preserves an extensive paleontological record, described below.

Vicksburg Group (Lower Oligocene)

The lower (early) Oligocene Vicksburg Group is a globally significant assemblage of highly fossiliferous marine sand, clay, and limestone units that record the paleoecological, spatial, and faunal evolution of the Gulf of Mexico as sea levels transgressed (rose) and regressed (fell). Rocks of the Vicksburg Group are exposed in Alabama, Florida, Georgia, Louisiana, Mississippi, and Texas. However, the exposures within Mississippi, and near Vicksburg as the name suggests, are exceptional and contain what is probably the best preserved lower Oligocene marine fauna in North America (Dockery 1982a). In addition, as it follows the transition between the Eocene and Oligocene epochs, the Vicksburg Group records a period of global cooling as ice began to form at the poles (see Prothero et al. 2003).

The current stratigraphic interpretation of the Vicksburg Group involves its separation into seven formations as redefined by Dockery (1982a) and MacNeil and Dockery (1984). In ascending order (oldest to youngest), the Vicksburg Group contains the Red Bluff Formation, Forest Hill Formation, Mint Spring Formation, Marianna Limestone, Glendon Limestone, Byram Formation, and Bucatunna Formation. Five of these formations were originally described in Mississippi. The only exceptions are the Marianna (Florida) and Glendon (Alabama) limestones. Of special significance to VICK, the type locality of the Mint Spring Formation is located within the Vicksburg National Cemetery, part of VICK, at the Mint Spring Bayou falls. The Glendon Limestone and Byram Formation are also well exposed at the Mint

Spring Bayou falls locality. Within the park, only the Red Bluff Formation of the Vicksburg Group is not exposed (D. Dockery, personal communication, 2005).

Vicksburg Group (Lower Oligocene)-Invertebrates
Altogether the Vicksburg Group formations preserve an abundant marine fauna consisting primarily of mollusks including 144 bivalve species or forms (Dockery 1982a) and 411 gastropod, scaphopod and cephalopod species, subspecies, or varieties (MacNeil and Dockery 1984). As noted above, these mollusks are the cornerstone of what is likely the best preserved lower Oligocene marine fauna in North America. Many of these species were first described in the Vicksburg area and continue to be studied for their contribution to the understanding of the paleoecological evolution of the Gulf of Mexico. The invertebrate fauna is not limited to mollusks however. Microfossils are abundant and include nearly 200 species of foraminifera and calcareous nannofossils (Cushman 1922, 1923; Todd 1952; Bybell 1982) and 92 species of ostracodes (Hazel et al. 1980). In fact, Todd's (1952) Mint Spring Bayou section contained 149 different species, making it the richest in her study. Corals, bryozoans, barnacles, and echinoids are also known from the Vicksburg Group (see Lesueur's 1829 plates in Dockery 1982a,b; Cooke 1918). Numerous authors have collected or studied material from the Vicksburg Group exposures within Vicksburg National Military Park, particularly the Mint Spring Bayou type locality. Perusing the cited references, additional references, and papers cited therein reveals a remarkable depth and breadth of paleontological research conducted within and adjacent to VICK.

Vicksburg Group (Lower Oligocene)—Vertebrates
A variety of vertebrate fossils have also been discovered within the Vicksburg Group, summarized by Daly (1992) and include fish otoliths (ear bones), shark teeth and ray plates, marine mammal material, and even bones of terrestrial rhinoceros and amynodont (perrisodactyl) which were likely washed into the marine sediments. Although the seas which formed the Vicksburg Group sediments likely teemed with fish, there are very few skeletal elements preserved in the group's fossil record. However Frizzell and Lamber (1962) and Frizzell and Dante (1965) describe fish otoliths ("ear bones"), from the Vicksburg Group including *Corvina* sp. and those of the "*Conger*" type morphology from samples collected at the Mint Spring Bayou locality within VICK. Fish vertebrae, shark teeth and ray plates (teeth) from the Vicksburg Group, including the giant shark *Charcharodon auriculatus*, were first figured by Lesueur from his Walnut Hills locality within what is now VICK (Dockery 1982a,b; Dockery and Manning 1986). Lesueur also illustrated potential manatee ribs from this Walnut Hills locality (Dockery 1982a). For more information on Lesueur see the Significant Early Research section, below. The terrestrial fauna of the Vicksburg Group is quite limited, as to be expected for a marine unit. Significant specimens have been found in the Vicksburg Group (e.g. Manning et al. 1986; Dockery and Manning 1990), however none yet within or near Vicksburg.

Vicksburg Group (Lower Oligocene)-Significant Early Research
French naturalist Charles A. Lesueur was the first to scientifically document fossils from the bluffs around Vicksburg in 1829. In fact, his measured section of the bluffs ("Walnut Hills") at Vicksburg is likely the earliest detailed geological investigation in Mississippi, and one of the first in the Mississippi Valley (Gardner 1938; Dockery 1982b). The Walnut Hills bluffs Lesueur references are likely within current VICK boundaries, or immediately adjacent to them, as reported by Haber and Raup (1968, and reproduced in Dockery 1982b): "[Walnut Hills] was 250 or 300 feet high and crowned by the ruins of old Fort MacHenry [sic]. At the base of the hill was hidden a valuable deposit of bones, teeth and above all, shells…" The abandoned Fort McHenry was located on what is now Fort Hill, within VICK (T. Wenschel, personal communication, 2006). Lesueur's sketch, measured section, and some fossils from the Walnut Hills locality are reproduced on the cover of this report (from Dockery 1982a). Current park boundaries extend down Fort Hill and include the bluffs, shoreline, and adjacent waters. From this locality, Lesueur made an exceptional collection of fossil foraminifera, corals, bryozoans, gastropods, bivalves, crab claw, echinoids, shark teeth, ray teeth, fish vertebrae and otoliths, and potential manatee ribs from the Byram and Mint Spring formations (Dockery 1982b). Lesueur exquisitely illustrated these fossils, although his manuscript was never completely published. His plates are reproduced in Dockery (1982a,b). Lesueur's collection, sketches and notes were divided between the Paris Museum and the

Museum of Natural History in Le Havre in France (Gardner 1938). Copies of the plates are located in both the Academy of Natural Sciences of Philadelphia and the Smithsonian National Museum of Natural History.

British geologist Charles Lyell was one of the founding fathers of the modern geological science in the early-mid 1800s. Lyell made two extended visits to the United States, touring the country observing the geology and making fossil collections. During his second visit in 1846, published as Lyell (1849), Charles Lyell visited the Vicksburg area on his trip up the Mississippi River from New Orleans. He also visited the Natchez area as described further in the Natchez Trace Parkway section of this report. While at Vicksburg (March 19, 1846), Lyell collected "many shells and corals" from what is now known as the Vicksburg Group (Lyell 1849). As noted by Wilson (1998), Dockery and Lazouet (2003) and Dockery (personal communication, 2006), Lyell contributed greatly to understanding the stratigraphy in the middle Eocene Claiborne, upper Eocene Jackson, and lower Oligocene Vicksburg groups, utilizing the mollusk fossils from each group. Hence his visit to and collections from the Vicksburg area are significant, and allowed Timothy Abbott Conrad (see below) to place his fossils in proper stratigraphic order. As a side note, both Lyell and Conrad described the fossils as "newer" or "upper" Eocene. Today, those same layers are placed in the Oligocene epoch, which was named in 1854, while the term Eocene refers to older layers (Lyell and Conrad's "lower Eocene").

Working from collections made in 1844 in the area surrounding Vicksburg, paleontologist Timothy Abbott Conrad published the first monograph on Vicksburg fossils in a series of papers in the mid-late 1840s (Conrad 1846, 1848). Conrad, as was common at the time, did not give precise locality information instead referencing areas "near Vicksburg." Nevertheless, he named over 105 new Vicksburg mollusk species and was the first to compare them to other Coastal Plain fossil assemblages, including those from future NPS sites Fort Washington Park and Piscataway Park in Maryland (Kenworthy and Santucci 2004) and City Point in Petersburg National Battlefield (Kenworthy et al. 2006). He concluded correctly that the Vicksburg was younger "newer Eocene" (now known as the Oligocene) than many assemblages elsewhere on the Coastal Plain. Dockery (1982a) and MacNeil and Dockery (1984) represent the first monographs to redescribe the Vicksburg fauna following Conrad (1848).

Located within VICK, the Mint Spring Bayou waterfall is one of the classic Vicksburg Group fossil collecting and stratigraphy localities. It is the type section (place of original description) for the Mint Spring Formation and has yielded abundant fossils, primarily invertebrates. Numerous geologists and paleontologists have collected at the falls and their collections are now housed in museums across the county including the voluminous collections of the Smithsonian National Museum of Natural History. All of Conrad's specimens are housed at the Academy of Natural Sciences in Philadelphia. The University of California (Berkeley) Museum of Paleontology also curates a number of mollusk specimens, primarily turritellid gastropods. Many of these collections include type specimens. A brief summary of collections made between the late 1800s-early 1900s is here presented. See Dockery (1982a) and MacNeil and Dockery (1984) for additional collection information. While Charles A. Lesueur made the first collection near Vicksburg (see above) in 1829, he apparently did not visit the Mint Spring Bayou waterfall. T. Wayland Vaughn collected fossils at the Mint Spring Bayou (USGS Locality 3723) in 1900. C. Wythe Cooke (1918, 1922, 1923) defined and formally named Casey's (1903) "Upper and Lower Vicksburg" formations the Forest Hill Sand and Red Bluff Clay, Mariana Limestone (including Mint Spring marl), the Glendon Formation and the Byram marl. Cooke's localities at the Mint Spring waterfall included USGS localities 6451 and 6452. F. Stearns MacNeil and Wendell Clay Mansfield also collected at the site in the 1930s-1940s. Collections made by B.L. Clark, F.E. Turner, and J. Wyatt Durham of the University of California (Berkeley) from the Mint Springs Bayou waterfall are primarily from their locality UC A1050. In Dockery (1982a) and MacNeil and Dockery (1984), the Mint Spring Bayou is Mississippi Office of Geology Locality 108. There are many other localities very close to VICK and the surrounding area. Both Dockery (1982a) and MacNeil and Dockery (1984) include extensive lists of Vicksburg Group collecting localities.

Loess Deposits (Pleistocene)
The Pleistocene loess deposits within and surrounding the town of Vicksburg and VICK are characterized by tan or yellowish-buff silt-size grains, primarily composed of quartz. As described by Snowden and Priddy (1968), the loess has a "glacio-fluvial-eolian" origin. The source material was first ground into very fine rock flour by continental glaciers, then transported via water down the ancestral Mississippi River as glacial outwash, and finally swept up and deposited on leeward (eastern) bluffs by prevailing winds. There is an extensive literature base regarding loess of the Mississippi Valley since its first geologic identification by British geologist Charles Lyell who studied the loess near Natchez in 1847. Snowden and Priddy (1968) summarize the historical research and a detailed geologic study of Mississippi Loess; many of these references are listed below in the additional references section.

Today this loess forms steep hills and deep ravines, and at over 30 m (100 ft) thick near Vicksburg, these loess deposits are among the thickest in the United States. Geologically the loess is very significant. Undisturbed and unweathered loess has good structural integrity making it an excellent substrate for construction of the earthworks critical to both armies during the 1863 Civil War siege of Vicksburg as described in many articles (e.g. Morse 1935; Myers et al. 2004, 2005; Larson et al. 2004). Weathered and/or disturbed loess, however, loses its structural integrity eroding easily and rapidly. This creates numerous civil engineering challenges and loess erosion is a significant and ongoing resource management issue within VICK and the surrounding communities (e.g. NPS 2004, 2005).

Loess Deposits (Pleistocene)-Invertebrates
In addition to its unique geological qualities, the loess near Vicksburg also preserves an abundant and well preserved paleontological record consisting primarily of pulmonate (terrestrial) gastropods, first noted by Lyell in 1847. Aquatic snails and bivalves are occasionally found (Shimek 1930; Williams 1999) as are vertebrate remains, detailed below. Shimek (1902) described the loess fauna of the Vicksburg-Natchez area and compared the Pleistocene and modern faunas, which are very similar. His Vicksburg locality was within a "cut along the Vicksburg and Meridian R. R. at Vicksburg." This rail line was later known as the "Historic Southern Railroad of Mississippi," as labeled on park maps. The railroad crosses through the park with a large cut near Railroad Redoubt (T. Winschel; K. Foote, personal communication, 2006). This Railroad Redoubt cut is likely Shimek's Vicksburg locality. Shimek's (1902) detailed description of the fauna at this cut includes 21 species or varieties of snails with *Pyramidula alternata costata*, *Circinaria concava*, and *Polygyra hirsuta* being the most abundant. The loess at VICK near the National Cemetery has also yielded gastropod shells and was probably the "most readily accessible section of fairly well exposed beds" in the Vicksburg area (Morse 1935).

Snowden and Priddy (1968) include a list of 21 different gastropod species with updated taxonomy representative of loess deposits in Mississippi. Snowden and Priddy (1968) also report radiocarbon ages for the gastropods collected north of the park (along U.S. Highway 61 Bypass and near Redwood) ranging from 25,300-17,850 ybp. These ages are comparable to those from upper Mississippi Valley (Peorian and Farmdale) loess. A piece of fossil wood just below the loess near Vicksburg was dated to 25,600 ybp (Snowden and Priddy 1968).

As an interesting historical aside, John Wesley Powell, famed explorer of the west and director of the U.S. Geological Survey, served in the Federal army during the 1863 siege of Vicksburg. As summarized by Kenworthy and Santucci (2006), there are many accounts of him collecting fossils from the area around VICK, likely from earthworks excavated into the loess (e.g. Dellenbaugh 1902; USGS 1970; Worster 2001; Moring 2002). Although Worster (2001) mentions that Powell collected fossils for his "Wheaton museum" [likely the present-day Illinois State Natural History Survey], the current whereabouts of Powell's collection is unknown. Curators from the Smithsonian Institution, Illinois State Museum, Illinois State Natural History Survey, and U. S. Geological Survey have been contacted, but Powell's collection has not yet been definitively located (W. Blow; K. Cummings; C. Nelson; J. Saunders; B. Warran; M. Wiant; E. Yochelson, personal communication, 2006).

Pleistocene Loess-Vertebrates
While the gastropods dominate the paleontological fauna, vertebrates are also known from the loess with a bibliography of their occurrences listed by Daly (1992). The loess and underlying deposits surrounding Natchez yielded an abundant vertebrate fauna and is detailed further in the Natchez Trace Parkway section of this report. Within Mississippi, known vertebrates include lion, bear, ground sloth, tapirs, horse, deer, bison, mammoth and mastodon with the mammoth and mastodon being the most common (Lowe 1915, 1919). Some of these discoveries may have been from the "blue clay" (aqueous deposition of loess) near the base of the loess deposits rather than from the true loess (e.g Hay 1923, 1928). See the NATR section for information on the "blue clay." Many vertebrate discoveries were made near Vicksburg. For example, Lowe (1919) reported "mammal bones may be collected in the bluffs at Vicksburg." Priddy et al. (1966) utilized mastodon bones "near Vicksburg" to obtain radiometric dates. Mastodon material, producing radiocarbon dates ranging from 15,665-17,000 years old, was also excavated near the site of the Pemberton Square Mall approximately 1.9 km (1.2 miles) southwest of the current park boundary (Kolb et al. 1976; Knox and Pitts 1984). As reported by Knox and Pitts (1984), VICK staff, including Superintendent James R. McConaghie and Historian William C. Everhart, assisted in coordinating early study the specimen in the 1950s. The specimen was fully excavated in 1984 and is now on display at the Mississippi Museum of Natural History and is one of the most complete *Mammut americanum* skeletons found in Mississippi (Knox and Pitts 1984). Approximately 3.2 km (2 miles) north of the park along a U.S. Highway 61 Bypass road cut, mastodon bones and tusk were discovered in 1964 and are now on display in the Geotechnical Laboratory Foyer of the U.S. Army Corps of Engineers Waterways Experiment Station and figured by Kolb et al. (1976). Wailes (1854) indicated that a mastodon tooth, identified by Hay (1923) as fragments of an upper right last molar was discovered "in the deep cut of the railroad at Vicksburg." It is unclear whether this railroad cut is the same as Shimek's (1902) cut referenced above. If it is, it would be direct evidence of vertebrate fossil material from the loess within the park. Nevertheless, the proximity of many of the other discoveries to the park indicates the potential for similar finds within VICK.

Paleontological Resource Management, Preliminary Recommendations
In this section, we present a few preliminary recommendations for paleontological resource management within VICK. Kerbo and McDonald (2005) also included a number of recommendations regarding paleontological resources. For more information or assistance, contact the NPS Geologic Resources Division.

- The establishment of a small park study collection including representative fossils (and other natural history objects) may be highly beneficial to both park resource management and interpretation staff.
- Further, the park's scope of collections could also be revised to address the acquisition of collections regarding the park's significant natural resources (biology, geology, and paleontology).
- The addition of literature pertinent to the fossil resources especially Dockery (1982a) and MacNeil and Dockery (1984) would be a valuable addition to the park's resource management library.
- Significant paleontological resource localities (e.g. Mint Spring Bayou waterfall, and Lesueur's Walnut Hills locality) should be officially documented utilizing NPS Paleontological Resource Locality and Condition Assessment forms. These forms are currently being revised (Fall 2006); however the Geologic Resources Division will be able to provide support and additional recommendations for their utilization. Use of the forms satisfies GPRA goal Ia9: Paleontological Resources and provides baseline data for future resource management and monitoring, field studies, or interpretation.
- Field work, including the aforementioned documentation and condition evaluation of localities, and ANCS+ accessioning of collected fossils could be performed by seasonal employee or intern. The NPS Geoscientists In the Parks (GIP) program can help advertise and recruit for such a position.

- When the park's GMP is revised, including a section addressing geology and paleontology would likely be beneficial.
- The park should encourage, and when possible, support scientific research (including academic thesis work) utilizing the significant fossil resources present in the park. David Dockery of the Mississippi Office of Geology is a primary contact for the paleontology of the area.
- As mentioned in Kerbo and McDonald (2005), essentially all ground-disturbing activities in the park may uncover paleontological resources in the Pleistocene loess. Park staff should be made aware of such a possibility. While it may not be possible to mitigate all ground-disturbing activities due to the locally pervasive nature of the gastropod fossils, significant specimens should be collected. The Mississippi Office of Geology, Geologic Resources Division, or other appropriate institution should be contacted if articulated vertebrate, or otherwise significant specimens are uncovered. Vertebrate fossils have not yet been discovered in the loess within the park, and any such discovery would be exciting.

COOPERATIVE PROJECTS

- Geologic Resources Division Technical Assistance Request (September 2005). Ronal Kerbo and Greg McDonald (2005) visited the park and performed initial assessment and recommendations regarding paleontological resources and travertine deposits within the park.

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Data Sets

DS-VICK-XXX Vicksburg National Military Park Paleontological Archives. 5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

DS-VICK-XXX Smithsonian Institution, Museum of Natural History Collections. 1850s-present. (museum specimens; associated specimen notes; collection records; field notes; publications; historical photos and documents; maps; etc.). Originated by many museum and USGS staff and other researchers; status: Inactive.

DS-VICK-XXX Academy of Natural Sciences of Philadelphia Collections. 1840s-1850s. (museum specimens; associated specimen notes; collection records; field notes; publications; historical photos and documents; maps; etc.). Originated by Timothy Abbott Conrad; status: Inactive.

DS-VICK-XXX University of California, Berkeley, Museum of Paleontology Collections. 1850s. (museum specimens; associated specimen notes; collection records; field notes; publications; historical photos and documents; maps; etc.). Originated by J. Wyatt Durham, B.L. Clark, and F.E. Turner; status: Inactive.

DS-VICK-XXX Le Havre (France) Museum of Natural History Collections. 1850s. (museum specimens; associated specimen notes; collection records; field notes; etc.). Originated by Charles A. Lesueur; status: Inactive.

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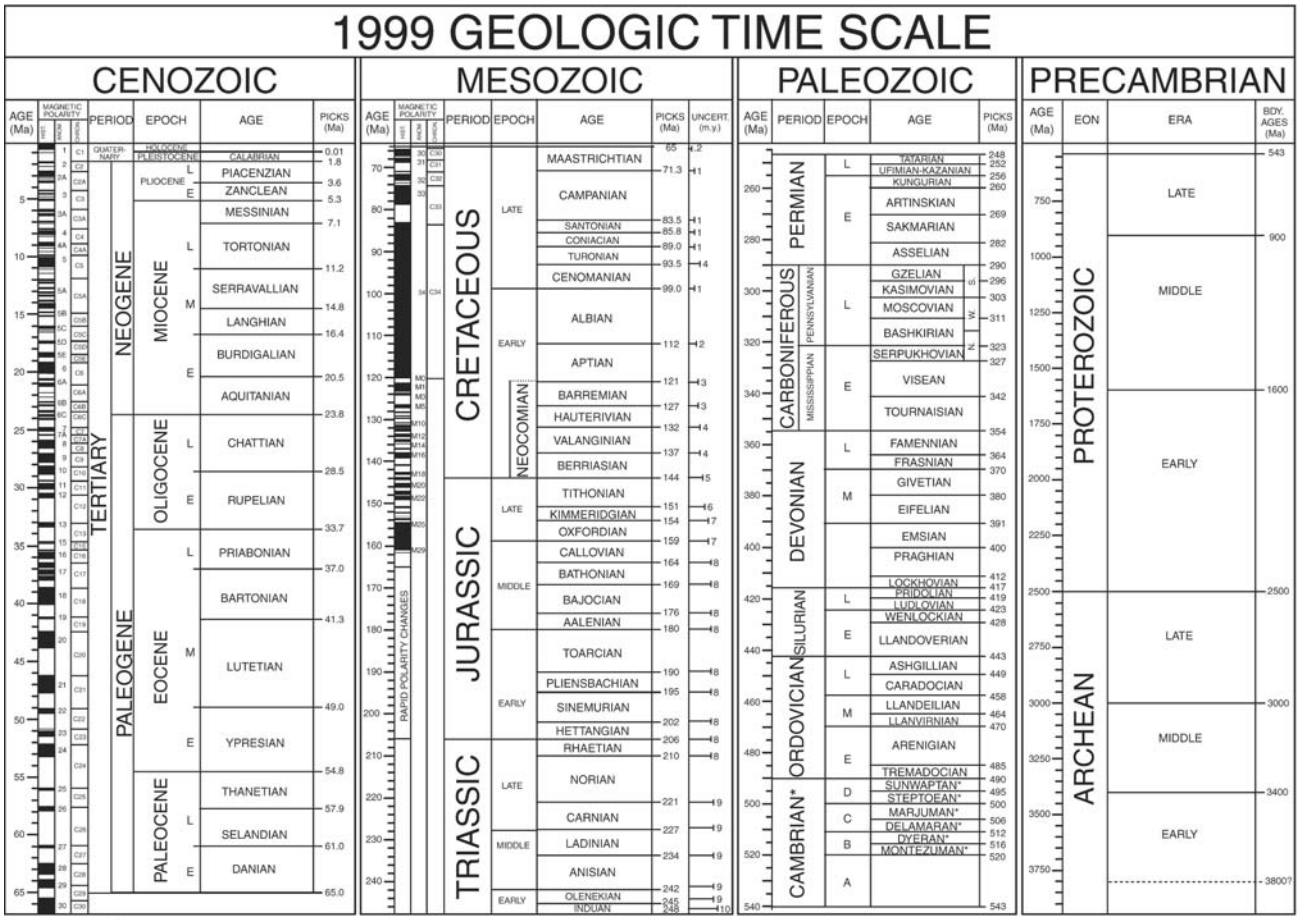
Appendix A: Geologic Time Scale



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

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

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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