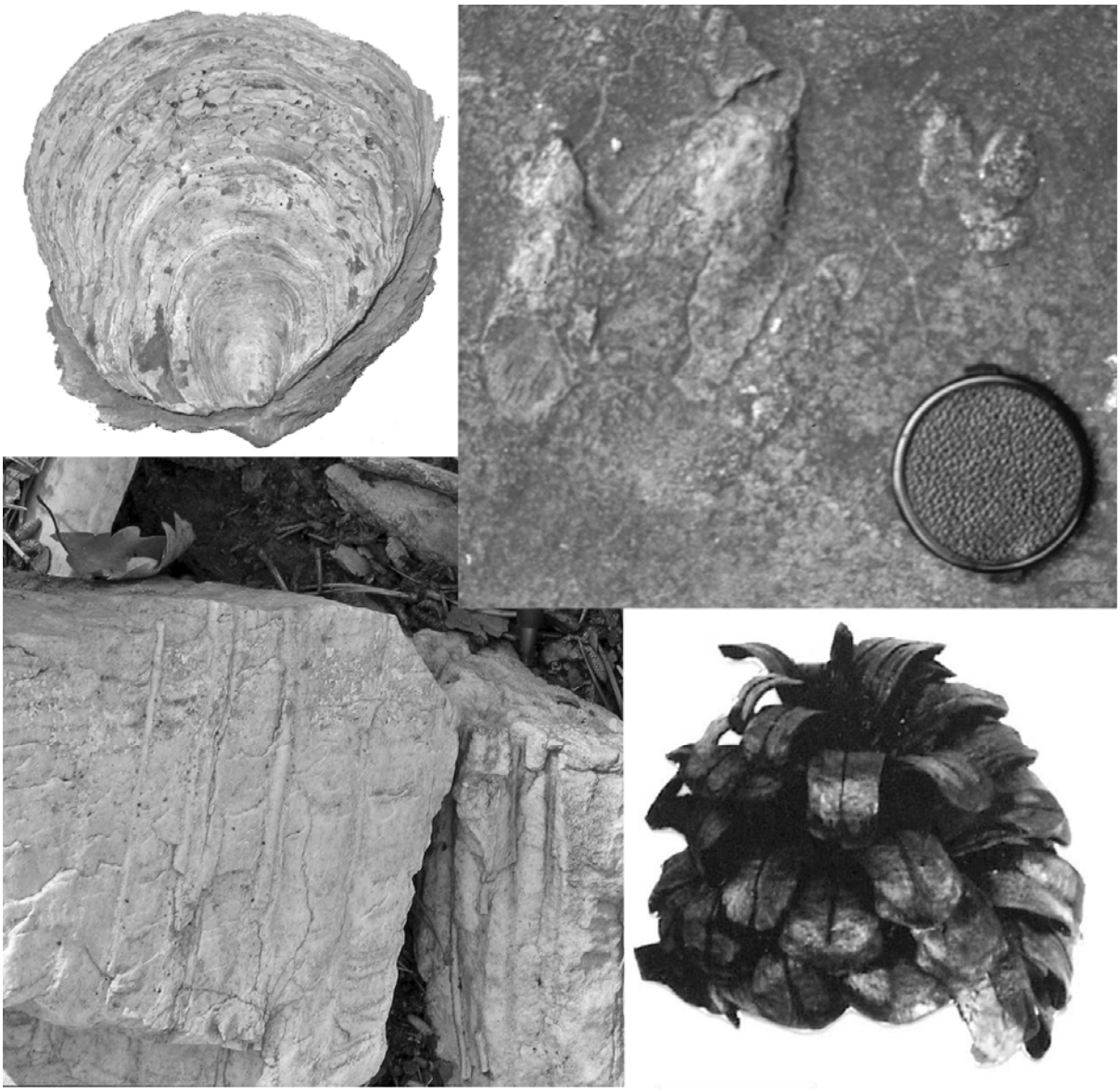
National Park Service
U.S. Department of the Interior

Mid-Atlantic Network

Paleontological Resource Inventory and Monitoring

Mid-Atlantic Network



Paleontological Resource Inventory and Monitoring
Mid-Atlantic Network

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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:
An assortment of fossils from Mid-Atlantic Network parks. Clockwise from top left: A large oyster collected in the 1800s by Richard Eppes near City Point (Petersburg NBP) typical of the fossiliferous Coastal Plain sediments exposed in the area (NPS photo/James Blankenship). Triassic dinosaur tracks (*Atreipus*) visible in the stones of a bridge parapet within Gettysburg NMP, lens cap for scale (NPS photo/Vincent Santucci). An extraordinarily well-preserved Pleistocene pitch pine cone (~4 cm wide) discovered in the late 1800s from Port Kennedy Bone Cave, located in what is now Valley Forge NHP (photo courtesy Ted Daeschler). A block of early Cambrian Erwin Formation sandstone from Shenandoah NP displaying the vertical tubes of the trace fossil *Skolithos*, interpreted as vertical worm burrows (~17 cm long; NPS photo/Eric Butler). For more information, refer to each park's section in this report.

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INTRODUCTION

Paleontological resources, or fossils, are any remains of past life preserved in geologic context. There are two main types of fossils: body fossils and trace fossils. Body fossils are parts 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, only a small percentage of those parks have adequate baseline paleontological resource data.

In conjunction with the NPS Geologic Resources Division and NPS Inventory and Monitoring (I&M) Program, paleontological resource inventories have been initiated in dozens of parks service-wide and are further described in the Methodology and Inventory Strategies section. This report presents paleontological resource inventory and monitoring data compiled for the parks of the Mid-Atlantic I&M Network (MIDN).

The Mid-Atlantic Network includes ten National Park Service areas in Virginia and Pennsylvania as shown in Figure 1: Appomattox Court House National Historical Park (Virginia; APCO), Booker T. Washington National Monument (Virginia; BOWA), Eisenhower National Historic Site (Pennsylvania; EISE), Fredericksburg and Spotsylvania National Military Park (Virginia; FRSP), Gettysburg National Military Park (Pennsylvania; GETT), Hopewell Furnace National Historic Site (Pennsylvania; HOFU), Petersburg National Battlefield (Virginia; PETE), Richmond National Battlefield Park (Virginia; RICH), Shenandoah National Park (Virginia; SHEN), and Valley Forge National Historical Park (Pennsylvania; VAFO). All together, the parks of the MIDN encompass over 230,000 acres and hosted more than 5.1 million visitors in FY2005. Six MIDN parks were preserved primarily for significant cultural and historic resources related to the Revolutionary War (VAFO) and Civil War (APCO, FRSP, GETT, PETE, and RICH). Three document the historical significance of individuals (Booker T. Washington-BOWA, and President Dwight D. Eisenhower-EISE), or industry (19th century iron plantations-HOFU). Only one park in the network was established primarily to preserve natural resources (SHEN).

While none of the parks were established specifically for paleontological resource stewardship, fossils are known from a number of MIDN parks including Gettysburg National Military Park, Petersburg National Battlefield, Richmond National Battlefield Park, Shenandoah National Park, and Valley Forge National Historical Park. Geologic formations that have produced fossils outside of park boundaries of Fredericksburg and Spotsylvania National Military Park and Hopewell Furnace National Historic Site are mapped within those parks. Such discoveries indicate the possibility for future fossil finds within the parks.

The paleontological resources found within MIDN parks are quite diverse, span more than 500 million years, and in some cases are nationally, or even globally significant. For example, Port Kennedy Cave, located within what is now Valley Forge National Historical Park produced one of the most significant assemblages of Pleistocene (about 750,000 years old) fossils in North America. Cambrian-aged worm burrows some 500 million or more years old have been found in the rocks of at least two MIDN parks (SHEN and VAFO) and have been found just outside of a third (HOFU). Evidence of dinosaurs can also be found in an MIDN park, as dinosaurian tracks were found in a bridge at Gettysburg National Military Park. Fossiliferous geologic formations are found in both Richmond National Battlefield Park and Petersburg National Battlefield and yielded many marine fossils of the Atlantic Coastal Plain.

Taken together, the paleontological resources of the Mid-Atlantic 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, Christy C. Visaggi, and Vincent L. Santucci—June 2006

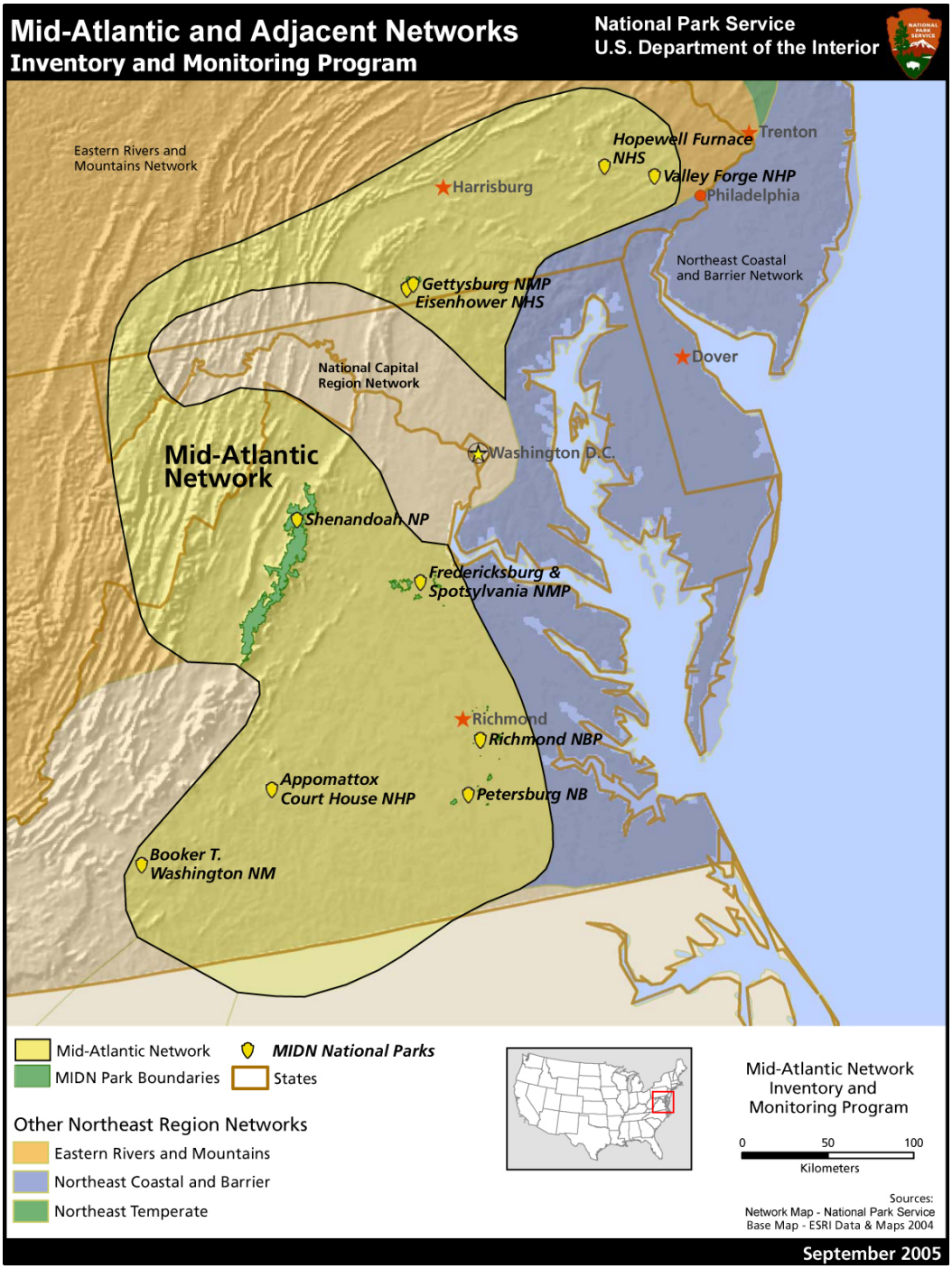


Figure 1. Map of Mid-Atlantic I&M Network parks and adjacent networks. Modified from MIDN network map.

NPS 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 and 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. Another example of a thematic paleontological resource inventory is the inventory of paleontological resources associated with NPS caves (Santucci et al. 2001). 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 I&M Network-based inventory. Network-based paleontological resource inventories are designed to compile baseline paleontological resource data for each of the parks assigned to a particular network. Network-based inventories have been completed for one-third of the 32 I&M Networks including: the Eastern Rivers and Mountains, Greater Yellowstone, Mediterranean Coast, Mojave Desert, National Capital Region, Northeast Coastal and Barrier, Northern Colorado Plateau, Rocky Mountain, Southern Plains, Southwestern Alaska, and Upper Columbia Basin networks. An inventory of the Gulf Coast Network is scheduled for completion in 2006. The NPS I&M Program will be providing funding to complete paleontological resource summaries for the remaining networks by FY2009. Citations for these reports are included in the Additional References section.

Inventory and Monitoring Network Paleontological Resource Inventory Methodology
Network-based paleontological inventories have been funded directly by the individual networks. Funds are used to provide stipends or salary for contractors, interns, or paleontological technicians who perform data mining activities. The Mid-Atlantic Network report represents a multi-faceted approach toward the completion of the report. To efficiently utilize available funding, data mining work for the MIDN paleontology summary was performed concurrently by a paleontology intern through the Student Conservation Association and a paleontology technician from the NPS Geologic Resources Division.

Funding for the MIDN report was made available through both the Geologic Resources Division and the Mid-Atlantic Network. 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 as are 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 2001 National Park Service Management Policies (§1.4.6) stipulates that paleontological resources are considered park resources and values that are subject to the "no impairment" standard set forth by the NPS Organic Act in 1916. Another legislative protection afforded to paleontological resources is found in the NPS Omnibus Management Act of 1998. Section 207, with the following statement, "Information concerning the nature and specific location of…paleontological objects within the units of the National Park System…may be withheld from the public source", safeguards paleontological locality information from requests under the Freedom of Information Act. Paleontological resource management issues were the subject of a Report of the Secretary of the Interior in May 2000. That report, an "Assessment of Fossil Management on Federal & Indian Lands" summarized a number of principles relating to paleontological resources and their management from a federal government point of view. The report was also prepared in response to a congressional request for an assessment of the need for a unified federal policy on the collection, storage and preservation of fossils and for standards that would maximize the availability of fossils for scientific study. The Paleontological Resources Management section of Natural Resource Management Reference Manual 77 provides guidance and additional information regarding the implementation and continuation of paleontological resource management programs. Links to the above documents are listed in the Additional References section. The Geologic Resources Division is also 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 (Spring 2006), the monitoring manual is in 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. and V. L. Santucci. In preparation. Paleontological Resource Inventory and Monitoring, Gulf Coast Network. National Park Service TIC# D-750.

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

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.

General MIDN Information

Mid-Atlantic I&M Network: http://www.nature.nps.gov/im/units/midn/

Geological Survey Websites

Virginia Division of Mineral Resources: http://www.mme.state.va.us/Dmr/home.dmr.html
Pennsylvania Bureau of Topographic and Geologic Survey: http://www.dcnr.state.pa.us/topogeo/
U.S. Geological Survey: http://www.usgs.gov
Geological Society of America: http://www.geosociety.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

Academy of Natural Sciences of Philadelphia: http://www.acnatsci.org/
Smithsonian National Museum of Natural History Dept. of Paleobiology: http://www.nmnh.si.edu/paleo//
Virginia Museum of Natural History (Martinsville): http://www.vmnh.net
Carnegie Museum of Natural History (Pittsburg): http://www.carnegiemnh.org/
State Museum of Pennsylvania (Harrisburg): http://www.statemuseumpa.org/

Resource Management/Legislation Documents

NPS 2001 Management Policies (§1.4): http://www.nps.gov/refdesk/mp/chapter1.htm#ParkManagement
NPS 1998 Omnibus Management Act (paleontological resource summary): http://www2.nature.nps.gov/geology/paleontology/paleo_5_1/index.htm
NPS Natural Resource Management Reference Manual #77 (paleontology section): http://www.nature.nps.gov/rm77/Paleo.htm
Assessment of Fossil Management on Federal & Indian Lands: http://www.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

Other geology/paleontology tools

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 Geographic Names Information System: http://geonames.usgs.gov/pls/gnispublic/
Paleobiology Database: http://paleodb.org/cgi-bin/bridge.pl
Paleontology Portal: http://www.paleoportal.org/

APPOMATTOX COURT HOUSE NATIONAL HISTORICAL PARK

Appomattox Court House National Historical Park (APCO) is located in central rural Virginia and marks the site where the Nation reunited in 1865. The park spans approximately 1800 acres encircling the village of Appomattox Court House, the former county seat for Appomattox County. APCO is primarily recognized for the McLean home - the surrender setting of Robert E. Lee and Confederate soldiers to Ulysses S. Grant and Union forces. Other historical landmarks include the home and burial place of Joel Sweeney, popularizer of the modern five string banjo, as well as 27 original 19th century structures. Appomattox Court House National Historical Park was originally designated Appomattox Battlefield Site on June 18, 1930. The site was transferred to the NPS in 1933 and authorized as a national historical monument in 1935. The McLean home reopened to the public on April 9, 1949, exactly 84 years after the historic meeting that reunited the country. The park was redesignated Appomattox Court House National Historical Park on April 15, 1954.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

The NPS Geologic Resources Division targeted a number of Virginia parks for geologic scoping in 2005 including Appomattox Court House National Historical Park. No formal paleontological resource inventories have been completed for APCO and no paleontological specimens exist in park collections. There are no records of paleontological discoveries at APCO or in exposures adjacent to park boundaries.

Appomattox Court House National Historical Park rests on top of the Smith River allochthon, a body of foreign rock composed of metamorphic schist and gneiss commonly found in the Piedmont province of central Virginia (Rader and Evans 1993; Roberts and Bailey 2003). The rolling topography of this physiographic region stretches across a number of states in the southern Appalachians and is characterized by poorly preserved sections and geologically complex rocks (Fenneman 1938; Conley 1978; Conley 1985; Bailey 1999). Though no geologic maps directly correspond to the area encompassed by APCO, a number of maps from proximal quadrangles are available for larger geologic reconstructions as listed in the Additional References section of this report. APCO straddles the Chatham fault of Mesozoic origin (Roberts and Bailey 2003); however the underlying and local bedrock geology primarily consists of metamorphic and igneous rock derived elsewhere during the Late Proterozoic to early Paleozoic (Conley 1978; Conley 1985; Rader and Evans 1993; Hibbard et al. 2003). No fossiliferous formations are mapped near park boundaries and due to the nature of the rock therein, the potential for future paleontological finds in the vicinity of APCO is doubtful.

REFERENCES CITED

Bailey, C. M. 1999. The geology of Virginia – Piedmont province. Department of Geology, The College of William and Mary. (http://www.wm.edu/geology/virginia/piedmont.html).

Conley, J. F. 1978. Geology of the Piedmont of Virginia – interpretation and problems. Pages 115-149 *in* Contributions to Virginia Geology III. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 7.

Conley, J. F. 1985. Geology of the southwestern Virginia Piedmont: Virginia Division of Mineral Resources, Charlottesville, VA. Publication 59. 33 pages. 1:125,000 scale map.

Fenneman, N. M. 1938. Physiography of the Eastern United States. McGraw-Hill Book Company, New York. 714 pages.

Hibbard, J. P., R. J. Tracy, and W. S. Henika. 2003. Smith River allochthon: A southern Appalachian peri-Gondwanan terrane emplaced directly on Laurentia? Geology **31**(3):215-218.

Rader, E. K. and N. H. Evans, editors. 1993. Geologic map of Virginia and expanded explanation. Virginia Division of Mineral Resources, Charlottesville, VA. 80 pages. 1:500,000 scale map.

Roberts, C. and C. M. Bailey. 2003. The geology of Virginia – Historic places. Department of Geology, The College of William and Mary. (http://www.wm.edu/geology/virginia/piedmont.html).

ADDITIONAL REFERENCES

Bartholomew, M. J. 1981. Geology of the Roanoke and Stewartsville quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 34. 23 pages. 1:24,000 scale map.

Brown, W. R. 1969. Geology of the Dillwyn quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 10. 1:62,500 scale map.

Cecil, K. K., R. C. Whisonant, and P. S. Sethi. 2000. Teacher's guide for the geology of Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. 132 pages.

Conley, J. F. and W. S. Henika. 1973. Field trip across the Blue Ridge anticlinorium, Smith River allochthon, and Sauratown Mountains anticlinorium near Martinsville, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Virginia Minerals **19**(4). Pages 37-44.

Conley, J. F., J. D. Marr, Jr., and C. R. Berquist, Jr. 1981. Stratigraphic relationships between rocks of the Blue Ridge anticlinorium and the Smith River allochthon in the southwestern Virginia Piedmont. Virginia Division of Mineral Resources, Charlottesville, VA. Annual Virginia Geology Field Conference 13. 34 pages.

Dietrich, R. V. 1990. Geology and Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. 213 pages.

Ern, E. H. 1968. Geology of the Buckingham quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 15. 1:62,500 scale map.

Espenshade, G. H. 1954. Geology and mineral deposits of the James River – Roanoke River manganese district, Virginia. U.S. Geological Survey, Reston, VA. Bulletin 1008. 1:62,500 scale map.

Henika, W. S. 1992. Stratigraphy of the eastern Blue Ridge sequence in the Roanoke 30 x 60 minute quadrangle, Virginia. Geological Society of America Abstracts with Programs **24**(2):21.

Henika, W. S. 1997. Geologic map of the Roanoke 30 x 60 minute quadrangle. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 148. 1:100,000 scale map.

Hibbard, J., K. G. Stewart, and W. S. Henika. 2001. Framing the Piedmont zone in North Carolina and Virginia. Pages 1-26 *in* C.W. Hoffman, editor. Field Trip Guidebook for the 50th annual meeting of the Southeastern Section of the Geological Society of America, Raleigh, NC.

Johnson, S. S., G. P. Wilkes, and T. L. Zeiler. 1985. Simple Bouguer gravity anomaly map of the Farmville, Briery Creek, Roanoke Creek, Randolph, and Scottsburg basins and vicinity, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 47. 1:125,000 scale map.

Marr, J. D., Jr. 1980. Geology of the Andersonville quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 26. 1:24,000 scale map.

Marr, J. D., Jr. 1980. Geology of the Willis Mountain quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 25. 1:24,000 scale map.

Meyertons, C. T. 1963. Triassic formations of the Danville basin. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 6. 1:62,500 scale map.

Pavlides, L. 1989. Early Paleozoic composite mélange terrane, central Appalachian Piedmont, Virginia and Maryland; its origin and tectonic history. Pages 135-193 *in* J.W. Horton Jr. and N. Rast, editors. Geological Society of America Special Paper 228.

Sethi, P. S., R. C. Whisonant, K. K Cecil, and P. L. Newbill. 2000. Geology of Virginia: Piedmont and Blue Ridge. (CD-ROM #3). Virginia Division of Mineral Resources, Charlottesville, VA. 2 CD-ROMs.

BOOKER T. WASHINGTON NATIONAL MONUMENT

Booker T. Washington National Monument (BOWA) preserves a 19th century 207-acre tobacco farm that is recognized as the birthplace of Booker T. Washington, a renowned advocate of emancipation, education, and equality for African Americans. He endured the life of a slave early in childhood, but rose to become one of the most powerful and influential African Americans in the United States. Washington helped found the Tuskegee Institute of Alabama in 1881 and held the position of first principal at age 26. The National Park Service authorized Booker T. Washington National Monument on April 2, 1956.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

The NPS Geologic Resources Division engaged in geologic scoping sessions for Booker T. Washington National Monument in 2005. There are no records of paleontological discoveries at the monument and no fossil specimens are listed in park collections. Paleontological resource inventories have not been previously completed for BOWA. There is little potential for future discoveries of paleontological resources within the park.

Booker T. Washington National Monument is centered on the eastern border of the Blue Ridge province in the gently rolling Piedmont of Virginia (Fenneman 1938; Hendrick 1978; De Lore 1998). This geologically complex region is subject to extreme weathering and is commonly underlain by Precambrian metamorphic schist and gneiss though granite may also be present (Conley 1978; Conley 1985; Rader and Evans 1993; De Lore 1998; Bailey 1999; Roberts and Bailey 2003). Investigations of soils at BOWA confirm the presence of such felsic crystalline rocks in the region as well as demonstrate the paucity of rock exposures at BOWA (Hendrick 1978). Soils at the monument and throughout Franklin County additionally contain economically important concentrations of mica that eroded from local Precambrian sections (Brown 1962).

The geologic map of the Roanoke quadrangle more clearly describes the underlying bedrock located at BOWA. Formations mapped within the park include the Ashe Formation and Alligator Back Formation of the Late Proterozoic Lynchburg Group as well as a Fries Thrust Sheet Amphibolite of perhaps slightly younger age (Henika 1992, 1997). These deposits are approximately 750 million years old and are the result of Iapetan rifting as the megacontinent Rodinia split into Laurentia and Gondwana (Dalziel 1995). The Ashe Formation is primarily composed of biotite gneiss and schist covering the southeastern half of BOWA. These are the oldest rocks mapped within park boundaries. Laminated mica gneiss (metagraywacke) of the overlying Alligator Back Formation is only known from a small area in the northwestern corner of the monument. The final section encompassed by BOWA is a dark green to black amphibolite that diagonally cuts through the center of the park in a southwesterly direction (Henika 1997). None of these formations are known to be fossiliferous within the park or elsewhere. The potential for paleontological finds at Booker T. Washington National Monument in the future is weak given the limited exposure of rocks within park boundaries as well as their complex metamorphic history unsuitable for fossil preservation.

REFERENCES CITED

Bailey, C. M. 1999. The geology of Virginia – Piedmont province. Department of Geology, The College of William and Mary. (http://www.wm.edu/geology/virginia/piedmont.html)

Brown, W. R. 1962. Mica and feldspar deposits of Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Mineral Resources Report 3. 195 pages.

Conley, J. F. 1978. Geology of the Piedmont of Virginia – interpretation and problems. Pages 115-149 *in* Contributions to Virginia Geology III. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 7.

Conley, J. F. 1985. Geology of the southwestern Virginia Piedmont: Virginia Division of Mineral Resources, Charlottesville, VA. Publication 59. 33 pages. 1:125,000 scale map.

Dalziel, I. W. D. 1995. Earth before Pangea: The North American continent may be more nomadic than any of its inhabitants. Scientific American **272**(1). Page 60.

De Lore, S. D. 1998. Geophysical investigations of the three areas within the boundaries of Booker T. Washington National Monument, Franklin County, VA. Intermountain Region Archaeological Project Report. Booker T. Washington National Monument, Hardy, VA. 36 pages.

Fenneman, N. M. 1938. Physiography of the Eastern United States. McGraw-Hill Book Company, New York. 714 Pages.

Hendrick, S. 1978. This is Your Soil and Water Conservation Plan. Booker T. Washington National Monument. Blue Ridge Soil and Water Conservation District, Virginia. 21 pages.

Henika, W. S. 1992. Stratigraphy of the eastern Blue Ridge sequence in the Roanoke 30 x 60 minute quadrangle, Virginia. Geological Society of America Abstracts with Programs **24**(2):21.

Henika, W. S. 1997. Geologic map of the Roanoke 30 x 60 minute quadrangle. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 148. 1:100,000 scale map.

Rader, E. K. and N. H. Evans, editors. 1993. Geologic map of Virginia and expanded explanation. Virginia Division of Mineral Resources, Charlottesville, VA. 80 pages. 1:500,000 scale map.

Roberts, C. and C. M. Bailey. 2003. The geology of Virginia – Historic places. Department of Geology, The College of William and Mary. (http://www.wm.edu/geology/virginia/piedmont.html)

Additional References

Bartholomew, M. J. 1981. Geology of the Roanoke and Stewartsville quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 34. 23 pages. 1:24,000 scale map.

Berquist, C. R., Jr. 1988. Geology of the Sandy Level and Callands quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 77. 1:24,000 scale map.

Campana, D. V. and D. G. Orr. 1985. Booker T. Washington National Historic Site Archeological Resistivity Survey. Archeological Field Report No. 3. Division of Archeology, Mid-Atlantic Region, National Park Service, Philadelphia.

Cecil, K. K., R. C. Whisonant, and P. S. Sethi. 2000. Teacher's guide for the geology of Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. 132 pages.

Conley, J. F. 1987. Mafic rocks in the Alligator Back Formation, the upper unit of the Lynchburg group, in the southwestern Virginia piedmont. An ophiolite sequence. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 74. Pages 55-68.

Conley, J. F. and W. S. Henika. 1973. Field trip across the Blue Ridge anticlinorium, Smith River allochthon, and Sauratown Mountains anticlinorium near Martinsville, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Virginia Minerals **19**(4). Pages 37-44.

Conley, J. F., J. D. Marr, Jr., and C. R. Berquist, Jr. 1981. Stratigraphic relationships between rocks of the Blue Ridge anticlinorium and the Smith River allochthon in the southwestern Virginia Piedmont. Virginia Division of Mineral Resources, Charlottesville, VA. Annual Virginia Geology Field Conference 13. 34 pages.

Cook, F. A., L. D. Grown, and J. E. Oliver. 1980. The southern Appalachians and the growth of continents. Scientific American 243. Pages 156-168.

Dietrich, R. V. 1990. Geology and Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. 213 pages.

Henika, W. S., J. Beard, R. Tracy, and J. R. Wilson. 2000. Structure and Tectonics Field Trip to Eastern Blue Ridge and Western Piedmont near Martinsville, Virginia. (Modified from Virginia minerals **46**(3). Pages 17-32). (http://www.geology.state.va.us/Pub/VAMINS/v46no3/vamin463.htm).

Hibbard, J., K. G. Stewart, and W. S. Henika. 2001. Framing the Piedmont zone in North Carolina and Virginia. Pages 1-26 *in* C.W. Hoffman, editor. Field Trip Guidebook for the 50th annual meeting of the Southeastern Section of the Geological Society of America, Raleigh, NC.

Marr, J. D., Jr. 1984. Geologic map of the Pittsville and Chatham quadrangles, Virginia. Virginia Division of Mineral Resources. Charlottesville, VA. Publication 49. 1:24,000 scale map.

McCollum, M. B. 1990. Geologic map of the Rocky Mount and Gladehill quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 90. 1:24,000 scale map.

Pavlides, L. 1989. Early Paleozoic composite mélange terrane, central Appalachian Piedmont, Virginia and Maryland; its origin and tectonic history. Pages 135-193 *in* J.W. Horton, Jr. and N. Rast, editors. Geological Society of America Special Paper 228.

Pfaff, L. J. 2004. Tectonics of the Blue Ridge Mountain Province. Emporia University, Kansas. (http://www.emporia.edu/earthsci/student/pfaff1/Blue_Ridge2.htm).

Rankin, D. W. 1970. Stratigraphy and structure of Precambrian rocks in northwestern North Carolina. Pages 227-245 *in* G. W. Fisher, F. J. Pettijohn, J. C. Reed, Jr., and K. N. Weaver, editors. Studies of Appalachian geology - central and southern. Interscience, New York.

Rankin, D. W., G. H. Espenshade, and K. W. Shaw. 1973. Stratigraphy and structure of the metamorphic belt in northwestern North Carolina, and southwestern Virginia: a study from the Brevard fault zone to the Sauratown Mountains anticlinorium. American Journal of Science. Cooper Volume 273-A. Pages 1-40.

Sethi, P. S., R. C. Whisonant, K. K Cecil, and P. L. Newbill. 2000. Geology of Virginia: Piedmont and Blue Ridge. (CD-ROM #3). Virginia Division of Mineral Resources, Charlottesville, VA. 2 CD-ROMs.

EISENHOWER NATIONAL HISTORIC SITE

Eisenhower National Historic Site (EISE) is located adjacent to Gettysburg National Military Park (see GETT section) in southeastern Pennsylvania. The site was established on November 27, 1967 to preserve President Dwight D. Eisenhower's home where he vacationed while serving as President and retired to after his term in office. The park includes 690 acres of historic structures, agricultural fields, and small patches of forest. The resources management staff of GETT is also responsible for EISE.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geological scoping sessions, sponsored by the Geologic Resources Division, were held in 2004 in conjunction with the scoping session for Gettysburg National Military Park. There have been no formal paleontological inventories completed for EISE and there are no paleontological specimens in EISE museum collections. Fossils are not yet known from within the park.

As the park is immediately adjacent to Gettysburg National Military Park, the underlying stratigraphy is the same, consisting primarily of the shales and sandstones ("red beds") of the Late Triassic Gettysburg Formation. Dikes of the Jurassic York Haven diabase cut through the shale layers, creating topographic highs and narrow stream valleys where the dikes are present.

The Gettysburg Formation is fossiliferous and has produced microfossils, invertebrates, plants and various invertebrate and vertebrate trace fossils. The York Haven diabase is an igneous rock and does not preserve fossils. The GETT section of this report has more extensive information and a bibliography regarding the geology and paleontology of the Gettysburg Formation.

There are very limited exposures of the Gettysburg Formation within EISE as most of the park is vegetated and has minimal topographic relief (Z. Bolitho, personal communication, 2005). This limits the potential for future discovery within the park, although an initial investigation of Gettysburg Formation exposures (if any) within EISE would be recommended.

FREDERICKSBURG AND SPOTSYLVANIA NATIONAL MILITARY PARK

Fredericksburg and Spotsylvania National Military Park (FRSP) encompasses four Civil War battlefields (Fredericksburg, Chancellorsville, Wilderness, and Spotsylvania Court House) as well as four associated historic landmarks (Chatham, Salem Church, Ellwood, and the house wherein Stonewall Jackson died). These battlefields represent the bloodiest landscape in North America as suffered by more than 85,000 wounded and at least 15,000 killed. Park grounds cover approximately 8,535 acres and collectively exhibit the struggles of a divided nation that upon reunion freed four million Americans. The establishment of Fredericksburg and Spotsylvania National Military Park occurred on February 14, 1927. The park was transferred from the War Department to the NPS on August 10, 1933.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

The NPS Geologic Resources Division sponsored geologic scoping sessions for Fredericksburg and Spotsylvania National Military Park in 2005. No formal paleontological resource inventories have been completed for FRSP and no fossil specimens exist in park collections. There are no records of paleontological discoveries inside park boundaries; however, fossiliferous material is abundant in localities near FRSP indicating the strong potential for future paleontological finds at the park.

Fredericksburg and Spotsylvania National Military Park incorporates pieces of land from Caroline County, Orange County, Spotsylvania County, Stafford County, and the city of Fredericksburg. This extensive geographic range allows for a unique geologic setting whereby the park covers portions of two physiographic provinces. The Piedmont province is characterized by igneous and metamorphic rocks that are generally poorly fossiliferous. These ancient rocks are economically important, however, as evidenced by the presence of zinc, lead, copper, gold, and diamonds at nearby localities (Lewis 1830; Lonsdale 1927; Poole 1974; Sweet 1975; Pavlides et al. 1982; Sweet and Trimble 1983; Sweet 1997). The fossiliferous sections mapped at the park primarily belong to the younger Coastal Plain province. These loosely consolidated sediments represent a variety of marine through freshwater paleoenvironments more suitable for fossil preservation. These sediments are also economically valuable containing diatomaceous clay and aquifers (Mixon et al. 2000). The boundary between the Piedmont and Coastal Plain provinces is called the Fall Line and roughly corresponds to the path along Lee Drive inside park limits, or Interstate 95 along much of the east coast. The topographical differences resulting from these physiographic provinces played an important role in Civil War military tactics and the outcome of several battles around Fredericksburg as discussed by Campbell (1940), Poole (1947), Ehlen and Abrahart (2002), Sherwood and Flora (2002), Ehlen (2004), and Whisonant et al. (2004).

There are 21 different stratigraphic units mapped in the areas encompassed by Fredericksburg and Spotsylvania National Military Park (Mixon et al. 2000). The Piedmont province includes the Po River Metamorphic Suite, Ta River Metamorphic Suite, Chopawamsic Formation, Mine Run Complex, Quantico Formation, Falls Run Granite Gneiss, and several other unnamed metamorphic layers therein. The Coastal Plain province at FRSP comprises the Potomac Formation, Aquia Formation, Calvert Formation, deposits equivalent to the Yorktown Formation, Moorings Unit, Charles City Formation, Windsor Formation, and a few unnamed sand and gravel deposits as well as alluvium from the Tertiary and Quaternary periods. These stratigraphic units are divided by physiographic province in the following section and further information is provided for fossiliferous formations.

<u>Piedmont Province</u>

Proterozoic-Cambrian-Ordovician metamorphic rock assemblages
The oldest rocks mapped at FRSP belong to the Po River Metamorphic Suite of Late Proterozoic or early Paleozoic age. Biotite gneiss and schist comprise these rocks that are underlain near the Spotsylvania Court House Battlefield (Mixon et al. 2000). The Ta River Metamorphic Suite of Cambrian age constitutes amphibolitic gneiss and is mapped in areas encompassed by Chancellorsville and Spotsylvania

Court House Battlefields (Mixon et al. 2000). The Chopawamsic Formation consists of Cambrian metavolcanic and metasedimentary lenses and stretches across land enclosed by the Battlefields at Wilderness and Chancellorsville (Mixon et al. 2000). There are no records of paleontological discoveries specific to this unit; however fossils are mentioned as part of an investigation of Southern Appalachian terranes including the Chopawamsic Formation (Secor 2000). The next youngest sequence mapped at FRSP incorporates a mixture of phyllite, schist, tonalite, and granodiorite that comprise the Mine Run Complex derived during the Cambrian or Ordovician. These phyllite mélange ("rock mixture") zones are known from the northwestern region of the Wilderness Battlefield (Mixon et al. 2000) and are not fossiliferous. The final non-fossiliferous unit of the Piedmont province mapped at Fredericksburg and Spotsylvania National Military Park is the Silurian Falls Run Granite Gneiss, a hornblende and biotite granitic gneiss overlain by the land at the Spotsylvania Court House Battlefield (Mixon et al. 2000). These five igneous and metamorphic units are not documented as fossiliferous and the potential for future paleontological finds in these sections is minimal.

Quantico Formation (upper Ordovician)
The Quantico Formation is the only known fossiliferous section of the Piedmont province mapped at FRSP. These rocks are primarily composed of phyllite and schist, but calc-silicate layers are locally present (Mixon et al. 2000). The formation is mapped at the Chancellorsville and Spotsylvania Court House Battlefields. Though no fossils are known from the Quantico Formation at FRSP, paleontological specimens of this age are recorded elsewhere in Virginia. Watson and Powell (1910) collected fossils in the Quantico Formation near Powells Creek that included a linguloid shell and examples of a pelecypod bivalve closely related to *Pterinea* of Ordovician age. Unfortunately, the original fossil collection is missing and the locality is presumed to be covered by road fill under I-95 near Prince William Forest Park, Virginia (Bassler et al. 1980). This lack of evidence as well as the discovery of pseudofossils in the area led some to dispute the age of these rocks as well as the presence of fossils in the Quantico Formation. However, recent paleontological discoveries of crinoids and a cephalopod in Dale City have reaffirmed the Ordovician age and presence of fossils in these rocks (Pavlides et al. 1980). Fossils in the Quantico Formation are extremely rare; nonetheless indicate the potential for future paleontological finds at FRSP.

Coastal Plain Province

There are a variety of Coastal Plain sediments mapped at Fredericksburg and Spotsylvania National Military Park. Most of these formations contain paleontological resources and are individually discussed in detail. Others deposited in similar paleoenvironments offer the potential for paleontological finds even though they are not characterized by fossils. These include the Pliocene Moorings Unit, unnamed sand and gravel units of the Miocene and Pliocene as well as Quaternary alluvial deposits. Many of these geologic formations are also exposed in NPS units of the National Capital Region (Kenworthy and Santucci 2004).

Potomac Formation (Lower Cretaceous)
Chatham and the Fredericksburg Battlefield are partially underlain by the Potomac Formation (Mixon et al. 2000), a series of clays and sands that represent a variety of fluvial and deltaic paleoenvironments including braided streams, river channels, floodplains, swamps, marshes, and abandoned channels (Glaser 1969, 1976, 2003). Sediments that comprise this unit are often collectively referred to as the Potomac Group encompassing (oldest to youngest) the Patuxent Formation, Arundel Clay, and Patapsco Formation. These divisions are not noted on the geologic map of the Fredericksburg quadrangle as many of the Cretaceous deposits in Virginia are not distinguishable at this formational level (Seiders and Mixon 1981; Meng and Harsh 1988; Drake and Froelich 1986). However, a brief review of these individual units and their paleontological significance is provided.

The Patuxent Formation has a history of freshwater and terrestrial fossils including pollen, ferns, horsetails, cycads, conifers, clams, and fish (Clark et al. 1911; Little 1917; Cooke 1952; Johnston 1962; Brenner 1963). The overlying Arundel Clay is renowned for its vertebrate faunas, especially dinosaurian material uncovered in Maryland and Washington D.C. as summarized by Carr (1950), Weishampel and

Young (1996), Lipka (1998), and Kranz (1989, 1996, 1998, 2003). Many of these fossils are extremely significant as they represent initial dinosaur discoveries of the United States before westward expansion. Other fossils uncovered in the Arundel Clay incorporate pollen, plants, freshwater mollusks, fish, amphibians, crocodiles, turtles, birds, small mammals, and vertebrate tracks preserved in iron nodules (Clark et al. 1911; Carr 1950; Kranz 1998; Cifelli et al. 1999; Rose et al. 2001). The most important fossils from the Potomac Group comprise angiosperm pollen and leaves that provide insight to the radiation of these flowering plants during the Cretaceous. The Patapsco Formation contains 25 different angiosperm species, lignitized stems and twigs, leaf and frond impressions, and pollen from ferns, horsetails, cycads, and conifers (Clark et al. 1911; Carr 1950; Cooke 1952; Johnston 1962; Glaser 1969). The Potomac Group flora and associated sedimentological features provide the longest and most complete record of early angiosperm evolution in the United States (Hickey 1984). More information on the early radiation of angiosperms can be obtained from the Additional References section of this report.

Though Mixon et al. (2000) and the U.S. Geological Survey do not differentiate the Patuxent Formation, Arundel Clay, and Patapsco Formation in Virginia, sedimentological facies are listed instead. Type I sediment consists of fine to coarse feldspar-rich quartz sand and sandstone that is poorly sorted and contains a large percentage of clay and silt. These gray to pinkish gray sediments are interpreted as channel-lag and channel-bar or point-bar deposits and commonly contain intraformational conglomerates of pebble-sized clay and silt clasts. Type II sediment is characterized by silty and sandy clay, clayey silt, and clayey fine sand of greenish gray color (Mixon et al. 2000). The frequent occurrence of clay-silt "plugs" in this layer is believed to be a result of abandoned stream channels filled by fine sediments during flood stages. Both of the above sedimentary facies locally contain coalified plant stems and the rare presence of silicified trunks of large coniferous trees (Mixon et al. 2000). Type III sediment comprises dark yellowish-brown to olive-gray, lignitic sandy silt, clay, and silty fine sand and sandstone. Leaf and stem impressions of ferns, cycads, and other gymnosperms are often well-preserved in this point bar and swampy flood plain deposit.

No paleontological resources are currently known from the Potomac Formation inside park boundaries, but strong potential exists for future finds as indicated by the diversity and abundance of local fossils. Pollen and leaf analyses from the map area confirm the presence of fossils near FRSP as do reports of abundant carbonized plant fragments and less common stem and leaf impressions of ferns, cycads, confers, and flowering plants (Mixon et al. 2000). Other reports of floral assemblages from the Fredericksburg region are published by Fontaine (1889), Berry (1910), Berry (1911), Hughes and Moody-Stuart (1966), Doyle and Hickey (1972, 1976), Hickey and Doyle (1977), Doyle and Robbins (1977), Reinhardt et al. (1980), Skog (1988) and Upchurch et al. (1994). Some of these localities are no longer in existence (Fontaine 1889; Doyle and Hickey 1976; Skog 1988), but specimens from these sites maintain their importance as new species in the collections at the Smithsonian National Museum of Natural History (Fontaine 1889) or in studies of angiosperm evolution (Doyle and Hickey 1972; Hickey and Doyle 1977). One notable fossiliferous locality within the map area is an abandoned sand and gravel pit immediately west of the Potomac River on Engineers Road (Mixon et al. 2000). Floral remains unearthed at this exposure comprise a horsetail, cycadophyte, nine conifer species, and 12 angiosperm species including an extinct relative of the water lotus (Upchurch et al. 1994).

Though Potomac Group sediments are notably fossiliferous, most vertebrate material has been uncovered from exposures in Maryland and Washington D.C. as previously mentioned. Recent discoveries of abundant fossil footprints at several localities in and around Fredericksburg, however, add 11 previously unrecognized fauna to the Patuxent Formation of Virginia (Weems and Bachman 2004). These ichnofossils suggest the presence of a frog, turtle, crocodile, and diverse dinosaurian assemblage composed of an ornithomimid, hypsilophodontid, hadrosaurid, sauropods, and iguanodontids in the region. Two of these dinosaur footprints may represent new ichnogenera and one of the sauropod footprints indicates the existence of the largest dinosaur from Virginia estimated at 21 m (70 ft) in length (Weems and Bachman 2004). The dominance of dinosaur footprints suggests that the coarse-grained sandstones of the Patuxent Formation at Fredericksburg are particularly favorable for dinosaur footprint preservation and not that of smaller animals (Weems and Bachman 2004). Other ichnofossils of the

Potomac Formation in Virginia comprise clay-filled, vertical to horizontal burrows possibly made by worms and root traces defined by radiating patterns of very small tubules (Reinhardt et al. 1980). Though fossils are not yet known from the Potomac Formation at Fredericksburg and Spotsylvania National Military Park, the abundance and diversity of floral and faunal remains in the region suggests strong future potential.

Potomac Formation: "Aquia Freestone" (Lower Cretaceous)
As a nomenclatural aside, the "Aquia Freestone" which was utilized within Fredericksburg Battlefield to construct the stone wall along Sunken Road (e.g. Flora and Sherwood 2001) is not from the Paleocene Aquia Formation described below. The "Aquia Freestone" is a trade name for building stones quarried from the Lower Cretaceous Potomac Group, described above. One interesting local exposure of the Potomac Group "Aquia Freestone" inside park boundaries is that of the stone wall along Sunken Road at Fredericksburg Battlefield. Flora and Sherwood (2001) report that the "Aquia Freestone" is the dominant rock type of that landmark and that the source rock used to build the wall was likely obtained from nearby quarries. Several abandoned quarries of the Potomac Group "Aquia Freestone" can be found within 3 km (2 miles) of Sunken Road. Though no paleontological resources are mentioned in the report by Flora and Sherwood (2001), fossiliferous material may be visible on wall surfaces and should be investigated.

Pamunkey Group: Aquia Formation (upper Paleocene)
The Paleocene glauconitic quartz sands of the Aquia Formation are mapped at the Fredericksburg Battlefield (Mixon et al. 2000). These olive gray to greenish black sands commonly contain sections of sandy and shelly limestones dominated by shallow marine molluscan faunas. Clark and Martin (1901) divided the Aquia Formation into the Piscataway Member and the Paspotansa Member, both of which are fossiliferous throughout the Coastal Plain. The older Piscataway Member is characterized by poorly sorted silty sands, *Ophiomorpha* burrows, and large bivalves including *Cucullaea gigantea, Ostrea alepidota, Crassatellites* sp., and *Dosiniopsis* sp. (Mixon et al. 2000 lists data from Ward 1984, 1985). The younger Paspotansa Member consists of moderately sorted sand that is less clayey and shelly than the lower Aquia, but commonly contains *Turritella mortoni*, *Ostrea sinuosa, Crassatellites alaeformis,* and *Cucullaea* sp. (Mixon et al. 2000). Maximum thickness for the Aquia Formation is 35 m (115 ft) and evidence from microfossils (forams, dinocysts, nannofossils, pollen) and mollusks support a late Paleocene age (Ward 1984, 1985).

No paleontological specimens are reported from this formation inside park boundaries as of yet; however neighboring areas are known for a variety of marine fossils from this stratigraphic unit. Slightly northeast of FRSP at Belvedere Beach in King George County, exposures near the Potomac River contain abundant *Turritella mortoni*, a high-spired gastropod frequently found in Paleocene sediments (Andrews 1974). Though molds and casts are often all that remains of shell concentrations in the Aquia Formation, Belvedere Beach is revered as one of the best sites for high quality preservation (Ward and Waller 1988). One remarkable discovery at this fossiliferous location is that of new bivalve species, *Pulvinites lawrencei*. This specimen had been preserved inside the closed valves of an oyster, *Ostrea sinuosa*, and is the only known member of *Pulvinitidae* in the Tertiary on either side of the Atlantic (Ward and Waller 1988). Molluscan faunas not previously mentioned that are often observed in the Aquia Formation of Virginia include *Pitar pyga, Pycnode* sp., *Venericardia regia*, and *Turritella humerosa* (Ward and Waller 1988; Ward and Powars 2004). Other fossiliferous sections of the Aquia Formation in the vicinity of Fredericksburg and neighboring counties are listed in Ward (1985).

Mollusks may be the most abundant fossils reported in the Aquia Formation; however other paleontological resources are frequently found as well. These fossils consist of foraminifera (Nogan 1962, 1964), ray and shark teeth (Clark and Martin 1901; Case 1989; Ward and Weist 1990), marine fish and crocodiles (Kranz and Santucci 2004), sea turtles (Weems 1988), birds (Olson 1994), and terrestrial mammals (Rose 2000). Other unique specimens comprise dinoflagellates and dinocysts including several from localities near FRSP in Stafford County (McLean 1972, 1974) and Caroline County (Edwards 1983).

The history of the Aquia Formation is extensive and most early paleontologists believed that these diverse assemblages existed during the Eocene. Later, paleontologists recognized the Paleocene age of these fossil assemblages. Summaries of 19th century reports are available through Clark and Martin (1901) and many of these papers are listed in the Additional References section of this report. These authors comment on the geology and paleontology of the Aquia Formation in Maryland and Virginia prior to stratigraphically placing the unit in the Paleocene. More recent summaries of the Aquia Formation are provided by Beauchamp (1984), Ward (1985), and Ward and Powars (2004). For more information on the history of the Aquia Formation and the importance of various localities in NPS areas outside of the Fredericksburg region refer to Kenworthy and Santucci (2004). Though no paleontological resources are yet known from FRSP, future finds in the Aquia Formation are highly probable.

Chesapeake Group: Calvert Formation (lower and middle Miocene)
The Stonewall Jackson Shrine and Fredericksburg Battlefield are partially underlain by the notably fossiliferous Miocene Calvert Formation (Mixon et al. 2000). Though characterized by very fine to fine quartz sands, this formation contains varying concentrations of silt and clay including diatomaceous layers. External molds of marine mollusks are locally common and other paleontological resources in the area may include fish teeth, fish scales, lignitized wood, silicoflagellates, dinocysts, and marine vertebrate bones. The Calvert Formation in this region extends up to 40 m (131 ft) and is divided outside of park boundaries into the Fairhaven, Plum Point Marl, and Calvert Beach Members (Ward 1992; Mixon et al. 2000).

The Calvert Formation is extremely fossiliferous throughout the Coastal Plain, but the most renowned localities are along the cliffs of Calvert County, Maryland. These wave-eroded bluffs have been a prominent source of fossil material for over one hundred years (Shattuck 1902, 1904) and continue to produce an array of paleontological resources such as abundant and diverse mollusks, shark teeth, and marine mammals. Over four hundred species of mollusks are known from these cliffs (McLennan 1973) and species frequently observed in Virginia sections of the Calvert Formation include *Chesapecten coccymelus, Crassatella melinus,* and *Ecphora tricosta* (Ward 1992; Mixon et al. 1989). Though some of the most spectacular molluscan assemblages in the fossil record are preserved at Calvert Cliffs, the majority of fossils collected from these beaches comprise shark teeth. Dominant genera represented in the Calvert Formation along the cliffs encompass *Carcharhinus* spp., *Isurus* spp., *Carcharias* spp., *Galeocerdo* spp., *Carcharocles* sp., and *Hemipristis serra* (Visaggi and Godfrey, in preparation; L. Ward, personal communication, 2006). Other marine faunas such as cetaceans and sirenians are commonly reported from the cliffs (Gottfried et al. 1994) and land mammals composed of mastodons, rhinos, horses, and dogs are also occasionally found (McLennan 1973). Plants derived from the Calvert consist of *Quercus* spp. (oak), *Ulmus* sp. (elm), *Pieres* sp. (fetterbrush), *Vaccinium sp.* (blueberry), *Berchemia* sp. (supplejack), *Phyllites* sp. and *Ilex* sp. (holly), *Caesalpina* sp. and *Cassia* sp. (bean leaves), and *Rhus* sp. (sumac) as listed by Carr (1950). Microfossil assemblages contain a high diversity of diatoms (Andrews 1985; Mixon et al. 1989) including local *Rhaphoneis diamantella* of stratigraphic significance (Andrews 1988) and ubiquitous foraminifera in Virginia comprise genera *Siphogenerina* and *Uvigerina* (Teifke 1973). More on the geology and paleontology of the Calvert Formation is summarized by authors Clark et al. (1904), Blackwelder and Ward (1976), Ward and Strickland (1985), Vogt and Eshelman (1987), Purdy (1990), Ward (1992), Ashby (1995), and Ward and Powars (2004).

There are no reports of paleontological finds in the Calvert Formation at FRSP; however the rich fossil record of this stratigraphic unit indicates the prospect for future discoveries. One exposure of the Calvert located halfway between Fredericksburg and Richmond in Carmel Church has produced a plethora of fossiliferous material including a new species of baleen whale (Dooley et al. 2004). The faunal list at this locality incorporates cetaceans (e.g., *Diorocetus, Hadrodelphis*), sharks (e.g., *Odontaspis, Carcharias, Isurus, Galeocerdo, Hemipristis, Notorynchus*), bony fish (e.g., *Mola, Tautoga, Pogonias*), sirenians, seals, crocodiles, turtles, pelagic birds, and terrestrial mammals (Dooley 1993; Fraser and Dooley 2000). Andrews (1985) notes a diverse diatom assemblage as well. Though this locality at Carmel Church Quarry contains an array of fossiliferous formations (Marr and Ward 1993), recent excitement involves the new species of baleen whale, *Eobalaenoptera harrisoni*, unearthed in the Calvert Formation. The emergence of

many modern mysticetes (baleen whales) and the decline of an extinct group of related mysticetes (cetotheres) occurred sometime during the Miocene (Fordyce and Barnes 1994; Gottfried et al. 1994; Whitmore 1994; Messenger and McGuire 1998). The shift in cetacean (whale) dominance may be associated with changes in sea temperature and ocean currents, but more research is needed (Fordyce 1980, 1992; Fordyce and Barnes 1994; Gottfried et al. 1994; Whitmore 1994; Geisler and Luo 1996). This new partially articulated skeleton is the oldest known member of its clade by several million years and extends the fossil record of this group closer to divergence times estimated by some molecular analyses (Dooley et al. 2004). One other recent unique whale discovery occurred on NPS land at Suitland Parkway during a Metrorail expansion. More on this amazing find is discussed in a paleontological report of the National Capital Region by Kenworthy and Santucci (2004). Like the discovery along Suitland Parkway, paleontological resources within Fredericksburg and Spotsylvania National Military Park may not be accessbile except during future construction or excavations.

Deposits equivalent to the Yorktown Formation (lower and upper Pliocene)
Marine, marginal-marine, and fluvial-deltaic deposits that are equivalent to the Yorktown Formation are mapped in a very small area at the southern end of Fredericksburg Battlefield (Mixon et al. 2000). These beds are composed of light to dark gray or blue gray sand and gravel that ranges in thickness from 3 m up to 25 m (10-82 ft) in southeastern Caroline County (Mixon et al. 1994). The deposits are considered "equivalent" to the Yorktown Formation because of similar lithology and stratigraphic level. However, their definitive correlation with well-defined beds of the Yorktown Formation has not been adequately shown (L. Ward, personal communication, 2006). The Yorktown Formation is renowned for its fossiliferous sections in southeastern Virginia, but locally contains shell concentrations and *Ophiomorpha* burrows likely made by a relative of the modern ghost shrimp *Callinassa major* (Frey et al. 1978; Mixon et al. 1992; Mixon et al. 2000).

No fossils are reported from these Yorktown-equivalent deposits at Fredericksburg and Spotsylvania National Military Park. Though the Yorktown Formation is extremely fossiliferous throughout the Coastal Plain, the small section mapped at FRSP limits the potential for future discoveries. Nonetheless, extensive paleontological resources exist in the Yorktown Formation, many of which have been useful in recent ecological, evolutionary, and isotopic investigations (Campbell 1976; Krantz 1990; Daley 1998; Daley 1999; Baugh and Lockwood 2003; Blow and Bailey 2003; Lockwood and Baugh 2003; Dietl and Kelley 2004; Tolcin and Lockwood 2004). Yorktown faunal assemblages comprise whales (Johnson 1972; Baum and Wheeler 1977; Whitmore 1994; Westgate and Whitmore 2002), walrus (Berry and Gregory 1906), fish (McLean 1956; Johnson 1972), cephalopod statoliths (Sabol 1960; Clarke and Fitch 1975), crabs (Blow 2003; Blow and Bailey 2003), gastropods (Twardy 1936; McLean 1956; Campbell 1993; Ward 1993; Tolcin and Lockwood 2004), and pelecypods (McGavock 1935, 1944; McLean 1956; Cecca 1982; McKeever 1985; Campbell 1993; Ward 1993; Blow and Bailey 2003). Other marine fossils include coral and sponge spicules (Sabol 1960; Johnson 1972), scaphopods (Johnson 1972), brachiopods (Johnson 1972; Ward 1993), bryozoans (McLean 1956; Sabol 1960; Johnson 1972), echinoids (McLean 1956; Johnson 1972; Kier 1972), barnacles (Sabol 1960; Ross 1964; Johnson 1972; Ward 1993), annelids (Johnson 1972), ostracodes (Schmidt 1939; McLean 1957, 1966; Hazel 1971), and foraminifera among other microfauna (McLean 1956, 1966; Gibson and Bybell 1984; Cronin et al. 1989; Dowsett and Wiggs 1992). Most Yorktown exposures are located in southeastern Virginia near the James and York Rivers; however sections from areas near Fredericksburg and adjacent counties are documented (Newell 1978; Marr and Ward 1987; Mixon et al. 1994). More on the Yorktown Formation is discussed in the chapter on Petersburg National Battlefield as only a small portion of this unit is mapped at FRSP limiting the potential for fossil discoveries.

Windsor Formation (upper Pliocene or lower Pleistocene)
The Windsor Formation comprises sand and gravel of high-level terraces in northern Caroline County and eastern Spotsylvania County (Mixon et al. 2000). The lower member of this formation contains layers of silt and cross-bedded sand and the upper member ranges among silty-clay, sandy-silt, and clayey sand (Johnson 1972). The only *in situ* fossils recorded for the Windsor Formation are vertical knobby burrows similar to those formed by the modern ghost shrimp, *Callianassa major* (Johnson 1972). The molds of

several molluscan faunas have been found in goethite, hematite, and limonite of the lower member; however these are likely mollusks reworked from the Yorktown Formation (Johnson 1972). Pollen assemblages documented for the Windsor Formation are listed in Groot et al. (1990). Though fossiliferous material may occur in the Windsor Formation, poor exposures in the map area are not favorable for paleontological finds and in fact may represent the stratigraphically lower Moorings Unit of Pliocene age instead (Mixon et al. 2000). The Moorings Unit described by Oaks and Coch (1973) exists primarily as a surficial deposit and is not documented as fossiliferous. This sand and gravel unit is mapped inside park boundaries at the northwestern corner of Fredericksburg Battlefield near the National Cemetery. The Stonewall Jackson Shrine overlies the only sediments categorized as the Windsor Formation at FRSP.

Charles City Formation (lower Pleistocene)
This upward-fining sequence consists of gravelly sand that grades into moderately well sorted sand, silt, and clay and comprises nearly the entire area underlain by Chatham and parts of the Fredericksburg Battlefield (Mixon et al. 2000). The presence of small abundant invertebrate burrows suggests an estuarine paleoenvironment as exposed at localities along the Potomac River (Mixon et al. 2000). Fossils in other outcrops of this formation are not documented other than pollen assemblages (Groot et al. 1990), but may exist based on the depositional environment. There are no records of paleontological resources uncovered in the Charles City Formation at FRSP; however the presence of ichnofossils at nearby exposures along the Potomac River offer some potential for future finds.

Surficial Deposits (Quaternary)
Nearly all of battlefields and landmarks at Fredericksburg and Spotsylvania National Military Park are underlain by Quaternary alluvial deposits (Mixon et al. 2000). Salem Church is the only exception. Pleistocene alluvial terrace deposits are mapped at Stonewall Jackson Shrine and are characterized by poorly exposed sediments that range in size. These surficial deposits can be found along the Poni and Mattaponi Rivers as well as their tributaries in Caroline County, Virginia (Mixon et al. 2000). Holocene alluvium is present in areas encompassed by the Wilderness, Chancellorsville, Spotsylvania Court House, and Fredericksburg Battlefields as well as the Stonewall Jackson Shrine. This recent unit deposited in channel, point-bar, and flood plain paleoenvironments grades into colluvium along steeper valley walls (Mixon et al. 2000). Paleontological resources are not likely to be preserved in either of these alluvial deposits; however eroded fossils from older units may end up in these surficial deposits as a result of flood plain events. Cambrian *Skolithos* and Devonian brachiopods that eroded out of outcrops over 100 km (62 miles) west of the Fall Line are documented in Piedmont gravels north of FRSP at Pohick Creek (Galvin 2004) and diamonds derived from the Blue Ridge and Valley and Ridge provinces are often discovered in Quaternary alluvium having been removed from their original bedrock source (Sweet 1997). Fossils buried in earlier sediments may similarly end up in alluvial deposits of the Pleistocene and Holocene.

Paleontological Resource Potential and Monitoring
The array of fossiliferous sections mapped at Fredericksburg and Spotsylvania National Military Park offer the potential for numerous future paleontological discoveries. The geology of the region also suggests that the influence of natural hazards should be considered in the preservation of fossiliferous exposures. Not only do the Chopawamsic, Long Branch, and Spotsylvania thrust faults run through land encompassed by FRSP (Mixon et al. 2000), but floods and earthquakes are historically common as well (Bollinger 1971; Dodd et al. 1995; McConnell and Ulrich 1995). These catastrophes can inflict damage on fossiliferous exposures including sediment destabilization and erosion, but such natural processes may also unearth otherwise buried specimens. Periodic monitoring of any fossiliferous outcrops at FRSP would be recommended. The discovery of paleontological resources contained in fossiliferous strata overlain by park landmarks, however, might only occur as a result of excavation during archaeological surveys or park development.

REFERENCES CITED

Andrews, H. E. 1974. Morphometrics and functional morphology of *Turritella mortoni*. Journal of Paleontology **48**(6):1126-1140.

Andrews, G. W. 1985. Unpublished report on diatoms of the Carmel Church Quarry. U.S. Geological Survey, Reston, VA. Examine and Report on Referred Fossils (E&R) Report. 1 page.

Andrews, G. W. 1988. A revised marine diatom zonation for Miocene strata in the southeastern United States. U.S. Geological Survey, Reston, VA. Professional Paper 1481. 29 pages.

Ashby, W. L. 1995. Fossils of Calvert Cliffs. Calvert Marine Museum Press, Solomons, MD. 20 pages.

Bassler, R. S., L. Pavlides, J. Reinhardt, A. R. Bobyarchick, J. Pojeta, Jr., M. Gordon, Jr., and R. L. Parsley. 1980. Ordovician age of the Quantico Formation reaffirmed. U.S. Geological Survey, Reston, VA. Professional Paper 1775. Pages 72-73.

Baugh, H. L. and R. Lockwood. 2003. Does abundance promote survivorship during background extinction intervals? A case study using bivalve species from the Yorktown Formation. Geological Society of America Abstracts with Programs **35**(1):69.

Baum, G. R. and W. H. Wheeler. 1977. Cetaceans from the St. Mary's and Yorktown Formations, Surry County, Virginia. Journal of Paleontology **51**(3):492-504.

Beauchamp, R. G. 1984. Stratigraphy and depositional environments of the Brightseat and Aquia formations Maryland and Virginia. Pages 78-111 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwest Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Berry, E. W. 1910. A revision of the fossil plants of the genera *Acrostichopteris, Toeniopteris, Nilsonia*, and *Sapindopsis* from the Potomac Group. Proceedings of the United States National Museum **38**:625-644.

Berry, E. W. 1911. A revision of several genera of gymnospermous plants from the Potomac group in Maryland and Virginia. Proceedings of the United States National Museum **40**:289-318.

Berry, E. W. and W. K. Gregory. 1906. *Prorosmarus alleni*, a new genus and species of walrus from the Upper Miocene of Yorktown, Virginia. American Journal of Science 21:444-450.

Blackwelder, B. W. and L. K. Ward. 1976. Stratigraphy of the Chesapeake Group of Maryland and Virginia; Field Trip Guidebook. 55 pages.

Blow, W. C. 2003. New brachyuran crabs (Crustacea, Decapoda) from the upper Pliocene Yorktown Formation of southeastern Virginia. Proceedings of the Biological Society of Washington **116**(1):168-189.

Blow, W. C. and R. H. Bailey. 2003. A late Pliocene pea crab infestation of the slipper-shell *Crepidula fornicate* (Linnaeus, 1758) from the Yorktown Formation of southeastern Virginia. Geological Society of America Abstracts with Programs **35**(6):58.

Bollinger, G. A. 1971. The Fredericksburg, Virginia earthquakes of September 12, 1971. Earthquake Notes **42**(3-4):29-32.

Brenner, G. J. 1963. The spores and pollen of the Potomac Group of Maryland. Maryland Geological Survey, Baltimore. Bulletin 27. 215 pages.

Campbell, H. D. 1940. Significance of geological features in Jackson's Valley campaign. Virginia Journal of Science **1**(2):40-45.

Campbell, L. D. 1976. Paleoecology of the Lone Star Industries pit, Yorktown Formation (Pliocene), Chuckatuck, Virginia. University of South Carolina, Columbia, SC. Unpubished PhD Dissertation. 198 pages.

Campbell, L. D. 1993. Pliocene Mollusks from the Yorktown and Chowan River Formations in Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 127. 259 pages.

Carr, M. 1950. The District of Columbia: Its rocks and their geologic history. U.S. Geological Survey, Reston, VA. Bulletin 967. 59 pages.

Case, G. R. 1989. *Palaeocarcharodon orientalis* (Sinzow) (Neoselachii: Cretoxyrhinidae) from the Paleocene of Maryland, USA. Palaeovertebrata **19**(1):1-6.

Cecca, C. L. 1982. *Ostrea* from the Eastover and Yorktown formations of southeastern Virginia. Virginia Journal of Science Abstracts **33**(3):153.

Cifelli, R. L., T. R. Lipka, C. R. Schaff, and T. B. Rowe. 1999. First Early Cretaceous mammal from the eastern seaboard of the United States. Journal of Vertebrate Paleontology **19**(2):199-203.

Clarke, M. R. and J. E. Fitch. 1975. First fossil records of cephalopod statoliths. Nature **257**:380-381.

Clark, W. B. and G. C. Martin. 1901. The Eocene deposits of Maryland. Pages 19-91 *in* Clark, W.B., editor. Eocene. Maryland Geological Survey, Baltimore. Systematic Report.

Clark, W. B., A. B. Bibbins, and E. W. Berry. 1911. The Lower Cretaceous deposits of Maryland. Pages 23-99 *in* C. Schuchert, C. K. Swartz, T. P. Maynard, and R. B. Rowe, editors. Lower Cretaceous. Maryland Geological Survey, Baltimore. Systematic Report.

Clark, W. B., C. R. Eastman, L. C. Glenn, R. M. Bagg, R. S. Bassler, C. S. Boyer, E. C. Case, C. A. Hollick, G. C. Martin, and T. W. Vaughan. 1904. Miocene. Maryland Geological Survey, Baltimore. Systematic Report. 507 pages.

Cooke, C. W. 1952. Sedimentary Deposits. Pages 1-52 *in* C. W. Cooke, R. O. R. Martin, and G. Meyer, editors. Geology and Water Resources of Prince George's County. Maryland Geological Survey, Baltimore. Bulletin 10.

Cronin, T. M., H. J. Dowsett, L. B. Gosnell, and R. M. Ross. 1989. Pliocene marine micropaleontology of southeastern Virginia and northeastern North Carolina. U.S. Geological Survey, Reston, VA. Open-File Report. 27 pages.

Daley, G. M. 1998. Guild structure of paleocommunity types; an example from the Yorktown Formation (Pliocene) of Virginia. Geological Society of America Abstracts with Programs **30**(7):33.

Daley, G. M. 1999. Local paleocommunities and paleocommunity types, but no paleocommunities; an example from the Yorktown Formation (Pliocene) of eastern Virginia. Geological Society of America Abstracts with Programs **31**(7):470.

Dietl, G. P. and P. H. Kelley. 2004. Emergent effects of multiple predators on prey in the fossil record. Geological Society of America Abstracts with Programs **36**(5):480.

Dodd, C. M., A. M. Tuomey, K. C. Ulrich, R. L. McConnell. 1995. Development as a cause of flash flooding; the August 20, 1994 flood, Fredericksburg, Virginia. Geological Society of America Abstracts with Programs **27**(2):49.

Dooley, A. C., Jr. 1993. The vertebrate fauna of the Calvert Formation (middle Miocene) at the Caroline Stone Quarry, Caroline County, Virginia. Journal of Vertebrate Paleontology **13**(3 Supp.):33A.

Dooley, A. C. Jr., N. C. Fraser, and Z. -X. Luo. 2004. The earliest known member of the rorqual-gray whale clade (Mammalia, Cetacea). Journal of Vertebrate Paleontology **24**(2):453-463.

Dowsett, H. J. and L. B. Wiggs. 1992. Planktonic foraminiferal assemblage of the Yorktown Formation, Virginia, USA. Micropaleontology **38**:75-86.

Doyle, J. A. and L. J. Hickey. 1972. Coordinated evolution in Potomac Group angiosperm pollen and leaves. American Journal of Botany Abstracts **59**(6):660.

Doyle, J. A. and L. J. Hickey. 1976. Pollen and leaves from the mid-Cretaceous Potomac Group and their bearing on early angiosperm evolution. Pages 139-206 *in* C. B. Beck, editor. Origin and Early Evolution of Angiosperms. Columbia University Press, New York.

Doyle, J. A. and E. I. Robbins. 1977. Angiosperm pollen zonation of the continental cretaceous of the Atlantic Coastal Plain and its application to deep wells in the Salisbury embayment. Palynology **1**:43-78.

Drake, A. A., Jr. and A. J. Froelich. 1986. Geologic map of the Annandale quadrangle, Fairfax and Arlington Counties, and Alexandria City, Virginia. U.S. Geological Survey, Reston, VA. Geologic Quadrangle Map GQ-1601, 1:24,000 scale map.

Edwards, L. E. 1983. Paleocene and early Eocene dinocyst biostratigraphy. Geological Society of America Abstracts with Programs **15**(2):59.

Ehlen, J. 2004. Terrain and the Battle of Fredericksburg, December 13, 1862. Geological Society of America Abstracts with Programs **36**(2):48.

Ehlen, J. and R. J. Abrahart. 2002. Effective use of terrain in the American Civil War; the battle of Fredericksburg, December 1862. Pages 63-97 *in* Doyle, P. and M. R. Bennett, editors. Fields of battle; Terrain in military history. Geojournal Library 64. Pages 63-97.

Flora, S. P. and W. C. Sherwood. 2001. Study of the lithology and source of the stone wall along Sunken Road at Fredericksburg, Virginia. Virginia Journal of Science **52**:110.

Fontaine, W. M. 1889. The Potomac or younger Mesozoic flora. U.S. Geological Survey, Reston, VA. Monograph 15. 375 pages.

Fordyce, R. E. 1980. Whale evolution and Oligocene southern ocean environments. Palaeogeography, Palaeoclimatology, Palaeoecology **31**:319-336.

Fordyce, R. E. 1992. Cetacean evolution and Eocene/Oligocene environments. Pages 368-381 *in* D. Prothero and W. Berggren, editors. Eocene-Oligocene Climatic and Biotic Evolution. Princeton University Press, Princeton, NJ.

Fordyce, R. E. and L. G. Barnes. 1994. The evolutionary history of whales and dolphins. Annual Review of Earth and Planetary Sciences **22**:419-455.

Fraser, N. C. and A. C. Dooley, Jr. 2000. A diverse marine vertebrate assemblage from a locality in the Calvert Formation of Virginia. Journal of Vertebrate Paleontology **20**(3 Supp.):42A.

Frey, R. W., J. D. Howard, and W. A. Pryor. 1978. *Ophiomorpha*; Its morphologic, taxonomic, and environmental significance. Palaeogeography, Palaeoclimatology, Palaeoecology, **23:**199-229.

Galvin, C. 2004. Sedimentology across the northern Virginia Fall Line. Geological Society of America Abstracts with Programs **36**(5):374.

Geisler, J. H. and Z. -X. Luo. 1996. The petrosal and inner ear of *Herpetocetus* sp. (Mammalia: Cetacea) and their implications for the phylogeny and hearing of archaic mysticetes. Journal of Paleontology **70**:1045-1066.

Gibson, T. G. and L. M. Bybell. 1984. Foraminifers and calcareous nannofossils of Tertiary strata in Maryland and Virginia; a summary. Pages 181-189 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwestern Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Glaser, J. D. 1969. Petrology and origin of Potomac and Magothy (Cretaceous) sediments, Middle Atlantic Coastal Plain. Maryland Geological Survey, Baltimore. Report of Investigations 11. 101 pages.

Glaser, J. D. 1976. Geologic map of Anne Arundel County. Maryland Geological Survey, Baltimore. 1:62,500 scale map.

Glaser, J. D. 2003. Prince George's County geologic map. Maryland Geological Survey, Baltimore. Digital County Geologic Map Series. CD-ROM. 1:62,500 scale map.

Gottfried, M. D., D. J. Bohaska, and F. C. Whitmore, Jr. 1994. Miocene cetaceans of the Chesapeake Group. Pages 229-238 *in* A. Berta and T. Démère, editors. Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. Proceedings of the San Diego Society of Natural History.

Groot, J. J., K. W. Ramsey, and J. F. Wehmiller. 1990. Ages of the Bethany, Beaverdam, and Omar formations of southern Delaware. Delaware Geological Survey, Newark. Report of Investigations 47.

Hazel, J. E. 1971. Ostracode biostratigraphy of the Yorktown Formation (upper Miocene and lower Pliocene) of Virginia and North Carolina. U.S. Geological Survey, Reston, VA. Professional Paper 704. 13 pages.

Hickey, L. J. 1984. Summary and implications of the fossil plant record of the Potomac Group. Pages 213-244 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwest Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Hickey, L. J. and J. A. Doyle. 1977. Early Cretaceous fossil evidence for angiosperm evolution. The Botanical Review **43**(1):3-104.

Hughes, N. F. and J. Moody-Stuart. 1966. Descriptions of schizaeceous spores taken from Early Cretaceous macrofossils. Palaeontology **9**:274-289.

Johnson, G. H. 1972. Geology of the Yorktown, Poquoson West, and Poquoson East Quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 30. 57 pages.

Johnston, P. M. 1962. A visitors guide to the geology of the National Capital area. Prepared for the Third General Meeting of the International Mineralogical Association April 17-20, 1962. Washington, D.C. 32 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.

Kier, P. M. 1972. Upper Miocene Echinoids from the Yorktown Formation of Virginia and their environmental significance. Smithsonian Contributions to Paleobiology 13. 41 pages.

Krantz, D. E. 1990. Mollusk-isotope records of Plio-Pleistocene marine paleoclimate, U.S. Middle Atlantic Coastal Plain. Palaios **5**(4):317-335.

Kranz, P. M. 1989. Dinosaurs in Maryland. Maryland Geological Survey, Baltimore. Educational Series 6. 34 pages.

Kranz, P. M. 1996. Notes on the sedimentary iron ores of Maryland and their dinosaurian fauna. Pages 87-115 *in* D. K. Brezinski and J. P. Reger, editors. Studies in Maryland Geology - In Commemoration of the Centennial of the Maryland Geological Survey. Maryland Geological Survey, Baltimore. Special Publication 3.

Kranz, P. M. 1998. Mostly Dinosaurs: A review of the vertebrates of the Potomac Group (Aptian Arundel Formation) USA. Pages 235-238 *in* S. G. Lucas, J. I. Kirkland, and J. W. Estep, editors. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 14.

Kranz, P. M. 2003. Dinosaurs of the District of Columbia. Dinosaur Fund, Washington, D.C. (http://www.glue.umd.edu/~gdouglas/articles/Kranz6.pdf)

Kranz, P. M. and V. L. Santucci. 2004. Preliminary research for paleontological resources of the national parks of the National Capital Region.

Lewis, J. 1830. Virginia gold from Spotsylvania County, Virginia. American Farmer **12**:230.

Lipka, T. R. 1998. The affinities of the enigmatic theropods of the Arundel Clay Facies (Aptian): Potomac Formation, Atlantic Coastal Plain of Maryland. Pages 229-234 *in* S. G. Lucas, J. I. Kirkland, and J. W. Estep, editors. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 14.

Little, H. P. 1917. The geology of Anne Arundel County, Maryland. Maryland Geological Survey, Baltimore.

Lonsdale, J. T. 1927. Geology of the gold-pyrite belt of the northeastern Piedmont, Virginia. Virginia Geological Survey Bulletin 30. 110 pages.

Lockwood, R. and H. L. Baugh. 2003. Rarity and extinction during background intervals; are ecological patterns preserved in the fossil record? Geological Society of America Abstracts with Programs **35**(6):417.

Marr, J. D. and L. W. Ward. 1987. Geology of the Caroline Stone Quarry. Virginia Minerals **33**(4):28-33.

Marr, J. D. and L. W. Ward. 1993. Geology of the Caroline Stone Quarry. Virginia Explorer **9**:7-10.

McConnell, R. L. and K. C. Ulrich. 1995. Development as a cause of flash flooding in northern Virginia; implications for the next hurricane. Geological Society of America Abstracts with Programs **27**(6):143.

McGavock, C. B., Jr. 1935. An analysis of the Yorktown pelecypods. Virginia Journal of Science 71.

McGavock, C. B., Jr. 1944. New pelecypoda from the Yorktown Formation of Virginia. Notulae Naturae of the Academy of Natural Sciences of Philadelphia 139. 3 pages.

McKeever, L. J. 1985. Geographical variation in the genus *Astarte* (Phylum Mollusca; Class Bivalvia) from the Yorktown and Jackson Bluff Formations (early Pliocene) of the Atlantic Coastal Plain. Unpublished M.S. thesis. Virginia Polytechnic Institute and State University, Blacksburg.

McLean, D. M. 1972. *Cladopyxidium septatum*, n. gen., n. sp., possible Tertiary ancestor of the modern dinoflagellate *Cladopyxis hemibrachiata* Balech, 1964. Journal of Paleontology **46**(6):861-863.

McLean, D. M. 1974. Two new Paleocene dinoflagellates from Virginia and Maryland. Palaeontology **17**(1):65-70.

McLean, J. D., Jr. 1956. The Foraminifera of the Yorktown Formation in the York-James Peninsula of Virginia, with notes on the associated mollusks. Bulletins of American Paleontology **36**(160):261-394.

McLean, J. D., Jr. 1957. The Ostracoda of the Yorktown Formation in the York-James Peninsula of Virginia (with notes on the collection made by Denise Mongin from the area). Bulletins of American Paleontology **38**(167):57-103.

McLean, J. D., Jr. 1966. Miocene and Pleistocene Foraminifera and Ostracoda of southeastern Virginia. Virginia Division of Mineral Resources, Charlottesville. Report of Investigations 9. 202 pages.

McLennan, J. D. 1973. Calvert Cliffs, Maryland. Maryland Geological Survey, Baltimore. Pamphlet. (http://www.mgs.md.gov/esic/brochures/ccliffs.html).

Meng, A. A., III. and J. F. Harsh. 1988. Hydrogeologic framework of the Virginia Coastal Plain. U. S. Geological Survey, Reston, VA. Professional Paper 1404-C. 82 pages.

Messenger, S. L. and J. A. McGuire. 1998. Morphology, molecules, and the phylogenetics of cetaceans. Systematic Biology **40**:90-124.

Mixon, R. B., D. S. Powars, R. E. Weems, W. L. Newell, L. E. Edwards, L. W. Ward. 1992. Stratigraphic and structural framework of the inner Atlantic Coastal Plain, Fredericksburg 30' X 60' Quadrangle, Virginia and Maryland. Geological Society of America Abstracts with Programs **24**(2):54.

Mixon, R. B., C. R. Berquist, Jr., W. L. Newell, G.H. Johnson, D. S. Powars, J. S. Schindler, and E. K. Rader. 1989. Geologic map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia. U. S. Geological Survey, Reston, VA. Miscellaneous Investigations Series Map I-2033. 1:250,000 scale map.

Mixon, R. B., D. S. Powars, and D. L. Daniels. 1992. Nature and timing of deformation of upper Mesozoic and Cenozoic deposits in the inner Atlantic Coastal Plain, Virginia and Maryland. Pages 65-73 *in* G. S. Gohn, editor. Proceedings of the 1988 U. S. Geological Survey Workshop on the Geology and Geohydrology of the Atlantic Coastal Plain: U.S. Geological Survey Circular 1059.

Mixon, R. B., D. S. Powars, and J. S. Schindler. 1994. Sedimentary facies of the Pliocene Yorktown Formation and related stratigraphy, structure, and geomorphology of the inner coastal Plain, northeastern Virginia; A field guide for the American Association of Petroleum Geologists Eastern Section Meeting, September 19-21, 1993, Williamsburg, VA. Pages 127-139 *in* A. P. Shultz

and E. K. Rader, editors. Studies in Eastern Energy and the Environment, American Association of Petroleum Geologists Special Volume: Virginia Division of Mineral Resources, Charlottesville, VA. Publication 132.

Mixon, R. B., L. Pavlides, D. S. Powars, A. J. Froelich, R. E. Weems, J. S. Schindler, W. L. Newell, L. E. Edwards and L. W. Ward. 2000. Geologic map of the Fredericksburg 30' x 60' quadrangle, Virginia and Maryland. U.S. Geologic Survey, Reston, VA. Investigations Series Map I-2607. 1:100,000 scale map.

Newell, W. L. 1978. Upper Tertiary and Quaternary stratigraphy in the Fredericksburg area. Pages 44-47 *in* R. B. Mixon and W. L. Newell, editors. The Faulted Coastal Plain Margin at Fredericksburg, Virginia. Annual Virginia Geology Field Conference 10.

Nogan, D. S. 1962. Micropaleontology, stratigraphy, and paleoecology of the Aquia Formation of Maryland and Virginia. Rutgers University, New Brunswick, NJ. Unpublished PhD Dissertation. 350 pages.

Nogan, D. S. 1964. Foraminifera, stratigraphy, and paleoecology of the Aquia Formation of Maryland and Virginia. Cushman Foundation for Foraminiferal Research, Washington, D.C. Special Publication 7. 50 pages.

Oaks, R. Q., Jr. and N. K. Coch. 1973. Post-Miocene stratigraphy and morphology, southeastern Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 82. 135 pages.

Olson, S. L. 1994. A giant *Presbyornis* (Aves: Anseriformes) and other birds from the Paleocene Aquia Formation of Maryland and Virginia. Proceedings of the Biological Society of Washington **107**:429-435.

Pavlides, L. J., J. E. Gair, and L. J. Cranford. 1982. Massive sulfide deposits of the southern Appalachians. Economic Geology **77**(2):233-272.

Pavlides, L., J. Pojeta, Jr., M. V. Gordon, Jr., R. L. Parsley, and A. R. Bobyarchick. 1980. New evidence for the age of the Quantico Formation of Virginia. Geology **8**(6):286-290.

Poole, J. L. 1974. Notes on some abandoned copper, lead, and zinc mines in the Piedmont of Virginia. Virginia Minerals **20**(2):9-15.

Poole, S. P. 1947. Relationship of topography to the Valley Campaign of "Stonewall" Jackson. Virginia Journal of Science 101.

Purdy, R. W. 1990. A key to the common genera of Neogene shark teeth. Smithsonian Institution National Museum of Natural History Online Guide. (http://www.nmnh.si.edu/paleo//sharkteeth/index.html).

Reinhardt, J., R. A. Christopher, and J. P. Owens. 1980. Lower Cretaceous stratigraphy of the core. Pages 1-13 *in* Geology of the Oak Grove Core. Virginia Division of Mineral Resources, Charlottesville. Publication 20.

Rose, K. D. 2000. Land-mammals from the Late Paleocene Aquia Formation: The first early Cenozoic mammals from Maryland. Proceedings of the Biological Society of Washington **113**(4):855-863.

Rose, K. D., R. L. Cifelli, and T. R. Lipka. 2001. Second triconodont dentary from the Early Cretaceous of Maryland. Journal of Vertebrate Paleontology **21**(3):628-632.

Ross, A. 1964. Cirripedia from the Yorktown Formation (Miocene) of Virginia. Journal of Paleontology **38**(3):483-491.

Sabol, J. W. 1960. The microfauna of the Yorktown Formation from James River, Surry County, Virginia. Bulletins of American Paleontology **41**(191):211-246.

Schmidt, R. A. M. 1939. Miocene Ostracoda from Yorktown Formation, Virginia. Unpublished M.S. thesis. Columbia University, Teachers College, New York.

Secor, D. T., Jr. 2000. Terranes in the Southern Appalachians; history, configuration, and deformation paths. Geological Society of America Abstracts with Programs **32**(2):72.

Seiders, V. M. and R. B. Mixon. 1981. Geologic map of the Occoquan quadrangle and part of the Fort Belvoir quadrangle, Prince William and Fairfax Counties, Virginia. U.S. Geological Survey, Reston, VA. Miscellaneous Geological Investigations Map I-1175. 1:24,000 scale map.

Shattuck, G. B. 1902. The Miocene problem of Maryland. Science **15**:906.

Shattuck, G. B. 1904. Geological and paleontological relations, with a review of earlier investigations. Pages 33-87 *in* W. B. Clark, G. B. Shattuck, and W. H. Dall, editors. The Miocene Deposits of Maryland. Maryland Geological Survey, Baltimore.

Sherwood, W. C. and S. Flora. 2002. The role of geomorphic features in the 1862 Civil War Battle of Fredericksburg. Geological Society of America Abstracts with Programs **34**(2):105.

Skog, J. E. 1998. Reassignment of *Aspidium heterophyllum* to a new genus in the Family Matoniaceae. American Journal of Botany **75**(8):1120-1129.

Sweet, P. C. 1975. Road log to some abandoned gold mines of the gold-pyrite belt, northeastern Virginia. Virginia Minerals **21**(1):11.

Sweet, P. C. 1997. Diamonds in Virginia. Pages 269-276 *in* R. W. Jones and R. E. Harris, editors. Proceedings of the 32nd Annual Forum on the Geology of Industrial Minerals Public Information Circular. Geological Survey of Wyoming, Laramie, Wyoming.

Sweet, P. C. and D. Trimble. 1983. Virginia gold-resource data. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 45. 196 pages.

Teifke, R. H. 1973. Paleogeology of Early Cretaceous through Miocene Time. Pages 79-98 *in* Geologic Studies, Coastal Plain of Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 83.

Tolcin, A. C. and R. Lockwood. 2004. Abundance and paleoecology of gastropods in the Sunken Meadow Member, Yorktown Formation (Pliocene) of southeastern Virginia. Geological Society of America Abstracts with Programs **36**(2):110.

Twardy, S. A. 1936. A synopsis of Gastropoda of the Yorktown Formation. Virginia Journal of Science 68.

Upchurch, G. R., Jr., P. R. Crane, and A. N. Drinnan. 1994. The megaflora from the Quantico locality (upper Albian), Lower Cretaceous Potomac Group of Virginia: Virginia Museum of Natural History, Memoir 4. 57 pages.

Visaggi, C. C. and S. J. Godfrey. In Preparation. A census of fossil shark teeth from Calvert Cliffs, Maryland (Miocene: Chesapeake Group).

Vogt, P. R. and R. Eshleman. 1987. Maryland's cliffs of Calvert: A fossiliferous record of mid-Miocene inner shelf and coastal environments. Northeastern Section of the Geological Society of America Centennial Field Guide **5**:9-14.

Ward, D. J. and R. L. Weist, Jr. 1990. A checklist of Palaeocene and Eocene sharks and rays (Chondrichthyes) from the Pamunkey Group Maryland and Virginia, USA. Tertiary Research **12**(2):81-88.

Ward, L. W. 1985. Stratigraphy and characteristic mollusks of the Pamunkey Group (Lower Tertiary) and the Old Church Formation of the Chesapeake Group - Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1346. 78 pages.

Ward, L. W. 1992. Molluscan biostratigraphy of the Miocene, Middle Atlantic Coastal of North America. Virginia Museum of Natural History Memoir **2**:1-159.

Ward, L. W. 1993. The G. D. Harris 1890 Manuscript on the Stratigraphy of Miocene and Pliocene Beds at Yorktown, Virginia. Paleontological Research Institution Special Publication 20. 118 pages.

Ward, L. W. and D. S. Powars. 2004. Tertiary lithology and paleontology, Chesapeake Bay region. Pages 263-297 *in* S. Southworth and W. Burton, editors. Geology of the National Capital Region - Field Trip Guidebook. U.S. Geological Survey, Reston VA. Circular 1264.

Ward, L. W. and G. L. Strickland. 1985. Outline of Tertiary stratigraphy and depositional history of the U.S. Atlantic Coastal Plain. Pages 87-123 *in* C. W. Poag, editor. Geological Evolution of the United States Atlantic Margin. Van Nostrand Reinhold, New York.

Ward, L. W. and T. R. Waller. 1988. A new species of *Pulvinites* (Mollusca: Bivalvia) from the upper Paleocene Paspotansa Member of the Aquia Formation in Virginia. Journal of Paleontology **62**(1):51-55.

Watson, T. L. and S. L. Powell. 1910. Discovery of fossils in the Quantico slate belt, and the association of volcano-sedimentary beds with the slates of the Virginia crystalline region. Geological Society of America Bulletin **21**:782.

Weems, R. E. 1988. Paleocene turtles from the Aquia and Brightseat Formations with a discussion of their bearing on sea turtle evolution and phylogeny. Proceedings of the Biological Society of Washington **101**:109-145.

Weems, R. E. and J. M. Bachman. 2004. A dinosaur-dominated ichnofauna from the Lower Cretaceous (Aptian) Patuxent Formation of Virginia. Geological Society of America Abstracts with Programs **36**(2):116.

Weishampel, D. M. and L. Young. 1996. Dinosaurs of the East Coast. Johns Hopkins University Press, Baltimore. 300 pages.

Westgate, J. W. and F. C. Whitmore, Jr., 2002. *Balaena ricei*, a new species of bowhead whale from the Yorktown Formation (Pliocene) of Hampton, Virginia. Cenozoic mammals of land and sea; tributes to the career of Clayton E. Ray. Smithsonian Contributions to Paleobiology **93**:295-312.

Whisonant, R. C., S. A. Underwood, and J. D. Surber. 2004. Geologic analysis of the Battle of Chancellorsville using GIS/remote sensing technology. Geological Society of America Abstracts with Programs **36**(2):48.

Whitmore, F. C., Jr. 1994. Neogene climate change and the emergence of the modern whale fauna of the North Atlantic Ocean. Pages 223-228 *in* A. Berta and T. Démère, editors. Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. Proceedings of the San Diego Society of Natural History 29.

Additional References

Barnes, L., A. Dooley, Jr., and N. Fraser. 2004. A new Miocene sperm whale (Cetacea, Physeteridae) from Virginia. Society of Vertebrate Paleontology Abstracts **24**(3):36.

Bird, S. O. 1979. Using coastal plain stratigraphy near Fredericksburg, Virginia as a teaching tool. Pages 43-48 *in* J. D. Exline, editor. Guidebook for Field Trips in Virginia.

Brenner, G. J. 1963. The spores and pollen of the Potomac Group of Maryland. Maryland Geological Survey, Baltimore. Bulletin 27. 215 pages.

Burns, J. R. 1950. Geology of Fredericksburg and vicinity, Virginia. Virginia Journal of Science **1**(4):385.

Bybell, L. M. and D. L. Govoni. 1977. Preliminary calcareous nannofossil zonation of Brightseat and Aquia Formations (Paleocene) of Maryland and Virginia; stratigraphic implications. AAPG Bulletin **61**(5):773-774.

Clark, W. B. 1896. The Eocene deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia. U.S. Geological Survey, Reston, VA. Bulletin 141. 167 pages.

Cline, J.H., T.L. Watson, and F.J. Wright. 1921. A geological map of the pyrite-gold belt in Louisa and Spotsylvania counties, Virginia. Virginia Geological Survey.

Conrad, T. A. 1830. On the geology and organic remains of a part of the peninsula of Maryland. Journal of the Academy of Natural Sciences of Philadelphia **6**:205-217.

Conrad, T. A. 1834. Observations on the Tertiary and more recent formations of a portion of the Southern States. Journal of the Academy of Natural Sciences of Philadelphia **7**:116-129.

Conrad, T. A. 1835. Observations on a portion of the Atlantic Tertiary region. Transactions of the Pennsylvania Geological Society **1**:335-341.

Conrad, T. A. 1839. Notes on American Geology. Observations on characteristic fossils and upon a fall of temperature in different geological epochs. American Journal of Science **35**:237-251.

Davis, A. M., C. S. Southworth, J. E. Reddy, and J. S. Schindler. 2001. Geologic map database of the Washington D.C. area featuring data from three 30 x 60 minute quadrangles: Frederick, Washington West, Fredericksburg. U.S. Geological Survey, Reston, VA. Open-File Report 227. 1:100,000 scale map.

Dooley, A. C., Jr. 1993. The vertebrate fauna of the Calvert Formation (middle Miocene) at the Caroline Stone Quarry, Caroline County, Virginia. Society of Vertebrate Paleontology Abstracts **13**(3):33.

Doyle, J. A. 1969. Cretaceous angiosperm pollen of the Atlantic coastal plain and its evolution significance. Journal of the Arnold Arboretum **50**:1-35.

Doyle, J. A. 1973. The monocotyledons; their evolution and comparative biology; V, Fossil evidence on early evolution of the monocotyledons. The Quarterly Review of Biology **48**(3):399-413.

Ehlen, J. 2004. Terrain and the Battle of Fredericksburg, December 13, 1862. Pages 247-261 *in* Southworth, S. and W. Burton, editors. Geology of the National Capital Region-Field Trip Guidebook. U.S. Geological Survey, Reston, VA. Circular 1264.

Edwards, L. E. 1992. Dynamics of upper Paleocene deposits in the Salisbury Embayment, Virginia and Maryland. Pages 57-59 *in* G. S. Gohn, editor. Proceedings of the 1988 U.S. Geological Survey Workshop on the Geology and Geohydrology of the Atlantic Coastal Plain. U. S. Geological Survey, Reston, VA. Circular 1059.

Faris, C. D. 1982. Planktonic foraminiferal biostratigraphy and correlation of the Aquia Formation in the type area, along the Potomac River, Virginia. Virginia Polytechnic Institute and State University, Blacksburg, VA. Unpublished Master's Thesis. 84 pages.

Friis, E. M., W. G. Chaloner, and P. R. Crane, editors. 1987. The origins of angiosperms and their biological consequences. Cambridge University Press, Cambridge, MA.

Fontaine, W. M. 1888. The flora of the Potomac Formation in Virginia. Proceedings for the American Association for the Advancement of Science. **36**:275-276.

Frangos, W. and C. R. Geier. 2003. Geophysical investigation in support of archeological studies at the Fredericksburg Civil War battleground. Proceedings for the Symposium on the Application of Geophysics to Engineering and Environmental Problems. Pages 59-67.

Harris, G. D. 1893. Republication of Conrad's fossil shells of the Tertiary formations of North America. Paleontological Research Institution, Ithaca, NY.

Harrison, N. 1986. Fredericksburg's Battlefield Granite. Virginia Minerals **32**(3):27-30.

Heilprin, A. 1884a. Contributions to the Tertiary geology and paleontology of the United States. Philadelphia. 117 pages.

Heilprin, A. 1884b. The Tertiary geology of the eastern and southern United States. Journal of the Academy of Natural Sciences of Philadelphia **9**:115-154.

Hickey, L. J. 1978. Origin of the major features of the angiospermous leaf architecture in the fossil record. Advances in Angiosperm Palaeobotany International symposium. Courier Forschungsinstitut Senckenberg **30**:27-34.

Hickey, L. J. 1984. Road log and stops. Part 1. Northeast of Washington D.C. to Brooke, Virginia. Pages 193-209 *in* N. O Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwestern Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Horton, J. W., Jr., J. N. Aleinikoff, A. A. Drake, Jr., and M. C. Fanning. 1998. Significance of Middle to Late Ordovician volcanic-arc rocks in the Central Appalachian Piedmont, Maryland and Virginia. Geological Society of America Abstracts with Programs **30**(7):125.

Horton, J. W., Jr., and E. T. Cleaves. 1997. Geology of the Fredericksburg 30' X 60' quadrangle, northeastern Virginia and southern Maryland. Forum on Geologic mapping applications in the Washington-Baltimore urban area. U. S. Geological Survey, Reston, VA. Circular 1148. Page 34.

Lyell, C. 1842. On the Tertiary formations and their connection with the chalk in Virginia and other parts of the United States. Proceedings of the Geological Society of London **3**:735-742.

Maury, M. F. 1837. Notice of the gold veins of the United States Mine near Fredericksburg, Virginia. American Journal of Science **32**(2):325-330.

Morton, S. G. 1834. Synopsis of the organic remains of the Cretaceous group of the United States. Appendix: Catalogue of the fossil shells of the Tertiary formations of the United States. Key and Biddle, Philadelphia, PA. 88 pages.

Morton, S. G. 1835. Additional observations to Synopsis. Key and Biddle, Philadelphia, PA. 4 pages.

Pavlides, L. 1980. Revised nomenclature and stratigraphic relationships of the Fredericksburg Complex and Quantico Formation of the Virginia Piedmont. U.S. Geological Survey, Reston, VA. Professional Paper 1146. 29 pages.

Pavlides, L. 1995. Piedmont geology of the Stafford, Storck, Salem Church, and Fredericksburg quadrangles, Stafford, Fauquier, and Spotsylvania counties, Virginia. U.S. Geological Survey, Reston, VA. Open-File Report 577.

Pavlides, L., J. Pojeta, Jr., M. Gordon, Jr., R. L. Parsley, and A. R. Bobyarchick. 1980. New fossil and stratigraphic evidence for the Ordovician age of the Quantico Formation of Virginia and its regional implications. Geological Society of America Abstracts with Programs **12**(4):204-205.

Ruhle, J. L. 1962. Selected Tertiary fossil localities of the Virginia Coastal Plain. Virginia Minerals **8**(3):2-10.

Subitzky, S. 1955. Summary of geology and ground-water conditions in the Fredericksburg District, eastern Spotsylvania County, Virginia; a preliminary report. Virginia Division of Mineral Resources, Charlottesville, VA. Circular **4.** 32 pages.

Taylor, R. C. 1835. Sections in parts of Virginia and Maryland: also notice of certain fossil acotyledonous plants in the secondary strata of Fredericksburg. Geological Society of Pennsylvania Transactions **1**:314-325.

Uhler, P. R. 1888. Observations on the Eocene Tertiary and its Cretaceous associates in the State of Maryland. Transactions of the Maryland Academy of Sciences **1**:11-32.

Uhler, P. R. 1889. Additions to observations of the Cretaceous and Eocene formations of Maryland. Transactions of the Maryland Academy of Sciences **1**:42-53.

Uhler, P. R. 1890. Notes and illustrations to "Observations on the Cretaceous and Eocene formations of Maryland. Transactions of the Maryland Academy of Sciences **1**:97-104.

Upchurch, G. R., Jr., and P. R. Crane. 1985. Probable gnetalean megafossils from the Lower Cretaceous Potomac Group of Virginia. American Journal of Botany Abstracts **72**(6):903.

Ward, L. F. 1905. The Maryland Cycads. Pages 404-473 *in* Ward, L. F., W. M. Fontaine, A. B. Bibbins, and G. R. Wieland. Status of the Mesozoic floras of the United States. U.S. Geological Survey, Reston, VA. Monograph 48.

Ward, L. W. 1984a. Stratigraphy and molluscan assemblages of the Pamunkey and Chesapeake groups, upper Potomac River. Pages 3-77 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwestern Maryland and Northeastern Virginia.

Ward, L. W. 1984b. Stratigraphy of outcropping Tertiary beds along the Pamunkey River-central Virginia Coastal Plain. Pages 11-78 *in* L. W. Ward and K. Krafft, editors. Stratigraphy and Paleontology of the Outcropping Tertiary Beds in the Pamunkey River Region, Central Virginia, Coastal Plain. Guidebook for Atlantic Coastal Plain Geological Association 1984 Field Trip.

Ward, L. W. 1988. Late Pliocene molluscan biogeography of the Atlantic Coastal Plain. Geological Society of America Abstracts with Programs **20**(4):321.

Ward, L. W. and K. Krafft. 1984. Stratigraphy and Paleontology of the Outcropping Tertiary beds in the Pamunkey River Region, Central Virginia Coastal Plain. Guidebook for the Atlantic Coastal Plain Geological Association 1984 Field Trip. 280 pages.

Weems, R. E., D. S. Powars, and A. M. Clark. 1993. Detailed sections from auger holes in the Bowling Green, Penola, Sparta, and Supply quadrangles, Virginia. U.S. Geological Survey, Reston, VA. Open-File Report 93-581. 62 pages.

Wentworth, C. K. 1930. Sand and gravel resources of the Coastal Plain of Virginia. Virginia Geological Survey Bulletin **32**:1-146.

DATA SETS

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GETTYSBURG NATIONAL MILITARY PARK

Gettysburg National Military Park (GETT) preserves the site of one of the most significant battles waged not only during the Civil War, but in the history of the United States. The Battle of Gettysburg (July 1-3 1863), culminating with "Pickett's Charge", ended the Confederate General Robert E. Lee's second invasion of the North. This came, however, at a staggering cost of more than 51,000 soldiers killed, wounded, or captured on both sides. The park, encompassing 6,000 acres in southeastern Pennsylvania, was established as a National Military Park on February 11, 1895 and transferred from the War Department to the National Park Service in 1933.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geological scoping sessions were held for Gettysburg National Military Park in conjunction with the NPS Geologic Resources Division in 2004. However, no formal paleontological resource inventories have been completed for the park. Currently there are no paleontological items within the GETT museum collections. Nevertheless dinosaur tracks are known to occur within the park in a unique "exposure". Additional paleontological resources may be found within the park in the future.

Gettysburg National Military Park, like many parks in the MIDN is located within the Piedmont physiographic province. The park is specifically located in the Gettysburg-Newark Lowland Section of the Piedmont Province (Sevon 2000). This section is characterized by low rolling hills developed on Triassic-aged fluvial or lacustrine basin fill deposits. In the Gettysburg area, these formations are crossed by intrusive diabase dikes (a body of molten material, cutting through younger rocks) which form topographic highs and "bake" the surrounding sedimentary rock, forming hornfels (Sevon 2000). There are numerous maps, summaries, and field guides regarding the geology of the park, and its two primary geologic formations, the Late Triassic Gettysburg Formation and the Jurassic-aged York Haven Diabase ("Gettysburg Granite"). The Gettysburg Formation is sparsely fossiliferous, while the York Haven Diabase, as an igneous rock, does not preserve fossils. See Stose and Bascom (1929), Stose (1932), Brown (1962), Smith and Keen (2004), and Inners et al. (2004) for more information. Many of these publications describe the geology as it determined the local terrain, and in that light, directed the Battle of Gettysburg.

Gettysburg Formation (Upper Triassic)
The Upper (Late) Triassic Gettysburg Formation, or Gettysburg Shale, is generally characterized by grayish-red to red sandstone, siltstone, and mudstone. It is mapped throughout the park (e.g. Stose 1932); however exposures of the unit are limited due to vegetative cover (Z. Bolitho, personal communication, 2005). Within GETT, the formation is subdivided into the "undivided" Gettysburg Formation and the Heidlersburg Member (e.g. Stose 1932). The Heidlersburg Member is a cyclic unit consisting of red, gray, and black shale, argillite (weakly metamorphosed shale or hornfels), and siltstone (e.g. Inners et al. 2004). Numerous beds of harder white sandstone are also found in the Heidlersburg Member (Stose and Bascom 1929). The Gettysburg Formation was originally deposited as sandy and muddy stream and lake sediments during the Late Triassic, approximately 221-227 million years ago, when the area was semi-arid. The York Haven Diabase intruded into the Gettysburg Formation sediments during the Jurassic period, creating the localized areas of metamorphism and hornfels.

The Gettysburg Formation is part of the Newark Supergroup, which includes sediments from basins stretching up and down the east coast (GETT is in the Gettysburg Basin). These basins formed during Late Triassic rifting (tectonic plates splitting apart) which led to the formation of the Atlantic Ocean (e.g. Benson and Doyle 1988; Manspeizer 1988). The sedimentary rocks found within these basins are frequently red in color and are known as Triassic "red beds". Many of the basins contain fossil assemblages. The Stockton Formation (mapped in two MIDN parks, Valley Forge National Historical Park and Hopewell Furnace National Historical Site) represents similar, but slightly older sediments from the Newark Basin.

Paleontological resources are not abundant in the Gettysburg Shale but consist of microfossils, invertebrates, plants and a variety of invertebrate and vertebrate trace fossils. Litwin et al. (1993) described a species of fossil pollen found in the formation that is used as an important biostratigraphic marker. The invertebrates are limited to the conchostracan clam shrimp (*Cyzicus* sp., Olsen 1988), a small crustacean found near Middletown, Pennsylvania (*Estheria ovata,* Stose and Bascom 1929), and unidentified impressions "suggestive of oyster shells" (Wanner 1889). Wanner and Fontaine (1900) described 31 species of plants representing ferns, horsetails, cycads, ginkgos, conifers, and a grass-like plant. These fossils were discovered in the "Triassic of York County", primarily from a railroad cut south of York Haven and a pit near Little Conewago Creek outside of Manchester. Stose and Jonas (1939) more specifically indicated that Wanner and Fontaine's (1900) plant fossils were found in exposures of the Gettysburg Formation. The trace fossils from the Gettysburg Formation included: *Scoyenia* (arthropod feeding burrow), *Dicynodontipes?* (tracks of a dicynodont, an herbivorous "beaked" mammal-like reptile), *Brachychirotherium eyermani* (tracks of an aetosaur, a quadrapedal herbivorous non-dinosaurian reptile), *Grallator* (tracks of a small theropod dinosaur, a bipedal carnivore), and *Atreipus milfordensis* (tracks of an unknown ornithiscian dinosaur), which is described in greater detail below (Olsen 1988). In addition to the above forms, Olsen and Baird (1986) listed occurrences of *Apatopus?* (track of a phytosaur, a crocodile-like semi-aquatic reptile), *Rhynchosauroides?* and *Rhynchosauroides brunswickii* (tracks of a sphenodont, a small iguana-like reptile). The majority of the vertebrate tracks from the Gettysburg Formation have been found in two main quarries, one near Goldsboro in York County (approximately 40 km (25 miles) northeast of GETT), the other is the Trostle Quarry east of York Springs in Adams County (approximately 24 km (15 miles) northeast of GETT). A small assemblage of Gettysburg Formation tracks was also discovered near Yocumtown in York County (Ashley 1931; Hickok and Willard 1933; Stose and Jonas 1939; Kochanov 2002). The tracks from the Goldsboro quarry, as well tentatively identified mollusk impressions, plants, and "algae" were first described by Atreius Wanner (1889), at the time principal of York High School, and future namesake of the ichnogenus *Atreipus* (Olsen and Baird 1986; Yochelson et al. 2005). The Trostle Quarry is further described below.

Gettysburg Formation (Upper Triassic): Trostle Quarry and Gettysburg National Military Park
The Trostle Quarry was located in lightly metamorphosed rocks of the Gettysburg Formation about 5 km (3 miles) east of York Springs (approximately 24 km (15 miles) northeast of GETT) near the contact with the York Haven Diabase and where the Heidlersburg Member of the Gettysburg Formation are mapped (Cleaves 1937a; Stose 1932; Inners et al. 2004). The intrusion of the diabase has "baked" the rocks in parts of the quarry, making them better suited as building stones and altering their red color to a more greenish-gray color (Stose 1932; Cleaves 1937a; Key and Delano 1993).

During the middle 1930s, stone from the Trostle Quarry was used to construct bridges within GETT. One such bridge is the South Confederate Avenue Bridge over Plum Run, built in 1935 (GETT List of Classified Structures), which replaced a bridge built by the War Department in 1895 (Nicholson et al. 1895). At least two stones atop the bridge contain identifiable dinosaur tracks. One stone on the northern parapet displays a well-preserved dinosaur manus (hand) and pes (foot) print, figured on the cover of this report. Similar tracks from the Trostle Quarry were originally identified as *Grallator tenuis* and *Anchisauripus sillimani* (Cleaves 1937a). As knowledge of dinosaur footprint taxonomy increased over the ensuing decades, the tracks were reidentified as *Atreipus milfordensis* (Olsen and Baird 1986; Santucci and Hunt 1995). *Atreipus milfordensis* is interpreted as the hand and foot print of an unknown, very early ornithischian (herbivorous, "bird-hipped") dinosaur that was likely a functional quadruped (Olsen and Baird 1986; Santucci and Hunt 1995). As discussed by Olsen and Baird (1986), the ichnogenus *Atreipus* is a significant biostratigraphic marker. One stone atop the southern parapet of the bridge displays an "*Anchisauripus*" track (theropod dinosaur track, J. Jones, personal communication, 2006). Vincent Santucci subsequently photographed the track in February 2006. An additional dinosaur track, tentatively identified as *Otozoum* (tracks of a prosauropod dinosaur) is also visible in a stone atop the southern parapet (J. Jones, personal communication, 2006) however it is very poorly preserved. Cuffey (2006) also mentions the tracks in the bridge and includes line drawings illustrating their morphologies. It is unclear when or who first identified the dinosaur tracks in the park's bridge (W. Peterson, personal

communication, 2006), however it is likely that the mason(s) chose those particular blocks and orientations to display the preserved fossils.

Additional dinosaur-track bearing slabs were discovered in the quarry in July of 1937 (Cleaves 1937a). Subsequent excavation yielded approximately 50 slabs of dinosaur tracks, originally identified as *Grallator tenuis*, *Anchisauripus sillimani*, and *Anomoepus* sp. (Cleaves 1937a; Baird 1993). The tracks have been reidentified as *Atreipus milfordensis*, *Brachychirotherium eyermani*, *Rhynchosauroides brunswickii*, and *Pentasauropus* (Baird 1993). Media attention has surrounded the tracks (one is known as "Old Tulip Foot") since their discovery, and continues today (e.g. Author unknown 1937a, b; Author unknown 1979; Bartlett 1995; Kauffman 2003). Some of the tracks were displayed at GETT shortly after their discovery. In fact, according to letters in GETT files dating from 1937 through 1940, the park's superintendent (James R. McConaghie) and assistant historian (Frederick Tilberg) at the time encouraged their interpretation and unofficially coordinated distribution of a number of the fossil bearing slabs to various museums. These museums included the Smithsonian National Museum of Natural History (Washington, D.C.), Carnegie Museum of Natural History (Pittsburgh), and the State Museum of Pennsylvania (Harrisburg).

Although an interesting specimen, the park does not actively interpret the *Atreipus* dinosaur track, in order to minimize resource impact and subsequent management (Z. Bolitho, personal communication, 2005). However, park staff and licensed battlefield guides are generally aware of the specimen and can provide informal interpretation (Z. Bolitho, personal communication, 2005).

The slightly younger Upper (Late) Triassic New Oxford Formation, mapped about 16 km (10 miles) east of the town of Gettysburg, has more diverse and abundant paleontological resources including clams, clam shrimp, ostracodes, fish, amphibians, phytosaurs, dinosaurs, plants, and invertebrate burrows, as described in many publications, summarized by Olsen (1988).

Other Historic Structures within Gettysburg National Military Park
There are more than 1,400 monuments, markers, and tablets located throughout the park. There are also dozens of roads, bridges, and other structures built with local or "imported" building stones. Most of these structures are listed on the park's List of Classified Structures, which includes a table of building materials. A cursory examination of the building materials for the park's historic structures revealed that the vast majority were constructed with granite, some of which may actually be the local York Haven Diabase ("Gettysburg Granite"). At least ten were constructed with "limestone" or "marble" stones, and as such may contain visible fossils.

An informal site visit by the authors (February 2006, VLS and JPK) noted the presence of fossils within the Peace Memorial and the 14th Indiana Infantry Monument. Both monuments were constructed with similar tan colored Mississippian-aged limestone and display abundant fragmentary marine invertebrate fossils such as foraminifers, crinoids, bryozoans, and various shells. The limestone of the Peace Memorial was quarried in Franklin County, Alabama ("Rockwood Limestone"). Interestingly the memorial contains stones from both the north (Maine granite) and the south (Alabama limestone), presumably to symbolize the union of the North and South after the Civil War. The 14th Indiana Infantry monument is likely "Indiana Limestone" from the Mississippian Salem Formation, a well-known and extensively quarried (especially near Bedford, Indiana) building stone. Future field examinations may identify additional structures with visible fossils. While the authors do not necessarily recommend establishing a paleontological resource monitoring program specifically for these historic structures, it is worth noting their potential to display fossils.

REFERENCES CITED

Ashley, G. H. 1931. A syllabus of Pennsylvania geology and mineral resources. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. General Geology Report 1.

Author unknown. 1937a. Eight additional dinosaur footprints discovered at York Springs. Harrisburg [PA] Evening News. July 30, 1937. Pages 1 and 13.

Author unknown, 1937b. Pre-Historic animal toes here are rare. The Gettysburg Times[?]. August 7, 1937.

Author unknown, 1979. Dinosaur footprints found in county 41 years ago now in many museums. [Unknown paper]. January 8, 1979.

Baird, D. 1993. The Trostle Quarry footprints and their makers. Pages 36-37 *in* Britcher, R. W., editor. South Mountain and the Triassic in Adams County. Harrisburg Area Geological Society, Harrisburg, PA. Guidebook for the 12th Annual Field Trip.

Bartlett, J. 1995. Adams Co. dinosaur tracks remain a mystery. Community Sun [Hanover, Pa.]. October 8, 1995.

Benson, R. N. and R. G. Doyle. 1988. Early Mesozoic rift basins and the development of the United States Middle Atlantic continental margin. Pages 99-127 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Brown, A. 1962. Geology and the Gettysburg Campaign [originally printed 1962; slightly revised 1997]. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Educational Series 5. 14 pages. (http://www.dcnr.state.pa.us/topogeo/education/es5/es5.pdf)

Cleaves, A. B. 1937a. Quarry gives up dinosaur foot prints after millions of years. Pennsylvania Department of Internal Affairs Monthly Bulletin **4**(3):12-15.

Cuffey, R. J. 2006. Dinosaur footprints on the Plum Run Bridge. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Open File Report 06-02. Pages 26a-26b.

Hickok, W. O., IV and B. Willard. 1933. Dinosaur foot tracks near Yocumtown, York County, Pennsylvania. Proceedings of the Pennsylvania Academy of Science. **7**:55-58.

Inners, J. D., R. J. Cuffey, R. C. Smith, III, J. C. Neubaum, R. C. Keen, G. M. Fleeger, L. Butts, H. L. Delano, V. A. Neubaum, and R. H. Howe. 2004. Rifts, diabase, and the topographic "Fishhook": Terrain and military geology of the Battle of Gettysburg—July 1-3, 1863. Geological Society of America, Boulder, CO. Guidebook to Pre-Meeting Field Trip 4. Joint Meeting of the Northeast-Southeast Section, Tysons Corner, VA. March 24, 2004.

Kauffman, C. 2003. Dinosaur made lasting impression. York Sunday News. December 14, 2003. Pages C1 and C6.

Key, M. M., Jr. and H. L. Delano. 1993. The Triassic dinosaurs and the Trostle Quarry. Pages 28-34 *in* Britcher, R. W., editor. South Mountain and the Triassic in Adams County. Harrisburg Area Geological Society, Harrisburg, PA. Guidebook for the 12th Annual Field Trip.

Litwin, R. J., J. P. Smoot, and R. E. Weems. 1993. *Froelichsporites* gen. nov.—A biostratigraphic marker palynomorph of Upper Triassic continental strata in the conterminous U.S. Palynology **17**:157-168.

Manspeizer, W. 1988. Triassic-Jurassic rifting and opening of the Atlantic: An overview. Pages 41-70 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Nicholson, J. P, W. M. Robbins, and C. A. Richardson. 1895. Annual report of the Gettysburg National Military Park Commission to the Secretary of War, 1895.

Olsen, P. E. 1988. Paleontology and paleoecology of the Newark Supergroup (Early Mesozoic, Eastern North America). Pages 185-230 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Olsen, P. E. and D. Baird. 1986. The ichnogenus *Atreipus* and its significance for Triassic biostratigraphy. Pages 61-87 *in* Padian, K., editor. The beginning of the Age of Dinosaurs. Cambridge University Press, Cambridge.

Santucci, V. L., and A. P. Hunt. 1995. Late Triassic dinosaur tracks reinterpreted at Gettysburg National Military Park. Park Science **15**(2):9.

Sevon, W. D. (compiler). 2000. Physiographic provinces of Pennsylvania (4th Edition). Pennsylvania Topographic and Geologic Survey, Middletown, PA. Map 13. (http://www.dcnr.state.pa.us/topogeo/maps/map13.pdf)

Smith, R. C., II, and R. C. Keen. 2004. Regional rifts and the Battle of Gettysburg. Pennsylvania Geology **34**(3):2-12. (http://www.dcnr.state.pa.us/topogeo/pub/pageolmag/pageolonline.aspx)

Stose, G. W. 1932. Geology and mineral resources of Adams County Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Bulletin C 1. 153 pages.

Stose, G. W. and F. Bascom. 1929. Fairfield-Gettysburg Folio. U.S. Geological Survey, Reston, VA. Geologic Atlas of the United States Folder 225. 1:62,500 scale. 22 pages.

Stose, G. W. and A. I. Jonas. 1939. Geology and mineral resources of York County, Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Bulletin C 67. 199 pages.

Wanner, A. 1889. The discovery of fossil tracks, algae, etc. in the Triassic of York County, Pennsylvania. Pages 21-35 *in* Pennsylvania Topographic and Geologic Survey, Middletown, PA. Annual Report 1887.

Wanner, A. and W. M. Fontaine. 1900. Triassic Flora of York County, Pennsylvania. Pages 233-255 *in* Mesozoic flora of the United States, Part 2. U.S. Geological Survey, Reston, VA. Annual Report 20.

Yochelson, E. L., J. Lloyd, and G. R. Ganis. 2005. A forgotten local geologist-Atreus Wanner of York, Pennsylvania. Pennsylvania Geology **35**(1):2-9. (http://www.dcnr.state.pa.us/topogeo/pub/pageolmag/pageolonline.aspx)

ADDITIONAL REFERENCES

Berg, T. M., M. K. McInerney, J. H. Way, and D. B. MacLachlan. 1983. Stratigraphic correlation chart of Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. General Geology Report G-75.

Cleaves, A. B. 1937b. Vegetation changes cited among reasons for dinosaur extinction. Pennsylvania Department of Internal Affairs Monthly Bulletin **4**(4):8-11.

Cornet, B. 1977. The palynostratigraphy and age of the Newark Supergroup. Unpublished PhD Dissertation. Department of Geosciences, Pennsylvania State University, University Park. 505 pages.

Cornet, B. and P. E. Olsen. 1985. A summary of the biostratigraphy of the Newark Supergroup of eastern North America, with comments on early Mesozoic provinciality. Pages 67-81 *in* Weber, R., editor. Symposio Sobre Flores del Triasico Tardio su Fitografia y Paleoecologia, Memoria. Proceedings of the Third Latin-American Congress on Paleontology. Isituto de Geologia Universidad Nacional Autonoma de Mexico.

Dicken, C. L., S. W. Nicholson, J. D. Horton, S. A. Kinney, G. Gunther, M. P. Foose, and J. A. L. Mueller. 2005. Preliminary integrated geologic map database for the United States: Delaware, Maryland, New York, Pennsylvania, and Virginia. U. S. Geological Survey, Reston, VA. Open File Report OF-2005-1325. Maps 1:100,000 scale.

Froelich, A. J. and P. E. Olsen. 1984. Newark Supergroup, a revision of the Newark Group in Eastern North America. Pages A55-A58 *in* Stratigraphic Notes, 1983. U. S. Geological Survey, Reston, VA. Bulletin 1537-A.

Glaeser, J. D. 1963. Lithostratigraphic nomenclature of the Newark-Gettysburg basin. Pennsylvania Academy of Sciences Proceedings **37**:179-188.

Glaeser, J. D. 1966. Provenance, dispersal, and depositional environments of Triassic sediments in the Newark-Gettysburg Basin. Pennsylvania Topographic and Geologic Survey, Middletown, PA. General Geology Report G-43. 168 pages.

Higgins, B. 2002. Viewing the Civil War through a geological window. Cultural Resource Management **25**(4):21-25.

Higgins, R. D. 2001. Viewing the Civil War through a natural resource window. Pages 279-285 *in* Harmon, D., editor. Crossing boundaries in park management: Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands. George Wright Society, Hancock, MI.

Hoskins, D. M. 1969. Fossil collecting in Pennsylvania. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. General Geology Report G-40. 215 pages.

Lorenz, J. C. 1988. Triassic-Jurassic rift-basin sedimentology. Van Nostrand Reinhold, New York. 315 pages.

Root, S. I. 1977. Geology and mineral resources of the Harrisburg West area, Cumberland and York counties, Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Atlas A-148ab. 106 pages.

Sinclair, W. J. 1918. A large parasuchian from the Triassic of Pennsylvania. American Journal of Science (4th ser.) **45**:457-462.

Smoot, J. P. and P. E. Olsen. 1988. Massive mudstones in basin analysis and paleoclimatic interpretation of the Newark Supergroup. Pages 249-274 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Stose, G. W. 1953. Geology of the Carlisle Quadrangle, Pennsylvania. U.S. Geological Survey, Reston, VA. Geologic Quadrangle Map GQ-28. 1:62,500 scale.

Stose, G. W. and A. I. Jonas. 1939. Geology and mineral resources of York County, Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. County Report C-67. 199 pages.

Sullivan, R. M., K. Randall, M. Hendricks, and W. E. Kochanov. 1994. The Graterford dinosaurs: Tracking Triassic travelers. Pennsylvania Geology **25**(4):2-9.

Van Houten, F. B. 1961. Climatic significance of red beds. Pages 89-139 *in* Nairn, A. E. M., editor. Descriptive paleoclimatology. Wiley Interscience, New York.

Wanner, A. 1892. Fossil tracks in the Trias of York Co., Pennsylvania. American Association for the Advancement of Science Proceedings **40**:286.

Wanner, H. E. 1921. Some faunal remains from the Trias of York County, Pennsylvania. Proceedings of the Academy of Natural Sciences of Philadelphia **73**:25-37.

Wanner, H. E. 1927. Some additional faunal remains from the Trias of York County, Pennsylvania. Proceedings of the Academy of Natural Sciences of Philadelphia **78**:21-28.

Willard, B. 1934. Additional Triassic dinosaur tracks from Pennsylvania. Science **80**:73-74.

Willard, B. 1940. Manus impression of *Anchisauripus* from Pennsylvania. Proceedings of the Pennsylvania Academy of Science **14**:37-39

Wood, C. R. 1980. Groundwater resources of the Gettysburg and Hammer Creek Formations, southeastern Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Water Resources Report W-49. 87 pages.

Wood, C. R. and H. E. Johnston, 1964. Hydrology of the New Oxford Formation in Adams and York counties, Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Water Resources Report W-21. 66 pages.

DATA SETS

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

DS-GETT-XXX Gettysburg National Military Park Files and Archives. 8/1937–present. (letters, notes, exhibit text, etc. regarding Trostle Quarry footprints). Originated by GETT staff; status: Inactive.

HOPEWELL FURNACE NATIONAL HISTORIC SITE

Hopewell Furnace National Historic Site (HOFU) preserves one of the finest examples of a rural American 19th century iron plantation. Hopewell Furnace was operated from 1771 until 1883. The site was originally established as Hopewell Village National Historic Site on August 3, 1938 and was renamed Hopewell Furnace on September 19, 1985. There are 14 restored structures within the park including the blast furnace, the ironmaster's mansion, and various auxiliary structures.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Paleontological scoping sessions have not been completed for HOFU, and no paleontological resource inventories have been completed for the park. Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division were held for HOFU in 2004. Currently there are no paleontological specimens within the HOFU museum collections. There are no documented fossil occurrences within the park. However, the underlying geology of the park presents some potential for future fossil discovery.

Hopewell Furnace National Historic Site, like many parks in the MIDN, is located within the Piedmont physiographic province. Inners and Fergusson (1996) summarized and mapped the geology of HOFU and French Creek State Park, which surrounds most of HOFU. Bascom and Stose (1938) and Berg and Socolow (1981) also produced geologic maps of the area including HOFU. Geologic units mapped within HOFU include: Precambrian gabbroic and graphitic gneiss (~1 billion years old), Cambrian Chickies Formation, Cambrian Vintage Dolomite, and two Triassic formations, the Hammer Creek Formation and the Stockton Formation. Fossils are not found in gneiss, which is a highly metamorphosed rock. Fossils have been found near HOFU within the Chickies Formation and the Stockton Formation. Fossils are rare in the Vintage Dolomite and none are reported near HOFU. Fossils have not yet been reported within the Hammer Creek Formation.

Chickies Formation (lower Cambrian)
The lower (early) Cambrian Chickies Formation, also known as the Chickies Quartzite, is a white quartzite unit that is highly resistant to erosion. The Chickies Formation underlies the topographic highs in the southern reaches of the park (Inners and Fergusson 1996). Mount Pleasure, adjacent to the western boundary of HOFU is also underlain by the Chickies. The formation was originally deposited as sandy beach sediment during the early Cambrian, over 520 million years ago. This sand was later subjected to high temperatures and/or pressure (metamorphism) and subsequently recrystallized into quartzite.

While metamorphism frequently destroys fossils, the Chickies Formation is known to contain the trace fossil *Skolithos*. In fact, Chickies Rock in Lancaster County, part of Chickies Rock County Park, is the type locality (place of original description) for both the Chickies Formation and the trace fossil *Skolithos linearis* (e.g. Wise 1960; Alpert 1974; Schlegel 2004). This trace fossil, interpreted as a vertical worm burrow, is usually quite conspicuous and can be locally abundant. Sediment-filled *Skolithos* tubes in the Chickies near HOFU are generally 0.25-0.50 cm (0.1-0.2 in) in diameter and up to 30 cm (1 ft) long (Inners and Fergusson 1996). Inners and Fergusson (1996) describe abundant *Skolithos* tubes from the western flanks of Mount Pleasure about 1.6 km (1 mile) outside of HOFU within French Creek State Park. Similar fossils are not yet known from within HOFU. However if good exposures of the Chickies Formation are present within the park, it is likely that *Skolithos* tubes may be found within them. The Chickies Formation within Valley Forge National Historical Park (VAFO) is known to contain *Skolithos* tubes. For more information regarding *Skolithos* and the Chickies Formation, see the VAFO section of this report. *Skolithos* fossils are also known from Shenandoah National Park, and an example from SHEN is figured on the cover of this report.

Vintage Dolomite (lower Cambrian)
Bascom and Stose (1938) mapped the lower (early) Cambrian Vintage Dolomite within what is now HOFU. Inners and Fergusson (1996) do not include the Vintage Dolomite on their simplified geologic

map of the area. The Vintage Dolomite is characterized by thick bedded gray and dark-blue dolomite, which is a rock-forming mineral similar to calcium carbonate (limestone), but containing magnesium and calcium instead of just calcium. Unlike, the Chickies Formation, the Vintage Dolomite is more susceptible to weathering and underlies the lowlands around French Creek southeast of the village of Hopewell (Bascom and Stone 1938). Exposures of the Vintage Dolomite in the park are likely very limited.

Fossils are rare in the Vintage Dolomite. Bascom and Stose (1938) reported no fossils from the formation in the areas around HOFU. A "few fossils" are reported by Bascom and Stose (1938) near Lancaster, but they give no further details. Specimens of the enigmatic mollusk-like fossil *Salterella* were found near Thomasville, Pennsylvania. The specimens were "remarkably well preserved" (Yochelson 1968). A bed of echinoderm "debris" was also discovered above one of the beds containing *Salterella*. Because of the limited exposure and no reports of fossils within the Vintage Dolomite near HOFU, it is unlikely that many fossils, if any, will be found in the Vintage Dolomite within HOFU.

Stockton Formation (Upper Triassic)
The Upper (Late) Triassic Stockton Formation is characterized by pinkish-gray sandstone and reddish-brown mudstone. The Stockton Formation underlies the upper middle third of HOFU (Bascom and Stose 1938; Berg and Socolow 1981; Inners and Fergusson 1996). The formation was originally deposited as sandy and muddy stream sediments during the Late Triassic, about 221-227 million years ago. The Stockton Formation is part of the Newark Supergroup, which includes sediments from basins throughout the east coast (HOFU is in the Newark Basin). These basins were formed during Late Triassic rifting (tectonic plates splitting apart), which eventually led to the formation of the Atlantic Ocean. The sedimentary rocks found within these basins are frequently red in color and are known as Triassic "red beds". Many of the basins have rich fossil assemblages. The Stockton Formation is also mapped in Valley Forge National Historical Park.

Stockton Formation fossils have not yet been found within HOFU. Exposures of the Stockton Formation within the Newark Basin produced invertebrate body and trace fossils, and reptilian (including dinosaurian) body and trace fossils (e.g. Olsen 1988; Olsen and Flynn 1989). Some fossils were found in exposures near Phoenixville, Sheedy, and Coventryville. These locations in Pennsylvania are between HOFU and Valley Forge National Historical Park, and their fossils are described in greater detail in the VAFO section of this report. The discovery of Stockton Formation fossils within a few kilometers of HOFU, indicates their potential to be found inside the park if good exposures of the formation exist. HOFU has only limited rock exposures, most in the southern reaches of the park according to HOFU Park Ranger Steven Ambrose (personal communication, 2005).

REFERENCES CITED

Alpert, S. P. 1974. Systematic review of the genus *Skolithos*. Journal of Paleontology **48**(4):661-669.

Bascom, F. and G. W. Stose. 1938. Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania. U.S. Geological Survey, Reston, VA. Bulletin 891. 145 pages.

Berg, T. M. and A. A. Socolow, compilers. 1981. [Preliminary geologic map of the] Elverson Quadrangle. Page 195 *in* Berg, T. M. and C. M. Dodge, editors. Atlas of preliminary geologic quadrangle maps of Pennsylvania. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Map 61. Scale 1:62,500.

Inners, J. D and W. B. Fergusson. 1996. French Creek State Park, Berks and Chester Counties: Piedmont rocks and Hopewell Furnace. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Park Guide 6. 10 pages. (http://www.dcnr.state.pa.us/topogeo/parkguides/pg06.pdf)

Olsen, P. E. 1988. Paleontology and paleoecology of the Newark Supergroup (early Mesozoic, eastern North America). Pages 185-230 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental

breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Olsen, P. E. and J. J. Flynn. 1989. Field guide to the vertebrate paleontology of Late Triassic age rocks in the southwestern Newark Basin (Newark Supergroup, New Jersey and Pennsylvania). The Mosasaur **4**:1-43.

Schlegel, M. A. 2004. Preservation of key geologic sites in Lancaster and York Counties, Pennsylvania. Geological Society of America Abstracts with Programs **36**(2):115.

Wise, D. U. 1960. Chickies Rock. Stop 8 *in* Wise, D. U. and M. E. Kauffman, editors. Some tectonic and structural problems of the Appalachian Piedmont along the Susquehanna River. Field Conference of Pennsylvania Geologists, Harrisburg, PA. 25th Annual Guidebook.

Yochelson, E. L. 1968. The lower Cambrian genus *Salterella* at Thomasville, Pennsylvania. Page 384 *in* Abstracts for 1968. Geological Society of America, Boulder, CO. Special Paper 121.

ADDITIONAL REFERENCES

Baird, D. 1986. Some Upper Triassic reptiles, footprints, and an amphibian from New Jersey. The Mosasaur **3**:125-153.

Barwis, J.H. 1985. Tubes of the modern polychaete *Diopatra cuprea* as current velocity indicators and as analogs for *Skolithos-Monocraterion*. Pages 225-235 *in* Curran, H. A., editor. Biogenic structures: Their use in interpreting depositional environments. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 35.

Heath, T. J. and S. C. Good. 1996. Depositional environments of bivalve-bearing strata of the Newark Supergroup basins of Pennsylvania. Geological Society of America Abstracts with Programs **28**(3):63.

Olsen, P. E. 1980. The latest Triassic and Early Jurassic formations of the Newark Basin (eastern North America, Newark Supergroup); stratigraphy, structure and correlation. Bulletin of the New Jersey Academy of Science **25**(2):25-51.

Olsen, P. E. 1980. Triassic and Jurassic formations of the Newark Basin. Pages 2-39 *in* Manspeizer, W., editor. Field studies of New Jersey geology and guide to field trips. New York State Geological Association, Albany. 52nd Annual Meeting Guidebook.

Olsen, P. E. 1988. Paleontology and paleoecology of the Newark Supergroup (early Mesozoic, eastern North America). Pages 185-230 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Olsen, P. E. and J. J. Flynn. 1989. Field guide to the vertebrate paleontology of Late Triassic age rocks in the southwestern Newark Basin (Newark Supergroup, New Jersey and Pennsylvania). The Mosasaur **4**:1-43.

Olsen, P. E., R. W. Schlische, and P. J. W. Gore. 1989. Tectonic, depositional, and paleoecological history of Early Mesozoic rift basins, eastern North America. American Geophysical Union, Washington, DC. 28th International Geological Congress Field Trip Guidebook T-351.

O'Neill, B. J. 1976. Our mineral heritage; Hopewell Village. Pennsylvania Geology **7**(3):2-5.

Shultz, C. H., editor. 1999. The geology of Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Special Publication SP 1. 888 pages.

Turner-Peterson, C. E. and J. P. Smoot. 1985. New thoughts on facies relationships in the Triassic Stockton and Lockatong formations, Pennsylvania and New Jersey. Pages 10-17 *in* Robinson, G. R., Jr. and A. J. Froelich, editors. Proceedings of the Second U.S. Geological Survey workshop on the early Mesozoic basins of the Eastern United States. U.S. Geological Survey, Reston, VA. Circular 946.

DATA SETS

DS-HOFU-XXX	Hopewell Furnace National Historic Site Paleontological Archives. 5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

PETERSBURG NATIONAL BATTLEFIELD

Petersburg National Battlefield (PETE) preserves the setting of a 10 month campaign led by Union forces to seize the city of Petersburg in 1864-1865. The Confederate collapse that led to the fall of the city and eventually Richmond occurred along the western edge of current park boundaries at Five Forks Battlefield. Other park units that comprise the almost 2,660 acres of PETE include the Crater, Taylor Farm, Confederate batteries, Poplar Grove National Cemetery, numerous forts, and Appomattox Manor at City Point in Hopewell, VA. The park was established as a national military park in 1926, transferred to the NPS in 1933, and redesignated as a national battlefield on August 24, 1962.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

The NPS Geologic Resources Division completed geologic scoping sessions for Petersburg National Battlefield in 2005. No formal paleontological resource inventories have been completed for PETE; however paleontological discoveries inside park boundaries date to the middle 1800s. Some of these reports relate to military engagements at Petersburg and a small number of fossil specimens are accessioned in park collections. Future paleontological finds are anticipated inside the park as multiple fossiliferous formations are mapped in the area of Petersburg National Battlefield.

Theodore Lyman, a biologist accompanying Meade and Grant at Petersburg during the Civil War, recorded in his journal that "all this country is underlain more or less by marl beds" derived from "old sea bottoms full of a good many different shells" (Lyman 1994). Though he may have previously understood the geology of the region, a drought in 1864 verified that indeed many of the local battlefields rest upon fossiliferous ground. The lack of water that summer forced Union soldiers to dig wells, one of which yielded a "quantity of shells" that Lyman intended on sending to naturalist Louis Agassiz for investigation (Lyman 1994). It is not certain if this scientific find occurred on land now enclosed inside Petersburg National Battlefield, but the historical account does confirm that fossil-bearing sediments cover much of the region and that future discoveries in and around the park are highly probable. Agassiz established Harvard's Museum of Comparative Zoology in 1859, and the specimens may have been curated there. Museum staff will be reworking the Tertiary collection, which may provide information regarding the current disposition of Lyman's specimens (F. Collier, personal communication, 2006).

Petersburg National Battlefield lies on the border between the Piedmont and Coastal Plain physiographic provinces. This boundary, commonly called the Fall Line, runs through the battlefields at PETE. Hence, Paleozoic rocks are mapped in western areas of the park such as Burgess Mill and Five Forks Battlefield, while Cenozoic sediments cover remaining land in the central and eastern portions of PETE. The Piedmont region is characterized by rolling hills of igneous and metamorphic rocks that are commonly not fossiliferous. Though much of the area enclosed by Petersburg National Battlefield has not been extensively mapped, larger geologic maps of Virginia suggest that the battlefields at Five Forks and Burgess Mill are underlain by Paleozoic granitic rocks such as the Late Mississippian Petersburg Granite (Wright et al. 1975; Inners et al. 1995). This grayish pink, medium grained to porphyritic granite is a common basement material in eastern Virginia (Goodwin 1979). The 330 million-year-old unit is reported from a number of localities around Petersburg including exposures along the Appomattox and James Rivers (e.g., Goodwin 1979; Inners et al. 1995). There is very little potential for unearthing paleontological resources in the Piedmont section of PETE as such igneous and metamorphic rocks are usually not suitable for fossil preservation.

Coastal Plain units that comprise the underlying sediments at Petersburg National Battlefield are composed of the Cretaceous Potomac Formation, Paleocene-Eocene Pamunkey Group (Paleocene Aquia Formation), Miocene-Pliocene Chesapeake Group (Miocene Eastover Formation, Pliocene Yorktown Formation), Pliocene Bacons Castle Formations, Pleistocene Shirley Formation and other Quaternary surficial deposits. Many of these formations are fossiliferous throughout the Coastal Plain and several have yielded paleontological specimens in and around the park. Other Tertiary deposits belonging to the

Paleocene-Eocene Pamunkey and Miocene-Pliocene Chesapeake Groups may be present at PETE based on the geology of the region (e.g., Dischinger 1987; Inners et al. 1995); however none are mentioned in current geological descriptions of land encompassed by Petersburg National Battlefield. These unidentified units are not discussed in the following section, but can be found in the chapter on Richmond National Battlefield of this report.

Potomac Formation (Lower Cretaceous)
The fluvial-deltaic deposits of the Potomac Formation are partially overlain by the visitor center and main battlefield centrally located at PETE (Mixon et al. 1989, Inners et al. 1995). This Coastal Plain basal unit is uplifted east of Harrisons Creek by the Dutch Gap fault zone (Inners et al. 1995) and mapped extensively along the southern bank of the Appomattox River near City Point National Cemetery (Dischinger 1987). The Potomac Group consists of gravel, sand, silt, and clay commonly divided into the Patuxent Formation, Arundel Clay, and Patapsco Formation in coastal Maryland. Most geologists in Virginia do not separate Lower (Early) Cretaceous sediments, however, as they are difficult to differentiate at this level (Seiders and Mixon 1981, Meng and Harsh 1988, Drake and Froelich 1986, Mixon et al. 2000). See Fredericksburg and Spotsylvania National Military Park (FRSP) section of this report for more information.

The Potomac Formation contains a variety of paleontological resources including pollen, ferns, horsetails, cycads, conifers, mollusks, fish, amphibians, crocodiles, turtles, birds, small mammals, and ichnofossils (Clark et al. 1911; Little 1917; Carr 1950; Cooke 1952; Johnston 1962; Brenner 1963; Cifelli et al. 1999; Rose et al. 2001; Weems and Bachman 2004). Dinosaur remains are also reported from this formation by Carr (1950), Weishampel and Young (1966), Lipka (1998) and Kranz (1989, 1996, 1998, 2003) and are important as some of the initial dinosaur discoveries in this country before expeditions in the western United States. Floral assemblages from the Potomac Formation are also significant for studies of angiosperm evolution (e.g., Doyle and Hickey 1972, 1976). Some of these early angiosperm fossils derived from bluffs along the James River north of Petersburg National Battlefield (Hickey and Doyle 1977). New plant species are documented from a number of nearby exposures in Chesterfield County (Crane and Upchurch 1987) and Prince George County (Srinivasan 1992; Friis et al. 1995). Puddledock Pit of Prince George County is situated in the Hopewell quadrangle proximal to the City Point unit of PETE (Srinivasan 1992). Outcrops of the Potomac Formation are also observed at Point of Rocks on the Appomattox River, along the south bank of the abandoned James River channel near Farrar Island, and on the east bank of the Appomattox River next to Halls Island (Dischinger 1987). Exposures near Dutch Gap produced an abundant paleobotanical assemblage, however, these exposures have been obscured by riprap (L. Ward, personal communication, 2006). Though no paleontological resources of the Potomac Formation are presently documented at Petersburg National Battlefield, fossils from this deposit may be discovered in the future at the park.

Pamunkey Group: Aquia Formation (upper Paleocene)
Shallow marine environments of the Paleocene are preserved in this glauconitic, clayey silt unit of variable shell content at several localities in the vicinity of Petersburg (Ward 1985; Dischinger 1987). The Aquia Formation is divided into the lower Piscataway Member and upper Paspotansa Member (Clark and Martin 1901), both characterized by an assemblage of molluscan genera such as *Cucullaea, Ostrea, Crassatellites*, *Dosiniopsis,* and *Turritella* (Ward 1985; Mixon et al. 2000). Other fossils in the Aquia include *Ophiomorpha* burrows, (Mixon et al. 2000), dinoflagellates and dinocysts (McLean 1972, 1974; Edwards 1983), foraminifera (Nogan 1962, 1964), ray plates and shark teeth (Clark and Martin 1901; Case 1989; Ward and Weist 1990), marine fish and crocodiles (Kranz and Santucci 2004), sea turtles (Weems 1988), birds (Olson 1994), and terrestrial mammals (Rose 2000). For more information, see the FRSP section of this report.

Local exposures of the Aquia Formation are noted by Ward (1985) in his analysis of the Paleocene-Eocene Pamunkey Group of the Virginia Coastal Plain. North of Petersburg, a section on the right bank of the James River contains *Crassatellites, Turritella,* and *Ostrea* specimens of the older Piscataway Member. East of the city in Prince George County, an exposure of the upper Aquia is full of *Turritella*

mortoni and *Ostrea sinuosa* (Ward 1985). Molluscan faunas from the Paspotansa Member are also recognized above the Shirley Plantation across the river in Charles City County. The younger Aquia is further documented at City Point in Hopewell, VA (Ward 1985), a locality that closely corresponds to land enclosed by Petersburg National Battlefield.

Appomattox Manor and Grant's Cabin are historical landmarks preserved at the Hopewell unit of PETE. The Aquia Formation serves as the foundation for City Point and is partially exposed along the western edge of this peninsula (Dischinger 1987, National Park Service 2000, 2004). Dr. Richard Eppes, 19th century owner of the Appomattox Plantation, collected gigantic fossil oyster shells from one of his fields near City Point in Hopewell (J. Blankenship and C. Calkins, personal communication, 2006). He recorded his paleontological discoveries in a diary that is now in the care of the Virginia Historical Society in Richmond. Though Dr. Eppes may not have discovered these fossils inside the current boundaries of Petersburg National Battlefield, J. Blankenship and J. Costello (personal communication, 2006) recently confirmed that these oysters are part of the park collections. One is figured on the cover of this report.

Another prominent Virginian who historically collected fossils near Petersburg is Edmund Ruffin. Ruffin is famous for firing the first shot of the Civil War, but also pioneered the agricultural use of "marl" (lime derived from fossil shells from formations such as the Aquia) to revitalize Virginia farms in the early and middle 1800s (e.g. Mitchell 1981). As reported by Mitchell (1981) and Ward (personal communication, 2006), Ruffin kept a large fossil shell collection. His collection likely came from Tertiary exposures (e.g. Aquia Formation) along the James and Pamunkey rivers. While he lived in Petersburg, he may have collected shells from the local area, perhaps the well known exposures at City Point (L. Ward, personal communication, 2006). Many of Ruffin's possessions were destroyed or damaged during occupation of his properties by Federal soldiers during the Civil War, although it is not clear in Mitchell (1981) what fate befell his fossil collection.

Other fossils reported from the Hopewell unit at PETE comprise shark teeth uncovered during archaeological investigations at City Point. Several of these paleontological resources are catalogued in park collections and verify the presence of fossiliferous deposits inside park boundaries (J. Blankenship, personal communication, 2006). Both sets of fossils should be identified at the species level in order to confirm their stratigraphic assignment, but the local geology suggests that these paleontological resources likely derived from the Aquia Formation. The prospect for future fossiliferous finds in the Aquia at Petersburg National Battlefield is highly probable, especially in the area encompassed by City Point.

Chesapeake Group: Eastover Formation (upper Miocene)

Upper (late) Miocene shelly sands along the James River comprise the shallow marine deposits of the Eastover Formation in Virginia (Ward and Blackwelder 1980). These sediments near Petersburg are historically referred to as the St. Mary's Formation, but are now considered a separate unit composed of the lower Claremont Manor Member and upper Cobham Bay Member. *Spisula rappahannockensis* is a bivalve guide fossil for the Eastover Formation and is observed at a number of localities in the vicinity of Petersburg (Blackwelder and Ward 1976).

East of Petersburg, Ward (1985) comments on an exposure of the Eastover Formation that contains *Isognomon, Euloxa,* and *Chesapecten middlesexensis*. Near the Defense Line route at Lee Memorial Park, an outcrop along Lieutenant Run exhibits the Eastover-Yorktown contact. Several paleontological resources are described from this locality including *Ostrea compressirostra, Chesapecten middlesexensis,* and *Spisula rappahannockensis* (Mittwede 1982) as well as small abundant *Turritella*, *Mulinia congesta*, and microfossils (Andrews 1980). Numerous 19th century investigations of Miocene deposits from Petersburg are also recorded in the literature by Bailey (1843, 1844) and Riley (1880) among others, but recent research indicates that these diatomaceous and molluscan assemblages may belong to the Pliocene instead. Though the Eastover Formation is mapped in a number of areas outside of Petersburg National Battlefield, geologic research involving this deposit at the park is only reported from inside the tunnel beneath the Crater (Inners et al. 1995; National Park Service 2000). No fossils are recorded in this formation at the Crater, but bones and teeth derived from this unit are observed nearby at Ft. Stedman

and Poor Creek (L. Ward, personal communication, 2006). The prospect of finding future paleontological specimens from the Eastover at PETE is good.

Chesapeake Group: Yorktown Formation (lower and upper Pliocene)
The marine, marginal-marine, and fluvial sediments of the Yorktown Formation offer strong potential for discovery of paleontological resources at Petersburg National Battlefield. This extensively fossiliferous unit contains over 500 molluscan species (Campbell 1993) and is exposed throughout the Coastal Plain of North Carolina and Virginia (Mixon et al. 2000) including the city of Petersburg (Goodwin 1979). Geological investigations of the Yorktown Formation at PETE revealed coral, shark teeth, and shell debris of variable size from cores retrieved beneath the Crater (National Park service 2000).

The stratigraphy of the Yorktown Formation is divided into the Sunken Meadow, Rushmore, Morgarts Beach, and Moore House Members (Ward and Blackwelder 1980). The coarse-grained, poorly sorted sand of the Sunken Meadow Member contrasts strongly against the overlying fine-grained, well-sorted sand of the Rushmere Member. Sediments of the Morgarts Beach range from a very fine-grained sandy clay to silty clay commonly interspersed by beds of silty sand. Mollusks are ubiquitous in these lower and middle stratigraphic horizons, but are less abundant in the Moore House Member, the youngest Yorktown deposit (Ward and Blackwelder 1980). Mansfield (1943) divided the Yorktown Formation into zones based on molluscan assemblages instead. The lower zone contains a notable 105 molluscan species; however the upper zone is much more diverse at 507 molluscan species (Campbell 1993).

Yorktown molluscan assemblages are an important stratigraphic component of Pliocene near-shore deposits that stretch from New England to Florida (Campbell 1993). They are also frequently utilized in ecological, evolutionary, and isotopic investigations (Campbell 1976; Krantz 1990; Daley 1998, 1999; Baugh and Lockwood 2003; Blow and Bailey 2003; Lockwood and Baugh 2003; Dietl and Kelley 2004; Tolcin and Lockwood 2004). One interesting specimen analyzed by Palmer (1958) shed light on the reproductive habits of gastropod, *Turritella pilsbryi* (later assigned to *Turritella bipertita* by Campbell 1993). This shell contained evidence of over 100 embryos, thereby indicating that this "viviparous" species gave birth to live young. More on the molluscan faunas of the Yorktown Formation can be found in McGavock (1935, 1944), Twardy (1936), McLean (1956), Johnson (1972), Cecca (1982), McKeever (1985), Campbell (1993), Ward (1993), and Blow and Bailey (2003).

Campbell (1993) recorded more than 500 molluscan species in the Yorktown Formation, although a number are likely from the overlying Chowan River Formation (L. Ward, personal communication, 2006). The earliest documentation of fossils from this deposit originally classified as Miocene dates back to the late 17th century (Ward and Blackwelder 1975). Martin Lister published on the first described and figured fossil from North America in 1687, a scallop shell later named *Chesapecten jeffersonius*. This species is not only historically important as the earliest fossil representation from North America, but is now recognized as the state fossil of Virginia. The original specimen analyzed by Lister possibly derived from an area now within Colonial National Historical Park. This amazing story and other early descriptions of the Yorktown Formation are discussed in the Northeast Coastal and Barrier Network report by Kenworthy and Santucci (2003).

Marine macrofauna of the Yorktown Formation comprise whales (Johnson 1972; Baum and Wheeler 1977; Whitmore 1994; Westgate and Whitmore 2002), walrus (Berry and Gregory 1906), and fish (McLean 1956; Johnson 1972). Less common molluscan fossils such as cephalopod statoliths and scaphopods are noted by Sabol (1960), Johnson (1972), and Clarke and Fitch (1975). Crabs (Blow 2003; Blow and Bailey 2003), echinoids (McLean 1956; Johnson 1972; Kier 1972), brachiopods (Johnson 1972; Ward 1993), barnacles (Sabol 1960; Ross, 1964; Johnson 1972; Ward 1993), coral (Sabol 1960; Johnson 1972), and annelids (Johnson 1972) are additionally documented. Microfossils composed of bryozoans (McLean 1956; Sabol 1960; Johnson 1972), sponge spicules (Sabol 1960; Johnson 1972), ostracodes (Schmidt 1939; McLean 1957, 1966; Hazel 1971), and foraminifera are mentioned by McLean (1956, 1966), Gibson and Bybell (1984), Cronin et al. (1989), and Dowsett and Wiggs (1992). *Ophiomorpha* burrows are also

common in Virginia sections of the Yorktown Formation as noted by Mixon et al. (1992) and Mixon et al. (2000).

The best exposures of the Yorktown are located in southeastern Virginia near the James and York Rivers. Several investigations record ostracodes (Fountain 1972), barnacles (Campbell and Zullo 1988) and pelecypods (Mansfield 1943; Williams 1970; Ward 1985; Krantz 1990) from this deposit in the vicinity of Petersburg. Krantz (1990) utilized fossil scallops of the Yorktown for paleoclimate research of the Coastal Plain including specimens retrieved at Lieutenant Run in Petersburg. The Eastover-Yorktown contact is exposed at Lieutenant Run, a locality proximal to the Defense Line route near Lee Memorial Park (Ward and Blackwelder 1980). Fossils from this section are noted by numerous authors such as Andrews (1980) and Mittwede (1982). Paleontological resources are also reported from the Yorktown inside park boundaries after a geological analysis revealed fossiliferous sediments underlying the Crater.

Chesapeake Group: Yorktown Formation-"The Crater"
Prior to the capture of the city by Union forces, Colonel Henry Pleasants developed a plan to surprise the Confederate forces by setting off an explosion underneath Pegram's Redan (Inners et al. 1995). His men excavated an underground tunnel that measured nearly 179 m (586 ft) in length positioning them directly below the Confederates (Inners et al. 1995). However, numerous reports indicate that Union men came upon a bed of "marl" about 61 m (200 ft) from the opening that impeded their progress and ultimately caused them to proceed further at more dangerous, shallower depths (Inners et al. 1995, National Park Service 2000). The NPS Geologic Resources Division (GRD) investigated this "marl" layer as part of a plan to develop a detailed geologic map of Petersburg National Battlefield. GRD originally believed that a fault between Union and Confederate lines might be responsible for Union mining difficulties due to the presence of the local Dutch Gap fault zone, but after drilling they discovered that the dense clay bed of "marl" signified an abandoned channel deposit instead (Inners et al. 1995, National Park Service 2000). The geologic cross-section of the tunnel at Petersburg exhibits the Eastover Formation, Yorktown Formation, and Bacons Castle Formation. Tunneling activities before and after encountering the "marl" layer occurred primarily in the Yorktown and the origin of the abandoned channel deposit also corresponds to this Pliocene unit (National Park Service 2000). Typical lower layers of the Yorktown Formation reveal shark teeth, coral, and fragmentary molluscan material and upper layers consist of glauconitic sands that grade into clayey silts. As reported in National Park Service (2000), two shark teeth typical of the Yorktown Formation were discovered during the GRD investigation. These teeth were not formally curated into PETE collections, but may still be within natural resources office at the park (H. Pranger, R. Easterbrook, and T. Blumenschine, personal communication, 2006). The success of the tunnel explosion at Petersburg led to the development of an oblong crater that is 52 m (170 ft) long, 18-24 m (60-80 ft) wide, and nearly 9 m (30 ft) deep (Lykes 1985). The Crater now serves as an excellent reminder of how geologic conditions can influence military decisions (National Park Service 2000).

Bacons Castle Formation (upper Pliocene)
This upper (late) Pliocene sand and gravel deposit represents fluvial through intertidal paleoenvironments. Microfossils comprise the only paleontological resources recorded for this formation consisting of pollen from *Quercus, Carya, Pinus, Picea, Alnus, Betula, Nyssa,* and *Ulmus* (Groot et al. 1990). The visitor center at PETE lies on part of the Prince George upland, a surficial unit covering much of the area south and east of Petersburg all the way past Reams Station to the Nottoway River (Inners et al. 1995). This upland corresponds to the Chimborazo flat of the York-James Peninsula and is primarily underlain by the Bacons Castle Formation (Inners et al. 1995). Since microfauna are the only fossil specimens recorded in this deposit, potential for future paleontological finds inside the park is limited.

Shirley Formation (middle Pleistocene)
Sand, gravel, and clay of the Shirley Formation represents surficial river deposits once believed to be part of the upper Pleistocene Norfolk Formation (Mixon et al. 1989). The Shirley is fossiliferous in the lower James River and Rappahannock River sections. Paleontological resources include *Crassostrea virginica,*

Mulinia, Noetia, and *Mercenaria* among other mollusks documented by Mixon et al. (1989). The coral *Astrangia* and organic plant fragments are also present in the Shirley Formation.

The foundation of City Point in Hopewell is the Paleocene Aquia Formation; however most buildings are immediately underlain by the surficial deposits of the Shirley Formation (National Park Service 2000, 2004). Loose basal material of the Shirley is highly subject to erosion, thus ongoing recession of the bluffs at City Point is a concern in the preservation of land and cultural resources at Petersburg National Battlefield (National Park Service 2000, 2004). The NPS Geologic Resources Division (GRD) recently assessed the state of erosion at the bluffs and considered the need for measures of stabilization. Though many factors minimally affect ongoing erosion at City Point, increased occurrence of hurricanes and rising river levels expedite these natural processes (National Park Service 2000). Unfortunately, most means of stabilization are not affordable, not visually desirable, and not compatible in regards to NPS practices of maintaining natural processes. Long-term preservation of cultural resources at the bluffs now requires further investigation as artificial stabilization measures cannot be utilized (National Park Service 2000). The care of paleontological resources that erode out of the bluffs should also be considered in future preservation plans as this region is underlain by both Paleocene and Pleistocene fossiliferous formations.

Surficial Deposits (Quaternary)
Petersburg National Battlefield is underlain in part by an assortment of clay, silt, sand, and gravel from near shore fluvial-estuarine paleoenvironments of the Pleistocene and Holocene. The eastern edge of the unit at City Point and a number of other park areas are mapped as Quaternary alluvium (Dischinger 1987). These surficial deposits do not commonly contain paleontological resources; however discoveries of fossils that eroded out of previous stratigraphic units are documented in similar unconsolidated sediments. Fossilized wood from the Pleistocene is reported from gravel-rich sand islands near the Dutch Gap cutoff along the James River (L. Ward, personal communication, 2006) and paleontological resources reworked from older sediments may also be exposed in local Quaternary surficial deposits.

Paleontological Resource Potential and Monitoring
There is strong potential for fossiliferous finds at Petersburg National Battlefield in the future. Historical reports and recent archaeological and geological surveys confirm a variety of paleontological resources inside park boundaries. These fossil-bearing deposits include bluffs near the river at City Point, a locality that should be periodically monitored for preservation of cultural and paleontological resources. The Dutch Gap fault zone and the influence of rising rivers near Petersburg warrants consideration as well, in that natural hazards can easily endanger the stability of fossiliferous strata or perhaps unearth new and exciting finds instead. Hurricane Isabel (2003) may have increased the rate of erosion along the bluffs of City Point, and paleontological discoveries at Hopewell may be more likely to occur once the paleontologically prolific Aquia Formation is exposed. Other park areas offer the potential for future fossiliferous finds as well; however localities near streams and rivers may be more productive than park units requiring construction or archaeological surveys to reach the underlying fossil-bearing sediments.

COOPERATIVE PROJECTS

- Geologic Investigations (2000 and 2004)-NPS Geologic Resources Division staff worked with PETE to study the subsurface geology of The Crater and City Point (2000) and to assess City Point after a major hurricane (2004). Both investigations noted the presence of paleontological resources. Contact Hal Pranger (GRD) for additional information.

REFERENCES CITED

Andrews, G.W. 1980. Neogene diatoms from Petersburg, Virginia. Micropaleontology **26**(1):17-48.

Bailey, J. W. 1843. On infusorial deposits at Petersburg, Virginia. American Journal of Science **45**(2):313.

Bailey, J. W. 1844. Account of some new infusorial forms discovered in the fossil Infusoria from Petersburg, Virginia, and Piscataway, Maryland. American Journal of Science **46**(1):137-141.

Baugh, H. L. and R. Lockwood. 2003. Does abundance promote survivorship during background extinction intervals? A case study using bivalve species from the Yorktown Formation. Geological Society of America Abstracts with Programs **35**(1):69.

Baum, G. R. and W. H. Wheeler. 1977. Cetaceans from the St. Mary's and Yorktown Formations, Surry County, Virginia. Journal of Paleontology **51**(3):492-504.

Berry, E. W. and W. K. Gregory. 1906. *Prorosmarus alleni*, a new genus and species of walrus from the Upper Miocene of Yorktown, Virginia. American Journal of Science **21**:444-450.

Blackwelder, B. W. and L. K. Ward. 1976. Stratigraphy of the Chesapeake Group of Maryland and Virginia; Field Trip Guidebook. 55 pages.

Blow, W. C. 2003. New brachyuran crabs (Crustacea, Decapoda) from the upper Pliocene Yorktown Formation of southeastern Virginia. Proceedings of the Biological Society of Washington **116**(1):168-189.

Blow, W. C. and R. H. Bailey. 2003. A late Pliocene pea crab infestation of the slipper-shell *Crepidula fornicate* (Linnaeus, 1758) from the Yorktown Formation of southeastern Virginia. Geological Society of America Abstracts with Programs **35**(6):58.

Brenner, G. J. 1963. The spores and pollen of the Potomac Group of Maryland. Maryland Geological Survey, Baltimore, MD. Bulletin 27. 215 pages.

Campbell, L. D. 1976. Paleoecology of the Lone Star Industries pit, Yorktown Formation (Pliocene), Chuckatuck, Virginia. University of South Carolina, Columbia, SC. Unpublished PhD Dissertation. 198 pages.

Campbell, L. D. 1993. Pliocene Mollusks from the Yorktown and Chowan River Formations in Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 127. 259 pages.

Campbell, L. D. and V. A. Zullo. 1988. *Scalpellum multangulatum* (H.C. Lea, 1843) (Cirripedia, Scalpellidae), Senior Synonym of *S. gibbum* Pilsbry, 1907. Journal of Paleontology **62**(3):479-481.

Carr, M. 1950. The District of Columbia: Its rocks and their geologic history. U.S. Geological Survey, Reston, VA. Bulletin 967. 59 pages.

Case, G. R. 1989. *Palaeocarcharodon orientalis* (Sinzow) (Neoselachii: Cretoxyrhinidae) from the Paleocene of Maryland, USA Palaeovertebrata **19**(1):1-6.

Cecca, C. L. 1982. *Ostrea* from the Eastover and Yorktown formations of southeastern Virginia. Virginia Journal of Science Abstracts **33**(3):153.

Cifelli, R. L., T. R. Lipka, C. R. Schaff, and T. B. Rowe. 1999. First Early Cretaceous mammal from the eastern seaboard of the United States. Journal of Vertebrate Paleontology **19**(2):199-203.

Clark, W. B., A. B. Bibbins, and E. W. Berry. 1911. The Lower Cretaceous deposits of Maryland. Pages 23-99 *in* C. Schuchert, C. K. Swartz, T. P. Maynard, and R. B. Rowe, editors. Lower Cretaceous. Maryland Geological Survey, Baltimore, MD.

Clark, W. B. and G. C. Martin. 1901. The Eocene deposits of Maryland. Maryland Geological Survey, Baltimore, MD. Pages 19-91.

Clarke, M. R. and J. E. Fitch. 1975. First fossil records of cephalopod statoliths. Nature **257**:380-381.

Cooke, C. W. 1952. Sedimentary Deposits. Pages 1-52 *in* C. W. Cooke, R. O. R. Martin, and G. Meyer, editors. Geology and Water Resources of Prince George's County. Maryland Geological Survey, Baltimore, MD. Bulletin 10.

Crane, P. R. and G. R. Upchurch, Jr. 1987. *Drewria potomacensis* gen. et sp. nov., an Early Cretaceous member of Gnetales from the Potomac Group of Virginia. American Journal of Botany **74**(11):1722-1736.

Cronin, T. M., H. J. Dowsett, L. B. Gosnell, and R. M. Ross. 1989. Pliocene marine micropaleontology of southeastern Virginia and northeastern North Carolina. U.S. Geological Survey, Reston, VA. Open-File Report. 27 pages.

Daley, G. M. 1998. Guild structure of paleocommunity types; an example from the Yorktown Formation (Pliocene) of Virginia. Geological Society of America Abstracts with Programs **30**(7):33.

Daley, G. M. 1999. Local paleocommunities and paleocommunity types, but no paleocommunities; an example from the Yorktown Formation (Pliocene) of eastern Virginia. Geological Society of America Abstracts with Programs **31**(7):470.

Dietl, G. P. and P. H. Kelley. 2004. Emergent effects of multiple predators on prey in the fossil record. Geological Society of America Abstracts with Programs **36**(5):480.

Dischinger, J. B. 1987. Late Mesozoic and Cenozoic stratigraphic and structural framework near Hopewell, Virginia. U.S. Geological Survey, Reston, VA. Bulletin 1567. 48 pages. 1:24,000 scale map.

Drake, A. A., Jr. and A. J. Froelich. 1986. Geologic map of the Annandale quadrangle, Fairfax and Arlington Counties, and Alexandria City, Virginia. U.S. Geological Survey, Reston, VA. Geologic Quadrangle Map GQ-1601, 1:24,000 scale map.

Dowsett, H. J. and L. B. Wiggs. 1992. Planktonic foraminiferal assemblage of the Yorktown Formation, Virginia, USA. Micropaleontology **38**:75-86.

Doyle, J. A. and L. J. Hickey. 1972. Coordinated evolution in Potomac Group angiosperm pollen and leaves. American Journal of Botany Abstracts **59**(6):660.

Doyle, J. A. and L. J. Hickey. 1976. Pollen and leaves from the mid-Cretaceous Potomac Group and their bearing on early angiosperm evolution. Pages 139-206 *in* C. B. Beck, editor. Origin and Early Evolution of Angiosperms. Columbia University Press, New York, NY.

Edwards, L. E. 1983. Paleocene and early Eocene dinocyst biostratigraphy. Geological Society of America Abstracts with Programs **15**(2):59.

Fountain, A. W., II. 1972. Pelecypods of the Yorktown Formation (Miocene) of Petersburg, Virginia. Virginia State University, Petersburg, VA. Unpublished Master's Thesis. 48 pages.

Friis, E. M., K. R. Pedersen, and P. R. Crane. 1995. *Appomattoxia ancistrophora* gen. et. sp. nov., a new Early Cretaceous plant with similarities to Circaester and extant Magnoliidae. American Journal of Botany **82**(7):933-943.

Gibson, T. G. and L. M. Bybell. 1984. Foraminifers and calcareous nannofossils of Tertiary strata in Maryland and Virginia; a summary. Pages 181-189 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwestern Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Goodwin, B. K. 1979. Geology of the Richmond-Petersburg area. Pages 1-15 *in* J. D. Exline, editor. Guidebook for Field Trips in Virginia.

Groot, J. J., K. W. Ramsey, and J. F. Wehmiller. 1990. Ages of the Bethany, Beaverdam, and Omar formations of southern Delaware. Delaware Geological Survey, Newark, DE. Report of Investigations 47.

Hazel, J. E. 1971. Ostracode biostratigraphy of the Yorktown Formation (upper Miocene and lower Pliocene) of Virginia and North Carolina. U.S. Geological Survey, Reston, VA. Professional Paper 704. 13 pages.

Hickey, L. J. and J. A. Doyle. 1977. Early Cretaceous fossil evidence for angiosperm evolution. The Botanical Review **43**(1):3-104.

Inners, J. D., B. E. Inners, and D. M. Sayre. 1995. Military geology of the Richmond and Petersburg National Battlefield Parks, Virginia. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Open File Report 95-08. 75 pages.

Johnson, G. H. 1972. Geology of the Yorktown, Poquoson West, and Poquoson East Quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 30. 57 pages.

Johnson, G. H. and P. C. Peebles. 1985. Depositional and tectonic significance of upper Cenozoic deposits in the vicinity of Richmond, Virginia. Geological Society of America Abstracts with Programs **17**(7):620.

Johnston, P. M. 1962. A visitors guide to the geology of the National Capital area. Prepared for the Third General Meeting of the International Mineralogical Association April 17-20, 1962. Washington, D.C. 32 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.

Kier, P. M. 1972. Upper Miocene Echinoids from the Yorktown Formation of Virginia and Their Environmental Significance. Smithsonian Contributions to Paleobiology 13. 41 pages.

Krantz, D. E. 1990. Mollusk-isotope records of Plio-Pleistocene marine paleoclimate, U. S. Middle Atlantic Coastal Plain. Palaios **5**(4):317-335.

Kranz, P. M. 1989. Dinosaurs in Maryland. Maryland Geological Survey, Baltimore, MD. Educational Series 6. 34 pages.

Kranz, P. M. 1996. Notes on the sedimentary iron ores of Maryland and their dinosaurian fauna. Pages 87-115 *in* D. K. Brezinski and J. P. Reger, editors. Studies in Maryland Geology - In Commemoration of the Centennial of the Maryland Geological Survey. Maryland Geological Survey, Baltimore, MD. Special Publication 3.

Kranz, P. M. 1998. Mostly Dinosaurs: A review of the vertebrates of the Potomac Group (Aptian Arundel Formation) USA. Pages 235-238 *in* S. G. Lucas, J. I. Kirkland, and J. W. Estep, editors. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 14.

Kranz, P. M. 2003. Dinosaurs of the District of Columbia. Dinosaur Fund, Washington, D.C. 31 pages. (http://www.glue.umd.edu/~gdouglas/articles/Kranz6.pdf).

Kranz, P. M. and V. L. Santucci. 2004. Preliminary research for paleontological resources of the national parks of the National Capital Region. 13 pages.

Lipka, T. R. 1998. The affinities of the enigmatic theropods of the Arundel Clay Facies (Aptian): Potomac Formation, Atlantic Coastal Plain of Maryland. Pages 229-234 *in* S. G. Lucas, J. I. Kirkland, and J. W. Estep, editors. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 14.

Little, H. P. 1917. The geology of Anne Arundel County, Maryland. Maryland Geological Survey, Baltimore, MD. 232 pages.

Lockwood, R. and H. L. Baugh. 2003. Rarity and extinction during background intervals; are ecological patterns preserved in the fossil record? Geological Society of America Abstracts with Programs **35**(6):417.

Lykes, R. W. 1985. Campaign for Petersburg (Revised Edition). National Park Service Handbook. 80 pages.

Lyman, T. 1994. With Grant and Meade from the Wilderness to Appomattox. University of Nebraska Press, Lincoln, NE. 371 pages.

Mansfield, W. C. 1943. Stratigraphy of the Miocene of Virginia and the Miocene and Pliocene of North Carolina. Pages 1-19 *in* J. Gardner, editor. Mollusca from the Miocene and lower Pliocene of Virginia and North Carolina. U. S. Geological Survey, Reston, VA. Professional Paper 199-A.

McGavock, C. B., Jr. 1935. An analysis of the Yorktown pelecypods. Virginia Journal of Science 71.

McGavock, C. B., Jr. 1944. New pelecypoda from the Yorktown Formation of Virginia. Notulae Naturae of the Academy of Natural Sciences of Philadelphia 139. 3 pages.

McKeever, L. J. 1985. Geographical variation in the genus *Astarte* (Phylum Mollusca; Class Bivalvia) from the Yorktown and Jackson Bluff Formations (early Pliocene) of the Atlantic Coastal Plain. Virginia Polytechnic Institute and State University, Blacksburg, VA. Unpublished Master's Thesis.

McLean, D. M. 1972. *Cladopyxidium septatum*, n. gen., n. sp., possible Tertiary ancestor of the modern dinoflagellate *Cladopyxis hemibrachiata* Balech, 1964. Journal of Paleontology **46**(6):861-863.

McLean, D. M. 1974. Two new Paleocene dinoflagellates from Virginia and Maryland. Palaeontology **17**(1):65-70.

McLean, J. D., Jr. 1956. The Foraminifera of the Yorktown Formation in the York-James Peninsula of Virginia, with notes on the associated mollusks. Bulletins of American Paleontology **36**(160):261-394.

McLean, J. D., Jr. 1957. The Ostracoda of the Yorktown Formation in the York-James Peninsula of Virginia (with notes on the collection made by Denise Mongin from the area). Bulletins of American Paleontology **38**(167):57-103.

McLean, J. D., Jr. 1966. Miocene and Pleistocene Foraminifera and Ostracoda of southeastern Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 9.

Meng, A. A., III. and J. F. Harsh. 1988. Hydrogeologic framework of the Virginia Coastal Plain. U. S. Geological Survey, Reston, VA. Professional Paper 1404-C. 82 pages.

Mitchell, B. L. 1981. Edmund Ruffin: A biography. Indiana University Press, Bloomington.

Mittwede, S. K. 1982. The Eastover Formation-Yorktown Formation contact at the Lieutenant Run Exposure, Petersburg, Virginia. Geological Society of America Abstracts with Programs **14**(1-2):66.

Mixon, R. B., C. R. Berquist, Jr., W. L. Newell, G. H. Johnson, D. S. Powars, J. S. Schindler, and E. K. Rader. 1989. Geologic map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia. U. S. Geological Survey, Reston, VA. Miscellaneous Investigations Series Map I-2033. 1:250,000 scale map.

Mixon, R. B., L. Pavlides, D. S. Powars, A. J. Froelich, R. E. Weems, J. S. Schindler, W. L. Newell, L. E. Edwards and L. W. Ward. 2000. Geologic map of the Fredericksburg 30' x 60' quadrangle, Virginia and Maryland. U.S. Geologic Survey, Reston, VA. Investigations Series Map I-2607. 1:100,000 scale map.

Mixon, R. B., D. S. Powars, R. E. Weems, W. L. Newell, L. E. Edwards, L. W. Ward. 1992. Stratigraphic and structural framework of the inner Atlantic Coastal Plain, Fredericksburg 30' X 60' Quadrangle, Virginia and Maryland. Geological Society of America Abstracts with Programs **24**(2):54.

National Park Service. 2000. Trip and Technical Report, Petersburg National Battlefield (PETE), Geologic Resources Division. 10 pages.

National Park Service. 2004. Subsurface Exploration and Geotechnical Report. City Point Unit, Hopewell, VA. Petersburg National Battlefield. 5 pages.

Nogan, D. S. 1962. Micropaleontology, stratigraphy, and paleoecology of the Aquia Formation of Maryland and Virginia. Rutgers University, New Brunswick, NJ. Unpublished PhD Dissertation. 350 pages.

Nogan, D. S. 1964. Foraminifera, stratigraphy, and paleoecology of the Aquia Formation of Maryland and Virginia. Cushman Foundation for Foraminiferal Research, Washington, D.C. Special Publication 7. 50 pages.

Olson, S. L. 1994. A giant *Presbyornis* (Aves: Anseriformes) and other birds from the Paleocene Aquia Formation of Maryland and Virginia. Proceedings of the Biological Society of Washington **107**:429-435.

Palmer, K. V. W. 1958. Viviparous *Turritella pilsbryi* Gardner. Journal of Paleontology **32**(1):210-213.

Ramsey, K. W. 1987. Geology of the Bacons Castle Formation; York-James Peninsula, Virginia. Geological Society of America Abstracts with Programs **19**(2):125.

Riley, C. V. 1880. The Richmond diatomaceous earth. Science **1**(18):222.

Rose, K. D. 2000. Land-mammals from the Late Paleocene Aquia Formation: The first early Cenozoic mammals from Maryland. Proceedings of the Biological Society of Washington **113**(4):855-863.

Rose, K. D., R. L. Cifelli, and T. R. Lipka. 2001. Second triconodont dentary from the Early Cretaceous of Maryland. Journal of Vertebrate Paleontology **21**(3):628-632.

Ross, A. 1964. Cirripedia from the Yorktown Formation (Miocene) of Virginia. Journal of Paleontology **38**(3):483-491.

Sabol, J. W. 1960. The microfauna of the Yorktown Formation from James River, Surry County, Virginia. Bulletins of American Paleontology **41**(191):211-246.

Schmidt, R. A. M. 1939. Miocene Ostracoda from Yorktown Formation, Virginia. Columbia University, Teachers College, New York, NY. Unpublished Master's Thesis.

Seiders, V. M. and R. B. Mixon. 1981. Geologic map of the Occoquan quadrangle and part of the Fort Belvoir quadrangle, Prince William and Fairfax Counties, Virginia. U.S. Geological Survey, Reston, VA. Miscellaneous Geological Investigations Map I-1175. 1:24,000 scale map.

Srinivasan, V. 1992. Two new species of the conifer *Glenrosa* from the Lower Cretaceous of North America. Review of Palaeobotany and Palynology **72**(3-4):245-255.

Tolcin, A. C. and R. Lockwood. 2004. Abundance and paleoecology of gastropods in the Sunken Meadow Member, Yorktown Formation (Pliocene) of southeastern Virginia. Geological Society of America Abstracts with Programs **36**(2):110.

Twardy, S. A. 1936. A synopsis of Gastropoda of the Yorktown Formation. Virginia Journal of Science 68.

Ward, D. J. and R. L. Weist, Jr. 1990. A checklist of Palaeocene and Eocene sharks and rays (Chondrichthyes) from the Pamunkey Group Maryland and Virginia, USA. Tertiary Research **12**(2):81-88.

Ward, L. W. 1985. Stratigraphy and characteristic mollusks of the Pamunkey Group (Lower Tertiary) and the Old Church Formation of the Chesapeake Group - Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1346. 78 pages.

Ward, L. W. 1993. The G. D. Harris 1890 Manuscript on the Stratigraphy of Miocene and Pliocene Beds at Yorktown, Virginia. Paleontological Research Institution Special Publication 20. 118 pages.

Ward, L. W. and B. W. Blackwelder. 1975. *Chesapecten*, a New Genus of Pectinidae (Mollusca: Bivalvia) From the Miocene and Pliocene of Eastern North America. U.S. Geological Survey, Reston, VA. Professional Paper 861. 24 pages.

Ward, L. W. and B. W. Blackwelder. 1980. Stratigraphic revision of upper Miocene and lower Pliocene beds of the Chesapeake Group, middle Atlantic Coastal Plain. U.S. Geological Survey Bulletin 1482-D. 61 pages.

Weems, R. E. 1988. Paleocene turtles from the Aquia and Brightseat Formations with a discussion of their bearing on sea turtle evolution and phylogeny. Proceedings of the Biological Society of Washington **101**:109-145.

Weems, R. E. and J. M. Bachman. 2004. A dinosaur-dominated ichnofauna from the Lower Cretaceous (Aptian) Patuxent Formation of Virginia. Geological Society of America Abstracts with Programs **36**(2):116.

Weishampel, D. M. and L. Young. 1996. Dinosaurs of the East Coast. Johns Hopkins University Press, Baltimore, MD. 300 pages.

Westgate, J. W. and F. C. Whitmore, Jr., 2002. *Balaena ricei*, a new species of bowhead whale from the Yorktown Formation (Pliocene) of Hampton, Virginia. Cenozoic mammals of land and sea; tributes to the career of Clayton E. Ray. Smithsonian Contributions to Paleobiology **93**:295-312.

Whitmore, F. C., Jr. 1994. Neogene climate change and the emergence of the modern whale fauna of the North Atlantic Ocean. Pages 223-228 *in* A. Berta and T. Démère, editors. Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. Proceedings of the San Diego Society of Natural History 29.

Williams, D. S. 1970. Ostracoda of the Yorktown Formation (Miocene), (Petersburg, Virginia). Virginia State University, Petersburg, VA. Unpublished Master's Thesis. 68 pages.

Wright, J. E., A. K. Sinha, and L. Glover, III. 1975. Age of zircons from the Petersburg Granite, Virginia; with comments on belts of plutons in the Piedmont. American Journal of Science **275**(7):848-856.

Additional References

Abbott, W. H. 1978. Correlation and zonation of Miocene strata along the Atlantic margin of North America using diatoms and silicoflagellates. Marine Micropaleontology **3**:15-34.

Abbott, W. H. 1982. Diatom biostratigraphy of the Chesapeake Group, Virginia and Maryland. Florida Department of Natural Resources, Bureau of Geology, Special Publication **25**:23-34.

Bailey, J. W. 1842. A sketch of the Infusoria, of the family Bacillaria, with some account of the most interesting species which have been found in a recent or fossil state in the United States, Part 2. American Journal of Science and Arts **42**:88-105.

Bailey, J. W. 1845a. Ehrenberg's observations on the fossil Infusoria of Virginia and Maryland, and comparison of the same with those found in the Chalk formations of Europe and Africa. American Journal of Science and Arts **48**:201-205.

Bailey, J. W. 1845b. Fossil Infusoria of Virginia and Maryland. American Journal of Science and Arts **48**:330-337.

Burkhart, D. P. 1988. Four important East Coast Miocene formations. Fossils Quarterly **7**(2):5-16.

Campbell, M. R. 1995. Lithology and paleontology of the Sunken Meadow Member, Yorktown Formation (Pliocene), Virginia. Geological Society of America Abstracts with Programs **27**(2):40.

Conrad, T. A. 1863. Catalogue of the Miocene shells of the Atlantic slope. Academy of Natural Sciences of Philadelphia Proceedings **14**:559-582.

D'Orbigny, A. 1852. Prodrome de Paleontologie stratigraphique universelledes Animaux Mollusques et Rayonnes. Paris. 1017 pages.

Ehrenberg, C. G. 1843. Verbreitung und Einfluss des mikroskopischen Lebens in Süd- und Nord-Amerika. K. Preussische Akademie der Wissenschaften zu Berlin, Physikalische Abhandlungen, 1841:291-445.

Ehrenberg, C. G. 1844. Über 2 neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord-Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika. K. Preussische Akademie der Wissenschaften zu Berlin, Bericht, 1844:57-97.

Ehrenberg, C. G. 1854. Mikrogeologie. L. Voss. Leipzig. 374 pages.

Fairbanks, E. E. 1970. The toughness of silicified wood. Earth Science **23**(2):65-67.

Giles, A. W. 1918. The country about Camp Lee [near Petersburg], Virginia. Virginia Geological Survey Bulletin 16. 40 pages.

Heilprin, A. 1884. Contributions to the Tertiary Geology and Paleontology of the United States. Philadelphia. 117 pages.

Herman, J. D. 1991. The effects of groundwater leaching on fossil preservation in the Yorktown Fm. Virginia Journal of Science **42**(2):220.

Hofler, V. E. 1974. A geological field trip in the Petersburg, Virginia and surrounding areas. Virginia State University, Petersburg, VA. Unpublished Master's Thesis. 35 pages.

Inners, J. D. 1989. Colonel Henry Pleasants and the military geology of the Petersburg Mine; June-July, 1864. Pennsylvania Geology **20**(5):3-10.

Inners, J. D. and B. E. Inners. 2000. Anthracite miners at war; military geology and engineering of the Petersburg Mine; June-July 1864. Geological Society of America Abstracts with Programs **32**(2):27.

Johnson, G. H., L. W. Ward, and P. C. Peebles. 1987. Stratigraphy and paleontology of Pliocene and Pleistocene deposits of southeastern Virginia. Pages 189-218 *in* R. G. Whittecar, editor. Geological Excursions in Virginia and North Carolina.

Lea, H. C. 1843. Descriptions of some new fossil shells, from the Tertiary of Petersburg, Virginia. Philadelphia. 12 pages.

Lea, H. C. 1846. Descriptions of some new fossil shells, from the Tertiary of Petersburg, Virginia. Transactions of the American Philosophical Society **9**:229-274.

McGill, W. M. 1941. Diatomite in the Petersburg area, Virginia. Virginia Journal of Science **1**(7):242.

Meek, F. B. 1864. Checklist of the invertebrate fossils of North America, Miocene. Smithsonian Miscellaneous Collection 183. Pages 1-32.

Meyer, O. 1888. On Miocene invertebrates from Virginia. Proceedings of the American Philosophical Society **25**:135-144.

Miller, E. M. and P. N. Walker. 1973. Flood of October 1972 at Petersburg and Colonial Heights, Virginia. U.S. Geological Survey, Reston, VA. Hydrologic Investigations Atlas HA-505. 1:48,000 scale map.

O'Donnell, M. J., R. Lockwood, and G. H. Johnson. 2003. Brackish-water environments in the upper Yorktown Formation, Virginia. Geological Society of America Abstracts with Programs **35**(1):69.

Pilsbry, H. A. 1907. The barnacles (Cirripedia) contained in the collections of the United States National Museum. U.S. National Museum Bulletin 60. 122 pages.

Ruffin, E. 1828. Gypseous earth [from Petersburg, Virginia]. American Farmer **10**. Page 3.

Ruhle, J. L. 1962. Selected Tertiary fossil localities of the Virginia Coastal Plain. Virginia Minerals **8**(3):2-10.

Sever, C. K. 1972. Petrology and origins of the schistose xenoliths of the Petersburg Granite. Virginia Journal of Science **23**(3):136.

Stodder, C. 1876. A contribution to microgeology. Proceedings of the Boston Society of Natural History **18**:206-209.

Tuomey, M. 1843. Discovery of a new locality of the "Infusorial stratum" [Petersburg, Virginia]. American Journal of Science **44**(2):339-341.

DATA SETS

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

DS-PETE-XXX Petersburg National Battlefield Museum Collections. 7/1926–present. (museum specimens, collection records, specimen notes, ANCS+ records). Originated by PETE staff; status: Active.

RICHMOND NATIONAL BATTLEFIELD PARK

Richmond National Battlefield Park (RICH) stretches across 7,307 acres of land in eastern Virginia and commemorates more than 30 battles that transpired during the Civil War in and around the Confederate capital of Richmond. Renowned battlefields include Beaver Dam Creek, Cold Harbor, Drewry's Bluff, Gaines Mill, Glendale, and Malvern Hill. New Market Heights, the site of 14 Medals of Honor for the United States Colored Troops, is also preserved within park boundaries. Chimborazo Visitor Center houses a medical museum that recognizes the important hospital that once occupied Chimborazo Hill. The main visitor center is located at the foot of Gamble's Hill on the James River in the historic Tredegar Iron Works. The authorization of Richmond National Battlefield Park occurred on March 2, 1936.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

The NPS Geologic Resources Division held geologic scoping sessions for RICH in 2005. There is no record of paleontological resource inventories completed inside park boundaries and no paleontological specimens are presently catalogued in park collections. However, sediments exposed in the vicinity of Richmond are extremely fossiliferous and the literature suggests that several fossil bearing localities exist in and around Richmond National Battlefield Park. Uncovering more paleontological resources at the park in the near future is a strong possibility given the local stratigraphy and accessibility of potentially fossiliferous outcrops along sections of the James River.

Richmond National Battlefield Park is underlain by a series of fluvial and marine sediments that comprise the Virginia Coastal Plain. Every park unit at RICH lies to the east of the Fall Line—a divide between the Coastal Plain and Piedmont physiographic provinces. The Coastal Plain ranges in age from the Cretaceous to the Quaternary and is characterized by unconsolidated gravels, sands, silts, and clays (Meng and Harsh 1988). Most of the Coastal Plain sequence is recorded in and around Richmond; however detailed geologic mapping does not exist (Spring 2006) for some park areas. The Virginia Division of Mineral Resources recently completed new geologic maps for the Richmond area which may be available during late summer 2006 (R. Berquist, personal communication, 2006). Deposits described for Richmond National Battlefield Park include the Cretaceous Potomac Formation, a number of Pleistocene units such as the Bacons Castle Formation, Windsor Formation, Charles City Formation, and Chuckatuck Formation, and a recent surficial layer of Quaternary alluvium. The park also contains sections of the Paleocene to Eocene Pamunkey Group and the Miocene to Pliocene Chesapeake Group. These broad groups comprise a series of variably fossiliferous sediments, most of which are not distinguished inside park boundaries at the formation level. Nonetheless, the paleontological significance of these individual formations elsewhere indicates the likelihood of future fossil discoveries at RICH.

Potomac Formation (Lower Cretaceous)
Sand, gravel, silt, and clay of fluvial-deltaic origin comprise the Potomac Formation of northeastern Virginia (Glaser 1969; Reinhardt et al. 1980; Mixon et al. 1989a). These sediments are often individually referred to as the Patuxent Formation, Arundel Clay, and Patapsco Formation of the Potomac Group. Geologic maps of Virginia do not recognize these units, however, as most Cretaceous deposits in Virginia are difficult to discern at this level (Seiders and Mixon 1981; Meng and Harsh 1988; Drake and Froelich 1986; Mixon et al. 2000).

Paleontological resources of the Potomac Formation comprise pollen, ferns, horsetails, cycads, conifers, clams, fish, amphibians, crocodiles, turtles, birds, and small mammals (Clark et al. 1911; Little 1917; Carr 1950; Cooke 1952; Johnston 1962; Brenner 1963; Cifelli et al. 1999; Rose et al. 2001). Dinosaur remains and vertebrate ichnofossils are also documented and are historically significant as some of the first dinosaur finds in North America before discoveries in the Western U.S. (Carr 1950; Weishampel and Young 1996; Lipka 1998; Kranz 1989, 1996, 1998, 2003; Weems and Bachman 2004). Other important fossils from the Potomac Formation provide evidence for angiosperm evolution such as pollen and leaves from ferns, horsetails, cycads, and conifers (Clark et al. 1911; Carr 1950; Cooke 1952; Johnston 1962;

Glaser 1969; Doyle and Hickey 1972, 1976; Doyle and Robbins 1977; Hickey and Doyle 1977; Hickey 1984). More on the geology and paleontology of the Potomac Formation is discussed in the FRSP section of this report.

The Potomac Formation is located in Richmond National Battlefield Park at the base of Ft. Brady, along the bottom of Chimborazo Hill, in the valley of Gillie Run to the south, and on the steep face of Drewry's Bluff (Mixon et al. 1989a; Inners et al. 1995). The section exposed at Drewry's Bluff is composed of interbedded gravel, sand, and clay from point-bar, channel, and flood deposits. Fining upward sequences of cobbly gravel to silts and sandy clays are also present (Inners et al. 1995). Paleontological resources in the Cretaceous sediments exposed at Drewry's Bluff have been utilized in studies of angiosperm radiation by Hickey and Doyle (1977) and for investigations of pCO_2 levels in the Cretaceous (Haworth et al. 2005). Other localities in and around RICH include Deep Bottom and Trent's Reach (Hickey and Doyle 1977) as well as Dutch Gap Canal (Hickey and Doyle 1977). Most of these fossiliferous localities outcrop along the James River; however exposures of the Potomac Formation are also observed at Puddledock Pit in Prince George County (Srinivasan 1992) and on R Street in downtown Richmond (Johnson et al. 1987). Two new species of the conifer *Glenrosa* were discovered at Puddledock Pit, a locality between the battlefields at Richmond and Petersburg in the Hopewell quadrangle (Srinivasan 1992).

Pamunkey Group (Paleocene -Eocene)
The Paleocene Brightseat and Aquia Formations, Paleocene Marlboro Clay, Eocene Nanjemoy, Piney Point, and Chickahominy Formations comprise the sands, silts, and clays of the Pamunkey Group in Coastal Plain Virginia. These glauconitic deposits are not differentiated in most geologic maps of Richmond National Battlefield Park even though they compose the lower section of the steep bluffs surrounding Chimborazo Hill (Inners et al. 1995). Brief summaries of individual formations in the Pamunkey Group are provided using Ward's (1985) summary of the stratigraphy and characteristic mollusks of the Pamunkey Group. Mixon et al. (1989b), in their summary of the Haynesville core, which was collected near Richmond, utilize paleontological data from Ward's 1985 publication (L. Ward, personal communication, 2006).

Pamunkey Group: Aquia Formation (upper Paleocene)
The Brightseat Formation forms the base of the Pamunkey Group southeast of Washington D.C., but is not exposed in Paleocene sections near Richmond (Ward 1985; Mixon et al. 1989b). The base of the Pamunkey Group in the Richmond vicinity is the notably fossiliferous Aquia Formation, a variably shelly and glauconitic unit composed of quartz sands and sandy limestones (Ward 1985). Clark and Martin (1901) divided the Aquia Formation into the older Piscataway Member and younger Paspotansa Member, both richly fossiliferous throughout the Coastal Plain. Scattered, well-preserved bivalves such as *Ostrea alepidota*, *Gryphaeostrea* sp., and *Pecten* sp. comprise the Piscataway Member near Richmond (Ward 1985). These molluscan assemblages are less diverse than more northerly exposures that commonly contain additional bivalves, *Cucullaea gigantea, Crassatellites* sp., and *Dosiniopsis* sp. (Ward 1985; Mixon et al. 2000). Fragmentary echinoids, bryozoans, planktonic forams, benthic forams, and dinocysts are also present in the Piscataway Member of the Haynesville cores (Edwards 1989; Mixon et al. 1989b; Poag 1989). The younger Paspotansa Member is less clayey and shelly containing only sparse fragments of leached shell material (Mixon et al. 1989b). This member is slightly more prolific elsewhere as evidenced by abundant *Turritella mortoni* and other mollusks including *Ostrea sinuosa, Crassatellites alaeformis,* and *Cucullaea sp.* (Ward 1985; Mixon et al. 2000). The cores from Haynesville lack such fossiliferous material. Planktonic and benthic forams of the Paspotansa Member are present in cored sections; dinocysts are more common at other localities (Edwards 1989; Poag 1989). Exposures of the Aquia in the vicinity of Richmond are documented by Goodman (1975), Witmer (1975), Witmer and McLean (1975), and Johnson et al. (1987). One locality proximal to RICH at the Shirley Plantation is noted by Ward (1985) as containing molds of molluscan faunas.

Pamunkey Group: Marlboro Clay (Paleocene)
The Marlboro Clay comprises the final Paleocene unit of the Pamunkey Group; however Mixon et al. (1989b) place this thin layer of red and gray clay in the upper part of the Aquia Formation based on the

Haynesville cores. This poorly fossiliferous unit is characterized at other localities by a low diversity of dinocysts, agglutinated foraminifera, and freshwater algae (Nogan 1964; Gibson et al. 1980; Edwards et al. 1984) indicative of brackish water conditions. The Marlboro Clay also contains a few molds of small indeterminate snails east of Hopewell on the James River (Ward 1985).

Pamunkey Group: Nanjemoy Formation (lower Eocene)
The lower Eocene Nanjemoy Formation unconformably rests on the Marlboro Clay (Mixon et al. 1989b). This poorly sorted, fine-grained unit is less calcareous than the underlying Aquia and overlying Piney Point. The Nanjemoy is composed of an older Potapaco Member and younger Woodstock Member as named by Clark and Martin (1901). Both members contain evidence of intense burrowing and forams useful for paleoenvironmental reconstruction (Mixon et al. 1989b). Few molluscan remains are observed in the Potapaco Member of the Haynesville cores. Molds, casts, and beds of *Venericardia potapcoensis* common in this shallow marine unit are not present in the cored sections (Glaser 1984; Ward 1985), but planktonic and benthic forams as well as dinocysts are abundant (Poag 1989; Edwards 1989). The Woodstock Member is also generally fossiliferous containing a diverse and abundant molluscan fauna; however only a few, small poorly preserved shells are documented in the cored material (Mixon et al. 1989b). Rich dinocyst and foraminiferal assemblages and the absence of characteristically ubiquitous *Venericardia ascia* are reported (Ward 1985; Edwards 1989; Poag 1989). Dinoflagellates from the Nanjemoy Formation are additionally documented in the Richmond area by Witmer and McLean (1975).

Pamunkey Group: Piney Point Formation (middle Eocene)
The middle Eocene Piney Point Formation is a richly fossiliferous, poorly sorted unit that unconformably lies on top of the Nanjemoy Formation (Mixon et al. 1989b). This sand and limestone layer is economically important as an aquifer (Meng and Harsh 1988) and stratigraphically significant containing the oyster guide fossil, *Cubitostrea sellaeformis*. Valves and fragments of *Cubitostrea sellaeformis* are present in cored sections as well as molds and casts of aragonitic mollusks including *Macrocallista* sp. and *Turritella* sp. Rich and diverse foraminiferal and dinoflagellate assemblages are also observed as noted by Ward (1985).

Pamunkey Group: Chickahominy Formation (upper Eocene)
The Chickahominy Formation is the final unit of the Pamunkey Group; it is not reported in the Haynesville cores (Mixon et al. 1989b), and is not found near Richmond (L. Ward, personal communication, 2006). The only paleontological resources documented for this formation comprise a rich assemblage of microfossils from cored sections in Maryland (Poag 2002). This concludes the summary of deposits in the Pamunkey Group mapped at Richmond National Battlefield Park. Though individual formations are not identified at Chimborazo Hill, paleontological resources may be preserved in these sediments at RICH.

Chesapeake Group (Miocene and Pliocene)
The shelly and diatomaceous sediments of the Chesapeake Group comprise the Old Church, Calvert, Choptank, St. Mary's, Eastover, and Yorktown Formations. These fossiliferous sands, silts, and clays are recorded in the upper steep bluffs surrounding Chimborazo Hill, across slope edges of the battlefield along Western Run, bordering both shores of Beaver Dam Creek, and in the upper part of Chickahominy Bluffs (Daniels and Onuschak 1974; Mixon et al. 1989a; Inners et al. 1995). Though these deposits are not differentiated inside the boundaries of Richmond National Battlefield Park, they are well exposed along both the Pamunkey and James Rivers and also within gullies near Richmond, such as those in Shockoe Valley (L. Ward, personal communication, 2006). Individual descriptions of these formations are provided and based in part on summaries by Ward (1984), Ward (1985), and geologic cores obtained near Haynesville (Mixon et al. 1989b).

Chesapeake Group: Old Church Formation (upper Oligocene-lower Miocene)
The upper (late) Oligocene (Mixon et al. 1989b) or lower Miocene (Ward 1985) Old Church Formation is composed of shelly, muddy, sparsely glauconitic sand. This unit is characterized by bivalve *Mercenaria capax* and abundant barnacle plates; both present in the Haynesville cores. Other fossils observed in the

cored material include echinoid fragments, foraminifera, and dinoflagellate cysts (Mixon et al. 1989b). Ward (1985) records the Old Church Formation east of Richmond in Henrico County and places it at the base of the Chesapeake Group.

Chesapeake Group: Calvert Formation (lower Miocene)
The extensively fossiliferous Miocene Calvert Formation overlies the Old Church Formation in the cores at Haynesville (Mixon et al. 1989b) and is present in numerous exposures throughout the Rappahannock, Mattaponi, Pamunkey, James and Potomac River basins (Ward 1984, 1985). This renowned deposit is regionally composed of diatomaceous, variably shelly, fine quartz sand and sandy clay-silt (Mixon et al. 1989b). The Calvert Formation in Maryland is characterized by abundant paleontological resources particularly mollusks, shark teeth, and marine mammals. Terrestrial fauna and flora are also commonly preserved (Carr 1950; McLennan 1973). This unit is usually divided into the Fairhaven, Plum Point, and Calvert Beach Members; however these divisions are not noted at Richmond National Battlefield Park. Fossils preserved in the Haynesville cores comprise mollusks, forams, diatoms, and burrows (Mixon et al. 1989b; Poag 1989). Molluscan faunas frequently include *Ostrea* sp., *Pecten* sp., *Mercenaria* sp., and *Turritella* sp. Marine vertebrates, fish teeth, and pieces of wood recorded in the Calvert Formation of Maryland are not observed in the cored material (Mixon et al. 1989b). Sparse molds and casts of mollusks, burrows, sponge spicules, and diatoms are noted instead. Fragments of the barnacle *Balanus* sp. are also present (Mixon et al. 1989b). Calcitic shells are well-preserved; aragonitic shells are often leached. Other localities of the Calvert in the vicinity of Richmond are documented by Darton (1911), Brown (1939), Wildy (1972), Hall (1984), and Ray (1985). Fossils derived from local Miocene deposits that may belong to the Calvert Formation include microfossils at Church Hill and Shockoe Hill (Stodder 1876; Riley 1880), sponge spicules (Riley 1880), mollusks (Riley 1880), fish teeth (Wyman et al. 1850), seals (Wyman 1850), and bone fragments preserved in a 23 cm (9 in) coprolite (Wyman 1850). More on paleontological resources of the Calvert Formation is summarized in the FRSP section of this report including the fossiliferous Carmel Church Quarry located halfway between Fredericksburg and Richmond (Dooley et al. 2004).

Chesapeake Group: Choptank Formation (middle Miocene)
The Choptank Formation is best exposed along the western shore of the Chesapeake Bay in Maryland (Ward and Powars 2004). This unit is less fossiliferous than the Calvert; however mollusks and shark teeth are commonly found (Ward and Powars 2004; Visaggi and Godfrey, in preparation). The Choptank is not observed in the Haynesville cores, but is documented in Richmond (Andrews 1986; Johnson et al. 1987), including an exposure behind the city jail (L. Ward, personal communication, 2006).

Chesapeake Group: St. Mary's Formation (upper Miocene)
The upper (late) Miocene St. Mary's Formation consists of variably shelly, very fine, muddy sand and clayey silt (L. Ward, personal communication, 2006). This deposit is identified in the cored material and fossils include poorly preserved mollusks as identified by Lauck Ward including gastropods (*Turritella* sp.), bivalves (*Anadara* sp., *Cardium* sp., *Chesapecten* sp., *Isognomon* sp., *Mercenaria* sp., *Thracia* sp.), and ichnofossils. Diatoms are notably absent and aragonitic shells are frequently leached (Mixon et al. 1989b). Though paleontological resources are known in the St. Mary's, other fossiliferous sections of this formation near Richmond are not recorded in the literature.

Chesapeake Group: Eastover Formation (upper Miocene)
The Eastover Formation represents a shallow open-marine paleoenvironment from the upper (late) Miocene (Mixon et al. 1989b). Few molds and casts are observed in the Haynesville cores, but nearby outcrops are notably more fossiliferous. One locality south of Garlands Millpond on Rt. 620 contains numerous bivalves (*Nucula* sp., *Nuculana sp.*, *Arca* sp., *Chesapecten* sp., *Anomia* sp., *Parvilucina* sp.) and gastropods (*Vitrinella* sp., *Crepidula* sp., *Busycotypus* sp., *Crucibulum* sp., *Nassarius* sp., *Bulliopsis* sp., *Fusinus* sp., *Terebra* sp., *Acteocina* sp.), a brachiopod, *Discinisca lugubris,* and a crustacean, *Balanus* sp. (Mixon et al. 1989b). *Spisula rappahannockensis*, a guide fossil for the Eastover Formation is also present (Blackwelder and Ward 1976; Mixon et al. 1989b). Other local exposures include Union Mills, Carmel Church Quarry (Dooley et al. 2004), and along the Rappahannock River below Bowlers Wharf (Ward and

Blackwelder 1980). Richmond localities of the Eastover are noted by Hall (1984), Johnson and Peebles (1985), Andrews (1986), and Johnson et al. (1987).

Chesapeake Group: Yorktown Formation equivalent deposits (lower Pliocene)
The final unit in the Chesapeake Group comprises the fossiliferous sands and gravels that are near shore equivalents of the early Pliocene Yorktown Formation. This deposit is documented in Richmond by Goodwin (1979), Hall (1984), and Johnson and Peebles (1985). Ichnofossils (trace fossils) present in the Yorktown include *Ophiomorpha* shrimp burrows and biogenic structures resembling heart urchin burrows (Howard 1971, Inners et al. 1995). Other common paleontological resources such as marine mammals, mollusks, and microfossils are listed in FRSP and PETE sections of this report. The Yorktown Formation in the Haynesville cores is poorly fossiliferous as most fossils are leached out (Mixon et al. 1989b). Though this deposit is not officially identified inside park boundaries as of yet, an early Pliocene unit of gravelly sand, sandy gravel, and fine to coarse sand that commonly contains ichnofossils similar to the Yorktown is mapped at Gaines Mill and Cold Harbor Visitor Center of RICH (Mixon et al. 1989a; Inners et al. 1995). Ichnofossils are the only paleontological resources noted by Berquist (personal communication, 2006) in the Yorktown equivalent deposits near Richmond.

Bacons Castle Formation (upper Pliocene)
The high ground at Ft. Harrison, Ft. Johnson, Chimborazo Hill, Malvern Hill, and Glendale are partially underlain by the sands and gravels of the Bacons Castle Formation (Mixon et al. 1989a; Inners et al. 1995). This upper (late) Pliocene unit represents fluvial to intertidal paleoenvironments and is exposed at several localities in the vicinity of Richmond (Johnson and Peebles 1985; Ramsey 1987). A landslide following Tropical Storm Gaston (2004) exposed an "excellent" section of Bacons Castle Formation at Chimborazo Hill (R. Berquist, personal communication, 2006). While no paleontological resources were noted within the park, similar slides have uncovered historic artifacts and human remains in the Richmond area (R. Berquist, personal communication, 2006). Paleontological resources recorded for this formation consist of *Quercus*, *Carya*, *Pinus*, *Picea*, *Alnus*, *Betula*, *Nyssa*, and *Ulmus* pollen (Groot et al. 1990). Well-rounded, iron-oxide stained pebbles common in the Bacons Castle Formation are often observed in Chimborazo Park adjacent to the visitor center at RICH Headquarters (Inners et al. 1995). Slightly older sediments comparable to deposits of the Bacons Castle Formation are mapped at the Cold Harbor Visitor Center and possibly at Gaines Mill (Daniels and Onuschak 1974; Inners et al. 1995). Microfossils are the only paleontological specimens known from the Bacons Castle Formation limiting the potential for future fossil finds inside park boundaries.

Windsor Formation (upper Pliocene or lower Pleistocene)
The Windsor Formation is mapped to the south and west of Ft. Harrison and is characterized by glauconitic gray and yellowish-brown, mottled sand and gravel (Mixon et al. 1989a; Inners et al. 1995). *Ophiomorpha* burrows comprise the only *in situ* macrofossils documented for this formation (Johnson 1972). These vertical knobby burrows are similar to those formed by the modern ghost shrimp, *Callianassa major*. Molds of molluscan faunas are also reported in Windsor Formation; however these are likely reworked from the older, more fossiliferous Yorktown Formation (Johnson 1972). Floral remains present include *Quercus, Liquidambar*, *Pinus, Tsuga, Alnus,* and *Betula* in the form of pollen (Groot et al. 1990). Deposition of the Windsor Formation in the vicinity of Richmond is noted by Johnson and Peebles (1985). No fossils are currently known from this unit at RICH, yet future finds may be possible.

Charles City Formation (lower Pleistocene)
This sand, silt, and clay unit is marginally present in land at Drewry's Bluff (Mixon et al. 1989a). Fossils are not common in this deposit; however small invertebrate burrows are abundant at localities of the Charles City Formation along the Potomac River (Mixon et al. 2000). These ichnofossils suggest estuarine conditions in the lower Pleistocene. Johnson and Peebles (1985) comment on the presence of the Charles City Formation around Richmond, but do not mention fossiliferous material. The potential for finding

paleontological resources in this formation at RICH is small. The unit is not very fossiliferous and is only irregularly exposed in a thin layer along the upper edge of Drewry's Bluff (Berry 1912; Mixon et al. 1989a).

Chuckatuck Formation (middle Pleistocene)
The extreme western edge of the battlefield along Western Run is underlain by the Chuckatuck Formation (Mixon et al. 1989a). This surficial deposit is composed of sand, silt, clay, and minor amounts of peat suggestive of an estuarine paleoenvironment in the middle Pleistocene (Mixon et al. 1989a). Fossils recorded for the Chuckatuck Formation are limited to *Ophiomorpha* shrimp burrows. Johnson and Peebles (1985) mention the occurrence of the Chuckatuck around Richmond, but do not comment on the presence of fossils. Since this formation is only mapped in a small area at RICH and is not notably fossiliferous, the prospect for unearthing paleontological specimens is minimal.

Surficial Deposits (Quaternary)
Several park units at Richmond National Battlefield Park are partially underlain by Quaternary alluvium and associated surficial deposits. These include Parker's Battery, Ft. Brady, Ellerson's Mill, Chickahominy Bluff, Cold Harbor, Gaines Mill, and in the vicinity of Beaver Dam Creek (Daniels and Onuschak 1974; Dischinger 1987). Most alluvial deposits are composed of organic and poorly sorted sediment of fluvial origin that ranges in size from clay to gravel (Daniels and Onuschak 1974). Paleontological resources are not commonly preserved in Quaternary surficial deposits; however eroded fossils from older units sometimes end up in these sediments. The gravel-rich sand islands near the cutoff at Dutch Gap along the James River are noted for fossilized fragments of Pleistocene wood (L. Ward, personal communication, 2006). Other fossils reworked from older sediments may also be present in these deposits offering the potential for future paleontological discoveries.

Paleontological Resource Potential and Monitoring
Richmond National Battlefield Park contains a variety of fossiliferous units that may hold a wealth of paleontological resources inside park boundaries. Some of these deposits are exposed along the bluffs of the James River providing accessible outcrops that are not otherwise present in the park due to the proximal Piedmont physiographic province (K. Allen, personal communication, 2005). Drewry's Bluff at Fort Darling is a leading example of a fossiliferous section exposed at RICH. This locality is also cause for concern as natural erosion processes of the James River threaten the stability of these slopes (Virginia Geotechnical Services 1992). The effects of erosion management have been assessed for military earthworks at RICH (Aust et al. 2003), but perhaps future studies should consider the significance of paleontological resources that are also preserved in exposed sediments. The geology of the region suggests that other natural hazards may affect fossiliferous exposures as well. These include a history of floods (e.g., Miller 1969a,b,c) and earthquakes (e.g., Ayers 1972; Davidson and Bode 1987) in the vicinity of Richmond. Periodic monitoring of any paleontologically significant outcrops at RICH would be recommended. The discovery of paleontological resources contained in fossiliferous strata overlain by other park units, however, might only be revealed as a result of construction on park lands or future archaeological surveys.

REFERENCES CITED

Andrews, G. W. 1986. Miocene diatoms from Richmond, Virginia. Journal of Paleontology **60**(2):497-538.

Aust, W. A., A. Azola, and J. E. Johnson. 2003. Management effects on erosion of Civil War military earthworks: Journal of Soil and Water Conservation **58**(1):13-20.

Ayers, R. L. 1972. A note on the Richmond; Virginia Earthquake of September 5, 1972. Earthquake Notes **43**(4):17-21.

Berry, E. W. 1912. Lower Cretaceous. Pages 61-86 *in* W. B. Clark and B. L. Miller. Physiography and Geology of the Coastal Plain in Virginia. Virginia Geotechnical Survey Bulletin 4.

Blackwelder, B. W. and L. K. Ward. 1976. Stratigraphy of the Chesapeake Group of Maryland and Virginia; Field Trip Guidebook. 55 pages.

Brenner, G. J. 1963. The spores and pollen of the Potomac Group of Maryland. Maryland Geological Survey, Baltimore, MD. Bulletin 27. 215 pages.

Brown, W. R. 1939. The Calvert Formation in the Richmond area, Virginia. Virginia Journal of Science. Page 57.

Carr, M. 1950. The District of Columbia: Its rocks and their geologic history. U.S. Geological Survey, Reston, VA. Bulletin 967. 59 pages.

Cifelli, R. L., T. R. Lipka, C. R. Schaff, and T. B. Rowe. 1999. First Early Cretaceous mammal from the eastern seaboard of the United States. Journal of Vertebrate Paleontology **19**(2):199-203.

Clark, W. B., A. B. Bibbins, and E. W. Berry. 1911. The Lower Cretaceous deposits of Maryland. Pages 23-99 *in* C. Schuchert, C. K. Swartz, T. P. Maynard, and R. B. Rowe, editors. Lower Cretaceous. Maryland Geological Survey, Baltimore, MD.

Clark, W. B. and G. C. Martin. 1901. The Eocene deposits of Maryland. Maryland Geological Survey, Baltimore, MD. Pages 19-91.

Clark, W. B. and B. L. Miller. 1912. Physiography and geology of the Coastal Plain province of Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 4. 274 pages.

Cooke, C. W. 1952. Sedimentary Deposits. Pages 1-52 *in* C. W. Cooke, R. O. R. Martin, and G. Meyer, editors. Geology and Water Resources of Prince George's County. Maryland Geological Survey, Baltimore, MD. Bulletin 10.

Daniels, P. A., Jr. and Onuschak, E., Jr. 1974. Geology of the Studley, Yellow Tavern, Richmond, and Seven Pines quadrangles. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 38. 75 pages. 1:24,000 scale maps.

Darton, N. H., 1911, Economic geology of Richmond, Virginia, and vicinity: U.S. Geological Survey, Reston, VA. Bulletin 483. 48 pages.

Davidson, F. C., Jr., and M. J. Bode. 1987. A note on the December 1986-January 1987 Richmond, Virginia, felt earthquake sequence. Seismological Research Letters **58**(3):73-80.

Dischinger, J. B. 1987. Late Mesozoic and Cenozoic stratigraphic and structural framework near Hopewell, Virginia. U.S. Geological Survey, Reston, VA. Bulletin 1567. 48 pages. 1:24,000 scale map.

Dooley, A. C. Jr., N. C. Fraser, and Z. -X. Luo. 2004. The earliest known member of the rorqual-gray whale clade (Mammalia, Cetacea). Journal of Vertebrate Paleontology **24**(2):453-463.

Doyle, J. A. and L. J. Hickey. 1972. Coordinated evolution in Potomac Group angiosperm pollen and leaves. American Journal of Botany Abstracts **59**(6):660.

Doyle, J. A. and L. J. Hickey. 1976. Pollen and leaves from the mid-Cretaceous Potomac Group and their bearing on early angiosperm evolution. Pages 139-206 *in* C. B. Beck, editor. Origin and Early Evolution of Angiosperms. Columbia University Press, New York, NY.

Doyle, J. A. and E. I. Robbins. 1977. Angiosperm pollen zonation of the continental cretaceous of the Atlantic Coastal Plain and its application to deep wells in the Salisbury embayment. Palynology **1**:43-78.

Drake, A. A., Jr. and A. J. Froelich. 1986. Geologic map of the Annandale quadrangle, Fairfax and Arlington Counties, and Alexandria City, Virginia. U.S. Geological Survey, Reston, VA. Geologic Quadrangle Map GQ-1601. 1:24,000 scale map.

Edwards, L. E. 1989. Dinoflagellate cysts from the lower Tertiary formations, Haynesville cores, Richmond County, VA. Pages C1-C12 *in* R. B. Mixon, editor. Geology and Paleontology of the Haynesville Cores – Northeastern Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1489.

Edwards, L. E., D. K. Goodman, and R. J. Witmer. 1984. Lower Tertiary (Pamunkey Group) dinoflagellate biostratigraphy, Potomac River area, Virginia and Maryland. Pages 121-134 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure,

Southwest Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Gibson, T. G., G. W. Andrews, L. M. Bybell, N. O. Fredericksen, T. Hansen, J. E. Hazel, D. M. McLean, R. J. Witmer, and D. S. Van Nieuwenhuise. 1980. Biostratigraphy of the Tertiary strata of the core. Pages 14-30 *in* Geology of the Oak Grove Core: Virginia Division of Mineral Resources, Charlottesville, VA. Publication 20.

Glaser, J. D. 1969. Petrology and origin of Potomac and Magothy (Cretaceous) sediments, Middle Atlantic Coastal Plain. Maryland Geological Survey, Baltimore, MD. Report of Investigations 11. 101 pages.

Glaser, J. D. 1984. Geologic Map of the Port Tobacco Quadrangle, Prince Georges and Charles Counties, Maryland. Maryland Geologic Survey, Baltimore, MD. 1:24000 scale map.

Goodman, D. K. 1975. Lower Eocene dinoflagellate assemblages from the Maryland Coastal Plain South of Washington, D.C. Unpublished M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Goodwin, B. K. 1979. Geology of the Richmond-Petersburg area. Pages 1-15 *in* Exline, J.D., editor. Guidebook for Field Trips in Virginia.

Groot, J. J., K. W. Ramsey, and J. F. Wehmiller. 1990. Ages of the Bethany, Beaverdam, and Omar formations of southern Delaware. Delaware Geological Survey, Newark, DE. Report of Investigations 47.

Hall, M. C. 1984. Upper Tertiary stratigraphy and structure of the inner Atlantic Coastal Plain near Richmond, Virginia. Virginia Journal of Science **35**(2):120.

Haworth, M., S. P. Hesselbo, J. C. McElwain, S. A. Robinson, J. W. Brunt. 2005. Mid-Cretaceous pCO_2 based on stomata of the extinct conifer *Pseudofrenelopsis* (Cheirolepidiaceae). Geology. **33**(9):749-752.

Hickey, L. J. 1984. Summary and implications of the fossil plant record of the Potomac Group. Pages 213-244 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary Stratigraphy, Paleontology, and Structure, Southwest Maryland and Northeastern Virginia. American Association of Stratigraphic Palynologists. Field Trip Volume and Guidebook.

Hickey, L. J. and J. A. Doyle. 1977. Early Cretaceous fossil evidence for angiosperm evolution. The Botanical Review **43**(1):3-104.

Howard, J. D. 1971. Comparison of the beach-to-offshore sequence in modern and ancient sediments. Pages 148-183 *in* J. D. Howard, J. W. Valentine, and J. E. Warme, editors. Recent Advances in Paleoecology and Ichnology. American Geological Institute Short Course, Washington, D.C. Lecture Notes.

Inners, J. D., B. E. Inners, and D. M. Sayre. 1995. Military geology of the Richmond and Petersburg National Battlefield Parks, Virginia. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Open File Report 95-08. 75 pages.

Johnson, G. H. 1972. Geology of the Yorktown, Poquoson West, and Poquoson East Quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 30. 57 pages.

Johnson, G. H., B. K. Goodwin, and K. W. Ramsey. 1987. The "R" Street exposure; a marine and fluvial sedimentary sequence near the fall zone at Richmond, VA. Geological Society of America Abstracts with Programs **19**(1):22.

Johnson, G. H. and P. C. Peebles. 1985. Depositional and tectonic significance of upper Cenozoic deposits in the vicinity of Richmond, Virginia. Geological Society of America Abstracts with Programs **17**(7):620.

Johnston, P. M. 1962. A visitors guide to the geology of the National Capital area. Prepared for the Third General Meeting of the International Mineralogical Association April 17-20, 1962. Washington, D.C. 32 pages.

Kranz, P. M. 1989. Dinosaurs in Maryland. Maryland Geological Survey, Baltimore, MD. Educational Series 6. 34 pages.

Kranz, P. M. 1996. Notes on the sedimentary iron ores of Maryland and their dinosaurian fauna. Pages 87-115 *in* D. K. Brezinski and J. P. Reger, editors. Studies in Maryland Geology - In Commemoration of the Centennial of the Maryland Geological Survey. Maryland Geological Survey, Baltimore, MD. Special Publication 3.

Kranz, P. M. 1998. Mostly Dinosaurs: A review of the vertebrates of the Potomac Group (Aptian Arundel Formation) USA. Pages 235-238 *in* S. G. Lucas, J. I. Kirkland, and J. W. Estep, editors. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 14.

Kranz, P. M. 2003. Dinosaurs of the District of Columbia. Dinosaur Fund, Washington, D.C. 31 pages. (http://www.glue.umd.edu/~gdouglas/articles/Kranz6.pdf).

Lipka, T. R. 1998. The affinities of the enigmatic theropods of the Arundel Clay Facies (Aptian): Potomac Formation, Atlantic Coastal Plain of Maryland. Pages 229-234 *in* S. G. Lucas, J. I. Kirkland, and J. W. Estep, editors. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Museum of Natural History and Science, Albuquerque, NM. Bulletin 14.

Little, H. P. 1917. The geology of Anne Arundel County, Maryland. Maryland Geological Survey, Baltimore, MD. 232 pages.

McLennan, J. D. 1973. Calvert Cliffs, Maryland. Maryland Geological Survey, Baltimore, MD. Pamphlet. (http://www.mgs.md.gov/esic/brochures/ccliffs.html).

Meng, A. A., III. and J. F. Harsh. 1988. Hydrogeologic framework of the Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1404-C. 82 pages.

Miller, E. M. 1969a. Flood of August 1969, Bon Air quadrangle, Richmond, Virginia. U.S. Geological Survey, Reston, VA. Hydrologic Investigations Atlas. HA-409. 1:24,000 scale map.

Miller, E. M. 1969b. Flood of August 1969, Drewry's Bluff quadrangle, Richmond, Virginia. U.S. Geological Survey, Reston, VA. Hydrologic Investigations Atlas. HA-411. 1:24,000 scale map.

Miller, E. M. 1969c. Flood of August 1969. Richmond quadrangle, Virginia. U.S. Geological Survey, Reston, VA. Hydrologic Investigations Atlas. HA-410. 1:24,000 scale map.

Mixon, R. B., C. R. Berquist, Jr., W. L. Newell, G. H. Johnson, D. S. Powars, J. S. Schindler, and E. K. Rader. 1989a. Geologic map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia. U.S. Geological Survey, Reston, VA. Miscellaneous Investigations Series Map I-2033. 1:250,000 scale map.

Mixon, R. B., L. Pavlides, D. S. Powars, A. J. Froelich, R. E. Weems, J. S. Schindler, W. L. Newell, L. E. Edwards and L. W. Ward. 2000. Geologic map of the Fredericksburg 30' x 60' quadrangle, Virginia and Maryland. U.S. Geologic Survey, Reston, VA. Investigations Series Map I-2607. 1:100,000 scale map.

Mixon, R. B., D. S. Powars, L. W. Ward, and G. W. Andrews. 1989b. Lithostratigraphy and molluscan and diatom biostratigraphy of the Haynesville cores – Outer Coastal Plain of Virginia. Pages A1-A48 *in* R. B. Mixon, editor. Geology and Paleontology of the Haynesville Cores – Northeastern Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1489.

Nogan, D. S. 1964. Foraminifera, stratigraphy, and paleoecology of the Aquia Formation of Maryland and Virginia. Cushman Foundation for Foraminiferal Research, Washington, D.C. Special Publication 7. 50 pages.

Poag, C. W. 1989. Foraminiferal stratigraphy and paleoenvironments of Cenozoic strata cored near Haynesville, Virginia. Pages D1-D20 *in* R. B. Mixon, editor. Geology and Paleontology of the

Haynesville Cores – Northeastern Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1489.

Poag, C. W. 2002. Biospheric consequences of the Chesapeake Bay bolide impact. Geological Society of America Abstracts with Programs **34**(6):467.

Ramsey, K. W. 1987. Geology of the Bacons Castle Formation; York-James Peninsula, Virginia. Geological Society of America Abstracts with Programs **19**(2):125.

Ray, C. 1985. Fossil seals from the Calvert Formation of the Pamunkey River, Hanover County, Virginia. Pages 232-235 *in* L. W. Ward and K. Krafft, editors. Stratigraphy and Paleontology of the Outcropping Tertiary Beds in the Pamunkey River Region, Central Virginia Coastal Plain.

Reinhardt, J., W. L. Newell and R. B. Mixon. 1980. Tertiary lithostratigraphy of the core. Pages 1-13 *in* Geology of the Oak Grove core: Virginia Division of Mineral Resources Publication 20.

Riley, C. V. 1880. The Richmond diatomaceous earth. Science **1**(18):222.

Rose, K. D., R. L. Cifelli, and T. R. Lipka. 2001. Second triconodont dentary from the Early Cretaceous of Maryland. Journal of Vertebrate Paleontology **21**(3):628-632.

Seiders, V. M. and R. B. Mixon. 1981. Geologic map of the Occoquan quadrangle and part of the Fort Belvoir quadrangle, Prince William and Fairfax Counties, Virginia. U.S. Geological Survey, Reston, VA. Miscellaneous Geological Investigations Map I-1175. 1:24,000 scale map.

Srinivasan, V. 1992. Two new species of the conifer *Glenrosa* from the Lower Cretaceous of North America. Review of Palaeobotany and Palynology **72**(3-4):245-255.

Stodder, C. 1876. A contribution to microgeology. Proceedings of the Boston Society of Natural History 18. Pages 206-209.

Virginia Geotechnical Services. 1992. Report of subsurface exploration and preliminary geotechnical evaluation for the proposed Fort Darling stabilization project, Chesterfield, Virginia. VGS No. Gt-625. 12 pages.

Visaggi, C. C. and S. J. Godfrey. In Preparation. A census of fossil shark teeth from Calvert Cliffs, Maryland (Miocene: Chesapeake Group).

Ward, L. W. 1984. Stratigraphy and molluscan assemblages of the Pamunkey and Chesapeake Groups, Upper Potomac River. Pages 3-50 *in* N. O. Frederiksen and K. Krafft, editors. Cretaceous and Tertiary stratigraphy, paleontology, and structure, southwestern Maryland and northeastern Virginia. American Association of Stratigraphic Palynologists Field Trip Volume and Guidebook.

Ward, L. W. 1985. Stratigraphy and characteristic mollusks of the Pamunkey Group (Lower Tertiary) and the Old Church Formation of the Chesapeake Group - Virginia Coastal Plain. U.S. Geological Survey, Reston, VA. Professional Paper 1346. 78 pages.

Ward, L. W. and B. W. Blackwelder. 1980. Stratigraphic revision of upper Miocene and lower Pliocene beds of the Chesapeake Group, middle Atlantic Coastal Plain. U.S. Geological Survey Bulletin 1482-D. 61 pages.

Ward, L. W. and D. S. Powars. 2004. Tertiary lithology and paleontology, Chesapeake Bay region. Pages 263-297 *in* S. Southworth and W. Burton, editors. Geology of the National Capital Region - Field Trip Guidebook. U.S. Geological Survey, Reston VA. Circular 1264.

Weems, R. E. and J. M. Bachman. 2004. A dinosaur-dominated ichnofauna from the Lower Cretaceous (Aptian) Patuxent Formation of Virginia. Geological Society of America Abstracts with Programs **36**(2):116.

Weishampel, D. M. and L. Young. 1996. Dinosaurs of the East Coast. Johns Hopkins University Press, Baltimore, MD.

Wildy, V. L. 1972. Diatomaceous Earth deposits (Calvert Formation, Cenozoic Era) in Richmond, Virginia. Virginia State University, Petersburg, VA. Unpublished Master's Thesis. 61 pages.

Witmer, R. J. 1975. Taxonomy and biostratigraphy of Lower Tertiary dinoflagellate assemblages from the Atlantic coastal plain near Richmond, Virginia. Virginia Polytechnic Institute and State University, Blacksburg, VA. Unpublished Master's Thesis.

Witmer, R. J. and D. M. McLean. 1975. Lower Tertiary dinoflagellate assemblages from the Virginia coastal plain near Richmond, Virginia. Geological Society of America Abstracts with Programs **7**(6):883.

Wyman, J. 1850. On the remains of seals and a coprolite from Richmond, Virginia. Proceedings of the Boston Society of Natural History **3**:323.

Wyman, J., H. D. Rogers, and E. Desor. 1850. On teeth of fishes from the Tertiary deposit of Richmond, Virginia (with discussion by H. D. Rogers and E. Desor). Proceedings of the Boston Society of Natural History **3**:246-247.

Additional References

Abbott, W. H. 1978. Correlation and zonation of Miocene strata along the Atlantic margin of North America using diatoms and silicoflagellates. Marine Micropaleontology **3**:15-34.

Abbott, W. H. 1982. Diatom biostratigraphy of the Chesapeake Group, Virginia and Maryland. Florida Department of Natural Resources, Bureau of Geology, Special Publication **25**:23-34.

Andrews, G. W. 1985. Miocene diatomaceous beds of the Pamunkey River area, Hanover and King William counties, Virginia. Pages 117-123 *in* L. W. Ward and K. Krafft, editors. Stratigraphy and Paleontology of the Outcropping Tertiary Beds in the Pamunkey River Region, Central Virginia Coastal Plain.

Bailey, J. W. 1842. A sketch of the Infusoria, of the family Bacillaria, with some account of the most interesting species which have been found in a recent or fossil state in the United States, Part 2. American Journal of Science and Arts **42**:88-105.

Bailey, J. W. 1845a. Ehrenberg's observations on the fossil Infusoria of Virginia and Maryland, and comparison of the same with those found in the Chalk formations of Europe and Africa. American Journal of Science and Arts **48**:201-205.

Bailey, J. W. 1845b. Fossil Infusoria of Virginia and Maryland. American Journal of Science and Arts **48**:330-337.

Barham, S. D., III. 1967. A geologic field trip in the Richmond, Virginia area. Unpublished M.S. Thesis. Virginia State University, Petersburg, VA. 32 pages.

Bevan, A. C. 1935. The geological making of the Richmond area. Virginia Journal of Science. Pages 69-70.

Brown, W. R. 1939. Coastal-plain geology of the Richmond area, Virginia. Unpublished M.S. Thesis. University of Virginia, Charlottesville, VA. 111 pages.

Burkhart, D. P. 1988. Four important East Coast Miocene formations. Fossils Quarterly **7**(2):5-16.

Clark, W. B. and B. L. Miller. 1906. A brief summary of the geology of the Virginia Coastal Plain. Virginia Geological Survey Bulletin 2. Pages 11-24.

Coryell, M. 1876. Diatomaceous sands of Richmond, Virginia. Transactions of the Society of Mining Engineers of American Institute of Mining, Metallurgical and Petroleum Engineers, Incorporated (AIME). Pages 230-232.

Darton, N. H. 1951. Structural relations of Cretaceous and Tertiary formations in part of Maryland and Virginia. Geological Society of America Bulletin **62**(7):745-779.

Ehrenberg, C. G. 1843. Verbreitung und Einfluss des mikroskopischen Lebens in Süd- und Nord-Amerika. K. Preussische Akademie der Wissenschaften zu Berlin, Physikalische Abhandlungen, 1841: 291-445.

Ehrenberg, C. G. 1844. Über 2 neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord-Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika. K. Preussische Akademie der Wissenschaften zu Berlin, Bericht, 1844:57-97.

Ehrenberg, C. G. 1854. Mikrogeologie. L. Voss. Leipzig. 374 pages.

Goodwin, B.K. 1970. Geology of the Hylas and Midlothian quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 23. 1:24,000 scale map.

Goodwin, B. K. 1980. Geology of the Bon Air quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 18. 1:24,000 scale map.

Goodwin, B. K. 1981. Geology of the Glen Allen quadrangle, Virginia. Virginia Division of Mineral Resources. Publication 31. 1:24,000 scale map.

Johnson, G. H. and P. C. Peebles. 1985. Stratigraphy of late Tertiary and Pleistocene deposits between the Pamunkey and James rivers, inner Coastal Plain, Virginia. Pages 79-91 *in* L. W. Ward and K. Krafft, editors. Stratigraphy and Paleontology of the Outcropping Tertiary Beds in the Pamunkey River Region, Central Virginia Coastal Plain. Atlantic Coastal Plain Geological Association, Guidebook for 1984 Field Trip.

McReynolds, J. A. and G. H. Johnson. 1986. Stratigraphy and origin of late Tertiary gravels in the Richmond, Virginia area. Geological Society of America Abstracts with Programs **18**(3):254.

Morrell, C. C. 1984. Morphologic variation of middle Eocene oysters of the genus *Cubitostrea*, central Virginia coastal plain. Geological Society of America Abstracts with Programs **16**(3):182.

Parrott, W. T. 1963. New Eocene deposits in the Richmond, Virginia area. Virginia Journal of Science **14**(4):242.

Pegau, A. A. 1939. Geology and mineral resources of the Piedmont in the vicinity of Richmond, Virginia. Virginia Journal of Science 1938-1939. Pages 58-59.

Pierce, J. 1826. On the shell-marl region of the eastern parts of Virginia and Maryland, and upon the bituminous-coal formation in Virginia and contiguous region. American Journal of Science **11**(1)54-59.

Rice, K. C., R. M. Moberg, K. G. Allen, and D. L. Vana-Miller. 2003. Water resources management plan; Richmond National Battlefield Park, Virginia. NPS D-40. 209 pages.

Rice, K. C., D. L. Vana-Miller, and M. D. Flora. 2000. Water resources management plan; Cold Harbor and Gaines Mill units; Richmond National Battlefield Park, Virginia. 81 pages.

Roberts, J. K. 1941. Field trip in the Richmond area. Virginia Journal of Science **2**(6):216.

Rogers, W. B. 1841. Infusorial stratum and associated Tertiary beds in the vicinity of Richmond. Virginia Geological Survey Report of 1840. Pages 38-42.

Shaler, N. S. 1837. On the geology of the region about Richmond, Virginia. Proceedings of the American Academy of Arts and Sciences **8**:307-308.

Ward, L. W. and K. Krafft. 1984. Stratigraphy and Paleontology of the Outcropping Tertiary beds in the Pamunkey River Region, Central Virginia Coastal Plain. Guidebook for the Atlantic Coastal Plain Geological Association 1984 Field Trip. 280 pages.

Weems, R. E. 1981. Geology of the Hanover Academy quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 30. 1:24,000 scale map.

Weems, R. E. 1986. Geology of the Ashland quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 64. 1:24,000 scale map.

Wyman, J. 1850. Notice of remains of vertebrate animals found at Richmond, Virginia. American Journal of Science **10**(2):228-235.

DATA SETS

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

SHENANDOAH NATIONAL PARK

Shenandoah National Park (SHEN) encompasses more than 777 square kilometers (300 square miles) of western Virginia's Blue Ridge Mountains, which are the easternmost mountains of the Appalachians. Skyline Drive follows this ridgeline through the park for 169 km (105 miles). The peaks and valleys of the Blue Ridge contribute to a variety of habitats, dominated by hardwood forest, and natural features. Shenandoah is the only park in the Mid-Atlantic Network whose mission is primarily to preserve natural resources, and at over 197,000 acres, it is by far the largest park area in the network. Originally authorized on May 22, 1926, Shenandoah National Park was fully established on December 26, 1935.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Geologic scoping sessions, sponsored by the NPS Geologic Resources Division for Shenandoah National Park were held in 2005. There have been no formal paleontological resource inventories completed for SHEN. However, fossils have been discovered within the park and there are paleontological specimens within the park's museum collections.

The park's limited collections of paleontological material include three sandstone blocks, likely of the Erwin Formation, that contain the trace fossil *Skolithos*, see below for more information (E. Butler, personal communication, 2006). These blocks are typical of those found within the park, and were probably collected inside SHEN. Eric Butler (SHEN Geology Consultant, personal communication, 2006) also reported a Pennsylvanian-aged (approximately 290-323 million years old) Filicophyta (fern) specimen in the park's natural history collections. This specimen was not collected in the park, but markings indicate that it came to SHEN from the Smithsonian Institution in 1960. Perhaps the specimen was part of an interpretive display of rocks from different time periods (E. Butler, personal communication, 2006). Pennsylvanian-aged rocks are not found in the Blue Ridge province. In Virginia, Pennsylvanian-aged rocks are only found in the Appalachian Plateau province, where they contain abundant coal deposits. Butler (personal communication, 2006) is developing a geology study collection for the park that will contain approximately 200 rock specimens from throughout SHEN. A few blocks with *Skolithos* tubes, including some that show bioturbation of sediment layers by the worm burrow, will be included.

Shenandoah National Park lies primarily within the Blue Ridge physiographic province. The park and surrounding areas have been the subject of numerous geologic studies and mapping projects, summarized by the National Park Service (2005). These maps are listed in the Additional References section, below. Gathright (1976) produced the only geologic map focusing specifically on the park as a whole. Currently, the United States Geological Survey (USGS) is involved in a project to update geologic mapping for the park with an expected completion date around 2008. Morgan et al. (2004) include geologic information on the colluvial fans and terraces within the park and also summarize the nomenclature surrounding the bedrock geology.

The geologic rock formations exposed within the park include those of Proterozoic (Precambrian), and Cambrian ages. Triassic diabase (intrusive igneous rock) dikes cut though some of the older rocks (e.g. Gathright 1976). Fossils, which are summarized below, are only preserved in the Cambrian Hampton and Erwin formations of the Chilhowee Group. Other Proterozoic formations mapped in the park include a complex of Grenville-aged (approximately 1.2 billion years old) granites and gneisses including the distinctive Old Rag Granite, the metamorphosed sediments and volcanic ash of the Swift Run Formation, and the metamorphosed basaltic lava ("greenstone") of the Catoctin Formation. The metamorphosed alluvial sediments of the Cambrian Weverton Formation and the Triassic-aged diabase dikes (intrusive igneous rock), likewise do not preserve fossils. Interestingly, the Grenville-aged granites and gneisses with SHEN are the oldest rocks found within the Mid-Atlantic Network, and indeed, some of the oldest rocks exposed in the United States.

Hampton (Harpers) Formation (lower Cambrian)
As described by Gathright (1976), the lower (early) Cambrian-aged Hampton Formation is characterized by a thick sequence of greenish-gray to brown metamorphosed sandstone and siltstone and dark grayish-green phyllite (metamorphosed shale). Particularly good exposures of the unit are found along Big Run. The Hampton Formation is considered stratigraphically equivalent to the Harpers Formation, which is well exposed at Harpers Ferry National Historical Park in West Virginia (e.g. Southworth and Brezinski 1996; Kenworthy and Santucci 2004). The Hampton Formation is a unit of the late Proterozoic-early Cambrian Chilhowee Group.

Fossils from the Hampton Formation are limited to trace fossils, but, at over 500 million years old, are the oldest fossils found within the park and the Mid-Atlantic Network. The most common fossil is the vertical worm burrow, *Skolithos*, which can be locally abundant in some exposures of the Hampton, including those along Big Run (Gathright 1976). The *Skolithos* tubes are straight, vertical, and cylindrical with diameters of about 2-5 mm. Some early papers use the now-abandoned spelling *Scolithus* (see Alpert 1974). Gathright (1976) also described other trace fossils found within the Hampton Formation of SHEN. These include slightly larger "U-shaped" burrows as well as tracks and "sinuous" trails of "free-moving surface-feeding organisms." *Rusophycus* trace fossils, interpreted as the "resting trace" of a trilobite are known from the Harpers Formation in Maryland and West Virginia (Nikelson 1956; Brezinski 1992) indicating their potential presence in the stratigraphically equivalent Hampton Formation. The trace fossils and sand/silt lithology of the unit suggest a beach or near-shore marine (Brezinski 1992) or lagoonal (Gathright 1976) depositional environment.

Erwin (Antietam) Formation (lower Cambrian)
Thick bedded light-gray to white quartzite characterizes the Erwin Formation within SHEN (Gathright 1976). Quartzite, like that of the Erwin, is very resistant to erosion, hence the Erwin tends to form ridges, peaks, ledges, and cliffs where it is present. As such, the quartzites of the Erwin Formation are well exposed within SHEN. There are also some beds of less resistant metamorphosed sandstones and shales, similar to those in the Hampton Formation (Gathright 1976). Schwab (1970) described, in detail, Erwin (Antietam) Formation geology from Page, Rockingham, Augusta, Rockbridge, and Botetourt counties in Virginia. Exposures within or near SHEN were likely studied for Schwab's (1970) publication. The Erwin Formation, the uppermost (youngest) formation of the Late Proterozoic-early Cambrian Chilhowee Group, is considered stratigraphically equivalent to the Antietam Formation of Maryland, West Virginia, and central Virginia.

Like the Hampton Formation, the most common fossil in the Erwin Formation is the vertical worm burrow *Skolithos* (Gathright 1976). The *Skolithos* burrows of the Erwin, up to three feet in length in the lower part of the formation, are locally abundant and can be found in many of the Erwin Formation exposures within SHEN. Butler (personal communication, 2005) noted the presence of *Skolithos* at many outcrops during field work in summer 2005. Some examples have been photographed. Interestingly, *Skolithos* tubes are commonly exposed along fractures and cracks in the quartzite, as large assemblages of *Skolithos* "perforate" the rocks, creating a plane of weakness (see photo in Gathright 1976 and on cover of this report). *Skolithos* tubes are the only fossils mentioned by Gathright (1976) within the Erwin Formation exposures of SHEN. However the stratigraphically equivalent Antietam Formation in Maryland, central Virginia, and West Virginia is known to preserve other trace fossils including *Rusophycus*, *Monocraterion* (vertical burrow similar to *Skolithos*, but with a funnel-shaped top) and *Planolites* (meandering or horizontal worm burrow) (Brezinski 1992; Simpson 1991). The Erwin Formation within SHEN contains very pure quartzite with interbeds of silty sediments. The pure quartzite suggests a primarily beach or bar environment with deposition of finer sediments occurring as local sea level fluctuates (Gathright 1976; E. Butler, personal communication, 2006). Skoog et al. (1994) describe a modern polychaete worm (*Diopatra cuprea*) that may serve as an analog for the Cambrian worms that formed the *Skolithos* burrows. *Skolithos* worm burrows are commonly found in or near at least two other MIDN parks, as described in their sections of this report: Valley Forge National Historical Park, and just outside of Hopewell Furnace National Historical Site.

Within SHEN, *Skolithos* fossils are also visible in some of the guardrails along Skyline Drive (S. Hurlbert, personal communication, 2006) which were constructed of local stone. Additional historic structures within the park, constructed with local stone from the Hampton or Erwin formations may also display *Skolithos* tubes.

Body fossils in the Erwin (Antietam) Formation are extremely rare. Butts (1940) reported species of *Olenellus* (trilobite), *Hyolithes* (small enigmatic animals with distinctive conical shells), and *Obolella* (brachiopod) within exposures of the formation in the Appalachian Valley, without naming specific localities. Brezinski (1992) also reported *Olenellus*, hyolithids, brachiopods, and ostracodes from Antietam Formation exposures in Maryland. Brent (1960) reported no fossils other than *Skolithos* from Rockingham County, Virginia. King (1950) likewise mentioned only *Skolithos* fossils near Elkton, Virginia. Fossils other than *Skolithos* are not yet known from within SHEN.

REFERENCES CITED

Alpert, S. P. 1974. Systematic review of the genus *Skolithos*. Journal of Paleontology **48**(4):661-669.

Brent, W. B. 1960. Geology and mineral resources of Rockingham County. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 76. 174 pages.

Brezinski, D. K. 1992. Lithostratigraphy of the western Blue Ridge cover rocks in Maryland. Maryland Geological Survey, Baltimore. Report of Investigations 55. 69 pages.

Butts, C. 1940. Geology of the Appalachian Valley in Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 52. 586 pages.

Gathright, T. M., II. 1976. Geology of the Shenandoah National Park, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 86. 93 pags. Map scale 1:62,500.

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

King, P. B. 1950. Geology of the Elkton area, Virginia. U.S. Geological Survey, Reston, VA. Professional Paper 230. 82 pages.

Morgan, B. A., L. S. Eaton, and G. F. Wieczorek. 2004. Pleistocene and Holocene Colluvial Fans and Terraces in the Blue Ridge Region of Shenandoah National Park, Virginia. U.S. Geological Survey, Reston, VA. Open File Report OF 03-410. (http://pubs.usgs.gov/of/2003/of03-410/)

National Park Service. 2005. Overview of known geologic mapping in Shenandoah National Park Area. Report of the NPS Geologic Resources Division/Geologic Resources Evaluation Program to SHEN. 17 pages.

Nickelsen, R. P. 1956. Geology of the Blue Ridge near Harpers Ferry, West Virginia. Geological Society of America Bulletin **67**:239-270.

Schwab, F. L. 1970. Origin of the Antietam Formation (late Precambrian?-lower Cambrian), central Virginia. Journal of Sedimentary Petrology **40**(1):354-366.

Simpson, E. L. 1991. An exhumed, Lower Cambrian tidal flat: the Antietam Formation, central Virginia, U.S.A. Pages 123-134 *in* D. G. Smith, G. E. Reinson, B. A. Zaitlin, and R. A. Rahmani, editors. Clastic Tidal Sedimentology. Canadian Society of Petroleum Geologists, Calgary, AB. Memoir 16.

Skoog, S. Y., C. Venn, and E. L. Simpson. 1994. Distribution of *Diopatra cuprea* across modern tidal flats: Implications for *Skolithos*. Palaios **9**:188-201.

Southworth, C. S. and D. K. Brezinski. 1996. Geologic map of the Harpers Ferry quadrangle, Virginia, Maryland, and West Virginia. U.S. Geological Survey, Reston, VA. Bulletin 2123. 33 pages. (http://pubs.usgs.gov/bul/b2123/index.html)

ADDITIONAL REFERENCES

Allen, R. M., Jr. 1963. Geologic map of Greene and Madison counties, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 78. 1:62,500 scale map.

Allen, R. M., Jr. 1967. Geology and mineral resources of Page County. Virginia Division of Mineral Resources, Charlottesville, VA. Bulletin 81. 78 pages.

Duncan, I. J., E. V. Campbell, S. T. Williams, H. A. Hibbitts, and J. M. Floyd. 2004. Central Shenandoah Valley Digital Geologic Compilation. Virginia Division of Mineral Resources, Charlottesville, VA. Open-File Report 04-03.

Gathright, T. M., II, W. S. Henika, and J. L. Sullivan, III. 1977. Geology of the Waynesboro East and Waynesboro West quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 3. 1:24,000 scale map.

Gathright, T. M., II, W. S. Henika, and J. L. Sullivan, III. 1978a. Geology of the Grottoes quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 10. 1:24,000 scale map.

Gathright, T. M., II, W. S. Henika, and J. L. Sullivan, III. 1978b. Geology of the Mount Sidney quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 11. 1:24,000 scale map.

Gathright, T. M., II, W. S. Henika, and J. L. Sullivan, III. 1978c. Geology of the Fort Defiance quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 12. 1:24,000 scale map.

Gathright, T. M., II, W. S. Henika, and J. L. Sullivan, III. 1978d. Geology of the Crimora quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 13. 1:24,000 scale map.

Hackley, P. 2000. A hiker's guide to the geology of Old Rag Mountain, Shenandoah National Park, Virginia. U.S. Geological Survey, Reston, VA. Open-File Report 00-263. (http://pubs.usgs.gov/of/2000/of00-263/of00-263.pdf)

Luckert, M. T. and C. R. Halladay. 1980. Geology of the Massies Corner quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 17. 1:24,000 scale map.

Nuckols, E. B., III and M. T. Luckert. 1976. Geologic map of the Linden and Flint Hill quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 44. 1:24,000 scale map.

Rader, E. K. and T. H. Biggs. 1976. Geologic map of the Strasburg quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Report of Investigations 45. 1:24,000 scale map.

Rader, E. K. and T. H. Biggs. 2003. Bedrock geology of the Madison quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 157. 22 pages.

Rader, E. K. and T. M. Gathright, II. 2001a. Geologic map of the Augusta, Page, and Rockingham counties portion of the Charlottesville 30x60 minute quadrangle. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 159. 1:100,000 scale map.

Rader, E. K. and T. M. Gathright, II. 2001b. Geologic map of the Front Royal 30'x60' quadrangle, Virginia: Portions of Clarke, Frederick, Page, Shenandoah, and Warren counties, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 162. 1:100,000 scale map.

Rader, E. K., R. C. McDowell, T. M. Gathright, II, and R. C. Orndorff. 1996. Geologic map of Clarke, Frederick, Page, Shenandoah, and Warren Counties, Virginia: Lord Fairfax Planning District. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 143. 1:100,000 scale map.

Resser, C. E. and B. F. Howell. 1938. Lower Cambrian *Olenellus* zone of the Appalachians. Geological Society of America Bulletin **49**(2):195-248.

Rossman, D. L. 1991. Geology and mineral resources of the Boswells Tavern and Keswick quadrangles, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. Publication 107. 19 pages.

Whitaker, J. C. 1955. Geology of Catoctin Mountain, Maryland and Virginia. Geological Society of America Bulletin **66**:435-462.

DATA SETS

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

DS-SHEN-XXX Shenandoah National Park Museum Collections. 12/1935–present. (museum specimens, collection records, specimen notes, ANCS+ records). Originated by SHEN staff; status: Active.

VALLEY FORGE NATIONAL HISTORICAL PARK

Valley Forge National Historical Park (VAFO) in southeastern Pennsylvania preserves the site of the Continental Army's 1777-1778 winter encampment. This encampment has come to symbolize the perseverance and sacrifice associated with the American War for Independence. The park contains General George Washington's headquarters, original earthworks, a variety of monuments and markers, reconstructed log buildings, and replica cannon. Valley Forge National Historical Park, originally managed as Valley Forge State Park by the Commonwealth of Pennsylvania, was established as a unit of the NPS on the nation's bicentennial, July 4, 1976.

BASELINE PALEONTOLOGICAL RESOURCE INVENTORIES

Paleontological scoping sessions have not been completed for VAFO, and no formal paleontological resource inventories have been completed for the park. Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division were held for VAFO in 2004. The park has no collections of paleontological material. Nevertheless, within park boundaries is a very significant paleontological locality, the Port Kennedy Cave, summarized below. In addition to the large number of fossils discovered within Port Kennedy Cave, the park's bedrock geology and building stones preserve paleontological resources. Geologic formations summarized below, may produce additional paleontological material within park boundaries. The vegetative cover and forests of the park, however, preclude extensive exposures of the geologic formations.

Valley Forge National Historical Park, like many parks in the MIDN, is located within the Piedmont physiographic province. A preliminary geologic map has been compiled for the area surrounding VAFO by Socolow (1981). Wiswall (1993) summarized and mapped the geology of VAFO. The Pennsylvania Geological Survey is supporting projects to update geologic maps of the southeastern portion of the state, including the VAFO area. Geologic formations mapped and recognized within VAFO include: four Cambrian formations, the Chickies, Antietam, Ledger, and Elbrook and the Triassic Stockton Formation. All are known to be fossiliferous outside of VAFO, and many of the units have produced fossils within the park. Socolow's (1981) preliminary map also includes very small mapped areas of the Cretaceous Patapsco Formation (Potomac Group) and Miocene Pensauken/Bridgeton formations on the basal eastern flank of Mount Joy. However, more recent maps, e.g. Wiswall (1993), do not include those units. Dr. Gil Wiswall (West Chester University; personal communication 2005) and Dr. William Kochanov (Pennsylvania Topographic and Geologic Survey; personal communication 2005) also note the uncertainty surrounding the identification and mapping of the Cretaceous and Miocene units within the park.

Chickies Formation (lower Cambrian)
The lower (early) Cambrian Chickies Formation is characterized by a white (weathered) to dark gray (on fresh surfaces) medium grained quartzite. Within VAFO, the Chickies Formation, also known as the Chickies Quartzite, is mapped in the western portion of the park, and underlies Mount Misery (Wiswall 1993). The resistance of the Chickies Formation to erosion results in the development of topographic highs. Based on the formation's lithology, the Chickies is thought to have been deposited as beach sand during the early Cambrian, over 520 million years ago. Subsequent exposure to high temperatures and pressures recrystallized the sandstone into quartzite. The Chickies Formation is also found in Hopewell Furnace National Historic Site (see HOFU section of this report) about 26 km (16 miles) northwest of VAFO.

Metamorphism frequently destroys paleontological resources, however, fossils are still visible in the Chickies Formation. No body fossils are yet known from the Chickies, but trace fossils, especially *Skolithos* burrows, can be quite abundant. In fact, Chickies Rock in Lancaster County (Chickies Rock County Park) is the type locality (place of original description) for both the Chickies Formation and the trace fossil *Skolithos linearis* (Wise 1960; Alpert 1974; Schlegel 2004). *Skolithos* (the spelling "*Scolithus*" has been abandoned) burrows are vertical, cylindrical, tubes, now filled with sediment. They are interpreted

as the burrows of a marine worm. Within the park, Wiswall (1993) notes the presence of *Skolithos* within the exposures of the Chickies Formation along the Valley Creek Trail near the Upper Forge Site. A geologist with the Pennsylvania Topographic and Geologic Survey also confirms their presence within the park (W. Kochanov, personal communication, 2005). The Chickies Formation in southeastern Pennsylvania also preserves *Monocraterion* trace fossils as well (Goodwin and Anderson 1974). *Monocraterion* burrows are essentially *Skolithos* burrows with a "funnel" shaped burrow top. *Monocraterion* funnels are not yet reported from within VAFO.

Both vertical and horizontal cross sections of *Skolithos* are visible at an "unnatural" exposure of the Chickies Formation found as part of the façade of the lower visitor center's restroom building. It is unclear whether the stones were quarried within the park or another local source (M. Carfioli, personal communication, 2005). In 2005, VAFO Ecologist Margaret Carfioli documented the "Lower VC Restroom" as a paleontological locality, and, using the locality condition assessment form, assessed the locality in fair condition.

Antietam Formation (lower Cambrian)
The lower (early) Cambrian Antietam Formation in Pennsylvania is generally characterized by a gray (buff on weathered surfaces) quartzite that is very resistant to erosion. This resistance to erosion creates topographic highs where the Antietam is present. For example, Mount Joy is underlain by Antietam Formation as mapped by Socolow (1981) and Wiswall (1993). In areas where differentiating the Antietam Formation from the phyllites of the underlying Harpers Formation is difficult, they are mapped together (e.g. Socolow 1981). The Antietam Formation is the youngest (top) formation of the Chilhowee Group, and is also exposed as the stratigraphically equivalent Erwin Formation, in Shenandoah National Park (see SHEN section of this report).

Like the lithologically similar Chickies Formation, the most common fossil within the Antietam Formation is the trace fossil *Skolithos*, which is particularly abundant in the upper part of the formation. Wiswall (1993) describes several large boulders Antietam Formation rocks near the covered bridge over Valley Creek but does not mention any *Skolithos* fossils within them. If rocks from the upper portion of the formation are exposed within the park, it is likely that they contain *Skolithos* tubes.

Ledger Formation (middle Cambrian)
The middle Cambrian Ledger Formation, or Ledger Dolomite, is characterized by a light-gray, massive, very pure dolomite, indicative of a shallow marine depositional environment. Dolomite is a rock-forming mineral similar to calcium carbonate (limestone), but containing magnesium and calcium instead of just calcium. The formation was also known as the "Shenandoah Limestone" (e.g. Bascom 1909), "Auroral Limestone" (e.g. Wheatley 1871), and the "Potsdam limestone" (e.g. Cope 1871). These names are not currently valid. The Ledger Formation's pureness made it commercially valuable and many quarry operations, including a number within what is now VAFO, processed the Ledger Formation for its magnesium and lime content. Quarrying operations near Port Kennedy revealed the significant Port Kennedy Cave fossil deposit, summarized below. The Ledger Formation is mapped over much of the eastern portion of VAFO, and as a carbonate rock, is responsible for the karstic features and valley topography of the park (Reich 1974, Socolow 1981, Kochanov et al. 1993, Wiswall 1993).

Fossils are not common in the Ledger Formation near VAFO, although poorly preserved conodonts (teeth of an extinct group of enigmatic marine animals) are occasionally found (W. Kochanov, personal communication, 2005). Bascom (1909) also reports very limited fossil remains (four genera of gastropods and cephalopods) from the "Shenandoah Limestone" near Henderson Station. Closer to Lancaster, trilobite fossils have been found in a deeper-water facies of the Ledger Formation (Taylor and Durika 1990). Stromatolites (algal/bacterial mats layered with fine-grained sediment, indicative of shallower water) are known from the formation and have been found within the park. Stromatolites are visible (as wavy laminations) in the wall of an old dolostone quarry near the visitor center parking lot (Wiswall 1993, W. Kochanov and M. Carfioli, personal communication, 2005). VAFO ecologist Margaret Carfioli has documented the locality as the "Lower VC Wall" and assessed the locality in "poor" condition. This

assessment reflects the ease of visitor access to the site and evidence of vandalism, such as names scratched into the quarry wall (M. Carfioli, personal communication, 2005).

Elbrook Formation (middle-upper Cambrian)
The middle and/or upper (late) Cambrian Elbrook Formation is mapped within VAFO in a very narrow band on the southern border of the park (Socolow 1981; Wiswall 1993). The formation is characterized by a light gray or white interbedded limestone and marble, and underlies the valley south of VAFO. The Elbrook Formation is also mapped in south-central Pennsylvania (Franklin County), although the relationship between those exposures and exposures in Montgomery and Chester counties is unclear.

Like the Ledger Formation, fossils are not common in the Elbrook Formation near VAFO. Elbrook Formation exposures in Franklin County produced trilobite fossils including those from the genus *Glossopleura* (Wilson 1952; Brezinski 1996). Wilson (1952) and Brezinski (1996) also noted many other genera found in some layers of the Elbrook Formation in south-central Pennsylvania and Maryland, although Brezinski (1996) noted that trilobite occurrences are "rare". Such fossils are not yet known from the Elbrook Formation within or surrounding VAFO.

Stockton Formation (Upper Triassic)
The Upper (Late) Triassic Stockton Formation is characterized by a reddish-brown sandstone, siltstone, and mudstone. Thin, gray shale layers are also found in the formation. Socolow (1981) and Wiswall (1993) map the Stockton Formation in the northern half of VAFO on both sides of the Schuylkill River. The red sediments of the Stockton Formation form a distinct angular unconformity with the underlying gray Ledger Formation which dips (is tilted) to the south-southeast (Daeschler et al. 1993; Wiswall 1993). This interesting geological feature was particularly well exposed at the Port Kennedy Cave (see below). The Stockton Formation was originally deposited as sandy and muddy stream sediments during the Late Triassic, about 221-227 million years ago. The Stockton Formation is part of the Newark Supergroup, which includes sediments from basins throughout the east coast (VAFO is in the Newark Basin). These basins formed during Late Triassic rifting (tectonic plates splitting apart) which led to the formation of the Atlantic Ocean. The sedimentary rocks found within these basins are frequently red in color and are known as Triassic "red beds". Many of the basins have rich fossil assemblages. The Stockton Formation is also mapped in Hopewell Furnace National Historic Site (see HOFU section, this report). The Gettysburg Formation (see GETT section) represents similar sediments in the Gettysburg basin.

Stockton Formation fossils have not yet been found within VAFO. However, exposures of the Stockton Formation within the Newark Basin, especially those in New Jersey and New York, produced invertebrate body and trace fossils. Reptilian and dinosaurian body fossils and footprints have also been found (Olsen 1988; Olsen and Flynn 1989). Some fossil discoveries have been made closer to VAFO, and illustrate the potential for similar fossils within the park. Mollusk fossils, including those of the freshwater bivalve *Unio* and three other unnamed bivalve species, were discovered along the Schuylkill River near Mont Clare, about 6.4 km (4 miles) northwest of the park (Bascom and Stose 1938). This locality may, in fact, be near Phoenixville, not Mont Clare (Axsmith and Kroehler 1989). Fossil ostracodes, bivalves, beetles, and plant fossils were collected from the Stockton Formation near Phoenixville, 8 km (5 miles) northwest of VAFO as early as 1884 (Richards 1944; Axsmith and Kroehler 1989). Fish fossils were also collected by Lewis in 1884 (Axsmith and Kroehler 1989). Sinclair (1917) discovered a lower jaw bone of a large labyrinthodont amphibian (*Calamops paludosus*; very primitive group of land animals) near Holicong, Pennsylvania, about 40 km (25 miles) northeast of VAFO. Axsmith and Kroehler (1989) described a small fossil flora assemblage in the Stockton near Phoenixville. The assemblage consisted of leafy shoots and pinwheels of *Dinophyton spinosus* (poorly understood gymnosperm), leaves of *Zamites powelli* (cycad), leafy branches of *Pagiophyllum simpsonii* (conifer), *P. diffusum* (conifer), and *Striatotaxus triassicus* (conifer), and articulated *Glyptolepis* (conifer) cones. Fossil material tentatively identified as *Todites* (fern) was also recovered as were other isolated conifer plant structures. Most of the fossils were found in the thin gray shale layers of the Stockton (Olsen 1980). Wherry (1912) reported petrified wood (*Araucarioxylon* genus) discoveries near Sheeder and Coventry,

16 km and 19km (10 and 12 miles) northwest of VAFO, respectively. The petrified wood occurred in "considerable abundance" at the above localities (Bascom and Stose 1938).

Port Kennedy Cave (middle Pleistocene)
Port Kennedy Cave, located within VAFO, is one of the most significant Middle Pleistocene (Irvingtonian stage) fossil localities in North America (Kurtén and Anderson 1980; Daeschler et al. 1993). Only four Irvingtonian localities are known in the eastern United States (Guilday et al. 1984; Daeschler et al. 1993). Interestingly, two are in the Ledger Formation of Pennsylvania: Port Kennedy Cave in VAFO and Hanover Quarry No. 1 Fissure near Hanover 23 km (14 miles) east of Gettysburg National Military Park). Guilday et al. (1984) described the Hanover site and fossils in greater detail. Port Kennedy Cave, also called Bone Cave or Port Kennedy Bone Cave, is not a true "cave", but a sinkhole formed in the limestone of the Ledger Formation. This feature was briefly open to the surface during the Irvingtonian stage of the Pleistocene, approximately 750,000 years ago, and as such accumulated fossil plant and animal remains that were trapped in the sinkhole, or carried to it by predators (Daeschler et al. 1993; 2005).

In 1870, limestone quarrying operations into the early Cambrian Ledger Formation (Dolomite) uncovered the fossiliferous sinkhole deposit. Subsequent excavations at Port Kennedy Cave in 1870 and from 1894 through 1896 yielded a wealth of fossil vertebrates. Reflecting collecting biases of the time, only a few insects and plants were collected, and many fragmentary specimens went uncollected. Nevertheless, over 1,200 fossil specimens were collected from Port Kennedy Cave, the vast majority of which are now housed at the Academy of Natural Sciences in Philadelphia. A few specimens are housed at the American Museum of Natural History (New York) and one horse tooth, a cast of an Academy of Natural Sciences specimen, is in the collections of the University of Texas at Austin Texas Memorial Museum (E. Lundelius, personal communication, 2006). Specimen quality ranges from remarkable to fragmentary. Daeschler et al. (1993), for example, described one whole pitch pine cone (figured on the cover of this report) as "blackened but looking as if it had just fallen from a tree", while Kurtén and Anderson (1980) mention another author's description of one of Cope's *Microtus* specimens as "a hunk of mud with a tooth impression on it".

Fossils from these early excavations are detailed in the scientific reports of Charles M. Wheatley (1871), Edward Drinker Cope (1871, 1895, 1896, 1899), George H. Horn (1876), and Henry C. Mercer (1895, 1899). Recent scientific work has focused on the previously collected material, as the site is now buried (see below), and includes reviews of Port Kennedy turtles (Parris and Daeschler 1995), mustelids (otters/skunks/badgers/etc.; Hall 1936), microtine rodents (Hibbard 1955), *Miracinonyx* (cheetah-like cat; Van Valkenburgh et al. 1990), and mastodons (Daeschler 1996), among others.

Daeschler et al. (1993) prepared an updated taxonomic list for the Port Kennedy deposit which recognized 11 beetles, five reptiles, one bird, 34 mammal and 14 plant species in the collections of the Academy of Natural Sciences. Horn (1876) is the only researcher to describe the invertebrate remains uncovered at Port Kennedy, which consist of 11 species of ground and dung beetles. His specimens, unfortunately, are now lost (Daeschler et al. 1993). The reptilian fauna includes four species of terrestrial turtle (Hay 1908; Parris and Daeschler 1995) and one species of colubrid snake (racer or whipsnake). The only bird currently recognized from the Port Kennedy deposit is an unidentified turkey from the subfamily Meleagridinae. Mammals make up the vast majority of specimens collected from Port Kennedy and are summarized in greater detail by Kurtén and Anderson (1980) and Daeschler et al. (1993). A number of mammal species described are of particular significance, and are mentioned here. *Megalonyx wheatleyi* (Wheatley's ground sloth) remains found within Port Kennedy Cave represent at least 76 individuals, as reported by Mercer (1899). Port Kennedy is the type locality for the species and probably the largest known single-site assemblage (Daeschler et al. 1993; McDonald 2003). Port Kennedy was also the type locality for *Osmotherium spelaeum* (Port Kennedy skunk), *Neofiber diluvianus* (diluvian water rat), *Martes diluviana* (diluvian fisher), and *Smilodon gracilis* (gracile sabretooth cat). Port Kennedy Bone Cave also produced the earliest record of *Ursus americanus* (black bear), the largest single-site sample of *Arctodus pristinus* (lesser short-faced bear), and the only North American population sample for large Pleistocene tapirs including the common *Tapirus haysii*. Juvenile *Mammut americanum* (American

Mastodon) remains within the deposit account for nearly 90% of the mastodon teeth found (Daeschler 1996). This selective mortality appears to be the result of carnivore transport and accumulation as predators focused on younger, more vulnerable individuals (Daeschler 1996). The plants from Port Kennedy have received little mention in the scientific literature. Nevertheless, 14 species are recognized from the deposit with *Fagus grandifolia* (American beech) and *Carya* sp. (hickory) nuts being the most common.

Daeschler et al. (1993) described the remarkable history of the Port Kennedy fossils, the associated collection efforts, the significance of the fossils, and presented an updated list of fossil species. Their publication also served as a major source of information for this summary. Santucci et al. (2001) included a brief summary of Port Kennedy Cave in their inventory of paleontological resources associated with National Park Service caves. Publications such as Witte (1957), Wiswall (1993), and McCarthy (1994) also summarized the paleontology and geology of the site. Daeschler et al. (2005) and Hojdila et al. (2005) summarized the recent successful efforts to determine the precise location of the cave within the eponymous "Cave Quarry". Until the Daeschler et al. (2005) and Hojdila et al. (2005) study, the precise location was not known with certainty, although Cave Quarry was long the suspected site of the Port Kennedy Cave.

Infiltration of groundwater hampered early fossil recovery efforts (Mercer (1899) described the water-saturated bones as having the consistency of "over-ripe pears"), and the fossiliferous deposit was never fully excavated. Many water-damaged specimens were also lost during the early collection efforts. The quarry itself was filled in during the early 1900s with waste from the nearby Ehret Magnesium Manufacturing Company, burying the remaining fossils under some 12 m (40 ft) of asbestos-containing waste (Daeschler et al. 2005). Vegetative cover now obscures most of the quarry fill and surrounding geology, which also displayed a well-defined angular unconformity with the overlying red shales of the Late Triassic Stockton Formation. VAFO Ecologist Meghan Carfioli (personal communication, 2005) documented the locality in June 2005 and assessed it in "good" condition, owing to it's isolation from weathering, erosion, and vandalism. However, the cover protecting the site also presents many challenges toward future field studies or even a limited re-excavation of the Port Kennedy deposit. Regardless, the Academy of Natural Science's collection would benefit greatly from additional research and description (Daeschler et al. 1993; 2005). Port Kennedy Cave, and the story of its fossils and those that studied them, would be an excellent theme for future interpretive materials.

The Ledger Formation is responsible for the karstic geomorphology exhibited within the park. Other karst features in the park include the two "Valley Forge Caves" found north of the memorial arch in VAFO. Other unnamed caves, including two southwest of Port Kennedy, likely near Cave Quarry, and another in an a "long abandoned limestone quarry densely overgrown" are also found within the park. These caves are described by Reich (1974) and are not known to have produced any paleontological material. While the park was managed by the Commonwealth of Pennsylvania as Valley Forge State Park (1896-1976), many karst features were filled with construction debris and other waste. From 1976, when the NPS began stewardship of the site, until 2004, the National Park Service also filled karst features with rocks and soil. In 2004, the practice of backfilling karst features in the park was finally ended (Davis et al. 2005).

COOPERATIVE PROJECTS

- Port Kennedy Cave (1990s-present)-VAFO provided logistical assistance and funding (through PMIS) to support Academy of Natural Sciences of Philadelphia research regarding the fossils of Port Kennedy and the precise location of the deposit. Dr. Ted Daeschler of the Academy is the primary researcher.

REFERENCES CITED

Alpert, S. P. 1974. Systematic review of the genus *Skolithos*. Journal of Paleontology **48**(4):661-669.

Axsmith, B. J. and P. A. Kroehler. 1989. Upper Triassic *Dinophyton* Zone plant fossils from the Stockton Formation in southeastern Pennsylvania. The Mosasaur **4**:45-47.

Bascom, F. 1909. Philadelphia Folio: Norristown, Germantown, Chester, and Philadelphia quadrangles, Pennsylvania-New Jersey-Delaware. U.S. Geological Survey, Reston, VA. Geologic Atlas of the United States Folder 162. 23 pages. 1:62,500 scale.

Bascom, F. and G. W. Stose. 1938. Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania. U.S. Geological Survey, Reston, VA. Bulletin 891. 145 pages.

Brezinski, D. K. 1996. Stratigraphy of the Elbrook Formation (Middle to Upper Cambrian) in Maryland and adjacent states. Pages 165-186 *in* Brezinski, D. K. and J. P. Reger, editors. Studies in Maryland Geology – In Commemoration of the Centennial of the Maryland Geological Survey. Maryland Geological Survey, Baltimore. Special Publication 3.

Cope, E. D. 1871. Preliminary report on the Vertebrata discovered in the Port Kennedy Bone Cave. Proceedings of the American Philosophical Society **12**:73-102.

Cope, E. D. 1895. The fossil Vertebrata from the fissure at Port Kennedy, Pa. Proceedings of the Academy of Natural Sciences of Philadelphia **47**:446-451.

Cope, E. D. 1896. New and little known Mammalia from the Port Kennedy bone deposit. Proceedings of the Academy of Natural Sciences of Philadelphia **48**:378-394.

Cope, E. D. 1899. Vertebrate remains from Port Kennedy bone deposit. Journal of the Academy of Natural Sciences of Philadelphia **11**:193-267.

Daeschler, E. B. 1996. Selective mortality of mastodons (*Mammut americanum*) from the Port Kennedy Cave (Pleistocene; Irvingtonian), Montgomery County, Pennsylvania. Pages 83-96 *in* Stewart, K. M. and K. L. Seymour, editors. Palaeocology and Palaeoenvironments of Late Cenozoic Mammals. University of Toronto Press, Toronto.

Daeschler, E. B., M. C. Lamanna, and M. A. Carfioli. 2005. On the trail of an important Ice-Age fossil deposit. Park Science **23**(2):31-34.

Daeschler, E., E. E. Spamer, and D. C. Parris. 1993. Review and new data on the Port Kennedy local fauna and flora (Late Irvingtonian), Valley Forge National Historical Park, Montgomery County, Pennsylvania. The Mosasaur **5**:23-41.

Davis, C., J. Comiskey, and C. Callahan. 2005. Park Profiles. Appendix 1 *in* National Park Service, Mid-Atlantic Inventory and Monitoring Network, Phase 1 Report.

Goodwin, P. W. and E. J. Anderson. 1974. Associated physical and biogenic structures in environmental subdivision of a Cambrian tidal sand body. Journal of Geology **82**:779-794.

Guilday, J. E., J. F. P. Cotter, D. Cundall, E. B. Evenson, J. B. Gatewood, A. V. Morgan, A. Morgan, A. D. McCrady, D. M. Peteet, R. Stuckenrath, and K. Vanderwal. 1984. Paleoecology of an Early Pleistocene (Irvingtonian) Cenote: Preliminary report on the Hanover Quarry No. 1 Fissure, Adams County, Pennsylvania. Pages 119-132 *in* Mahaney, W. C., editor. Correlation of Quaternary Chronologies, from a symposium on Correlation of Quaternary Chronologies (May 26-29, 1983, Toronto).

Hall, E. R. 1936. Mustelid mammals from the Pleistocene of North America; with systematic notes on some recent members of the genera Mustela, Taxidea, and Mephitis. Pages 41-119 *in* Studies of Tertiary and Quaternary Mammals of North America. Carnegie Institution of Washington, Washington, DC. Publication 473.

Hay, O. P. 1908. The fossil turtles of North America. Carnegie Institution of Washington, Washington, DC. Publication 75. 568 pages.

Hay, O. P. 1923. The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of Longitude 95°. Carnegie Institution of Washington, Washington, DC. Publication 322. 499 pages.

Hibbard, C. W. 1955. Notes on the microtine rodents from Port Kennedy Cave deposit. Proceedings of the Academy of Natural Sciences of Philadelphia 107:87-97.

Hojdila, J., T. DeMayo, T. Bechtel, and M. Carfioli. 2005. The long-lost cave has been found! Park Science **23**(2):35-36.

Horn, G. H. 1876. Notes on some coleopterous remains from the bone cave at Port Kennedy, Penna. Transactions of the American Entomological Society **5**:241-245. (http://chla.library.cornell.edu/c/chla/browse/title/5077659.html)

Kochanov, W. E., J. F. Lichtinger, and M. Becker. 1993. Sinkholes and karst-related features of Montgomery County, Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Open File Report OF 93-02. 7 pages.

Kurtén, B. and E. Anderson. 1980. Pleistocene mammals of North America. Columbia University Press, New York. 442 pages.

McCarthy, C. 1994. The case of the disappearing cave. Lapidary Journal **47**(10): 55-56, 58, 60, 126-129.

McDonald, H. G. 2003. Sloth remains from North American caves and associated karst features. Pages 1-16 *in* Schubert, B. W., J. I. Mead, and R. Wm. Graham, editors. Ice Age Cave Faunas of North America. Indiana University Press, Bloomington.

Mercer, H. C. 1895. A preliminary account of the re-exploration in 1894 and 1895 of the "Bone Hole," now known as Irwins' Cave, at Port Kennedy, Montgomery County, Pennsylvania. Proceedings of the Academy of Natural Sciences of Philadelphia:443-446.

Mercer, H. C. 1899. The bone cave at Port Kennedy, Pennsylvania, and its partial excavation in 1894, 1895, and 1896. Journal of the Academy of Natural Sciences of Philadelphia **11**(2):268-286.

Olsen, P. E. 1980. Triassic and Jurassic formations of the Newark Basin. Pages 2-39 *in* Manspeizer, W., editor. Field studies of New Jersey geology and guide to field trips. New York State Geological Association, Albany. 52nd Annual Meeting Guidebook.

Olsen, P. E. 1988. Paleontology and paleoecology of the Newark Supergroup (early Mesozoic, eastern North America). Pages 185-230 *in* Manspeizer, W., editor. Triassic-Jurassic Rifting: Continental breakup and the origin of the Atlantic Ocean and passive margins. Elsevier, Amsterdam. Developments in Geotectonics 22 (Part A).

Olsen, P. E. and J. J. Flynn. 1989. Field guide to the vertebrate paleontology of Late Triassic age rocks in the southwestern Newark Basin (Newark Supergroup, New Jersey and Pennsylvania). The Mosasaur **4**:1-43.

Parris, D. C. and E. Daeschler. 1995. Pleistocene turtles of Port Kennedy Cave (Late Irvingtonian), Montgomery County, Pennsylvania. Journal of Paleontology **69**(3):563-568.

Reich, J. R., Jr. 1974. Caves of Southeastern Pennsylvania. Pennsylvania Topographic and Geologic Survey (4th ser.), Middletown, PA. General Geology Report 65. 120 pages.

Richards, H. G. 1944. Fossil molluscs from the Triassic of Pennsylvania. Proceedings of the Pennsylvania Academy of Science **18**:62-69.

Santucci, V. L., J. Kenworthy, and R. Kerbo. 2001. An inventory of paleontological resources associated with National Park Service caves. NPS Geologic Resources Division Technical Report NPS/NRGRD/GRDTR-01/02 (NPS D-2231). 50 pages. (http://www2.nature.nps.gov/geology/paleontology/pub/cavepaleo.pdf)

Schlegel, M. A. 2004. Preservation of key geologic sites in Lancaster and York Counties, Pennsylvania. Geological Society of America Abstracts with Programs **36**(2):115.

Sinclair, W. J. 1917. A new labyrinthodont from the Triassic of Pennsylvania. American Journal of Science (4th ser.) **43**:319-321.

Skoog, S. Y., C. Venn, and E. L. Simpson. 1994. Distribution of *Diopatra cuprea* across modern tidal flats: Implications for Skolithos. Palaios **9**:188-201.

Socolow, A. A (compiler). 1981. [Preliminary geologic map of the] Valley Forge Quadrangle. Page 591 *in* Berg T. M. and C. M. Dodge, editors. Atlas of preliminary geologic quadrangle maps of Pennsylvania. Pennsylvania Bureau of Topographic and Geologic Survey, Middletown, PA. Map 61. Scale 1:62,500.

Taylor, J. F. and N. J. Durika. 1990. Lithofacies, trilobite faunas, and correlation of the Kinzers, Ledger, and Conestoga Formations in the Conestoga Valley. Pages 136-155 *in* Scharnberger, C. K., editor. Carbonates, schists, and geomorphology in the vicinity of the lower reaches of the Susquehanna River. Field Conference of Pennsylvania Geologists, Harrisburg, PA. 55th Annual Guidebook.

Van Valkenburgh, B., F. Grady, and B. Kurtén. 1990. The Plio-Pleistocene cheetah-like cat *Miracinonyx inexpectatus* of North America. Journal of Vertebrate Paleontology **10**(4):434-454.

Wheatley, C. M. 1871. Notice of the discovery of a cave in Eastern Pennsylvania, containing remains of Post-Pliocene fossils, including those of Mastodon, Tapir, Megalonyx, Mylodon, etc. The American Journal of Science and Arts (3rd ser.) **1**(4):235-237.

Wherry, E. T. 1912. Silicified wood from the Triassic of Pennsylvania. Proceedings of the Academy of Natural Sciences of Philadelphia **64**:366-372.

Wilson, J. L. 1952. Upper Cambrian stratigraphy in the central Appalachians. Geological Society of America Bulletin **63**:275-322.

Wise, D. U. 1960. Chickies Rock. Stop 8 *in* Wise, D. U. and M. E. Kauffman, editors. Some tectonic and structural problems of the Appalachian Piedmont along the Susquehanna River. Field Conference of Pennsylvania Geologists, Harrisburg, PA. 25th Annual Guidebook.

Wiswall, C. G. 1993. Valley Forge National Historical Park. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Park Guide 8. 13 pages. (http://www.dcnr.state.pa.us/topogeo/ParkGuides/pg08.pdf)

Witte, W. H. 1957. The 1896 excavation of Port Kennedy Cave Pennsylvania and other recollections. Netherworld News **5**(3):4.1-4.4.

ADDITIONAL REFERENCES

Anderson, E. 1984. Review of the small carnivores of North America during the last 3.5 million years. Pages 257-266 *in* Genoways, H. H. and M. R. Dawson, editors. Contributions in Quaternary vertebrate paleontology: A volume in memorial to John E. Guilday. Carnegie Museum of Natural History, Pittsburgh, PA. Special Publication 8.

Berta, A. 1987. The sabrecat *Smilodon gracilis* from Florida and a discussion of its relationships. Bulletin of the Florida State Museum, Biological Sciences Series **31**(1):1-63.

Brown, B. 1908. The Conard fissure, a Pleistocene bone deposit in northern Arkansas: with descriptions of two new genera and twenty new species of mammals. Memoirs of the American Museum of Natural History **9**(4):155-208.

Cope, E. D. 1880. On the extinct cats of America. American Naturalist **14**:833-858.

Daeschler, E. and E. E. Spamer. 1993. Port Kennedy Local Fauna and Flora (Mid-Pleistocene), Valley Forge National Historical Park, Upper Merion Township, Montgomery County, Pennsylvania. Page 108 *in* Santucci, V. L., editor. National Park Service Paleontological Research Abstract Volume. National Park Service, Petrified Forest National Park, Holbrook, AZ. Natural Resources Technical Report NPS/NRPEFO/NRTR-93/11.

Frazier, M. K. 1981. A revision of the fossil Erethizontidae of North America. Bulletin of the Florida State Museum Biological Sciences Series **27**(1):1-76.

Gidley, J. W. and C. L. Gazin. 1938. The Pleistocene vertebrate fauna from Cumberland Cave, Maryland. United States National Museum, Washington, DC. Bulletin 171.

Gilmore, C. W. 1938. Fossil snakes of North America. Geological Society of America, Boulder, CO. Special Paper 9. 96 pages.

Goodwin, B. K. 1964. Guidebook to the geology of the Philadelphia area. Pennsylvania Topographic and Geologic Survey, Middletown, PA. General Geology Report G 41. 189 pages.

Grady, F. 1981. Fossil bone discovery. D.C. Speleograph (February):9.

Guilday, J. E. 1967. Trout [Cave] fishing. Netherworld News (September):188-192.

Heilprin, A. 1895. The Port Kennedy deposit. Proceedings of the Academy of Natural Sciences of Philadelphia **47**:451.

Hibbard, C. W. 1957. Notes on late Cenozoic shrews. Transactions of the Kansas Academy of Sciences **60**:321-336.

Hirschfeld, S. E. and S. David Webb. 1968. Plio-Pleistocene Megalonychid sloths of North America. Bulletin of the Florida State Museum, Biological Sciences Series **12**(5):213-296.

Holman, J. A. 1981. A review of North American Pleistocene snakes. Publications of the Museum-Michigan State University, Paleontological Series **1**(7):261-306.

Jones, C. A., J. R. Choate, and H. H. Genoways. 1984. Phylogeny and paleobiogeography of short-tailed shrews (genus *Blarina*). Pages 56-148 *in* Genoways, H. H. and M. R. Dawson, editors. Contributions in Quaternary vertebrate paleontology: A volume in memorial to John E. Guilday. Carnegie Museum of Natural History, Pittsburgh, PA. Special Publication 8.

Kurtén, B. 1967. Pleistocene bears of North America, Part 2. Genus *Arctodus*, short-faced bears. Societas pro Fauna et Flora Fennica, Helsinki, Finland. Acta Zoologica Fennica 117.

Kurtén, B. 1976. Fossil puma (Mammalia: Felidae) in North America. Netherlands Journal of Zoology **26**(4):502-534.

Lewis, H. C. 1884. Fossils in the Triassic shale of Phoenixville, Pennsylvania. Science **3**:295.

Martin, R. 1987. Notes on the classification and evolution of some North American fossil *Microtus*. Journal of Vertebrate Paleontology **7**(3):270-283.

McDonald, H. G. 1977. Description of the osteology of the extinct gravigrade edentate *Megalonyx* with observations on its ontogeny, phylogeny, and functional anatomy. Unpublished M.S. thesis. University of Florida, Gainesville.

Milstead, W. W. 1965. Notes on identities of some poorly known fossils of box turtle (*Terrapene*). Copeia 1965(4):513-514.

Nowak, R. M. 1979. North American Quaternary *Canis*. University of Kansas Museum of Natural History, Lawrence, KS. Monograph 6. 154 pages.

Olsen, P. E., R. W. Schlische, and P. J. W. Gore. 1989. Tectonic, depositional, and paleoecological history of Early Mesozoic rift basins, eastern North America. American Geophysical Union, Washington, DC. 28th International Geological Congress Field Trip Guidebook T-351.

Parris, D. C. 1993. Fossil turtles of Port Kennedy Cave (Pleistocene), Valley Forge National Historical Park, Pennsylvania. Page 109 *in* Santucci, V. L., editor. National Park Service Paleontological Research Abstract Volume. National Park Service, Petrified Forest National Park, Holbrook, AZ. Natural Resources Technical Report NPS/NRPEFO/NRTR-93/11.

Rader, H. L. 1951. Geology of Valley Forge Park and vicinity, Valley Forge, Pennsylvania. Unpublished M.S. Thesis. Lehigh University, Bethlehem, PA.

Ray, C. E. and A. E. Sanders. 1984. Pleistocene tapirs in the eastern United States. Pages 283-315 *in* Genoways, H. H. and M. R. Dawson, editors. Contributions in Quaternary vertebrate paleontology: A volume in memorial to John E. Guilday. Carnegie Museum of Natural History, Pittsburgh, PA. Special Publication 8.

Repenning, C. A. and F. Grady. 1988. The microtine rodents of the Cheetah Room Fauna, Hamilton Cave, West Virginia, and the spontaneous origin of *Synaptomys*. U.S. Geological Survey, Reston, VA. Bulletin 1853. 32 pages.

Rima, D. R., H. Meisler, and S. Longwill. 1962. Geology and hydrology of the Stockton Formation in southeastern Pennsylvania. Pennsylvania Topographic and Geologic Survey, Middletown, PA. Water Resources Report W-14. 111 pages.

Savage, D. E. and D. E. Russell. 1983. Mammalian paleofaunas of the world. Addison-Wesley Publishing Co., Reading, MA. 432 pages.

Simpson, G. G. 1941. Large Pleistocene felines of North America. American Museum of Natural History, New York. Novitates 1136.

Simpson, G. G. 1945. Notes on Pleistocene and Recent tapirs. Bulletin of the American Museum of Natural History **86**:33-82.

Steadman, D. W. 1980. A review of the osteology and paleontology of turkeys (Aves: Meleagrinidae). Pages 131-207 *in* Campbell, K. E., editor. Papers in avian paleontology honoring Hildegarde Howard. Natural History Museum of Los Angeles County, Los Angeles. Contributions in Science (Vertebrate Paleontology) 330.

Van der Meulen, A. J. 1978. Microtus and Pitymys (Arvicolidae) from Cumberland Cave, Maryland, with a comparison of some New and Old World species. Annals of the Carnegie Museum **47**(6):101-145.

White, J. A. 1970. Late Cenozoic porcupines (Mammalia, Erethizontidae) of North America. American Museum of Natural History, New York. Novitates 2421.

DATA SETS

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

DS-VAFO-XXX Academy of Natural Sciences of Philadelphia Collections. 1870-present. (museum specimens; associated specimen notes; collection records; field notes; publications; historical photos and documents; maps; etc.). Originated by museum scientists; status: Active (Dr. Ted Daeschler).

DS-VAFO-XXX American Museum of Natural History (New York). 1870-1896. (museum specimens; associated specimen notes; collection records; field notes). Originated by museum scientists; status: Inactive.

DS-VAFO-XXX University of Texas at Austin, Texas Memorial Museum. 1870-1896. (museum specimen; associated specimen notes). Originated by museum scientists; status: Inactive.

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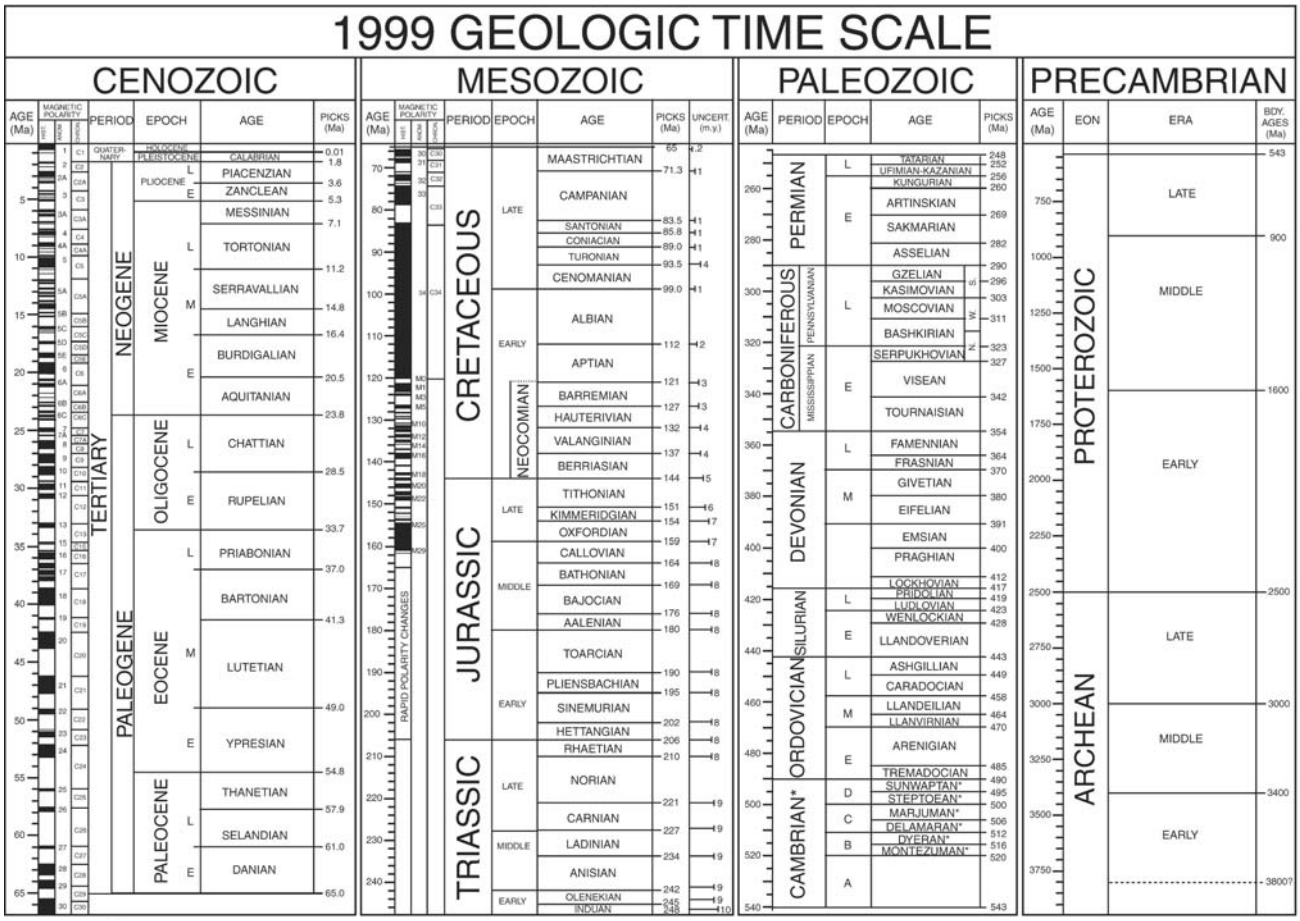
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APPENDIX A: GEOLOGIC TIME SCALE



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

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

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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