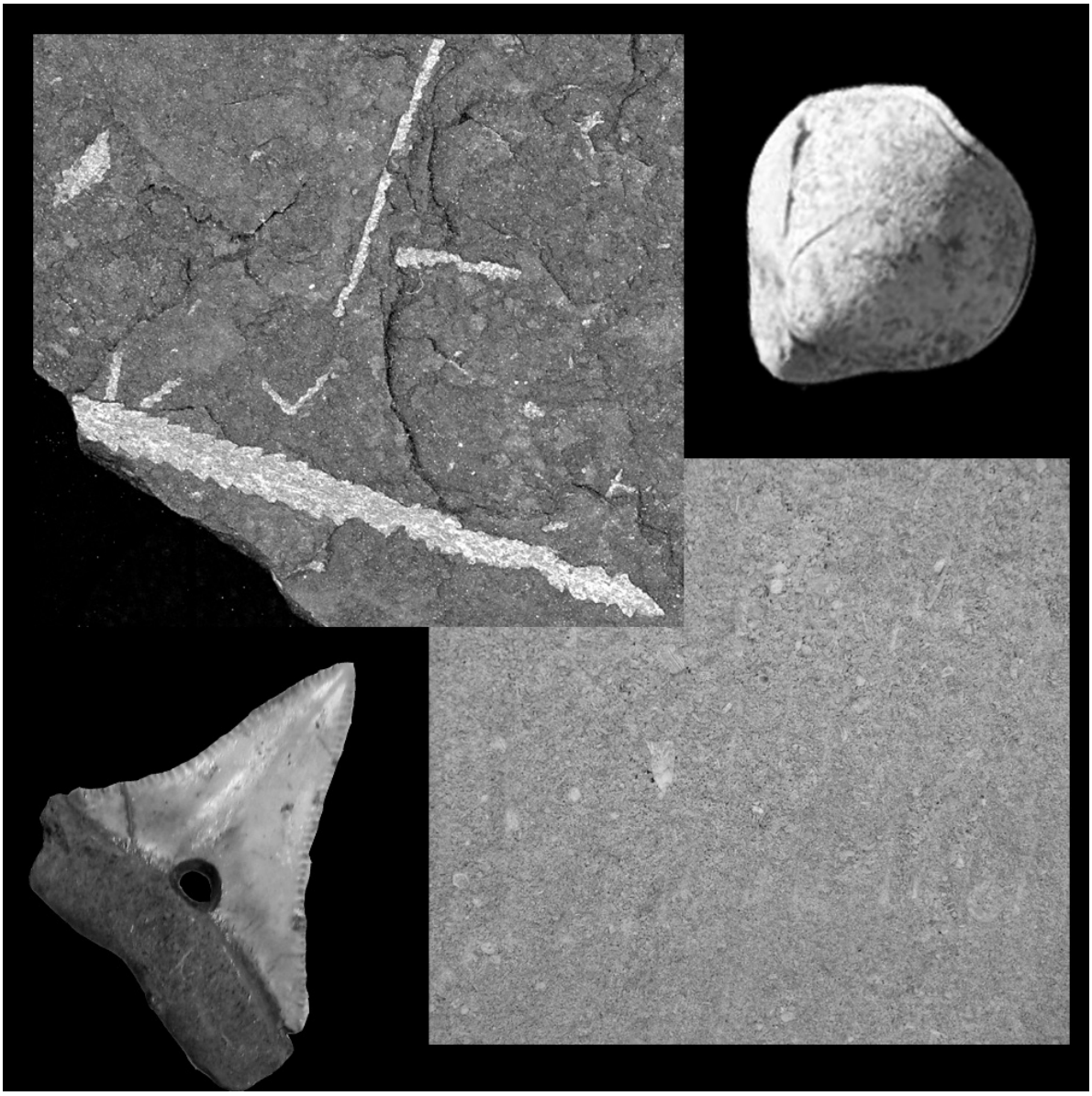
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

# Paleontological Resource Inventory and Monitoring
## *Heartland Network*

Natural Resource Technical Report NPS/NRPC/NRTR—2008/132



**ON THE COVER**
An assortment of Heartland Network fossils.

Top left: Graptolites from the Polk Creek Shale in Arkansas, near Hot Springs National Park. Graptolite fossils are known to occure in the Polk Creek Shale within the park, although the specimens in the park's collection come from outside the park. Image courtesy of Sharon Shugart (Hot Springs National Park).

Top right: Brachiopod (*Composita*) fossil from the Florena Shale, Tallgrass Prairie National Preserve. Brachiopod fossils are common in many of the HTLN parks. Image courtesy of Bob Sawin (Kansas Geological Survey).

Bottom left: A shark's tooth in the collections of Hopewell Culture National Historic Park. The fossil shark teeth are on exhibit at HOCU and were excavated from Mound 7 at Mound City in 1920-1921 by William C. Mills. These shark teeth are perforated on the root portion and were found in association with small shell beads, suggesting to Mills that they had been part of a necklace. Image courtesy of Kathy Brady Rawlins (Hopewell Culture National Historical Park).

Bottom right: Marine invertebrate fossils (foraminifera, corals, bryozoans, mollusks and crinoids) present in the limestone used as building stone for the Lincoln Boyhood National Memorial visitor center. Image courtesy of Mike Capps (Lincoln Boyhood National Memorial).

See the individual park sections for additional information.

# Paleontological Resource Inventory and Monitoring
## *Heartland Network*

Natural Resource Technical Report NPS/NRPC/NRTR—2008/132

ReBecca Hunt
National Park Service (Contractor)
Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287

Jason P. Kenworthy
National Park Service
Geologic Resources Division
Oregon State University
104 Wilkinson Hall
Corvallis, OR 97331

Vincent L. Santucci
National Park Service
George Washington Memorial Parkway
Turkey Run Park
McLean, VA 22101

**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.**

October 2008

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The Natural Resource Publication series addresses natural resource topics that are of interest and applicability to a broad readership in the National Park Service and to others in the management of natural resources, including the scientific community, the public, and the NPS conservation and environmental constituencies. Manuscripts are peer-reviewed to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and is designed and published in a professional manner.

The Natural Resources Technical Reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission. The reports provide contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations. Current examples of such reports include the results of research that addresses natural resource management issues; natural resource inventory and monitoring activities; resource assessment reports; scientific literature reviews; and peer reviewed proceedings of technical workshops, conferences, or symposia.

Views, statements, findings, conclusions, recommendations and data in this report are solely those of the author(s) and do not necessarily reflect views and policies of the U.S. Department of the Interior, NPS. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

Printed copies of reports in these series may be produced in a limited quantity and they are only available as long as the supply lasts. This report is also available from the Heartland I&M Network intranet (NPS access only) site (http://www1.nrintra.nps.gov/im/units/HTLN/index.cfm), the NPS Natural Resource Publications Management site (http://www.nature.nps.gov/publications/NRPM/), or by sending a request to the address on the back cover.

Please cite this publication as:

Hunt, R., J. P. Kenworthy, and V. L. Santucci. 2008. Paleontological resource inventory and monitoring—Heartland Network. Natural Resource Technical Report NPS/NRPC/NRTR—2008/132. National Park Service, Fort Collins, Colorado.

NPS D-66, October 2008

# Contents

Page

Figures ..... vii

Abstract ..... ix

Acknowledgements ..... xi

Introduction ..... 1

Paleontological Resource Inventory Strategies and Methodology ..... 5
- Comprehensive Park-Specific Paleontological Resource Inventories ..... 5
- Servicewide Thematic Paleontological Resource Inventories ..... 5
- Inventory and Monitoring Network Paleontological Resource Inventories ..... 5
- Paleontological Resource Management Legislation and Guidance ..... 7
- Additional References and Websites of Interest ..... 8

Arkansas Post National Memorial ..... 13
- Geologic Background ..... 13
- Potential Sources of Paleontological Resources ..... 13
- Park Collections ..... 13
- Paleontological Resource Management, Preliminary Recommendations ..... 13
- Literature Cited ..... 14
- Additional References ..... 15
- Data Sets ..... 15

Buffalo National River ..... 17
- Geologic Background ..... 17
- Sources of Paleontological Resources ..... 17
- Park Collections ..... 21
- Paleontological Resource Management, Preliminary Recommendations ..... 21
- Literature Cited ..... 22
- Additional References ..... 23
- Data Sets ..... 24

Cuyahoga Valley National Park ..... 25
- Geologic Background ..... 25
- Sources of Paleontological Resources ..... 25
- Potential Sources of Paleontological Resources ..... 27
- Park Collections and Fossils in Cultural Resource Contexts ..... 27
- Paleontological Resource Management, Preliminary Recommendations ..... 28
- Literature Cited ..... 28
- Additional References ..... 31
- Data Sets ..... 32

Effigy Mounds National Monument ..... 33
- Geologic Background ..... 33
- Sources of Paleontological Resources ..... 33
- Potential Sources of Paleontological Resources ..... 34
- Park Collections and Fossils in Cultural Resource Contexts ..... 35
- Paleontological Resource Management, Preliminary Recommendations ..... 35
- Literature Cited ..... 36
- Additional References ..... 37
- Data Sets ..... 37

George Washington Carver National Monument ..... 39
Geologic Background ..... 39
Potential Sources of Paleontological Resources ..... 39
Park Collections ..... 39
Paleontological Resource Management, Preliminary Recommendations ..... 40
Literature Cited ..... 40
Additional References ..... 40
Data Sets ..... 41

Herbert Hoover National Historic Site ..... 43
Geologic Background ..... 43
Potential Sources of Paleontological Resources ..... 43
Park Collections ..... 44
Paleontological Resource Management, Preliminary Recommendations ..... 44
Literature Cited ..... 44
Additional References ..... 44
Data Sets ..... 45

Homestead National Monument of America ..... 47
Geologic Background ..... 47
Potential Sources of Paleontological Resources ..... 47
Park Collections ..... 49
Paleontological Resource Management, Preliminary Recommendations ..... 49
Literature Cited ..... 49
Additional References ..... 50
Data Sets ..... 50

Hopewell Culture National Historical Park ..... 51
Geologic Background ..... 51
Sources of Paleontological Resources ..... 51
Potential Sources of Paleontological Resources ..... 51
Park Collections and Fossils in Cultural Resource Contexts ..... 54
Paleontological Resource Management, Preliminary Recommendations ..... 54
Literature Cited ..... 54
Additional References ..... 57
Data Sets ..... 58

Hot Springs National Park ..... 59
Geologic Background ..... 59
Sources of Paleontological Resources ..... 59
Potential Sources of Paleontological Resources ..... 60
Park Collections and Fossils in Cultural Resource Contexts ..... 61
Paleontological Resource Management, Preliminary Recommendations ..... 61
Literature Cited ..... 62
Additional References ..... 63
Data Sets ..... 64

Lincoln Boyhood National Memorial ..... 65
Geologic Background ..... 65
Sources of Paleontological Resources ..... 65
Potential Sources of Paleontological Resources ..... 65
Park Collections and Fossils in Cultural Resource Context ..... 66
Paleontological Resource Management, Preliminary Recommendations ..... 67
Literature Cited ..... 67
Additional References ..... 70

Data Sets ..... 71
Ozark National Scenic Riverways ..... 73
Geologic Background ..... 73
Sources of Paleontological Resources ..... 73
Potential Sources of Paleontological Resources ..... 74
Park Collections and Fossils in Cultural Resource Contexts ..... 76
Paleontological Resource Management, Preliminary Recommendations ..... 76
Literature Cited ..... 77
Additional References ..... 80
Data Sets ..... 81
Pea Ridge National Military Park ..... 83
Geologic Background ..... 83
Sources of Paleontological Resources ..... 83
Potential Sources of Paleontological Resources ..... 83
Park Collections ..... 85
Paleontological Resource Management, Preliminary Recommendations ..... 85
Literature Cited ..... 85
Additional References ..... 86
Data Sets ..... 86
Pipestone National Monument ..... 87
Geologic Background ..... 87
Park Collections ..... 87
Paleontological Resource Management, Preliminary Recommendations ..... 87
Literature Cited ..... 88
Additional References ..... 88
Data Sets ..... 88
Tallgrass Prairie National Preserve ..... 89
Geologic Background ..... 89
Sources of Paleontological Resources ..... 89
Potential Sources of Paleontological Resources ..... 94
Park Collections and Fossils in Cultural Resource Contexts ..... 94
Paleontological Resource Management, Preliminary Recommendations ..... 95
Literature Cited ..... 95
Additional References ..... 98
Data Sets ..... 99
Wilson's Creek National Battlefield ..... 101
Geologic Background ..... 101
Potential Sources of Paleontological Resources ..... 101
Park Collections ..... 102
Paleontological Resource Management, Preliminary Recommendations ..... 102
Literature Cited ..... 102
Additional References ..... 103
Data Sets ..... 104

# Figures

Page

Figure 1. Map of the Heartland Network Parks ..... 3

Figure 2. Geologic Time Scale ..... 105

# Abstract

Paleontological resources (fossils) are any remains of past life preserved in a geologic context. Paleontological resources are non-renewable resources found in at least 200 National Park Service (NPS) units. Despite the abundance and diversity of these resources throughout the NPS, until recently few parks have adequate baseline paleontological resource data.

The NPS National Inventory and Monitoring Program and the NPS Geologic Resources Division have developed various strategies to provide parks with the baseline paleontological resource data necessary for greater understanding and appropriate management of these resources. This report presents a paleontological resource summary for the parks of the Heartland Network. The summary was compiled through extensive literature reviews and interviews with park staff and professional geologists and paleontologists. Preliminary paleontological resource management recommendations are also included for each park. Similar summaries have already been prepared for 21 other NPS Inventory and Monitoring Networks. The National Inventory and Monitoring Program provided funding to complete these paleontological resource summaries for each of the remaining networks.

Fossils from the Heartland region are known from younger sedimentary rocks of the Paleozoic Era (Cambrian to Permian) and Pleistocene Epoch (approximately 11,477 years-1.8 million years old). Some of the oldest rocks in the Heartland Network extend back to the Cambrian period of the Paleozoic Era (Effigy Mounds National Monument and Ozark National Scenic Riverways). Rocks throughout the Heartland Network preserve the remains of ancient organisms, most from ancient marine sediments. These fossil remains consist typically of invertebrate fossils from the Paleozoic rocks. The fossilized remains of mammals are preserved in cave deposits of Pleistocene age at Buffalo National River and Ozark National Scenic Riverways.

The paleontological resources known from the parks of the Heartland Network are primarily limited to Paleozoic and late Cenozoic fauna and flora. Fossils are currently known from nine Heartland Network parks including Buffalo National River, Cuyahoga Valley National Park, Effigy Mounds National Monument, Hopewell Culture National Historical Park, Hot Springs National Park, Lincoln Boyhood National Memorial, Ozark National Scenic Riverways, Tallgrass Prairie National Preserve, and Wilson's Creek National Battlefield. Four parks could potentially yield fossils remains, including George Washington Carver National Monument, Homestead National Monument of America, and Pea Ridge National Military Park. Tallgrass Prairie National Preserve contains the largest diversity of both fossil genera and fossil bearing formations in the Heartland Network.

Collectively the paleontological resources of the Heartland Network parks are somewhat common fossils representing the large shallow inland sea that occupied much of North America during the Paleozoic Era. The Pleistocene fauna known from several caves within the Heartland Network also tells an interesting story of more recent geologic past. Further paleontological resource inventories will serve to expand this ever-widening base of paleontological knowledge represented throughout the National Park Service. Although at least 200 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.

# Acknowledgements

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

We wish to thank the National Park Service staff who graciously provided information, comments, suggestions, and/or reviewed their park's section: Leo Acosta (ARPO), Caven Clark and Chuck Bitting (BUFF), Meg Plona (CUVA), Sharon Greener and Dennis Lanzendorf (EFMO), Mark Blaeuer, Sharon Shugart, and Stephen Rudd (HOSP), Neil Korsmo, Sherry Middlemis-Brown, and Cary Wiesner (HEHO), Kathy Brady Rawlins and Jennifer Pederson (HOCU), Todd Arrington (HOME), Mike Capps (LIBO), Victoria Grant and Bryan Culpepper (OZAR), Kevin Eads (PERI), Gia Wagner (PIPE), Kristen Hase (TAPR), Gary Sullivan (WICR), Ann Vawser, Karin Roberts, Dawn Bringelson, Bill Hunt, Steve DeVore, Virgil Noble, and Mark Lynott (Midwest Archeological Center).

Other technical assistance was provided by Angela Chandler, Erica Doerr, and Scott Ausbrooks (Arkansas Geological Survey), John House (Arkansas Archeological Survey), Marvin Kay, Walter Manger, Doy Zachry, and Van Brahana (University of Arkansas), Doug Shrake (Ohio Division of Geological Survey), Mike Siemens, Mimi Garstang, and Tami Allison (Missouri Department of Natural Resources), Deborah Quade (Iowa Geological Survey), Paul Hanson (Nebraska Department of Natural Resources), John Charles Steinmetz, Henry Gray, and John Rupp (Indiana Geological Survey), John Repetski, David Weary, Randall Orndorff, Mark Hudson, Richard Harrison, and Robert Weems (US Geological Survey), Blaine Schubert (East Tennessee State University), Bob Sawin, Ron West and Greg Ludvigson (Kansas Geological Survey) and Douglas Dunn (Cleveland Museum of Natural History).

The continued valuable support and information provided by the National Park Service Geologic Resources Division (GRD), in particular, Tim Connors, Bruce Heise, Lindsay McClelland, Lisa Norby, Melanie Ransmeier, Jim F. Wood, and Jim C. Woods, is greatly appreciated.

Special thanks to Mike DeBacker (HTLN Network Coordinator), and Carmen Thomson (Midwest Regional I&M Coordinator) for their support and enthusiasm for this project.

Finally, this report would not have been possible without the funding from the National Inventory and Monitoring Program and the support of the HTLN Network and Geologic Resources Division. The enthusiasm and support of Bert Frost (Associate Director; NPS Natural Resource Science and Stewardship) and Gary Williams (recently retired National I&M Program Manager) is acknowledged. We extend a sincere thanks to Bert and Gary for providing the means upon which this work, and similar work, can be accomplished.

# Introduction

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

The establishment of baseline paleontological resource data is essential for the appropriate management of fossils found within National Park Service (NPS) areas. Although nearly 200 NPS areas have been identified with paleontological resources, few parks have adequate baseline paleontological resource data.

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

The Heartland Network is composed of 15 parks in eight Midwestern states as shown in Figure 1. These include Arkansas Post National Monument (ARPO), Buffalo National River (BUFF), Cuyahoga Valley National Park (CUVA), Effigy Mounds National Monument (EFMO), George Washington Carver National Monument (GWCA), Herbert Hoover National Historic Site (HEHO), Homestead National Monument of America (HOME), Hopewell Culture National Historic Park (HOCU), Hot Springs National Park (HOSP), Lincoln Boyhood National Memorial (LIBO), Ozark National Scenic Riverways (OZAR), Pea Ridge National Military Park (PERI), Pipestone National Monument (PIPE), Tallgrass Prairie National Preserve (TAPR), and Wilson's Creek National Battlefield (WICR).

The parks that comprise the Heartland Network vary in size from 75 ha (187 acres; HEHO) to nearly 37,155 ha (91,813.09 acres; BUFF). Heartland Network consists of parks in the interior Midwest of the United States, including Ohio, Indiana, Minnesota, Iowa, Nebraska, Kansas, Missouri and Arkansas. The Midwest primarily consists of prairies in most of the states west of the Mississippi River with the exception of eastern Minnesota, the Ozark Mountains of southern Missouri and northwestern Arkansas, and the Ouachitas of central Arkansas. East of the Mississippi River a high degree of topographical variety can be seen.

The geologic history of the HTLN area began nearly two billion years ago. The Penokean Orogeny (mountain or continent building event) assembled the continental fragments (terranes) that would eventually become Minnesota, Wisconsin, Michigan, southern Iowa, northern Missouri, and Central Missouri terrenes around 1.84 billion years ago. Around 1.7 to 1.6 billion years ago the Central Plains Orogeny accreted the terrane that would become Nebraska and western Kansas. These were major events in the formation of the North American continent, and happened during a world-wide period of mountain building and continent formation. Between 1.4 billion and 990 million years ago, further volcanic activity, crustal rifting, and filling of basins formed by rifting took place across the North American continent. Between 990 and 880 million years ago, a mountain range formed in eastern Ohio, although by 880 to 544 million years these mountains were eroded, reducing the landscape to a gently rolling surface during the early Paleozoic (see Figure 2 for a timescale).

The Paleozoic strata (sedimentary layers) of the Midwest are composed primarily of limestone deposited in shallow, warm seas. Volcanism and mountain building occurred in the eastern portion of this proto-North America. Retreating seas during the Ordovician of the Midwest are attributed to continued mountain building in the eastern portion of North America and massive glaciation taking place in Gondwana, a Southern Hemispher supercontinent existing during the Paleozoic. A minor uplift of the Ozark Dome in Missouri and Arkansas also occurs in the Middle Ordovician. Dry land first appears in

Midwest during the early Silurian, although it was covered with warm shallow seas again by the middle of the Silurian that persisted throughout the Devonian. Sea levels continue to rise and fall through the Mississippian with mountain building to the north east and east introducing mud and sandstones. A drop in sea level during the Pennsylvanian allows for the formation of coastal-plain swamps, with alternating terrestrial, freshwater and marine deposits. During the Pennsylvanian the collision of South America with North America compressed and uplifted portions of central Arkansas into the present day Ouachita Mountains. During the end of the Paleozoic, the Midwest underwent a variety of changes. Sea levels continued to rise and fall, forming the Flint Hills area of Kansas, while erosion occurred in portions of Ohio and Arkansas.

Rocks from the Mesozoic Era are largely absent in the rock record of the Midwest. This is due to the non-marine, often terrestrial state of this area, where more erosion than deposition was taking place. During the Jurassic period a shallow marine sea occupied part of Arkansas. This sea persisted into the Cretaceous with volcanic activity occurring in the central, southwest and eastern portions of the state. By the Cretaceous, Kansas and Nebraska were also covered by a shallow inland sea that stretched from Canada to the Gulf of Mexico. The New Madrid Rift Zone also reactivated in Missouri and portions of Arkansas, with volcanism occurring in some areas. Marine and near-marine sediments deposited in this rift zone. The Mississippi Embayment was formed as subsidence occured, filling in this area with Cretaceous to Eocene age sediments.

Rocks of the Cenozoic Era of the Midwest tell a story of mass glaciation and erosion. Massive glaciers covered the northern portions of the Midwest, including Ohio, Indiana, Iowa and Minnesota, with portions of Kansas, Missouri and Nebraska having minor glaciated periods. All of the glacial outwash would flow south, forming many of the spectacular caves found in Missouri and Arkansas. The erosion and deposition of glacial outwash by the ancestral Mississippi and Ohio rivers continue to fill the Mississippi Embayment in Missouri and Arkansas and also form the western and eastern lowlands in Arkansas, along with Crowley's Ridge. The Holocene has seen more erosion take place in the Midwest, with frequent flooding of rivers resulting in the deposition of alluvium, along with the down cutting of valleys.

While none of the parks were established specifically for paleontological resource stewardship, fossils are known from the geologic deposits and/or park collections of nine HTLN parks including Buffalo National River, Cuyahoga Valley National Park, Effigy Mounds National Monument, Hopewell Culture National Historical Park, Hot Springs National Park, Lincoln Boyhood National Memorial, Ozark National Scenic Riverways, Tallgrass Prairie National Preserve, Wilson's Creek National Battlefield, and three that could potentially yield fossils remains, including George Washington Carver National Monument, Homestead National Monument of America, and Pea Ridge National Military Park. Arkansas Post National Memorial, Herbert Hoover National Historic Site, and Pipestone National Monument have very limited potential for future fossil discovery.

Many of the parks contain a similar fossil fauna, including BUFF, CUVA, EFMO, OZAR which contain the remains of Paleozoic marine invertebrate fossils, such as brachiopods and trilobites. HOSP preserves similar fauna of marine invertebrate and trace fossils from the mid-Paleozoic. TAPR contains the largest diversity of both fossil genera and fossil-bearing formations in the Heartland Network. Pleistocene mammals have been found from the OZAR and BUFF corridors. Culturally significant fossil remains which were used as jewelry are known from HOCU (sharks teeth) and EFMO (crinoid stems).

Collectively, the paleontological resources of the HTLN Network contribute 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 nearly 200 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.

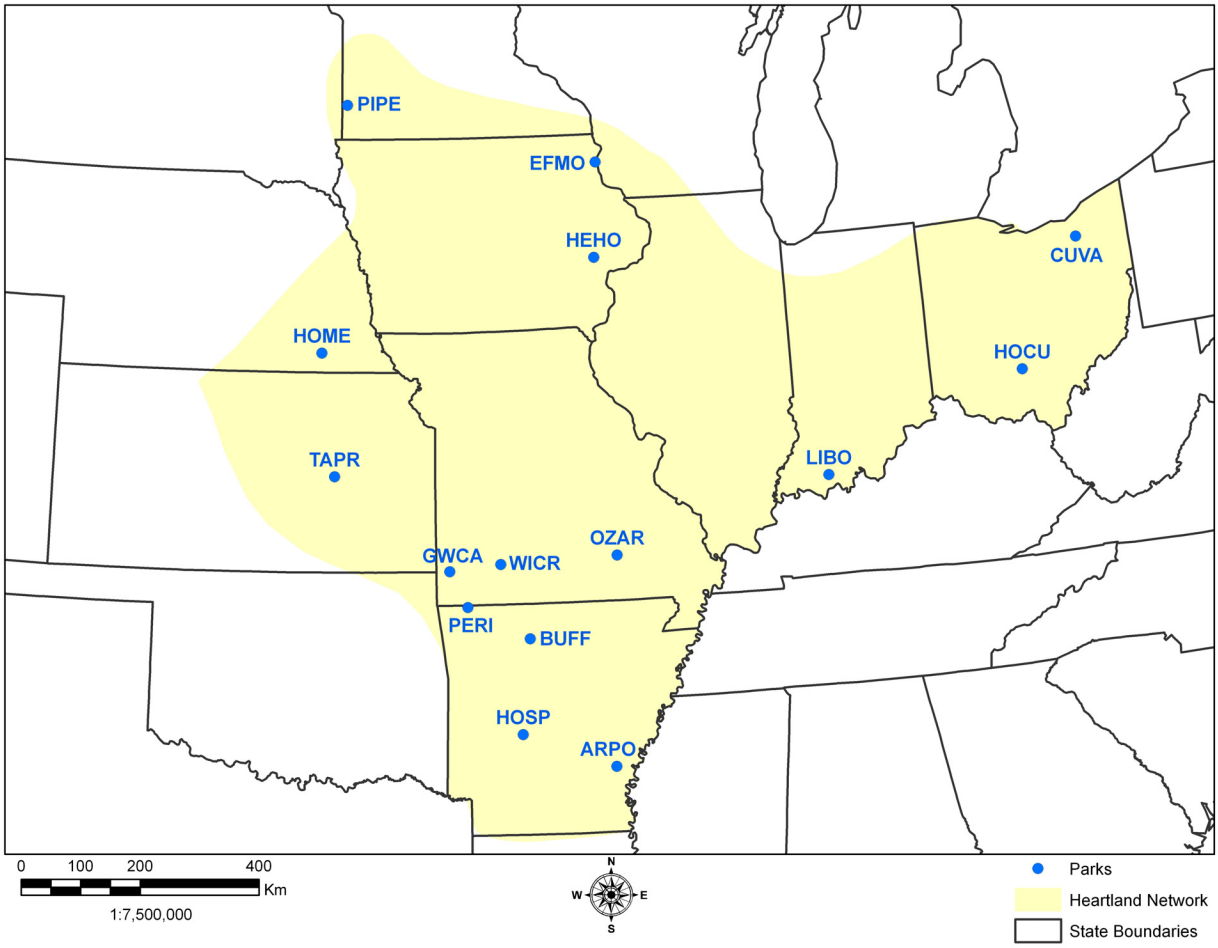



Figure 1. Map of HTLN network parks. Map courtesy HTLN staff.
ARPO: Arkansas Post National Memorial
BUFF: Buffalo National River
CUVA: Cuyahoga Valley National Park
EFMO: Effigy Mounds National Monument
GWCA: George Washington Carver National Monument
HEHO: Herbert Hoover National Historic Site
HOCU: Hopewell Culture National Historical Park
HOME: Homestead National Monument of America
HOSP: Hot Springs National Park
LIBO: Lincoln Boyhood National Memorial
OZAR: Ozark National Scenic Riverways
PERI: Pea Ridge National Military Park
PIPE: Pipestone National Monument
TAPR: Tallgrass Prairie National Preserve
WICR: Wilson's Creek National Battlefield

# Paleontological Resource Inventory Strategies and Methodology

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

## Comprehensive Park-Specific Paleontological Resource Inventories

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

## Servicewide Thematic Paleontological Resource Inventories

Servicewide thematic paleontological resource inventories compile data regarding specific types of paleontological resources that occur in parks throughout the NPS. The first thematic paleontological resource inventory identified 19 NPS units that preserve fossil vertebrate tracks (Santucci et al. 1998). Subsequent discoveries have increased the number of parks identified with fossil vertebrate tracks to 25 and warranted an updated publication (Santucci et al. 2006). Another thematic inventory identified paleontological resources associated with NPS caves in 35 parks (Santucci et al. 2001). Cave fossils occur in two contexts: First, fossils can be preserved in the marine limestones in which caves develop; second, the remains of Pleistocene/Holocene animals and plants that lived, died or were transported into caves after death are common types of cave fossils. Servicewide thematic inventories have also been initiated for fossil fish (Hunt et al. 2006) and fossils found in cultural resource contexts (Kenworthy and Santucci 2006).

## Inventory and Monitoring Network Paleontological Resource Inventories

Network-based paleontological resource inventories compile baseline paleontological resource data for each of the parks within a particular network. Network-based inventories have been completed for 22 of the 32 I&M Networks including: the Appalachian Highlands, Chihuahuan Desert, Eastern Rivers and Mountains, Great Lakes, Greater Yellowstone, Gulf Coast, Heartland (this report), Mediterranean Coast, Mid-Atlantic, Mojave Desert, National Capital Region, Northeast Coastal and Barrier, Northern Colorado Plateau, Pacific Island, Rocky Mountain, San Francisco Bay Area, Sierra Nevada, Sonoran Desert, Southern Plains, Southeastern Alaska, Southwestern Alaska, and Upper Columbia Basin networks. Research for summaries of the Arctic, Northern Great Plains, South Florida/Caribbean and Southeast Coast networks are currently underway. NPS I&M Program funding is targeted to complete paleontological resource summaries for the remaining networks by the end of FY2009. Citations for the completed reports are in the Additional References section.

## *I&M Network Paleontological Resource Inventory Methodology*

Network-based paleontological inventories were funded directly by the individual networks from 2002-2006. In FY2006, the National I&M Program provided funds to complete reports for the remaining networks between FY2006-2009. These funds provide stipends or salary for contractors, interns, or paleontological technicians who perform data mining activities. A brief summary outlining the basic techniques used to assemble an I&M Network-based inventory follows below.

The most valuable component of any paleontological resource inventory is an intensive literature search. Various databases contain citations for geology or paleontology themed publications. The American Geological Institute's GeoRef is the primary database for geology references and contains millions of references from the middle 1700s through today. GeoRef, available in both online or CD-ROM versions, is accessible at many major university libraries. The NPS NatureBib (which supersedes PaleoBib) is an internet-based database for scientific citations presented as bibliographic references but does not yet contain a comprehensive paleontology bibliography. The USGS Library in Reston, Virginia is a premier repository for geologic publications, and houses most of the publications obtained for the network-based paleontological resource inventories. Additionally, museum libraries such as at the Smithsonian Institution's National Museum of Natural History, and university libraries provide access to a wide range of geological and paleontological publications. Individual state geological surveys are also excellent sources of information as are geologists familiar with local geology and paleontology.

The literature search also includes unpublished material (gray literature) from individual park files, museum archives, local newspapers, field notes, etc. These are often excellent sources of anecdotal information about park resources. In addition to literature searches, interviews with park staff, university faculty, geologists from the USGS and state surveys, and even local amateur geologists or paleontologists can yield information regarding park paleontological resources. These interviews frequently result in capturing data that might otherwise be undocumented and potentially lost or unrecognized. Bibliographic searches include a search for geologic maps associated with each park. The NPS Geologic Resources Division maintains a database of geological map coverage for many parks (current contact is Tim Connors). In addition, the USGS National Geologic Map Database (NGMDB; see citation below in Additional References section) lists maps for a given geographic area or place name and provides information on where to obtain maps. Geologic maps show the types of rocks and the associated geological formations within a park area. These maps, alone, will often indicate the potential for paleontological resources to occur within a park.

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

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

The paleontological resource inventory reports synthesize information regarding the scope and significance of fossils documented from each park. Fossils are assessed and organized based upon

taxonomy, stratigraphy, and paleoecology. Paleontological resources can be divided into six taxonomic groups: protists (unicellular plants and animals – typically plankton), microbes (fossil bacteria – typically found in stromatolites or as coatings on fossils), paleobotany (fossil plants), invertebrates (multicellular animals without backbones), vertebrates (animals with backbones), and trace fossils (evidence of biological activity such as tracks, traces, burrows, etc.). Fossils typically have a finite stratigraphic range and occurrence in geologic time (a geologic time scale is included in Appendix A). The period between the first and final occurrences of a fossil species is referred to as the stratigraphic range zone. Thus specific groups of fossils may be identified directly with a particular stratigraphic unit or stratigraphic range. Likewise, rock units often represent specific ancient sedimentary depositional environments. Paleoecologically, fossil groups may occur primarily, or in some instances only, in specific environmental conditions (temperature, aquatic, terrestrial, etc.). Thus many fossils may be useful as indicators of past environmental conditions. The reports are organized stratigraphically presenting the geologic and paleontologic information chronologically from oldest to youngest. Important fossils documented from localities outside a park are often reported in the park inventory, as these data may indicate the potential for fossils in similar stratigraphic units exposed within park boundaries.

Given the tremendous diversity of past life, the existence of life for over a billion years, and the range of environments to which life has adapted, there is a broad spectrum of research interests in paleontology. It is not surprising that most of what is to be learned about the history of life remains to be discovered. Through research, nearly 200 NPS areas have been identified as containing paleontological resources. However, the paleontological research for a particular park may vary widely from an incidental fossil discovery to over a century of intensive paleontological investigations. The inventory reports include information on the history of paleontological research, descriptions of current cooperative projects, identification of any museums or universities serving as repositories for park fossils, and a comprehensive list of publications related to paleontological research associated with the park. The reports include all bibliographies that may be associated with a park's paleontological resources. However, bibliographic data are subdivided in the report into those cited in the narrative (References Cited) and other associated bibliographies (Additional References). The cooperative projects section highlights paleontological resources projects, if any, that the park has funded or supported. Formal datasets are established for known associated paleontological collections, research, or activities.

## Paleontological Resource Management Legislation and Guidance

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

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

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

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

## Additional References and Websites of Interest

Website addresses are current as of September 2008.


Elder, W. P., T. Nyborg, J. P. Kenworthy, and V. L. Santucci. 2008. Paleontological resource inventory and monitoring—**San Francisco Bay Area Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2008/078. National Park Service, Fort Collins, Colorado.

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., J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. America's Antiquities (Proceedings of the 7th Federal Fossil Conference). New Mexico Museum of Natural History & Science, Albuquerque, New Mexico. Bulletin 34.

Hunt, R. K., V. L. Santucci and J. P. Kenworthy. 2007. Paleontological resource inventory and monitoring, **Pacific Islands Network**. National Park Service TIC# D-24.

Kenworthy, J. P. and V. L. Santucci. 2003. Paleontological resource inventory and monitoring, **Southwestern Alaska Network**. National Park Service TIC# D-93.

Kenworthy, J. P. and V. L. Santucci. 2003. Paleontological resource inventory and monitoring, **Northeast Coastal and Barrier Network**. National Park Service TIC# D-340.

Kenworthy, J. P. and V. L. Santucci. 2004. Paleontological resource inventory and monitoring, **National Capital Region.** National Park Service TIC# D-289.

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., J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. America's Antiquities (Proceedings of the 7th Federal Fossil Conference). New Mexico Museum of Natural History & Science, Albuquerque, New Mexico. Bulletin 34.

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.

Kenworthy, J. P., V. L. Santucci, and C. C. Visaggi. 2007. Paleontological resource inventory and monitoring, **Gulf Coast Network**. National Park Service TIC# D-750.

Kenworthy, J. P., C. C. Visaggi, and V. L. Santucci. 2006. Paleontological resource inventory and monitoring, **Mid-Atlantic Network**. National Park Service TIC# D-800.

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.

Koch, A. L. and V. L. Santucci. 2002. Paleontological resource inventory and monitoring, **Northern Colorado Plateau Network**. National Park Service TIC# D-206.

Koch, A. L. and V. L. Santucci. 2003. Paleontological resource inventory and monitoring, **Southern Plains Network**. National Park Service TIC# D-107.

Koch, A. L. and V. L. Santucci. 2003. Paleontological resource inventory and monitoring, **Greater Yellowstone Network**. National Park Service TIC# D-1025.

Koch, A. L. and V. L. Santucci. 2003. Paleontological resource inventory and monitoring, **Mediterranean Coast Network**. National Park Service TIC# D-177.

Koch, A.L. and V. L. Santucci. 2004. Paleontological resource inventory and monitoring, **Eastern Rivers and Mountains Network**. National Park Service TIC# D-265.

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

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

Santucci, V. L. and J. P. Kenworthy. 2007 Paleontological resource inventory and monitoring, **Sierra Nevada Network.** Natural Resource Technical Report NPS/NRPC/NRTR—2007/053. National Park Service, Fort Collins, Colorado.

Santucci, V. L. and J. P. Kenworthy. 2008 Paleontological resource inventory and monitoring, **Southeast Alaska Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2008/108. National Park Service, Fort Collins, Colorado.

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.

Santucci, V. L., J. P. Kenworthy, and C. C. Visaggi. 2007. Paleontological resource inventory and monitoring, **Chihuahuan Desert Network**. National Park Service TIC# D-500.

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.

Santucci, V. L., R. McKenna, J. P. Kenworthy, and T. Connors. 2008. Paleontological resource inventory and monitoring, **Appalachian Highlands Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2008/080. National Park Service, Fort Collins, Colorado.

Tweet, J., V. L. Santucci, and J. P. Kenworthy. 2008. Paleontological resource inventory and monitoring, **Sonoran Desert Network**. Natural Resource Technical Report NPS/NRPC/NRTR—2008/130. National Park Service, Fort Collins, Colorado.

### *General HTLN Information*
HTLN I&M Network: http://www.nature.nps.gov/im/units/htln/index.cfm

### *Geological Survey Websites*
Arkansas Geological Survey: http://www.geology.arkansas.gov/home/index.htm
Indiana Geological Survey: http://igs.indiana.edu/
Iowa Geological Survey: http://www.igsb.uiowa.edu/
Kansas Geological Survey: http://www.kgs.ku.edu/
Minnesota Geological Survey: http://www.geo.umn.edu/mgs/
Missouri Division of Geology and Land Survey: http://dnr.missouri.gov/geology/index.html
Nebraska Geological Survey: http://snr.unl.edu/csd/surveyareas/geology.asp
Ohio Division of Geological Survey: http://www.dnr.state.oh.us/Home/gsdefault/tabid/7105/Default.aspx
U.S. Geological Survey: http://www.usgs.gov
Geological Society of America: http://www.geosociety.org
American Geological Institute: http://www.agiweb.org

### *Library catalogs*
U.S. Geological Survey Library Catalog: http://igsrglib03.er.usgs.gov:8080/
Smithsonian Institution Libraries Catalog: http://www.siris.si.edu/

### *Museums*
University of Kansas Natural History Museum: http://nhm.ku.edu/
University of Nebraska State Museum: http://www-museum.unl.edu/
Cleveland Museum of Natural History: http://www.cmnh.org/site/index.aspx
Smithsonian National Museum of Natural History Dept. of Paleobiology: http://www.nmnh.si.edu/paleo/

### *Resource Management/Legislation Documents*
NPS 2006 Management Policies (§1.4; Park Management): http://www.nps.gov/policy/mp/chapter1.htm
NPS 2006 Management Policies (§4.8.2.1; Paleontological Resources):
http://www.nps.gov/policy/mp/chapter4.htm
NPS 1998 Omnibus Management Act (paleontological resource summary):
http://www2.nature.nps.gov/geology/paleontology/paleo_5_1/index.htm
NPS Natural Resource Management Reference Manual #77 (paleontology section):
http://www.nature.nps.gov/rm77/paleo.cfm
Assessment of Fossil Management on Federal & Indian Lands: http://www.fs.fed.us/geology/fossil.pdf

### *National Park Service Paleontology Program sites*
NPS Geologic Resources Division: http://www.nature.nps.gov/geology/
NPS Paleontology Program: http://www.nature.nps.gov/geology/paleontology/
NPS Park Paleontology Newsletter (1998-2004):
http://www.nature.nps.gov/geology/paleontology/newsletter.cfm
I&M Network paleontological resource summary project website and PDFs of all reports (InsideNPS):
http://inside.nps.gov/waso/custommenu.cfm?lv=4&prg=753&id=4518
NPS Technical Information Center (Denver, repository for technical (TIC) documents):
http://etic.nps.gov/

### *Other geology/paleontology tools*
Bates, R. L. and J. A. Jackson, editors. American Geological Institute dictionary of geological terms (3rd Edition). Bantam Doubleday Dell Publishing Group, New York.
U.S. Geological Survey Geologic Terms Glossary:
http://wrgis.wr.usgs.gov/docs/parks/misc/glossarya.html

U.S. Geological Survey National Geologic Map Database (NGMDB): http://ngmdb.usgs.gov/
U.S. Geological Survey Geologic Names Lexicon (GEOLEX; geologic unit nomenclature and summary): http://ngmdb.usgs.gov/Geolex/geolex_home.html
U.S. Geological Survey Geographic Names Information System (GNIS; search for place names and geographic features, and plot them on topographic maps or aerial photos): http://gnis.usgs.gov/
Paleobiology Database (search for fossil taxonomy, localities, or geologic formations): http://paleodb.org/cgi-bin/bridge.pl
Paleontology Portal (general fossil info based on geographic location or geologic time): http://www.paleoportal.org/
University of California-Berkeley Museum of Paleontology online paleontology exhibits: http://www.ucmp.berkeley.edu/
U.S. Geological Survey, description of physiographic provinces: http://tapestry.usgs.gov/Default.html

# Arkansas Post National Memorial

Arkansas Congressman W. F. Norrell introduced a bill to establish Arkansas Post as a unit of the National Park Service on March 26, 1959. President Dwight D. Eisenhower signed the bill into law on July 6, 1960, establishing Arkansas Post National Monument (ARPO). Today ARPO is composed of 307 ha (758 acres), encompassing the site of the village of Arkansas Post, Civil War entrenchments and a small buffer of adjacent land (Carrera 1986; Coleman 1987).

## Geologic Background

ARPO is situated in the Mississippi River Embayment that consists of a flat to gently sloping broad floodplain. The Mississippi River Embayment is commonly fossiliferous but mantled in the ARPO area with low terraces of Quaternary alluvium and loess. Crowley's Ridge has some loess, but the low terrace areas of this are not composed of loess. The area is mostly flat, with the exception of sharp terrace scarps and natural levees that rise above the adjacent river channels. The main unit (Memorial Unit) of the memorial is located entirely within the 7.5-minute Arkansas Post quadrangle whereas the Osotuoy Unit (aka. Menard Mound unit) is within the Watson 7.5-minute quadrangle. The existing maps are Gillett 15' (containing the Arkansas Post 7.5'; Haley 2007a), Red Fork 15' (containing the Watson 7.5'; Haley 2007b), Arkansas state geologic map (Stoeser et al. 2005), and the Little Rock-Helena 1x2 Quaternary map (Saucier 1994).

## Potential Sources of Paleontological Resources

Potential for sources of Paleontological Resources at ARPO is limited to Pleistocene/Holocene deposits that may be exposed during times of low flow on the Arkansas and Mississippi rivers or during erosional periods. Fossils have not yet been documented from the following formations within ARPO. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units known to preserve fossils outside of the park.

### *Pleistocene / Holocene Surficial Deposits*

The Quaternary units in the ARPO area are composed of Pleistocene and Holocene loess and alluvium. In the lower Mississippi River Valley these Pleistocene terrace deposits include unconsolidated gravels, sands, silty sands, silts, clayey silts and clays. At least three terraces are recognized with variable thicknesses throughout. Petrified wood, invertebrate and vertebrate fossils are occasionally found in the Pleistocene deposits in south Arkansas (Fay 1959; Carson Davis et al. 2000; Graham 1990), but are unknown from the ARPO area. The Pleistocene fauna of Arkansas is better known from the northern portion of the state (Brown 1905, 1908; Dowling 1958; Quinn 1972; Carson Davis 1972; Graham 1972; Megivern 1982; Semken 1984a, 1984b). The Holocene alluvium was deposited by streams or overbank deposits associated with nearby streams. Modern bison remains were collected by Ford in 1958 at the Menard-Hodges mound complex within the Osotuoy Unit of ARPO (J. House, Arkansas Archeological Survey, pers. comm., May 2008).

## Park Collections

No fossil remains are reposited within the ARPO park collections (L. Acosta, ARPO Resource Management Specialist, pers. comm., May 2008).

## Paleontological Resource Management, Preliminary Recommendations

- The NPS Geologic Resources Division sponsored geologic resource scoping sessions for ARPO (National Park Service 2007). Paleontological resources are not currently known from within the geological exposures in ARPO and there are no fossils within the park's museum collections.

There is some potential for fossil discovery in the Pleistocene loess of ARPO based on discoveries in similar geologic formations outside of the park.

- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


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**:155-208.

Brown, B. 1905. Recent exploration of a Pleistocene fissure in northern Arkansas. Science **21**:300.

Carrera, G. 1986. The founding of Arkansas Post – 1686. Arkansas colonial dames of the Seventeenth Century. DeWitt Publishing Co., DeWitt, Arkansas.

Carson Davis, L. 2000. Large Pleistocene box turtle from Southwest Arkansas. Proceedings of the Arkansas Academy of Science **54**:147-149.

Carson Davis, L. 1973. The herpetofauna of Peccary Cave, Newton County, Arkansas. Unpublished Masters thesis, University of Arkansas, Fayetteville.

Coleman, R. E. 1987. The Arkansas Post Story: Arkansas Post National Monument. Southwest Cultural Resource Center, Santa Fe, New Mexico. Professional Paper 12.

Dowling, H. G. 1958. Pleistocene snakes of the Ozark Plateau [Arkansas]. American Museum of Natural History, New York. Novitates 1882.

Fay, G. E. 1959. A mastodon find from southwestern Arkansas. Proceedings of the Arkansas Academy of Science **13**:103-105.

Graham, R. W. 1990. The extinct stout-legged llama (*Paleolama mirifica*) in the Lower/central Mississippi River valley. Pages 207-209 *in* Guccione, M. J. and E. M. Rutledge, editors. Field guide to the Mississippi Alluvial Valley; northeast Arkansas and southeast Missouri. Friends of the Pleistocene South-Central Cell.

Graham, R. W. 1972. Biostratigraphic and climatic significance of selected taxa from the Conard Fissure local fauna, Newton County, Arkansas. Geological Society of America Abstracts with Programs **7**(2):169.

Haley, B. R. 2007a. Reconnaissance Geologic Map of the Gillett 15', Quadrangle, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Unpublished Geologic Worksheet. 1:62,500 scale.

Haley, B. R. 2007b. Reconnaissance Geologic Map of the Red Fork 15' Quadrangle, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Unpublished Geologic Worksheet. 1:62,500 scale.

Megivern, K. J. 1982. Paleoclimatic significance of the Pleistocene Insectivora and Rodentia of Trench 24, Peccary Cave, Newton County, Arkansas. Thesis. University of Iowa, Iowa City.

National Park Service. 2007. Geologic Resource Evaluation scoping summary: Arkansas Post National Memorial. National Park Service, Geologic Resources Division, Denver, Colorado. Online: (http://www.nature.nps.gov/geology/inventory/publications/s_summaries/ARPO_scoping_summary_2007-0731.pdf) Accessed 3 June 2008.

Quinn, J. H. 1972. Geological factors concerning the age of Peccary Cave and Conard Fissure. Society of Vertebrate Paleontology 32nd Annual Meeting Abstracts with Programs:7.

Saucier, R. T. 1994. Quaternary deposits of the Helena-Little Rock 1x2 sheets. Plate 7 *in* Geomorphology and Quaternary geologic history of the lower Mississippi Valley Volume II. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 1:250,000 scale.

Semken, H. A. 1984a. Changes in mammalian community structure across the Pleistocene/Holocene boundary, Peccary Cave sequence, northwestern Arkansas. International Geological Congress, Abstracts. Geologique International, Resumes **27**(1):308-309.

Semken, H. A. 1984b. Paleoecology of a late Wisconsinan/Holocene micromammal sequence in Peccary Cave, northwestern Arkansas. Pages 405-431 *in* Carnegie Museum of Natural History, Pittsburgh. Special Publication 8.

Stoeser, D. B., G. N. Green, L. C. Morath, W. D. Heran, A. B. Wilson, D. W. Moore, B. S. Van Gosen. 2005. Preliminary integrated geologic map databases for the United States: central states -- Montana, Wyoming, Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana. U.S. Geological Survey, Reston, Virginia. Open-File Report OF-2005-1351. 1:100,000 scale.

## Additional References

McFarland, J. D. 1998. Stratigraphic summary of Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Information Circular 36.

## Data Sets

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

# Buffalo National River

On March 1, 1972, Buffalo National River (BUFF) was established "for the purposes of conserving and interpreting an area containing unique scenic and scientific features, and preserving as a free-flowing stream an important segment of the Buffalo River in Arkansas for the benefit and enjoyment of present and future generations." BUFF is one of few remaining unpolluted, free-flowing rivers in the lower 48 states. The National Park Service manages a 217 km (135 mile) stretch of the river that includes multi-colored bluffs and numerous springs, with the entire unit covering some 38,741 ha (95,730 acres), including 37,155 ha (91,813 acres) under Federal administration and 14,567 ha (36,000 acres) of designated wilderness.

## Geologic Background

The Buffalo National River drains a large portion of the southern Springfield Plateau and the northern Boston Mountains, along with the Salem Plateau on its lower end, cutting its way down through the Paleozoic rocks that comprise this portion of north central Arkansas. The strata of BUFF are highly fossiliferous, with fossil remains known from twelve of the thirteen formations present within the park's boundaries. The strata found in this area are characteristic of what one finds in this area Arkansas, limestones with interbedded sandstones and dolomite, with units ranging from Ordovician to Pennsylvanian in age, overlain by Quaternary sediments. These Paleozoic rocks and fossil remains were deposited in the clear waters of a sea that once covered most of modern day North America. Modern and paleo-karst features are also present in this limestone and dolomite dominated environment, including sink holes and caves. The oldest formation exposed within the park is the lower Ordovician Powell Dolomite, which can be found in the Ponca Wilderness Area of BUFF (Hudson and Murray 2003) and near the confluence into the White River near Buffalo City (Glick 1970). Some caves within BUFF preserve Pleistocene fossils as does the important Conard Fissure locality located just outside of BUFF.

The NPS Geological Resources Division conducted its geological scoping summary on April 25, 2007, with a geologic resources evaluation currently underway (National Park Service 2007). The watershed for Buffalo River contains all or part of 41 7.5-minute USGS quadrangles. The USGS and Arkansas Geological Survey (AGS) have been conducting geologic mapping at 1:24,000 scale of quadrangles in the Buffalo River watershed. Currently five geologic quadrangle maps have been produced for BUFF by the USGS (Hudson 1998; Hudson and Turner 2007; Hudson and Murray 2003, 2004; Hudson et al. 2001, 2006), with four geologic quadrangle maps by the AGS (Braden and Ausbrooks 2003a, b, c, and Hutto and Smart 2008), while portions of two more that lie within the watershed have been developed. USGS is currently developing two additional full quadrangle maps. The AGS has produced twelve 7.5' quadrangle geologic maps in recent years. They are currently mapping three additional quadrangles, and plan to map an additional four. While the Paleozoic rocks of BUFF have been the subject of many publications (McFarland 1979, 1988; Craig 1988; Murray and Hudson 2002), no one formation within BUFF has had a concentrated study done. A thematic inventory on cave paleontology within National Park Service units included a discussion on fauna known from some of the over 300 caves within BUFF (Santucci et al. 2001).

## Sources of Paleontological Resources

Fossils have been documented from the following geologic formations and museum collections within BUFF. These fossils present opportunities for resource management (including field surveys, inventory, and monitoring), education, interpretation, and continued or future scientific research in the park.

### *Powell Dolomite (Lower Ordovician)*

The oldest fossiliferous formation exposed within the park is the Ordovician Powell Dolomite, which can be found in the Ponca and Buffalo City regions of BUFF, with the only complete section exposed in

Hemmed-In Hollow (McFarland 1988; Hudson and Murray 2003). The fine-grained, argillaceous to silty, gray dolomite with dark-gray shale interbeds is noted to contain stromatolites within the Hemmed-In Hollow area (Hudson and Murray 2003). The contact with overlying Everton Formation is unconformable, with the Powell beds possibly truncated with slight local angular unconformity.

### *Everton Formation (Middle Ordovician)*

The Middle Ordovician Everton Formation is composed of interbedded sandstone, dolomite and limestone's which are divided into three members: the lower, the Newton Sandstone, and the upper. The upper part of Everton Formation contains light-to dark-gray dolomite and limestone beds interbedded with sandstone. The Newton Sandstone member forms the prominent bluffs seen along the Buffalo River. The member is a quartz arenite containing well-sorted, well-rounded, and fine-to medium-grained quartz grains (Hudson and Murray 2003). The Newton member contains the remains of gastropods, ostracods, and other "invertebrate" fossils within BUFF (McFarland 1979; Hudson et al. 2001; Hudson and Turner 2007). The interbedded sandstone, limestone, and dolomite of the lower part consist of light gray, finely crystalline, thin to medium bedded, commonly laminated, and locally stromatolitic limestone beds. These limestone-rich sections of the lower Everton are a common host of paleokarst features that consist of vertical columns of highly fractured or brecciated sandstone collapsed from overlying horizons (Hudson and Murray 2003).

### *Plattin Limestone (Middle Ordovician)*

Present in only a few localized spots within BUFF, the Plattin Limestone is a very thin unit that varies from a dismicrite to a very fine grained dolomite. The Plattin is reported to contain 'fossiliferous calcarenites' and calcirudites, with a single species of conodont (*Erismodus*) known from near the base of a tributary to Cane Branch Creek (McFarland 1979, 1988; Hudson et al. 2006). McKnight (1935) described a loose block of light-gray sandstone that he correlated to the Middle Ordovician Kimmswick Limestone (on the basis of echinoderm fauna) in an isolated locality in a tributary to Mill Branch. No other Kimmswick Limestone outcrops have been identified in BUFF. Hudson et al. (2006) believe McKnight (1935) may have miscorrelated a sandstone interbedded within the upper calcarenite interval of the Plattin Limestone with the Kimmswick Limestone.

### *Fernvale Limestone (Upper Ordovician)*

The Fernvale Limestone is typically a thin- to medium-bedded, coarse-crystalline bioclastic unit, with light to medium gray limestone. This unit contains the abundant cylindrical to barrel-shaped remains of crinoid ossicles that are known within the park's outcrops (McFarland 1988; Santucci et al. 2001; Hudson et al. 2001; Hudson and Murray 2003; Hudson and Turner 2007). Continuous outcrop of this unit is restricted to the southwest part of the Ponca quadrangle, southwestern portion of the Hasty quadrangle, northeastern Boxley quadrangle, and the south-central portion of the Jasper quadrangle, with local lenses recognized farther east in the Ponca quadrangle (Hudson and Murray 2003, 2004; Hudson et al. 2001; Hudson and Turner 2007). The Fernvale Limestone is also present in the Mt. Judea quadrangle along the river, with outcrops also present near the town of Gilbert, Arkansas (A. Braden, AGS Geologist, pers. comm. July 2008; Braden and Ausbrooks 2003a).

### *Cason Shale (Upper Ordovician)*

The Cason Shale consists of several rock types, including phosphatic sandstone and shale, oolitic limestone, pelmatozoan limestone (Brassfield Limestone), and sandy, calcareous shale containing oncolites (sedimentary structures formed out of layered spherical growth structures formed by cyanobacterial growth). Phosphatic brachiopods are found in some beds with agglutinated foraminifera and conodonts. At no place is the entire Cason Formation's sequence preserved (McFarland 1998). Exposures of the Cason in BUFF can be found on the Marshall Quadrangle near the town of Gilbert (Hutto and Smart 2008; A. Braden, AGS Geologist, pers. comm., August 2008).

### *Brassfield Limestone (Lower Silurian)*
The Brassfield is a light-gray to deep-red, fossiliferous, biomicritic limestone. The Brassfield's lithologies can be indistinguishable from the Fernvale and St. Clair limestones. The most common fossils include crinoid fragments, bryozoans, brachiopods, gastropods, trilobites (McFarland 1988). Nautiloids are easily identified in BUFF near the Gilbert area (A. Braden, AGS Geologist, pers. comm. July 2008).

### *St. Clair Limestone (Lower Silurian)*
The St. Clair Limestone is coarse-grained, highly fossiliferous, generally light-gray to pinkish-gray limestone present in the Marshall quadrangle of BUFF near the town of Gilbert. The lower portions of the unit are typically pyritic and commonly contain spherical algal "buttons" similar to the flattened oncolites of the Cason Shale. This formation contains the well preserved remains of brachiopods, ostracods, and trilobites (Hutto and Smart 2008). Fragmentary remains of crinoids, corals, bryozoans, bivalves, gastropods, and cephalopods are also found, although it is unclear if any of these fossils are present within the St. Clair exposures within the park. The St. Clair is unconformable at its base and may rest on the Brassfield, Cason, or Fernvale formations (McFarland 1998; Hutto and Smart 2008).

### *Lafferty Limestone (Upper Silurian)*
The Lafferty Limestone is generally an gray-green to red micrite or sparsely fossiliferous biomicrite present in the Gilbert area of the Marshall Quadrangle. Fossils are few in the Lafferty Formation, but agglutinated foraminifers are known from this formation elsewhere. The formation rests conformably on the St. Clair Limestone. This lower boundary is marked at the top of the last abundant coarse-grained, bioclastic, crinoid limestone of the St. Clair Formation (McFarland 1998).

### *Boone Formation (Upper to Lower Mississippian)*
The highly fossiliferous Boone Formation is composed of fine- to coarse-grained limestone along with chert that formed at the same time and/or after limestone deposition. Limestones are light to medium gray on fresh surfaces and generally coarsely crystalline. A thin bed of oolitic limestone is present at the top of this formation. Dense, fine-grained beds of limestone are present in the upper third of the unit. These beds are typically parallel planar to wavy, with channel fills locally present in the lower part of the unit. This unit preserves the abundant remains of crinoid ossicles, brachiopod casts, coral, bryozoans, blastoids and occasional sharks' teeth, with trilobites being known from outside of the park (Taylor 1968; McFarland 1988; C. Bitting, BUFF Geologist, pers. comm. May 2001; Santucci et al. 2001; Hudson et al. 2001; Hudson and Murray 2003; Hudson and Turner 2007). Caves and sinkholes are common in the Boone Formation (Hudson and Murray 2003). Refer to the "Paleontological Resources Associated with BUFF Caves" section below for information on fossils found within the caves of the Boone Formation.

The St. Joe Limestone member of the Boone Formation is a thin-bedded, coarse-crystalline bioclastic limestone that preserves the remains of crinoids within the park (McFarland 1979, 1988; Santucci et al. 2001; Hudson et al. 2001; Hudson and Turner 2007). This member is commonly pink to red limestone beds. These hues are due to hematite staining. The beds are thin and wavy in form, with chert nodules uncommon but, where present, are nodular and reddish (Hudson and Murray 2003).

### *Batesville Formation (Upper Mississippian)*
Unconformably above the Boone Formation is the Batesville Formation, which consists of fine-to very fine grained, light-to medium-brown, calcite-cemented sandstone with interbedded limestone (Hudson and Murray 2003; McFarland 1988). These limestone beds contain crinoids and brachiopod remains throughout the unit within the Jim Bluff Park area and north and south of the river in the bluffs of the Ponce Quadrangle of BUFF (Hudson and Murray 2003).The sandstones are noted to contain burrows on bedding plane surfaces (Hudson et al. 2001; Hudson and Turner 2007; National Park Service 2007). The Batesville is commonly ledge forming, forming many small waterfalls along streams. The top of the Batesville is typically a topographic flat that contains sinkholes formed by collapse into dissolution cavities in underlying Boone Formation (Hudson and Murray 2003).

The Hindsville Limestone Member of the Batesville Formation is a thin-bedded, fine to coarsely crystalline limestone that is present in the Cecil Creek drainage (Purdue and Miser, 1916, Braden and Ausbrooks, 2003c). This member is distinguished by the presence of sub-angular clasts of white chert which were probably derived from the Boone Formation, indicating a depositional break between the Boone and Batesville and is not noted to contain fossils in the park (Hudson and Turner 2007).

### *Fayetteville Shale (Upper Mississippian)*

The Fayetteville Shale consists of fine-grained sandstone and siltstone of Wedington Sandstone Member that grade downward into black, fissile clay shale of the main body of the unit (Hudson and Murray 2003). The main body of the Fayetteville Shale is poorly exposed black fissile shale that may contain medium-to light-gray septarian concretions, with the lower portion outcropped along stream gullies. The Wedington Sandstone Member is a brown, well-indurated, calcite-cemented sandstone and siltstone that forms a distinctive unit in the upper part of the Fayetteville Shale. This member is reported to contain the remains of brachiopod casts as common fossils within gullies in the park (McFarland 1988; Hudson et al. 2001; Hudson and Murray 2003; Hudson and Turner 2007; National Park Service 2007).

### *Pitkin Limestone (Upper Mississippian)*

Another Upper (Late) Mississippian age formation, the Pitkin Limestone, is generally medium- to dark-gray, fetid (gives off a sulfurous odor) limestone that varies from micritic to coarse grained and is locally oolitic. This unit generally forms a prominent ledge or cliff within BUFF. Fossils known from within park boundaries include abundant crinoids, brachiopods, corals, the bryozoan *Archimedes*, and the ammonoid *Goniatites* (Santucci et al. 2001; Hudson et al. 2001; Hudson and Murray 2003; Hudson and Turner 2007; National Park Service 2007).

### *Hale Formation (Lower Pennsylvanian)*

Unconformably overlying the Mississippian Pitkin Limestone is the lower Pennsylvanian Hale Formation. This unit consists of two members: the interbedded sequence of shale, siltstone, and sandstone that make up the older Cane Hill Member and the fine- to medium-grained calcite-cemented sandstones of the younger Prairie Grove Member. The Cane Hill Member includes crinoid-bearing limestone clasts, wood as carbonized fragments or clasts, the bryozoan *Archimedes*, and the ammonoid *Goniatites* as common fossils are likely present within the units in BUFF (Santucci et al. 2001; Hudson et al. 2001; Hudson and Murray 2003; Hudson and Turner 2007).

### *Bloyd Formation (Lower Pennsylvanian)*

The Bloyd Formation, which is separated into upper and lower parts, with a middle sandstone. The base of the lower Bloyd consists of a coarse bioclastic limestone that contains clasts of fossil fragments, and is conformable with lower Hale Formation, but is not persistent throughout the BUFF area. The upper Bloyd is composed of sandstone with interbedded siltstone and shale, with the upper sandstone beds being very heavily bioturbated, preserving abundant burrows along with clast of *Lepidodendron* wood fragments, although none have been mentioned from the park at this time (Santucci et al. 2001; Hudson et al. 2001; Hudson and Murray 2003; Hudson and Turner 2007). The middle Bloyd sandstone is a thin to massive, medium to coarse grained, cross-bedded quartz or iron cemented sandstone. The sandstone contains abundant lycopod fossils (Braden and Ausbrooks 2003c).

### *Atoka Formation (Middle Pennsylvanian)*

The Middle Pennsylvanian Atoka Formation consists of alternating shale, siltstone, and sandstones. The Atoka Formation has the largest areal extent of any of the Paleozoic formations found in the state of Arkansas. This unit forms the highest hills within BUFF and is poorly exposed and lacks body fossils. The sandstones are tan, thin to medium bedded, fine to very fine grained, which hold up ledges. These sandstone beds are typically ripple-trough laminated, locally bioturbated, and often contain the remains

of burrows. Siltstones are thinly bedded with ripple cross-lamination, with the shale component being dark gray to black (Hudson and Murray 2003; Hudson and Turner 2007).

### *Paleontological Resources associated with BUFF Caves (Pleistocene)*

Several caves within BUFF are known to contain mammoth, mastodon and cave bear bones, with many of these remains being lost to theft. *Ursus* Tomb, located approximately 9.7 km (6 miles) north of Conard Fissure, is a 43 m (140 ft) deep pit in the Boone Formation within Buffalo National River. The pit is the only known cave at BUFF that preserves a bear skeleton (C. Bitting, BUFF Geologist, pers. comm. 2001; Santucci et al. 2001). Fossils associated with BUFF caves were highlighted in an inventory by the Geologic Resources Division (Santucci et al. 2001; National Park Service 2007). Just north (1.6 km or 1 mile) of the Buffalo River in Newton County, the remains of Pleistocene fossils are known from Conard fissure, a paleontologically significant sink hole in the Boone Formation that preserves 51 mammal species, seven amphibian and reptile species, and seven species of birds (Brown 1908, all specimens reposited in the American Museum of Natural History). The possibility is very high that other sink holes could be found with in the park boundaries that would preserve fossilized remains, due to the park's highly karsted topography.

## Park Collections

There are 21 specimens held within the BUFF collections. Many of these came from within the park, while others came from outside the park, but were collected from formations that are found within BUFF. Several of the items are bone and tooth fragments from the Conard Fissure which lies just outside of the park boundaries. One *Lepidodendron* fossil cast is in the park collection. The remaining specimens are within a matrix of Boone Limestone and include a horn coral, a brachiopod, and several crinoid elements (C. Bitting, BUFF Geologist, pers. comm. July 2008).

## Paleontological Resource Management, Preliminary Recommendations

- The NPS Geologic Resources Division sponsored geologic resource scoping sessions for BUFF in April 2007 (National Park Service 2007). *In situ* fossils are documented from many of the marine limestones, sandstones, and shales in the park. Fossils are also known from BUFF caves. Twenty-one specimens of paleontological resources within the park collections are from the park or geologic formations mapped within the park. There is excellent potential for continued fossil discovery.
- The park should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels), and caves for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- A forthcoming (late 2008 or early 2009) Geologic Resource Monitoring Manual by the Geological Society of America and NPS Geologic Resources Division includes a section on paleontological resource management.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Braden, A. K. and S. M. Ausbrooks. 2003a. Geologic map of the Mt. Judea Quadrangle, Newton County, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Digital Geologic Quadrangle Map DGM-AR-00590.

Braden, A. K. and S. M. Ausbrooks. 2003b, Geologic map of the Eula Quadrangle Newton and Searcy counties, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Digital Geologic Quadrangle Map DGM-AR-00269.

Braden, A. K. and S. M. Ausbrooks. 2003c. Geologic map of the Snowball Quadrangle, Searcy County, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Digital Geologic Quadrangle Map DGM-AR-00800

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):157-208.

Craig, W. W. 1988. Geology of the Buffalo River Valley in the vicinity of U.S. 65, Arkansas Ozarks. Pages 211-214 *in* Geological Society of America, Boulder, Colorado. Centennial Field Guide, South-central Section.

Glick, E. E. 1970. Reconnaissance geologic map of the Buffalo City Quadrangle, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Unpublished Worksheet.

Hudson, M. R. 1998. Geologic map of parts of the Jasper, Hasty, Ponca, Gaither, and Harrison quadrangles in and adjacent to Buffalo National River, northwestern Arkansas. U.S. Geological Survey, Reston, Virginia. Open-File Report 98-116, 1:24,000 scale.

Hudson, M. R., and K. E. Murray. 2004. Geologic map of the Hasty Quadrangle, Boone, and Newton Counties, Arkansas. U.S. Geological Survey, Reston, Virginia. Scientific Investigations Map SIM-2847. 1:24,000 scale.

Hudson, M. R., and K. E. Murray, K. E. 2003. Geologic map of the Ponca Quadrangle, Newton, Boone, and Carroll counties, Arkansas. U.S. Geological Survey, Reston, Virginia. Miscellaneous Field Studies Map MF-2412. 1:24,000 scale.

Hudson, M. R., K. E. Murray, and D. Pezzutti. 2001. Geologic map of the Jasper Quadrangle, Newton and Boone counties, Arkansas. U.S. Geological Survey, Reston, Virginia. Miscellaneous Field Studies Map MF-2356, 1:24,000 scale.

Hudson, M. R., and K. J. Turner. 2007. Geologic map of the Boxley Quadrangle, Newton and Madison counties, Arkansas. U.S. Geological Survey, Reston, Virginia. Scientific Investigations Map SIM-2991. 1:24,000 scale.

Hudson, M. R., K. J. Turner, and J. E. Repetski. 2006. Geologic map of the Western Grove Quadrangle, Northwestern Arkansas. U.S. Geological Survey, Reston, Virginia. Scientific Investigations Map 2921. 1:24,000 scale.

Hutto, R. S. and E. E. Smart. 2008. Geologic map of the Marshall Quadrangle, Searcy County, Arkansas. Arkansas Geological Survey, Little Rock, Arkansas. Digital Geologic Quadrangle Map DGM-AR-00532.

McFarland, J. D. 1988. The Paleozoic rocks of the Ponca region, Buffalo National River, Arkansas. Pages 207-210 *in* Geological Society of America, Boulder, Colorado. Centennial Field Guide, South-central Section.

McFarland, J. D. 1979. Geologic float guide on the upper Buffalo National River. Arkansas Geological Survey, Little Rock, Arkansas.

McKnight, E. T. 1935. Zinc and lead deposits of northern Arkansas. U.S. Geological Survey, Reston, Virginia. Bulletin 853.

Murray, K. E. and M. R. Hudson. 2002. Three-dimensional geologic framework modeling in the Buffalo National River, Arkansas. Geological Society of America Abstracts with Programs **34**(6):120.

National Park Service. 2007. Geologic resource evaluation scoping summary: Buffalo National River. National Park Service, Geologic Resources Division, Denver, Colorado. Online. (http://www.nature.nps.gov/geology/inventory/publications/s_summaries/BUFF_scoping_summary_2007-0731.pdf). Accessed May 2008.

Purdue, A. H. and H. D. Miser. 1916. Descriptions of the Eureka Springs and Harrison quadrangles. U.S.Geological Survey, Reston, Virginia. Geological Atlas, Folio 202. scale 1:125,000.

Santucci, V. L., J. Kenworthy, and R. Kerbo. 2001. An inventory of paleontological resources associated with National Park Service caves. Geologic Resources Division, Denver, Colorado. Technical Report NPS/NRGRD/GRDTR-01/02.

Taylor, J. D. 1968. Proetid trilobite from the Boone Formation in Arkansas. Arkansas Academy of Science **22**:102-104.

## Additional References

Glick, E. E., and S. E. Frezon. 1953. Lithologic character of the St Peter Sandstone and Everton Formation in the Buffalo River Valley, Newton County, Arkansas. U.S. Geological Survey, Reston, Virginia. Circular 249.

Henderson, J. G. 1972. Geology of the Jasper quadrangle, Newton and Boone counties, Arkansas. Thesis. University of Arkansas, Fayetteville.

Hudson, M. R. and R. T. Cox. 2003. Late Paleozoic tectonics of the southern Ozark Dome. Pages 15-32 *in* Cox, R. T., compiler. Field trip guidebook for joint South-Central and Southeastern Sections, Geological Society of America. Tennessee Division of Geology, Nashville. Report of Investigations 51.

Hudson, M. R. 2002. Three-phase late Paleozoic deformation of the southern Ozark Dome, western Buffalo River region, northern Arkansas. Geological Society of America Abstracts with Programs **34**(6):79.

Hudson, M. R. 2000a. Coordinated strike-slip and normal faulting in the southern Ozark Dome of northern Arkansas: Deformation in a late Paleozoic foreland. Geology **28**(6):511-514.

Hudson, M. R. 2000b. Multiphase late Paleozoic deformation in the western Buffalo River region of northern Arkansas: A foreland record of an evolving Ouachita Orogeny. Geological Society of America Abstracts with Programs **32**(3):15.

Hudson, M. R., and K. J. Turner. 2006. Three-phase late Paleozoic deformation on the southern flank of the Ozark Dome, northern Arkansas. Geological Society of America Abstracts with Programs **38**(6):12.

Manger, W. L., and P. K. Sutherland, P. K. 1992. Analysis of sections presumed to be complete across the Mississippian-Pennsylvanian boundary, southern mid-continent. Pages 69-79*in* Sutherland, P. K., and W. Manger, editors. Recent advances in middle Carboniferous biostratigraphy—A symposium. Oklahoma Geological Survey, Norman. Circular 94.

Suhm, R. A. 1974. Stratigraphy of Everton Formation (early Medial Ordovician), northern Arkansas. American Association of Petroleum Geologists Bulletin **58**:685-707.

Sutherland, P. K. 1988. Late Mississippian and Pennsylvanian depositional history in the Arkoma Basin area, Oklahoma and Arkansas. Geological Society of America Bulletin **100**:1787-1802.

Zachry, D. L. 1977. Stratigraphy of middle and upper Bloyd strata (Pennsylvanian, Morrowan), northwestern Arkansas, Pages 61-66 *in* Sutherland, P. K., and W. L. Manger, editors. Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas. Oklahoma Geological Survey, Norman. Guidebook 18.

Zachry, D. L., and P. K. Sutherland. 1984. Stratigraphy and depositional framework of the Atoka Formation (Pennsylvanian), Arkoma basin of Arkansas and Oklahoma. Pages 9-17 *in* Sutherland, P. K., and W. L. Manger editors. The Atokan series (Pennsylvanian) and its boundaries—A symposium. Oklahoma Geological Survey, Norman. Bulletin 136.

## Data Sets

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

*Buffalo National River Museum Collections.*
1972-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by BUFF staff; status: Active.

# Cuyahoga Valley National Park

Cuyahoga Valley National Park (CUVA) was first established as a national recreation area on December 27, 1974 and later redesignated by Congress as a national park on October 11, 2000. The park protects 13,354 ha (33,000 acres) along the banks of the Cuyahoga River between Cleveland and Akron, Ohio to preserve and protect for public use and enjoyment the historic, scenic, natural and recreational values of the Cuyahoga River Valley. The total area within the boundary of CUVA is about 13,354 ha (33,000 acres). Of this, approximately 7,284 ha (18,000 acres) are federally owned. Local public agencies own 3,642 ha (9,000 acres) of the remaining land area, and the balance is either privately owned, private with NPS easements, or compatible institutional ownership.

## Geologic Background

Cuyahoga Valley National Park is located in northeastern Ohio. The bedrock underlying and exposed in CUVA is composed of mid- to late-Paleozoic sedimentary rocks. During the early Devonian most of Ohio was an arid terrestrial environment, with the warm, shallow seas returning by the middle Devonian. These seas deposited limy sediments, mud and some volcanic ash forming the limestones, dolomites, mudstones, shales and sandstones. By the end of the Devonian the seas had become stagnant, with large amounts of black, organic rich mud deposited, eventually forming black shales, such as the Ohio Shale. During the latest Devonian and early Mississippian the dark, organic rich muds gave way to the fluvial and deltaic systems, preserved as sandstone and siltstones. During the late Mississippian a shallow sea once again returned, depositing limy mud that would eventually turn into limestone. During the Pennsylvanian, Ohio was a relatively flat open coastal plain. Fluctuating sea levels produced alternating sequences of terrestrial, freshwater and marine deposits (Ohio Division of Geological Survey 2001).

The Ohio Division of Geological Survey recently completed a geologic map at 1:500,000 scale (Slucher et al. 2006).

## Sources of Paleontological Resources

Fossils have been documented from the following geologic formations and museum collections within CUVA. These fossils present opportunities for resource management (including field surveys, inventory, and monitoring), education, interpretation, and continued or future scientific research in the park.

### *Paleozoic units*

The Paleozoic units within CUVA span the upper Devonian, Mississippian, and lower Pennsylvanian and are composed of two groups and five geologic formations dominated by sandstone, shale, limestone and dolomite. All of these formations are fossiliferous throughout the state, with the Ohio Shale, Bedford Shale and Cuyahoga Formation currently known to preserve fossils within CUVA.

### *Ohio Shale (Upper Devonian)*

The Ohio Shale consists of three members, in ascending order: Huron, Chagrin, and Cleveland members. The Olentangy Shale is present and underlies the Ohio Shale in this area but is not mapped as a separate unit on Slucher et al. (2006) because of the small map scale. The lower Huron Member is a black, carbonaceous shale that contains calcareous concretions in its lower portions (Hansen, 1994). Conodonts, fish, shark spores, and the occasional plant impression are preserved in this member (Szmuc 1970a). Fifty-seven species of radiolarian have also been described from the Huron Member throughout Ohio (Foreman 1959, 1963; Slucher et al. 2006). The middle Chagrin Member is a gray to greenish gray shale, siltstones, and fine-grained sandstone. Nineteen brachiopod and four bivalve taxa have been described from this member in the Brandywine Falls area of CUVA, along with cephalopods, conodonts, small, branching burrows, and the annelid worm(?) *Sphenothallus* are described from the Chagrin Member (Hannibal and Feldmann 1987; Schwimmer and Feldmann 1990; Feldmann and Hackathorn

1996; Neal and Hannibal 2000). Sixty-five specimens of these marine invertebrate fossils are curated at the Cleveland Museum of Natural History, Invertebrate Paleontology Department (D. Dunn, CMNH curatorial assistant, pers. commun., September 2008). Trace fossils can be seen in the Chagrin Member near the Pinery Narrows section of CUVA, with carbonized plant fragments, fish bones, and other fossils reported from outside the park (Corbett and Manner 1988). The Cleveland Member is a black shale that is thickest in the north-central portion of the state and thins to the south and east, being completely absent in the northeastern portion of Ohio (Carlson 1987; Slucher et al. 2006). This member contains the remains of plant spores (the most common fossils from this member), carbonized plants, arthropods, conodonts, and placoderm fish, with trace fossils also present (Szmuc 1970a; Corbett and Manner 1988).

Foraminifera, ammonites (*Sporadoceras*, *Cyrtoclymenia*, *Platyclymenia*, *Cymaclymenia*, *Sporadoceras*, *Pionoceras*, *Prionoceras quadripartitum*, and *Pleuroclymenia ohioense;* House et al. 1986), crinoids, conodonts (*Polygnathus pennatulus*, *Bryantodus germanus*, *B. inclinatus*, *Panderodella subrecta*, *Hindeodella recta*, *Synprioniodina alternate* and *Lonchodina subtilis;* Cooper 1931; Bond 1937, 1947), fish, wood, and ferns have been described from the Ohio Shale throughout the state (Orton 1889; Berry 1932; Wells 1941; Carr 1995; Papazis 2005).

### *Bedford Shale and Berea Sandstone (Upper Devonian)*

The Bedford Shale and Berea Sandstone are mapped together as "undivided" units within northeastern Ohio (Slucher et al. 2006). The Bedford Shale (upper Devonian) is a gray to brown, very fine-grained sandstone with interbeds of siltstone common in upper portion of the unit. Ripple marks are common in the sandstone beds, with brachiopods, pelecypods, plants and spore casings described from this formation throughout the state (Szmuc 1970b, Pringle 1982). The remains of the brachiopod *Lingula* along with trace fossils can be found in this unit in the Tinkers Creek and Brandywine Falls areas of CUVA (Corbett and Manner 1988; Szmuc 1970b). The middle Berea Sandstone (upper Devonian) is a very fine grained to silty sandstone that occurs in shades of brown and is mostly in planar to lenticular beds with local shale interbeds (Slucher et al. 2006). Brachiopods, trace fossils, and plants, such as wood (*Callixylon*) described from near Amherst, Ohio, and *Annularia* from Lorain and Cuyahoga counties, have all been reported from the Berea Sandstone (Corbett and Manner 1988; Beck et al. 1983; Szmuc 1970b).

### *Cuyahoga and Logan Formations (Lower Mississippian)*

In northeastern Ohio the Cuyahoga and Logan formations are mapped together as undivided units (Slucher et al. 2006). The Cuyahoga Formation is composed of four members in northeastern Ohio: the basal Orangeville, followed by the Sharpsville, Strongsville and uppermost Meadville members. These members are composed of interbedded sandstone, siltstone, and shale are mainly represented in shades of gray, olive, brown, and yellow. The sandstone is silty to conglomeratic and occurs in thin to massive beds. The siltstone and shale units occur in thin to thick beds, with the shale being locally red in color and fossiliferous. The Orangeville Member preserves the remains of brachiopods in the Cuyahoga Falls (city area) and Brandywine Creek areas of CUVA (Szmuc 1970b). The Sharpsville Member is a cross laminated sandy siltstone that contains brachiopods in the Brandywine Falls area of CUVA (Corbett and Manner 1988). In this same area of the park the Meadville Member is present, which happens to be the most fossiliferous unit in northeastern Ohio. Fossils from this member include125 species of sponge, coral, bryozoans, gastropods and mollusks (the rostronconchs *Hippocardia herricki* from Wayne County, Ohio, *Aphelakardia alternistriata*, and *Pseudomulceodens cancellatum*), ammonoids (*Muensteroceras oweni*, *Imitoceras sciotoensis*, and *Kazakhstania colubrella*), brachiopods, crinoids and a trilobite (*Brachymetopus nodosus*) from Lodi, Ohio (Manger 1971; Wilson 1979; Roeser 1985; Corbett and Manner 1988; Hoare 1990).

The overlying Logan Formation is composed of gray, yellow and brown sandstones and siltstones. The sandstone is silty to medium grained, and locally contains lenses and beds of coarser sand grains and fine-pebble conglomerates. The siltstones of the Logan Formation are clayey to sandy and locally contain shale interbeds and partings (Fagadau 1952; Slucher et al. 2006). This formation is also locally fossiliferous, containing the remains of mollusks (*Pseudomulceodens cancellatum;* Hoare 1990), ammonoids

(*Karagandoceras bradfordi* from Wayne County, *Kazakhstania colubrella* from Jackson County, *Imitoceras sciotoensis*, *Protocanites lyoni*, and *Gattendorfia andrewsi*; Manger 1971) fish, and trace fossils (Middleman 1976; Williams and Hannibal 1984).

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within CUVA. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Pottsville and Allegheny groups (Lower and Middle Pennsylvanian)*

The undifferentiated (mapped as one unit) rocks of the Pottsville and Allegheny groups are composed of shale, siltstone, sandstone, conglomerate, limestone, clays, coal, and chert. These units are located in the Broadview Heights, Hinckley, and north Royalton areas around CUVA, found on topographic highs that surround the valley. They are also mapped in the Happy Days Lodge area of CUVA. The sandstones are silty to pebbly with local quartzose and/or conglomeratic in lower one-third of unit. Siltstone and shale in these groups are clayey to sandy and locally contain marine fossils. The marine limestone mainly overlies coal or clay beds, with locally nonmarine beds that mainly occur within the underclay beds in upper one-third of unit. These units also contain economically viable coal beds. Chert beds contain marine fossils in localized pockets. Plant fossils are also locally common (Slucher et al. 2006). The Pottsville and Allegheny groups both contain the fossilized remains of foraminifera (*Climacammina cushmani, C. cylindrical, C. lucilleae, C. copiacellula, Deckerella clavata, D. laheei*, and *Palaeotextularia graphamensis*; Maloney et al. 1988), coral, ostracods and conodonts (*Neognathodus bothrops*, *N. medadultimus*, and *N. medexultimus*; Maple 1950; Colson 1963; Merrill 1972, 1974). Fossils from the Pottsville Group include fusulinids (*Fusulinella stouti* and *Ozawainella* from Muskingun County; Smyth 1974), nautiloids (*Endolobus* [=*Nautilus*] *ortoni* Murphy 1974), and four trilobite species from eastern Ohio (*Sevilla trinucleata* – the most common, *S. sevillensis*, *Ditomopyge scitula* and *Ameura missouriensis*; Brezinski 1988).

Fossils from the Allegheny Group include fusulinids (*Fusulina leei*, *F. serotina*, *F. carmani*, and *Wedekindellina euthysepta*; Smyth 1974), foraminifera (*Tetrataxis*, *Textularia*, *Climacammina*, Maloney et al. 1988), five species of gastropod (*Callistadia spirallia* from Tuscarawas County, *Spiromphalus pervius*, *Sturgeonospira tortula*, *Microdoma conicum* and *Anozyga bulla*, Sturgeon 1945; Hoare 1973, 1980a,b; Hoare and Sturgeon 1978), bivalves (*Dunbarella striata*, *Aviculopecten*, Hoare and Sturgeon 1976) and other mollusks (*Helminthochiton simplex*, *Pterochiton spatulatus*, and *Acutichiton pyrmidalus* from Mahoning, Tuscarawas, Holmes and Jackson counties, Hoare et al. 1972), nautiloids (*Kionoceras ungeri* from Mahoning County, Murphy 1966; *Domatoceras*, *Metacoceras*, *Liroceras*, and *Solenochilus* from Mahoning, Tuscarawas, and Columbian counties, Murphy 1970; *Temnocheilus bellicosus*, Whitfield and Murphy 1974), brachiopods (*Hustedia mormoni*, *Composita argentia*, *Composita*, *Phricodothyris perplexa*, *Beecheria bovidens*, Hoare and Sturgeon 1976), echinoderms from Vinton County, crinoids, two species of trilobites (*Ditomopyge scitula* and *Ameura missouriensis,* Brezinski 1988), crustacean (*Dithyrocaris,* Schram 1980), conodonts (*Cavusgnathus, Gnathodus, Hibbardella, Hindeodella, Ligonodina, Idiognathodus, Ozarkodina, Prioniodus, Spathognathodus*, and *Streptognathodus* in eastern Ohio; Sturgeon and Youngquist 1949) and a ray-finned fish vertebra (*Haplolepis*) in Jefferson County (Baum and Lund 1974).

## Park Collections and Fossils in Cultural Resource Contexts

Nine fossils of unknown taxa and origin, other than two "possible coral" pieces (CUVA 8419, 15071), a single "mollusk" (CUVA 23657) and "shell fossil" (CUVA 26838), are present in collections stored at the Midwest Archeological Center. The fossils were collected within a cultural context setting, not in their naturally occurring geologic contexts. No other details are available regarding specific taxon or geologic affinity for these specimens (K. Roberts, MWAC collections, pers. comm. May 2008; D. Bringelson, MWAC Archeologist, pers. comm. May 2008). As recommended below, further research into these fossils may yield indentifications or additional provenance data.

## Paleontological Resource Management, Preliminary Recommendations

- The NPS Geologic Resources Division-sponsored scoping sessions have not yet been held for CUVA. Formal paleontological inventories have likewise not yet been completed. Nevertheless fossils are known from the bedrock in the park and nine fossil specimens known from a cultural context are curated within MWAC collections.
- The park should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- Fossils found in a cultural context should be documented as other fossils, but will also require the input of an archeologist. Any fossil with cultural context may be culturally sensitive as well (e.g. subject to NAGPRA) and should be regarded as such until otherwise established. The Midwestern Archeological Center (MWAC) and the Geologic Resources Division can coordinate additional documentation/research of such material.
- A forthcoming (late 2008 or early 2009) Geologic Resource Monitoring Manual by the Geological Society of America and NPS Geologic Resources Division includes a section on paleontological resource management.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Baum, K. A. and R. Lund. 1974. Vertebral centra in *Haplolepis* (Haplolepidae, Paleonisciformes) from the Allegheny Group, Pennsylvanian. Journal of Paleontology 48:199-200.

Beck, C. B., K. Coy, and R. Schmid. 1982. Observations on the fine structure of *Callixylon* wood. American Journal of Botany **69**:54-76.

Berry, E. W. 1932. A remarkable specimen of *Callixylon newberryi* (Dawson) Elkins et Wieland, from the Ohio shale. Ohio Journal of Science **32**:385-388.

Bond, R. H. 1947. Ohio shale conodonts [Franklin County, Ohio]. Ohio Journal of Science **47**:21.

Bond, R. H. 1937. A study of some conodonts from the lower part of the Ohio Shale in central Franklin County, Ohio. Thesis. The Ohio State University, Columbus, Ohio.

Brezinski, D. K. 1988. Appalachian Carboniferous Trilobites. Journal of Paleontology **62**:934-945.

Brown, J. and R. Baby. 1966. Mound City Revisited. Unpublished manuscript on file. Department of Archaeology, Ohio Historical Society, Columbus, Ohio.

Carr, R. K. 1995. Opportunity knocked and no one was home; aspinothoracid arthrodires (Placodermi) from the Ohio Shale Formation (Upper Devonian, North America). Geobios, Memoire Special **28**(2):81-83.

Colson, C. T. 1963. Pottsville and Allegheny corals of Ohio. Thesis. Ohio University at Athens, Athens.

Corbett, R. G. and B. M. Manner. 1988. Geology and habitats of the Cuyahoga Valley National Recreation Area, Ohio. Ohio Journal of Science **88**:40-47.

Feldmann, R. M. and M. Hackathorn. 1996. Fossils of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 70.

Foreman, H. P. 1963. Upper Devonian Radiolaria from the Huron Member of the Ohio Shale. Micropaleontology **9**:267-304.

Foreman, H. P. 1959. A new occurrence of Devonian Radiolaria in calcareous concretions of the Huron member of the Ohio shale [Ohio-Kentucky]. Journal of Paleontology **33**:76-80.

Hannibal, J. T. and R. M. Feldmann. 1987. The Cuyahoga Valley National Recreation Area, Ohio: Devonian and Carboniferous clastic rocks. Pages 403-406 *in* Biggs, D. L., editor. Geological Society of America, Boulder, Colorado. Centennial Field Guide – North-central section.

Hansen, M. C. 1994. Ohio Shale concretions. Ohio Division of Geological Survey, Columbus, Ohio. GeoFacts 4.

Hoare, R. D. 1990. Mississippian rostroconch mollusks from Ohio. Journal of Paleontology **64**:725-732.

Hoare, R. D. 1980a. New Pennsylvanian gastropods from Ohio. Journal of Paleontology **54**:1035-1040.

Hoare, R. D. 1980b. Variation and predation of the Pennsylvanian gastropod *Microdoma conicum* Meek and Worthen. Ohio Journal of Science **80**:59-63.

Hoare, T. B. 1973. The mirogastropods of the Putnam Hill Shale (Allegheny Group) in southeastern Ohio. Thesis. Bowling Green State University, Bowling Green, Ohio.

Hoare, R. D. and M. T. Sturgeon. 1984. Pennsylvanian Echinoid *Pedicellariae*. Journal of Paleontology **58**:895-897.

Hoare, R. D. and M. T. Sturgeon. 1978. Color pattern variation in *Callistadia spirallia* n. (Pennsylvanian, Gastropoda). Journal of Paleontology **52**:532-536.

Hoare, R. D. and M. T. Sturgeon. 1976. Echinoid remains from the Pennsylvanian Vanport Limestone (Allegheny Group), Ohio. Journal of Paleontology **50**:13-24.

Hoare, R. D., M. T. Sturgeon, and T. B. Hoare. 1972. Middle Pennsylvanian (Allegheny Group) Polyplacophora from Ohio. Journal of Paleontology **46**:675-680.

House, M. R., M. Gordon, and W. J. Hlavin. 1986. Late Devonian Ammonoids from Ohio and adjacent states. Journal of Paleontology **60**:126.

Kenworthy, J. P. and V. L. Santucci. 2006. A preliminary inventory of National Park Service paleontological resources in cultural resource contexts, Part 1: General overview. Pages 70-76 *in* Lucas, S. G., J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. Fossils from Federal Lands. New Mexico Museum of Natural History and Science, Albuquerque. Bulletin 34.

Maloney, M. M., R. D. Hoare, and M. T. Sturgeon. Pennsylvanian *Palaeotextulariid* Foraminifera from the Appalachian Basin. Journal of Paleontology **62**:724-730.

Manger, W. L. 1971. The Mississippian Ammonoids *Karagandoceras* and *Kazakhstania* from Ohio. Journal of Paleontology **45**:33-39.

Marple, M. F. 1950. Ostracodes from the Pottsville Formation in Ohio. Dissertation. The Ohio State University, Columbus, Ohio.

Merrill, G. K. 1974. Pennsylvanian conodont localities in northeastern Ohio. Ohio Division of Geological Survey, Columbus, Ohio.Guidebook 3.

Merrill, G. K. 1972. Taxonomy, phylogeny, and biostratigraphy of *Neognathodus* in Appalachian Pennsylvanian Rocks. Journal of Paleontology **46**:817-829.

Murphy, J. L. 1970. Coiled Nautiloid cephalopods from the Brush Creek Limestone (Conemaugh) of eastern Ohio and western Pennsylvania. Journal of Paleontology **44**:195-205.

Murphy, J. L. 1966. The Pennsylvanian Nautiloid *Kionoceras ungeri* (Sturgeon & Miller). Journal of Paleontology **40**:1388-1390.

Neal, M. L. and J. T. Hannibal. 2000. Paleoecologic and Taxonomic Implications of *Sphenothallus* and *Sphenothallus*-like specimens from Ohio and areas adjacent to Ohio. Journal of Paleontology **74**:369-380.

Ohio Division of Geological Survey. 2001. A brief summary of the geologic history of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Geo Facts 23. Online.(http://www.dnr.state.oh.us/Portals/10/pdf/GeoFacts/geof23.pdf). Accessed June 2008

Orton, E. 1889. The discovery of sporocarps in the Ohio Shale. American Association for the Advancement of Science, Proceedings:179-181.

Papazis, P. K. 2005. The widespread occurrence of agglutinated Foraminifera in black shales. Geological Society of America Abstracts with Programs **37**:188.

Pringle, P. 1982. Geologic study sites of the Cuyahoga Valley National Recreation Area – Southern Sector. Thesis. University of Akron, Akron, Ohio.

Roeser, E. W. 1985. A Lower Mississippian (Kinderhookian-Osagian) crinoid fauna from the Cuyahoga Formation of northeastern Ohio. Geological Society of America Abstracts with Programs **17**:702.

Schram, J. M. 1980. *Dithyrocaris* sp. (Phyllocarida) from the Allegheny Group of Ohio. Transactions of the San Diego Society of Natural History **19**(14):213-216.

Schwimmer, B. A. and R. M. Feldmann. 1990. Stratigraphic distribution of brachiopods and bivalves in the Upper Devonian (Famennian) Chagrin Shale in the Cuyahoga River Valley, northeast Ohio. Kirtlandia **45**:7-31.

Slucher, E. R., E. M. Swinford, G. E. Larsen, G. A. Schumacher, D. L. Shrake, C. L. Rice, M. R. Caudill, R. G. Rea, and D. M. Powers. 2006. Bedrock geologic map of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Map BG-1. 1:500,000 scale.

Smyth, P. 1974. Fusulinids in the Appalachian Basin. Journal of Paleontology **48**:856-858.

Sturgeon, M. T. 1945. Some fossil gastropods from the Allegheny Formation of eastern Ohio. Geological Society of America Bulletin **56**, Part 2:1203.

Sturgeon, M. T. and W. Youngquist. 1949. Allegheny conodonts from eastern Ohio. Journal of Paleontology **23**:380-386.

Szmuc, E. J. 1970a. The Devonian System. Pages 9-22 *in* Guide to the geology of northeastern Ohio. Northern Ohio Geological Society.

Szmuc, E. J. 1970b. The Mississippian System. Pages 23-67 *in* Guide to the geology of northeastern Ohio. Northern Ohio Geological Society.

Wells, J. W. 1941. Association of crinoids with *Callixylon* in the lower Ohio Shale. Palaeobiologica **7**:105-110.

Whitfield, R. P. and J. L. Murphy. 1974. R. P. Whitfield's Nautiloid species from the Pottsville Group of Ohio. Journal of Paleontology **48**:740-749.

Williams, M. E. and J. T. Hannibal. 1984. Recent additions to the history of fossil fish collecting in the Ohio Shale. Ohio Journal of Science **84**:92-93.

Wilson, M. A. 1979. A new species of the trilobite *Brachymetopus* from the Cuyahoga Formation (Lower Mississippian) of northeastern Ohio. Journal of Paleontology **53**:221-223.

## Additional References

Bird, D. L. 1988. Paleontology of the Meadville Member of the Cuyahoga Formation (Mississippian) in Medina County, Ohio. Thesis. West Virginia University, Morgantown.

Burke, J. J. 1979. *Diphuicrinus somersi* (Whitfield) n. comb. and *Contocrinus conspicuus* (Strimple) n. comb.; inadunate crinoid taxa previously attributed to *Graffhamicrinus*. Ohio Journal of Science **79**:28.

Claypole, E. W. 1888. Fossils from the Ohio Shale. Economic Geology:62-64.

Hoare, R. D. 1979. Pennsylvanian marine Bivalvia and Rostroconchia of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 67.

Hook, R. W. 1992. A new fish and tetrapod assemblage from the Allegheny Group (late Westphalian, Upper Carboniferous) of northeastern Ohio. Journal of Vertebrate Paleontology **12**:33A.

Hook, R. W. 1985. A paleoenvironmental model for the occurrence of vertebrate fossils in Carboniferous coal-bearing strata. Dissertation. University of Kentucky, Lexington.

Hoover, K. V. 1960. Devonian-Mississippian shale sequence in Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Information Circular 27.

Hyde, J. E. 1953. Mississippian formations of central and southern Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 51.

Kleffner, M. A. 1987. Conodonts of the Estill Shale and Bisher Formation (Silurian, southern Ohio); biostratigraphy and distribution. Ohio Journal of Science **87**:78.

Mapes, R. H. 1997. Pennsylvanian cephalopods of Ohio; Part 2, Ammonoid cephalopods. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 71.

Margolin, P. R. 2001. The sink hole at Bandana; a Blue Ridge mica mine reveals its prehistoric past. Geological Society of America Abstracts with Programs **33**:128.

Morningstar, H. 1922. Pottsville fauna of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 25.

Pavey, R. R., R. P. Goldthwait, C. S. Brockman, D. N. Hull, E. M. Swinford, and R. G. Van Horn. 1999. Quaternary geology of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Map M-2. 1:500,000 scale.

Sturgeon, M. T. 1997. Pennsylvanian cephalopods of Ohio; Part 1, Nautiloid and bactritoid cephalopods. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 71.

Sturgeon, M. T. 1949. An additional fossiliferous member in the Allegheny Formation (Pennsylvanian) of Ohio. Ohio Journal of Science **49**:1.

Williams, E. G. 1979. Marine and fresh water fossiliferous beds in the Pottsville and Allegheny groups of western Pennsylvania. Page 35-49 *in* Carboniferous depositional environments in the Appalachian region. University of South Carolina, Department of Geology, Columbia, SC.

## Data Sets

*Cuyahoga Valley National Park Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

*Cuyahoga Valley National Park Museum Collections*
1974-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by CUVA staff; status: Active.

*Midwest Archeological Center*
1969-present. (museum specimens; associated specimen notes; collection records; maps; etc.) Originated by MWAC staff; status: Active.

*Cleveland Museum of Natural History Collections*
1990s-present. (museum specimens; associated specimen notes; collection records; maps, etc. ) Originated by Department of Invertebrate Paleontology Staff; status: Active.

# Effigy Mounds National Monument

On October 25, 1949, President Harry Truman signed a proclamation establishing Effigy Mounds National Monument (EFMO). The monument consists of two areas: the Jennings-Liebhardt tract (South Unit) and the Yellow River Unit in Clayton County, northeastern Iowa (North Unit; HRA Gray and Pape 2003), which include 1,022 ha (2,526 acres). EFMO preserves 206 prehistoric American Indian mounds built along the Mississippi River between 450 B.C. and A.D 1300, including 31 effigy mounds in the shapes of birds and bears.

## Geologic Background

EFMO lies in a distinctive area of erosional topography that is drained by a complex system of rivers and streams. These erosional forces have cut through the area resulting in tall divides and steep bluffs. During the early portion of the Paleozoic Era warm shallow seas covered this area. The oldest layer exposed at EFMO is the Upper Cambrian Jordan Sandstone, found beneath the resistant ledges of the overlying Prairie du Chien Group exposed along the base of the east-facing bluffs. The Lower Ordovician Prairie du Chien Formation is the prevailing geologic strata exposed along EFMO river bluffs; however, other Ordovician formations occur within the boundaries of the monument. EFMO is located in a portion of Iowa known as the "driftless area," which was left unscathed by the advance and retreat of the continental ice sheets during the “Ice Age” (Witzke et al. 1998). Most of the formations below are also found along Mississippi National River and Recreation Area and St. Croix National Scenic River in Minnesota and Wisconsin (both part of the Great Lakes Network; Hunt et al. 2008).

## Sources of Paleontological Resources

Fossils have been documented from the following geologic formations and museum collections within EFMO. These fossils present opportunities for resource management (including field surveys, inventory, and monitoring), education, interpretation, and continued or future scientific research in the park. Some fossils at EFMO also occur in cultural resource contexts as described below.

### *Jordan Sandstone (Late Cambrian)*

The Jordan Sandstone is the oldest bedrock unit exposed within EFMO park boundaries. Exposures are limited to the river bluff area on the eastern boundary of the monument (Witzke and Anderson 2006). This formation is split into four members in northeast Iowa: the Norwalk, the Van Oser, Waukon (non fossiliferous), and the Coon Valley members (McKay 1993). The Norwalk Member is a fine- to coarse-grained feldspathic sandstone which contains bioturbated facies. The Van Oser Member is similar to the Norwalk Member in that it is a fine- to coarse-grained quartz arenite which also contain zones of *Skolithos* bioturbation. The Coon Valley Member in Iowa contains the Cambrian-Ordovician boundary and is composed of varying sandstone and quartz carbonate rocks (McKay 1993; Witzke and McKay 1987). The Coon Valley is the only member of the Jordan Sandstone present within EFMO known to typically contain fossils including: small stromatolites, gastropods, and occasional *Skolithos* burrows (McKay 1993; B. Witzke, Iowa Geological Survey, pers. comm., April 2008).

### *Prairie du Chien Group (Lower Ordovician)*

The Ordovician units of EFMO are composed of the Prairie du Chien Group, the St. Peter Sandstone, the Glenwood, Platteville, Decorah and Dunleith formations. The rocks of the Prairie du Chien Group were deposited during the Lower (Early) Ordovician in a broad sea and are now found in the bluffs along the Mississippi River and interior portion of EFMO (Witzke and Anderson 2006). The Prairie du Chien Group is sparsely fossiliferous to unfossiliferous and is divided into two formations, the lower (older) Oneota and the upper (younger) Shakopee formations (Witzke and McKay 1987; McKay 1993). The Oneota Formation is characterized by a relatively pure carbonate interval that commonly lacks sandy and shaly beds and is exposed throughout northeastern Iowa (Witzke and Anderson 2006). The Shakopee

Formation includes a basal sandstone and sandy dolomite interval (the New Richmond Member) that is overlain by sandy, cherty, and stromatolitic dolomite with scattered green-gray shale interbeds (Willow River Member; Witzke and Anderson 2006). The Prairie du Chien Group is similar here to outcrops present along Mississippi National River and Recreation Area and St. Croix National Scenic River in Minnesota and Wisconsin (both part of the Great Lakes Network; Hunt et al. 2008).

### *Oneota and Shakopee formations (Lower Ordovician)*

Marine invertebrate fossils are known from both the Oneota and the Shakopee formations. Fossils from the Oneota Formation are more well represented in the EFMO area (compared to that of the Shakopee) by stromatolites, gastropods, nautiloid cephalopods (*Eremoceras, Levisoceras, Oneotoceras*, and *Ellesmeroceras*), with the occasional brachiopods and trilobites (Furnish 1993; B. Witzke, Iowa Geological Survey, pers. comm., April 2008). Conodonts are also known from the Oneota Formation (McKay 1993; Witzke and McKay 1987). The Willow River Member of the Shakopee Formation includes the fossil remains of stromatolites, conodonts, and gastropod molds in the Lansing area to the south of EFMO (Witzke and McKay 1987).

### *Platteville Formation (Upper Ordovician)*

The Upper Ordovician Platteville Formation within EFMO is composed of two members, the Pecatonica and McGregor (Witzke and McKay 1987). The Platteville Formation includes limestone and dolomite intervals with one or more discrete transgressive-regressive cycles of marine deposition (Witzke and Anderson 2006). The limestone of the McGregor Member is known to contain fossils including: bryozoans, brachiopods, trilobites (Sloan et al. 1987), six species of crinoids (*Abludoglyptocrinus charltoni*, *Carabocrinus*, *Cupulocrinus plattevilleensis, Ectenocrinus simplex, Merocrinus britonensis*, and *Porocrinus pentagonius*; Brower 2007), cyclocystoids, rhombiferan, and the calceocrinid *Cremacrinus crossmani* (Brower and Strimple 1983).

A rockshelter near EFMO shows evidence that at least some prehistoric Woodland Indians used crinoid stems as jewelry items. These crinoids could possibly be sourced locally from the Platteville, as it is the only formation present within EFMO that contains crinoid remains (D. Lenzendorf, EFMO Park Ranger, pers. comm., April 2008). See the Cultural Resource Contexts section below.

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within EFMO. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park. Such fossils may be found in fossiliferous cobbles eroded by the Yellow and/or Mississippi rivers and deposited within the park.

### *Lone Rock Formation (Late Cambrian)*

The Lone Rock Formation is a distinctive greensand interval containing glauconitic siltstones and very fine- to fine-grained sandstone. The Reno Member of this formation preserves trilobite faunas of the *Ptychaspis-Prosaukia* Zone and the basal *Saukia* Zone (Witzke and McKay 1987; Witzke et al. 1998). The presence of this unit is not yet documented within EFMO, although it is exposed nearby in the Cota and Painted creeks and the Yellow River valley/drainages.

### *St. Lawrence Formation (Late Cambrian)*

The underlying St. Lawrence Formation is composed of dolomitic siltstones and silty dolomite. The Lodi Member of the St. Lawrence contains trilobites of the *Saukia* Zone, rare aglaspid merostome arthropods (*Aglaspis, Glypharthrus*), inarticulate brachiopods (*Lingulella, Westonia*) and articulate brachiopods (*Finkelnburgia*), gastropods and conodonts (*Proconodonyus*; Witzke and McKay 1987; Witzke et al. 1998). There are no currently known exposures of the St. Lawrence Formation within the park, although it occurs nearby in the Cota and Painted Creek and the Yellow River valley/drainages..

### *St. Peter Sandstone (Middle Ordovician)*
The youngest bedrock within the southern unit of EFMO is the St. Peter Sandstone, a pure very-fine to medium-grained quartzarenite of Middle Ordovician age (Witzke and Anderson 2006). Invertebrate fossils are not known from the St. Peter Sandstone within EFMO, but are present in other NPS units, including MISS (B. Witzke, Iowa Geological Survey, pers. comm., April 2008).

### *Glenwood Shale (Upper Ordovician)*
The Upper Ordovician Glenwood Shale is dominated by a green-gray, noncalcareous, sandy to silty (occasionally phosphatic) shale with minor siltstones and sandstones (Witzke and Anderson 2006). The Glenwood Shale is exposed within the interior of the park and occasionally contains conodonts, although none are noted from EFMO (Witzke and McKay 1987).

### *Decorah Formation (Upper Ordovician)*
The Upper Ordovician Decorah Formation comprised of interbedded green-gray calcareous shales and limestones, along with skeletal wakestones and packstones. The Decorah is a highly fossiliferous formation containing the calceocrinid *Cremacrinus punctatus* and conodonts, with brachiopods and bryozoans especially abundant in some beds around 48 km (30 miles) to the northwest of EFMO near Church, Iowa (Witzke and McKay 1987; Brower and Strimple 1983).

### *Dunleith Formation (Upper Ordovician)*
The youngest formation present within the park is the Upper Ordovician Dunleith Formation. This formation is dominated by slightly argillaceous dolomitic limestones that have high karst susceptibility. Fossils from the Dunleith Formation outside of EFMO include crustacean burrows; the crinoids *Calceocrinus gossmani, Cremacrinus gerki, C. guttenbergensis* and *C. punctatus* (in Clayton and Winneshiek Counties, Iowa); and the echinoderm *Pleurocystites strimplei* (Brower 1999; Brower and Strimple 1983). Fossils have not yet been identified within the Dunleith Formation exposures of EFMO.

## Park Collections and Fossils in Cultural Resource Contexts

A rockshelter near EFMO shows evidence that at least some prehistoric Woodland Indians used crinoid stems as jewelry items. These crinoid could possibly be sourced locally from the Platteville, as it is the only formation present within EFMO that contains crinoid remains (D. Lenzendorf, EFMO Park Ranger, pers. comm., April 2008). The park collections contain a large number of paleontological specimens, 635 (perhaps more than 3,000 individual specimens; K. Byrne, HFC Curator, pers. comm. January 2008). Hopewell Culture National Historical Park (see HOCU section of this report) also preserved fossil remains in a cultural context from American Indian mounds (Kenworthy and Santucci 2006).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for EFMO. Formal paleontological inventories have likewise not yet been completed. Nevertheless fossils are known from the bedrock in the park and are contained within park collections. The crinoid stem bead jewelry found in the EFMO area is an exceptional example of fossils found in a cultural resources context.
- The park should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their

usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.

- Fossils found in a cultural context should be documented as other fossils, but will also require the input of an archeologist. Any fossil with cultural context may be culturally sensitive as well (e.g. subject to NAGPRA) and should be regarded as such until otherwise established. The Midwestern Archeological Center (MWAC) and the Geologic Resources Division can coordinate additional documentation/research of such material.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Brower, J. C. 2007. Upper Ordovician crinoids from the Platteville Limestone of northeastern Iowa. Journal of Paleontology **81**(1):103-115.

Brower, J. C. 1999. A new Pleurocystitid Rhombiferan echinoderm from the Middle Ordovician Galena Group of northern Iowa and southern Minnesota. Journal of Paleontology **73**(1):129-153.

Brower, J. C. and H. L. Strimple. 1983. Ordovician calceocrinids from northern Iowa and southern Minnesota. Journal of Paleontology **57**(6):1261-1281.

Furnish, W. M. 1993. Discussion of the molluscan fauna. Pages 7-9 *in* R. M. McKay, editor. Selected aspects of Lower Ordovician and Upper Cambrian geology in Allamakee and northern Clayton counties. Geological Society of Iowa, Iowa City. Guidebook 57.

HRA Gray and Pape, LLC. 2003. Figures on the landscape: Effigy Mounds National Monument historic resource study. Online. (http://www.nps.gov/efmo/web/hrs/hrst.htm). Accessed May 2008.

Hunt, R. K., J. P. Kenworthy, and V. L. Santucci. 2008. Paleontological resource inventory and monitoring—Great Lakes Network. Natural Resource Technical Report NPS/NRPC/NRTR—2008/120. National Park Service, Fort Collins, Colorado.

Kenworthy, J. P. and V. L. Santucci. 2006. A preliminary inventory of National Park Service Paleontological resources in cultural resources contexts, Part 1: General Overview. Page 70-76, *in* Lucas, S. G., J. A. Spielmann, P. M. Hester, J. P. Kenworthy and V. L. Santucci, editors. Fossils from Federal Lands. New Mexico Museum of Natural History and Science, Albuquerque. Bulletin 34.

McKay, R. M. 1993. Selected aspects of Lower Ordovician and Upper Cambrian geology in Allamakee and northern Clayton counties. Geological Society of Iowa, Iowa City. Guidebook 57.

Sloan, R. E., D. R. Kolata, B. J. Witzke, and G. Ludvigson. 1987. Description of major outcrops in Minnesota and Iowa. Pages 197-231 *in* Minnesota Geological Survey, St. Paul. Report of Investigations 35.

Witzke, B. J. and R. R. Anderson. 2006. Bedrock geology of quadrangles containing the Yellow River Basin: Allamakee, Clayton, Fayette, and Winneshiek counties, Iowa. Iowa Geologic Survey, Iowa City. Open File Map 06-1.

Witzke, B. J., G. A. Ludvigson, R. M. McKay, R. R. Anderson, B. J. Bunker, J. D. Giglierano, J. P. Pope, A. E. Goettemoeller, and M. K. Slaughter. 1998. Bedrock geology of northeast Iowa. Digital geologic map

of Iowa, Phase 2: Northeast Iowa. Iowa Geological Survey, Iowa City. Open File Map 98-7. 1:250,000 scale.

Witzke, B. J. and R. M. McKay. 1987. Cambrian and Ordovician stratigraphy in the Lansing area, northeastern Iowa. Pages 81-87 *in* Geological Society of America, Boulder, Colorado. Centennial Field Guide, North-Central section.

## Additional References

Furnish, W. M. 1938. Conodonts from the Prairie du Chien beds of the upper Mississippi valley. Journal of Paleontology **12**:318-340.

Hughes, N. C. and S. P. Hesselbo. 1997. Stratigraphy and sedimentology of the St. Lawrence Formation, Upper Cambrian of the northern Mississippi valley. Milwaukee Public Museum. Contributions in Biology and Geology 91.

Runkel, A. C. 1994. Deposition of the uppermost Cambrian (Croixian) Jordon Sandstone, and nature of the Cambrian-Ordovician boundary in the Upper Mississippi Valley. Geological Society of America Bulletin **106**:492-506.

Sardeson, F. W. 1932. Fauna of the Jordan Sandstone. Pan-American Geologist **58**(2):103-106.

## Data Sets

*Effigy Mounds National Monument Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

*Effigy Mounds National Monument Museum Collections*
1949-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by EFMO staff; status: Active.

# George Washington Carver National Monument

On July 14, 1943, George Washington Carver National Monument (GWCA) was established to memorialize the life of George Washington Carver and preserve the setting of his birthplace to ensure that it is left unimpaired for the education, inspiration, and enjoyment of future generations. George Washington Carver is best known for his work with agricultural extension education and reputedly developed three hundred uses for peanuts along with hundreds of uses for soybeans, pecans and sweet potatoes. Located west of Diamond, Missouri, this park encompasses 84.98 ha (210 acres).

## Geologic Background

The stratigraphy of the GWCA area includes nearly flat-lying, relatively undeformed sedimentary strata, which were deposited in a shallow marine setting. The two primary geologic units in the park vicinity are the Mississippian-age Warsaw Formation and the undifferentiated Burlington and Keokuk Limestone (M. Siemens, Missouri Department of Natural Resources Geologist, pers. comm., July 2008). While all of the Mississippian units within GWCA are fossiliferous, no fossils are known from within the park or its collections at this time.

The NPS Geologic Resources Division has not yet conducted a geological scoping summary for GWCA. Currently only one geologic map has been produced for the GWCA area (Smith and Tangier 1907). GWCA is situated on the Grandby 7.5' quadrangle.

## Potential Sources of Paleontological Resources

No fossils have been documented from GWCA at this time. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Warsaw Limestone Formation (Upper Mississippian)*

The Warsaw Limestone Formation is a light-gray to blueish-gray medium- to coarsely crystalline limestone with lenticular nodules and discontinuous beds of light gray chert. The main fossils are of the bryozoan *Archimedes wortheni*, and the brachiopod *Spinifer pellaensis*. Other fossils include the bryozoan *Lioclema puncatata*, *Worthenopora spinosa*, *Rhombopora*, the brachiopod *Spirifera subaequalis*, the crinoid *Rhipidomella dubia,* and conodonts (Goebel 1968, M. Siemens, Missouri Department of Natural Resources Geologist, pers. comm., July 2008).

### *Burlington and Keokuk Limestone formations (Lower Mississippian)*

The undifferentiated rocks of the Burlington and Keokuk Limestone formations are a light- to medium-gray, medium- to coarsely- crystalline massive bedded, crinoidal limestone with isolated nodules and discontinuous beds of white to light-gray fossiliferous chert. The main fossils in the Burlington and Keokuk Limestones are crinoids. Less abundant fossils include the brachiopods *Tetracamera subtrigona*, *Delthyris similis*, *Chonetes illiniosensis*, *Pseudosyrinx keokuk*, *Torynifera pseudolineata*, *Buxtonia*, *Dictyoclostus*, *Linoproductus*, *Marginirugus, Echinoconchus alternatus*, and the crinoid *Cleiothyridina obmaxima* (M. Siemens, Missouri Department of Natural Resources Geologist, pers. comm., July 2008).

## Park Collections

No fossils are known from park collections (K. Byrne, HFC Curator, pers. comm., January 2008).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for GWCA. Paleontological resources are not currently known from within the geological exposures in GWCA and there are no fossils within the park's museum collections. There is some potential for fossil discovery in the various limestones within the park based on discoveries in similar geologic formations outside of the park.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- If significant fossil resources are discovered within the park, GWCA should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited

Goebel, E. D., T. L. Thompson, T. C. Waugh, and L. C. Mueller. 1968. Mississippian conodonts from the Tri-State District, Kansas, Missouri, and Oklahoma. Pages 21-25 *in* Kansas Geological Survey, Lawrence. Bulletin 191.

Smith, W. S. and W. S. Tangier. 1907. Joplin district folio, Missouri-Kansas. U.S. Geological Survey, Reston, Virginia. Geological Atlas Folio 148.

## Additional References

Banner, J. L. and J. Kaufman. 1994. The isotopic record of ocean chemistry and diagenesis preserved in non-luminescent brachiopods from Mississippian carbonate rocks, Illinois and Missouri. Geological Society of America Bulletin **106**:1074-1082.

Fay, R. O. 1960. Ptychoblastus, a new Mississippian blastoid from Missouri. Journal of Paleontology **34**:1198-1201.

Ghosh, B. and W. J. Meyers. 1991. Regional variation in microdolomite content of crinoids from the Mississippian Burlington-Keokuk Formation, Iowa, Illinois and Missouri. Geological Society of America Abstracts with Programs **23**:64

McLeod, J. D. 1973. Fossils of the Warsaw Limestone. Earth Science **26**:243-247

Rovey, C. W., K. R. Evans, K. L. Mickus, J. F. Miller, T. G. Plymate, and K. C. Thomson. 2003. Impact origin of the Weaubleau-Osceola structure in southwestern Missouri. Geological Society of America Abstracts with Programs **35**:339.

## Data Sets

*George Washington Carver National Monument Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

# Herbert Hoover National Historic Site

In 1965 President Lyndon B. Johnson signed Public Law 89-119, authorizing the establishment of Herbert Hoover National Historic Site (HEHO). Approximately 75 ha (186 acres) of land in the West Branch, Iowa area are preserved to honor and interpret the 31st President of the United States. HEHO is the location of Herbert Hoover's birthplace, his presidential library, and his final resting place.

## Geologic Background

The area around HEHO is part of the Southern Iowa Drift Plain Landform Region, which comprises most of southern Iowa. The uplands in this region are composed of highly eroded and dissected Pre-Illinoian age tills that are mantled by windblown silt and eolian sand. The upland surficial deposits were deposited between 2.2 million and 500,000 years ago. In contrast, the overlying windblown loess, eolian sand and colluvial deposits are much younger and were deposited between 30,000 to 12,000 years ago. More recently, during the Hudson Episode there has been further dissection of the loess-mantled landscape and downcutting of major stream valleys. These nearby floodplains are composed of alluvial sediments that are younger than 11,000 to 14,000 years ago. The underlying bedrock geology of the area is thought to be composed of the Silurian Gower or Scotch Grove Formations. During the Silurian this portion of the United States was covered under a shallow, warm sea. These Silurian formations are dolostones which include laminated unfossilferous and fossiliferous mounded facies (Tassier-Surine et al. 2007). The Silurian Formations in this area are not exposed within HEHO and the probability of them being disturbed during erosional activities or human disturbance is low (D. Quade, Iowa Geological Survey, pers. comm., May 2008).

## Potential Sources of Paleontological Resources

No fossils have been documented from HEHO at this time. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units known to preserve fossils outside of the park.

### *Quaternary Surficial Deposits*

The older Quaternary units in the HEHO area are composed of multiple Pre-Illinoian (at least 300,000 years old, ranging up to 1.8 million) tills of the Wolf Creek and Alburnett Formations with or without intervening clayey Farmdale/Sangamon Geosol (Tassier-Surine et al. 2007). In turn, these deposits are overlain by Wisconsin Episode loess and intercalated eolian sands (also known as the Peoria Formation-silt facies; 25,000 to 12,000 years before present). Sediments from the Peoria Formation are derived the wind reworking of valley-train outwash, with some facies (sand) reworked from older eolian sand deposits. Typically, the thickness of the Peoria Formation can vary from approximately 5-15 m (16-50 ft) of noncalcareous to calcareous silt loam, and interbedded, fine- to medium-grained, well sorted sand.

The younger Quaternary units are part of the Hudson Episode alluvium (DeForest Formation-Undifferentiated, less than11,000 to 14,000 years before present) that was originally deposited by or in water. A thickness of approximately 1-4 m (3-13 ft) of massive to weakly stratified, loam (a soil composed of relatively even distributions of sand, silt and clay), silt loam, clay loam, or loamy sand overlie coarse to fine feldspathic quartz sand, pebbly sand, and gravel and more than 3 m (9.8 ft) of pre-Wisconsin or Wisconsin Noah Creek Formation sand and gravel (Tassier-Surine et al. 2007). No fossils are known from these units within HEHO or the surrounding area (N. Korsmo, HEHO Chief Ranger and S. Middlemis-Brown, MWR Biologist, pers. comm., May 2008). However, the Gunder Member of the DeForest Formation near Mud Creek in east-central Iowa (near the Lilienthal locality, 80 km or 50 miles east of HEHO) includes plant macrofossils, pollen, invertebrate (gastropods, clams), and vertebrate (fish, amphibians, mammals) fossils (Work 1998; Work et al. 2005).

## Park Collections

No fossil remains are reposited within the HEHO park collections (C. Wiesner, HEHO Historian, and N. Korsmo, HEHO Chief Ranger, pers. comm., May 2008). Many parks, including LIBO and TAPR in the HTLN, contain structures that utilized fossiliferous building stones in their construction. This provides a unique "epsosure" of fossils and an opportunity for interpretation (see Kenworthy and Santucci 2006). While many of these structures within HEHO have limestone facia and foundations, they are unfossiliferous (N. Korsmo, HEHO Chief Ranger and S. Middlemis-Brown, MWR Biologist, pers. comm., May 2008).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for HEHO. Formal paleontological inventories have likewise not yet been completed. Paleontological resources are not currently known from within the geological exposures in HEHO and there are no fossils within the park's museum collections. There is little potential for future fossil discovery within HEHO.
- Due to the lack of documented *in situ* fossil occurrences within the park, and the unlikelihood of future macrofossil discovery within the park, establishment of a paleontological resource management plan is not necessary at this time.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited

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., J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. America's Antiquities (Proceedings of the 7th Federal Fossil Conference). New Mexico Museum of Natural History & Science, Albuquerque. Bulletin 34.

Tassier-Surine, S., D. J. Quade, J. D. Giglierano, and E. A. Bettis. 2007. Surficial geology of the Cedar Bluff (Iowa) 7.5' Quadrangle. Iowa Geological Survey, Iowa City. Open File Map 2007-4.

Witzke, B. J., R. R. Anderson, and B. J. Bunker. 2004. Bedrock geology of southeastern Iowa. Digital geologic map of Iowa, Phase 7: Southeastern Iowa. Iowa Geological Survey, Iowa City. Open File Map 2004-1.

Work, P. T., H. A. Semken, and R. B. Baker. 2005. Pollen, plant macrofossils and microvertebrates from mid-Holocene alluvium in east-central Iowa, USA: Comparative taphonomy and paleoecology. Palaegeography, Palaeoclimatology, Palaeoecology **223**(2005):204-221.

Work, P. T. 1998. Taphonomy and paleoecology of the middle Holocene Lilienthal fossil biota, Cedar County, Iowa. Dissertation. University of Iowa, Iowa City.

## Additional References

Corner, R. G. 1985. The stag-moose (*Cervalces scotti*) in the late Pleistocene of Nebraska. Proceedings of the Nebraska Academy of Sciences **95**:47.

Hickerson, W. J. 1997. A konservat-Lagerstaetten from the Silurian of eastern Iowa. Geological Society of America Abstracts with Programs **29**(4):20

Kluessendorf, J. 1999. Community distribution of North American Silurian polyplacophorans. World and Regional Geology **11**:799.

Philcox, M. E. 1971. Growth forms and role of colonial coelenterates in reefs of the Gower Formation (Silurian), Iowa. Journal of Paleontology **45**(2):338-346.

Witzke, B. J. 1983. Silurian benthic invertebrate associations of eastern Iowa and their paleoenvironmental significance. Transactions of the Wisconsin Academy of Sciences, Arts and Letters **71**(1):21-47.

Witzke, B. J. and H. L. Strimple. 1981. Early Silurian crinoids of eastern Iowa. The Proceedings of the Iowa Academy of Sciences **88**(3):101-137.

## Data Sets

*Herbert Hoover National Historic Park Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

# Homestead National Monument of America

Homestead National Monument of America (HOME) is located in Gage County, in southeastern Nebraska. In 1936 HOME was established by Congress "as an appropriate monument to retain for prosperity a proper memorial emblematical of the hardships and the pioneer life through which the early settlers passed in the settlement, cultivation, and civilization of the great West." HOME is composed of two units: the primary acreage that contains the 66 ha (163 acre) Daniel Freeman homestead and Palmer-Epard Cabin, and the 0.61ha (1.5 acre) Freeman Schoolhouse site.

## Geologic Background

The abundant marine fossils within the rocks exposed near HOME indicate that much of southeast Nebraska was once part of a large, open sea some 270 million years ago during the Permian Period. As time progressed the sea retreated and land was exposed, allowing soils to form on the surface, now preserved as paleosols (Odell Shale). After this brief period of land exposure, the seas once again rose, again covering the area that is now HOME. A large unconformity exists, where the rocks of the Mesozoic and much of the Cenozoic age have been removed, leaving behind only Pleistocene gravels and till.

The NPS Geologic Resources Division has not yet conducted a geological resource scoping meeting for HOME. The Nebraska Geological Survey has not yet produced a detailed geologic map of the HOME area, although a generalized geologic map is available for the state (Burchett 1986), with a brief geology and paleontology publication available for Gage County (Pabian 1977).

## Potential Sources of Paleontological Resources

The Lower Permian rocks within HOME are from the Big Blue Series of the Chase Group. This series includes four formations in the HOME area, dominated by shales and limestones of the Doyle and Winfield formations, Odell Shale and the Nolans Limestone. It is currently unclear which formations might be present within HOME boundaries, but the four known formations are present within Gage County (Pabian 1977). Erosional areas surrounding Cub Creek offer the greatest potential for exposure of the underlying geologic units. No fossils have been described from HOME at this time. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Doyle Formation (Lower Permian)*

The Doyle Formation is composed of three members from lowest (oldest) to uppermost (youngest): the Holmesville Shale, Towanda Limestone, and Gage Member. In Nebraska, only the Gage Member is exposed. This member's type section is described from 1.6 – 3.2 km (1-2 miles) to the west of Wymore, Nebraska, which is 24 km (15 miles) to the southeast of HOME in Gage County. This member consists of basal, middle and upper sections which are poorly exposed in gullies and low road cuts. The basal section that is composed of unfossiliferous shales, with mid-level silty, red mudstone, followed by green mudstone at the top. The middle section of the Gage Member consists of two thin beds of fossiliferous, shaly limestone, separated by an unfossiliferous yellow mudstone. Fossils in the middle section include foraminifera, brachiopods and crinoids. The upper section is a yellow to yellow brown-mudstone with common root traces, and sparse body fossils (pecten cast), with a greenish-yellow mudstone capping the member (Mazzullo et al. 1997). Paleosols (ancient soil layers) in the Gage Member indicate a shift from seasonally wet/dry conditions to a more arid climate (Montgomery and Mazzullo 1997). Fossils from this unit are not yet known from the park.

### *Winfield Formation (Lower Permian)*

The Winfield Formation is comprised of three members: the Stovall Limestone, the Grant Shale, and the Cresswell Limestone. The Stovall Limestone Member overlies the Gage Member of the Doyle Formation. The Stovall is a light yellow fossiliferous limestone with the upper portion composed of shale with angular nodules of chert. Fossils in the Stovall from Marion County, Kansas, include bryozoans, brachiopods (*Recticulatia* spp.), crinoids, and echinoderm fragments (Mazzullo et al. 1997).

The Grant Shale consists of about 5 m (16 ft) of bluish-gray to olive colored calcareous, occasionally silty, fossiliferous shale (Pabian 1977). Common fossils from this member in Dickinson County, Kansas, include bryozoans, brachiopods (*Derbyia* and *Composita*) and crinoids (Mazzullo et al. 1997).

The Cresswell Limestone Member is composed of a gray to light-buff, massive, pitted to vuggy limestone that weathers to a buff color. The Cresswell Limestone can be divided into a lower massive and sometimes fossiliferous layer and an upper locally shale layer (Pabian 1977). Common fossils in the Cresswell Limestone (from a location in Cowley County, Kansas; sues Mazzullo et al. 1997) include echinoderm spines and plates along with crinoid fragments, with foraminifera, bryozoans, gastropods, pelecypods, and brachiopods (*Derbyia*). This limestone is a popular building material in the Wichita and Winfield areas of Kansas (Grisafe 1983). It is separated above and below by a bluish-gray to yellowish-green shale. Both the Cresswell and Grant members are known to contain geodes that may be of interest to amateur rock collectors (Pabian 1977). Fossils from the Winfield Formation's members are not yet known from HOME.

### *Odell Shale (Lower Permian)*

This formation is dominated by gray, maroon and greenish, calcareous, non-bedded, unfossiliferous shales, with a few mudstone bands. The type section of the Odell Shale is 23 km (18 miles) south of HOME, near the town of Krider, Nebraska. A regression of the sea took place as the Odell was being deposited, indicated by greenish and brownish beds, with seams of calcite and gypsum indicating the development of a paleosols (ancient soil layer). These paleosols record relatively long-term climatic stability (Montgomery and Mazzullo 1997). This unit is overlain on some areas by much younger Pleistocene ("Ice Age") stream gravels described below (Pabian 1977). Fossils have not yet been described from this unit in the park.

### *Nolans Limestone (Lower Permian)*

The Nolans Limestone is composed of three members in Gage County: the Krider Member, the Paddock Shale, and the Herrington Limestone. The type section of the Krider and Paddock Members is 23 km (18 miles) south of HOME, near the town of Krider, Nebraska. The Krider Member (formerly the Krider Limestone) is composed of very fine granular to very finely crystalline, massive dolomudstones, overlain by pale-olive, moderately calcareous shales (Mazzullo et al. 1997, Pabian 1977). Fossils from the type location the Krider Member include lingulid brachiopods (*Myalina* and *Aviculopecten*) and casts of pelecypods (bivalves) (Mazzullo et al. 1997). A buff, silty shale above this member contains the remains of bryozoans (Pabian 1977). Such fossils are not yet known from the park.

The Paddock Shale is composed of medium gray to yellow mudrock and shale. Pecten (scallop) casts are present in the lowermost portion of this members type section, with the upper portion being unfossiliferous. The Herrington Limestone is a thinly-bedded, commonly unfossiliferous, light-yellow, shaly dolomudstone, which thins into a dolomitic mudstone towards its top (Mazzullo et al. 1997). Poorly preserved bivalves and gastropods are also present in the Paddock Shale and Herrington Limestone. These marine fossils indicate a return to marine environments during the time of the Nolans deposition. Algal "biscuits" have been described from the Krider and Herrington limestones in southern Kansas and northern Oklahoma, indicating shallow subtidal grassy sea-bottoms, within a lagoonal depositional setting (Toomey et al. 1988). Much younger Pleistocene gravels may also overlay portions of the Nolans Limestone (Pabian 1977). As with the Krider Member, fossils are not yet documented from the Paddock or Herrington members within HOME.

### *Stream gravel and glacial deposits (Pleistocene)*

Pleistocene gravels in the area overly the much older Permian units exposed within the HOME area. These gravels were deposited in the channel of a stream. Glacial till of Pleistocene age is also known from the area (Pabian 1977). Fossils are not yet known from the gravel or glacial deposits within or near HOME.

## Park Collections

Fossils are not present in the HOME or MWAC collections (T. Arrington, HOME Historian, pers. comm. May 2008; V. Nobel, MWAC Archaeologist, pers. comm. May 2008).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for HOME. Paleontological resources are not currently known from within the geological exposures in HOME and there are no fossils within the park's museum collections. There is some potential for fossil discovery in the Permian and Pleistocene-aged rocks within HOME based on discoveries in similar geologic formations exposed elsewhere in Gage County.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- If significant fossil resources are discovered within the park, HOME should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Burchett, R. R. 1986. Geologic bedrock map of Nebraska. Nebraska Geological Survey, Lincoln. Geologic Maps and Charts GMC-1. 1:1,000,000 scale.

Grisafe, D. A. 1983. Geology and characteristics of building limestones of Kansas. Pages 91-112 *in* Proceedings of 18th Forum on Geology and Industrial Minerals. Indiana Geological Survey, Bloomington, Indiana. Occasional Paper 37.

Mazzullo, S. J., C. S. Teal, and C. A. Burtnett. 1997. Outcrop stratigraphy and depositional facies of the Chase Group (Permian, Wolfcampian) in Kansas and Southeastern Nebraska. Kansas Geological Survey, Lawrence. Technical Series 6.

Montgomery, M. W. and S. J. Mazzullo. 1997. Analysis of paleosols in Chase Group strata (Lower Permian), south-central Kansas. American Association of Petroleum Geologist Bulletin **81**:1353.

Pabian, R. K. 1977. [Geology of] Gage County, Odell/Krider Area. Nebraska Geological Survey, Lincoln.Field Guide FG-4.

Toomey, D. F., R. W. Mitchell, and T. K. Lowenstein. 1988. 'Algal biscuits' from the Lower Permian Herington/Krider limestones of southern Kansas-northern Oklahoma; paleoecology and paleodepositional setting. Palaios **3**:285-297.

## Additional References

Beede, J. W. 1901. Fauna of the Permian of the Central United States: Part I. Transactions of the Kansas Academy of Science **17**:185.

Busch, R. M. 1988. Minor T-R units in the Lower Permian Chase Group, northeast Kansas. Pages 17-24 *in* Geological Society of America, Boulder, Colorado. Centennial Field Guide – South-Central Section.

Foreman, B. C. and L. D. Martin. 1988. A review of Paleozoic tetrapod localities of Kansas and Nebraska. Pages 133 -145 *in* Regional geology and paleontology of Upper Paleozoic Hamilton quarry area in southeastern Kansas. Kansas Geological Survey, Lawrence. Guidebook Series 6.

Pabian, R. K., D. R. Boardman, and H. L. Strimple. 1981. Lower Permian (Wolfcampian) crinoids from the North American Midcontinent. Geological Society of America Abstracts with Programs **13**:312.

Pabian, R. K. and H. L. Strimple. 1978. Aberrant Pennsylvanian and Permian crinoids. Transactions of the Nebraska Academy of Sciences **5**:45-57.

Pabian, R. K. and H. L. Strimple. 1971. Some Permian crinoids and associated fauna from Nebraska. Geological Society of America Abstracts with Programs **3**:274.

Schultze, H. P. 1985. Marine to onshore vertebrates in the Lower Permian of Kansas and their paleoenvironmental implications. University of Kansas Paleontological Institute, Lawrence. University of Kansas Paleontological Contributions Paper 113:

Wind, F. H. 1974. Biostratigraphy and paleoecology of conodonts of the Chase Group, Lower Permian, of Kansas. Geological Society of America Abstracts with Programs **6**:552.

## Data Sets

*Homestead National Monument of America Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

# Hopewell Culture National Historical Park

Mound City Group National Monument was established by President Warren G. Harding in 1923 to preserve prehistoric mounds of "great historic and scientific interest." In 1980 Congress expanded the monument by adding a portion of the nearby Hopeton Earthworks and authorized the investigation of other regional archeological sites to determine their suitability for preservation. The National Park Service recommended four additional sites be added to the monument. Hopewell Culture National Historical Park (HOCU) was then established in 1992 by a law that renamed Mound City Group National Monument, expanding boundaries at Hopeton Earthworks, and including High Bank Works, Hopewell Mound Group, and Seip Earthworks, totaling approximately 473 ha (1,170 acres). The park preserves the mounds and earthworks of the Hopewell culture that flourished in the woodlands of eastern North America between 200 B.C. and A.D. 500.

## Geologic Background

Hopewell Culture National Historical Park is located in south-central Ohio. All of the sites comprising HOCU are situated on Pleistocene outwash terraces. The bedrock underlying the sites is composed of mid- to late-Paleozoic sedimentary rocks. During the middle to late Silurian, Ohio was covered by warm, shallow seas that supported abundant life in reef environments. During the early Devonian most of Ohio was arid, with the warm, shallow seas returning by the middle Devonian. These seas deposited limy sediments, mud and some volcanic ash forming the limestones, dolomites, mudstones, shales and sandstones. By the end of the Devonian the seas had become stagnant, with large amounts of black, organic rich mud deposited. These deposits eventually formed black shales, such as the Ohio Shale. During the latest Devonian and early Mississippian the dark, organic rich muds gave way to the fluvial and deltaic systems, forming sandstone and siltstones. During the late Mississippian shallow seas once again returned, depositing limy mud that would eventually turn into limestone.

The Ohio Division of Geological Survey recently completed a geologic map at 1:500,000 scale, including the HOCU area in Ross County (Slucher et al. 2006).

## Sources of Paleontological Resources

Fossils have been documented from the museum collections within HOCU. These fossils present opportunities for education, interpretation, and continued or future scientific research in the park. They are described in the “Park Collections and Fossils in Cultural Resource Contexts” section, below.

## Potential Sources of Paleontological Resources

The Paleozoic units underlying the HOCU consist of three geologic groups and six geologic formations, composed of sandstone, dolomite, limestone, and shale. These units span the upper Silurian, upper Devonian, and Mississippian. Fossils have not yet been documented from the following geologic units within HOCU. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Undivided Middle to Upper Silurian Formations*

The Middle Silurian Bisher and Lilley formations and Peebles Dolomite are undifferentiated on geologic maps in Ross County, with the Tymochtee and Greenfield dolomites also present in some areas. The Bisher Formation is composed of a gray, argillaceous dolomite that occurs in thin to think beds, with small amounts of shale. Chitinozoans, brachiopods (*Meristina* and *Cryptothyrellacy lindrica*), crinoids and conodonts are present within this formation (Grahn 1985). The overlying Lilley Formation is a gray, fossiliferous dolomite that occurs in thin to thick beds, with sparse amounts of limestone, chert and shale. Above the Lilley Formation is the Peebles Dolomite, a vuggy, thick to massive bedded and bluish gray unit

(Slucher et al. 2006). Bioherms, or a mound built by small organisms and their remains, are common in the Lilley Formation, with conodonts being present in the Bisher and Lilley formations and the Peebles Dolomite in southern Ohio (Herring 1998, Kleffner 1998, 1988, 1987, 1985, 1984).

In southwestern Ross County the upper Silurian Tymochtee and Greenfield dolomites are also present, although these units are typically thin. The Tymochtee Dolomite is finely crystalline, occurs in thin to massive beds with carbonaceous shale layers and are gray and brown in color (Slucher et al. 2006). The Tymochtee Dolomite of Ohio records a low-diversity biota, with stromatolites, ostracodes, gastropods, bivalves, nautiloids and eurypterids representing the most common fossils preserved (Leutze 1958, Easterday and Babcock 1999). Trace fossils show a low diversity, including mostly small, vertical tubes and rare horizontal walking traces. One rare and interesting fossil is an arthropod body impression, thought to be a myriapod-like animal, from Pike County, Ohio (Easterday and Babcock 1999).

The very finely crystalline, argillaceous Greenfield Dolomite occurs as massive to laminar beds which are gray and brown in color. This unit is interbedded with the Salina Group in western portion of state, and thins southward (Slucher et al. 2006).The Greenfield Dolomite is locally brecciated in its lower portion and has been noted to contain the fossilized remains of conodonts (Kleffner 1992).

### *Salina Group (Silurian)*

The Silurian Salina Group is composed of dolomite, anhydrite, gypsum, salt, and shale. The thin to medium beds of dolomite are very fine grained, crystalline, and gray and brown in color. Locally, the Salina Group includes shale, anhydrite, and/or gypsum beds. Salts are restricted to the subsurface in the eastern portion of state. The Salina Group is absent south of Ross County, in which HOCU lies (Slucher et al. 2006). No fossils are known or expected to be found within HOCU from the Salina Group.

### *Ohio Shale (Upper Devonian)*

The Ohio Shale consists of three members in ascending (oldest to youngest) order: Huron, Chagrin, and Cleveland members. The Olentangy Shale is present and potentially fossiliferous, although it underlies the Ohio Shale in this area but is not mapped as a separate unit on Slucher et al. (2006) due to the small scale of the map. The lower Huron Member is a black, carbonaceous shale that contains calcareous concretions in its lower portions (Hansen 1994). Conodonts, fish, shark spores, and the occasional plant impression are preserved in this member (Szmuc 1970a). Fifty-seven species of radiolarian have also been described from the Huron Member throughout Ohio (Foreman 1963, 1959, Slucher et al. 2006).

The middle Chagrin Member is a gray to greenish gray shale, siltstones, and fine-grained sandstone. Brachiopod, bivalve, cephalopods, conodonts, small, branching burrows, and the annelid worm(?) *Sphenothallus* are described from the Chagrin Member (Schwimmer and Feldmann 1990, Hannibal and Feldmann 1987, Neal and Hannibal 2000). The middle Chagrin Member is a gray to greenish gray shale, siltstones, and fine-grained sandstone. While this member is thickest in the northern portion of Ohio, it thins to the southwest and becomes the Three Lick Bed in the southern portion of the state (Slucher et al. 2006). Brachiopods and the annelid worm(?) *Sphenothallus* are described from the Chagrin member (Neal and Hannibal 2000).

The Cleveland Member is a black shale that is thickest in the north-central portion of the state and thins to the south and east, being completely absent in the northeastern portion of Ohio (Slucher et al. 2006, Carlson 1987). This member contains the remains of plant spores (the most common fossils from this member), carbonized plants, arthropods, conodonts, and placoderm fish, with trace fossils also present (Szmuc 1970a; Corbett and Manner 1988). Wood, and fern remains are also known (Orton 1889). Fossils from the Ohio Shale are not yet known within the park.

### *Bedford Shale and Berea Sandstone (Upper Devonian)*

The Bedford Shale and Berea Sandstone are mapped together as “undivided” units within northeastern Ohio (Slucher et al. 2006). The Bedford Shale (upper Devonian) is a gray to brown very fine-grained

sandstone with interbeds of siltstone common in upper portion of the unit. Ripple marks are common in the sandstone beds, with brachiopods, pelecypods, plants and spore casings described from this formation throughout the state (Szmuc 1970b, Pringle 1982). The remains of the brachiopod *Lingula* along with trace fossils can be found in this unit in the Tinkers Creek and Brandywine Falls areas of CUVA (Corbett and Manner 1988; Szmuc 1970b). The middle Berea Sandstone (upper Devonian) is a very fine grained to silty sandstone that occurs in shades of brown and is mostly in planar to lenticular beds with local shale interbeds (Slucher et al. 2006). Brachiopods, trace fossils, and plants, such as wood (*Callixylon*) described from near Amherst, Ohio, and *Annularia* from Lorain and Cuyahoga counties, have all been reported from the Berea Sandstone (Szmuc 1970b; Beck et al. 1983; Corbett and Manner 1988) and illustrate the potential for similar fossils to be found within the park.

### *Sunbury Shale (Lower Mississippian)*

The Sunbury Shale (Lower Mississippian) is brownish black, carbonaceous, and pyritic (Slucher et al. 2006). Sponge and abundant conodont remains (*Synprioniodina alternate, Hindeodella subtilis, Polygnathus pennatulus*, *P. germanus*, *Panderodella truncate, Bryantodus inclinatus,* and *Lonchodina subtilis*) are known from this formation in centeral and southern Ohio but not yet within the park (Bucher 1929; Cooper 1931).

### *Cuyahoga and Logan Formations (Lower Mississippian)*

In Ohio the Cuyahoga and Logan formations are mapped together as undivided units (Slucher et al. 2006). Cuyahoga Formation is composed of interbedded sandstone, siltstone, and shale, mainly represented in shades of gray, olive, brown, and yellow. The sandstone is silty to conglomeratic and occurs in thin to massive beds. The siltstone and shale units occur in thin to thick beds, with the shale being locally red and fossiliferous. The unmapped Buena Vista Member occurs in this southern portion of Ohio (Slucher et al. 2006). Fossils in the Cuyahoga Formation include mollusk (*Hippocardia herricki* from Wayne County, Ohio, *Aphelakardia alternistriata*, and *Pseudomulceodens cancellatum*), ammonoids (*Muensteroceras oweni*, *Imitoceras sciotoensis*, and *Kazakhstania colubrella*), crinoids and a trilobite (*Brachymetopus nodosus*) from Lodi, Ohio (Manger 1971; Wilson 1979; Roeser 1985; Hoare 1990).

The overlying Logan Formation is composed of gray, yellow and brown sandstones and siltstones. The sandstone is silty to medium grained, and locally contains lenses and beds of coarser sand grains and fine-pebble conglomerates. The siltstones of the Logan Formation are clayey to sandy and locally contain shale interbeds and partings (Fagadau 1952; Slucher et al. 2006). This formation is also locally fossiliferous, containing the remains of mollusks (*Pseudomulceodens cancellatum;* Hoare 1990), ammonoids (*Karagandoceras bradfordi* from Wayne County, *Kazakhstania colubrella* from Jackson County, *Imitoceras sciotoensis*, *Protocanites lyoni*, and *Gattendorfia andrewsi*; Manger 1971) fish, and trace fossils (Middleman 1976; Williams and Hannibal 1984;).

### *Pleistocene Deposits*

Pleistocene deposits within Ross County are commonly referred to as the “Humboldt deposits”, and are present in the eastern portion of the county outside of HOCU. These deposits lie near the terminus of continental glaciation in southern Ohio. This region has been glaciated at least twice, with deposits identified from both the Illinoian and Wisconsin glaciers, resulting in considerable modification of the area around Buckskin Creek, filling the area with till and outwash. Nine units are present in the Humboldt deposits. The first three units are composed of gravel, till, and sand, followed by lacustrine deposits, which compose units four through eight. Unit nine is composed of a noncalcareous dark brown clay containing black shale fragments. Eighteen species of mollusk fossils are present in the lacustrine units and are thought to be early Wisconsinan in age (Reynolds 1959). All of the HOCU sites are located on outwash terraces located along regional waterways. These terraces are the result of meltwater flowing off receding glaciers.

## Park Collections and Fossils in Cultural Resource Contexts

Fifty fossil items are present in the HOCU collections with seven fossils present in the Midwest Archeological Center (K. Brady Rawlins, HOCU Curator, pers. comm. May 2008; D. Bringelson, MWAC Archeologist, pers. comm. May 2008). These include coral, sharks teeth, and crinoid stems. The fossil shark teeth are on exhibit and were excavated from Mound 7 at Mound City in 1920-1921 by William C. Mills. These shark teeth are perforated on the root portion and were found in association with small shell beads, suggesting to Mills that they had been part of a necklace (Mills 1922; Kenworthy and Santucci 2006). Further investigation may identify the age of the sharks teeth and their original source, as well as their connection to the Hopewell Indians. Mills also recovered fragments of mastodon or mammoth tusk from Mound 23 at Mound City, although the current locations of these remains are unknown (Mills 1922, K. Brady Rawlins, HOCU Curator, pers. comm. May 2008). During excavations in the 1960s and 1970s, small fragments of horn coral and branching coral were recovered from mounds at Mound City, and are present in the HOCU collections (Brown and Baby 1966, K. Brady Rawlins, HOCU Curator, pers. comm. May 2008). Mayor (2005) references a 1989 article by Jerry McDonald entitled "A collection of fossils from an Adena Mound in Athens County, Ohio, and notes on the collecting and uses of fossils by Native Americans." Attempts to locate a copy of this manuscript at HOCU, MWAC, and the Smithsonian Institution have thus far been unsuccessful (October 2008).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for HOCU. Formal paleontological inventories have likewise not yet been completed. Nevertheless fossils are contained within park and MWAC collections. The fossils were all discovered in a cultural resources context. There is potential for fossil discovery in the Palezoic and Pleistocene rocks of HOCU based on discoveries in similar geologic formations outside of the park.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- Fossils found in a cultural context should be documented as other fossils, but will also require the input of an archeologist. Any fossil with cultural context may be culturally sensitive as well (e.g. subject to NAGPRA) and should be regarded as such until otherwise established. The Midwestern Archeological Center (MWAC) and the Geologic Resources Division can coordinate additional documentation/research of such material.
- The park should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited

Beck, C. B., K. Coy, and R. Schmid. 1982. Observations on the fine structure of *Callixylon* wood. American Journal of Botany **69**:54-76.

Berry, E. W. 1932. A remarkable specimen of *Callixylon newberryi* (Dawson) Elkins et Wieland, from the Ohio Shale. Ohio Journal of Science **32**:385-388.

Bond, R. H. 1947. Ohio shale conodonts [Franklin County, Ohio]. Ohio Journal of Science **47**:21.

Bond, R. H. 1937. A study of some conodonts from the lower part of the Ohio Shale in central Franklin County, Ohio. Thesis. Ohio State University, Columbus, Ohio.

Brown, J. and R. Baby. 1966. Mound City Revisited. Unpublished manuscript on file, Department of Archaeology, Ohio Historical Society, Columbus, Ohio.

Bucher, W. H. 1929. *Tetractinellid* sponge in the Sunbury Shale of Ohio. Geological Society of America Bulletin **40**:222.

Carlson, E. H. 1987. Copperas Mountain: Black shale facies of the Upper Devonian Ohio Shale in south-central Ohio. Geological Society of America Centennial Field Guide-North-Central Section Trip **99**:427-430.

Carr, R. K. 1995. Opportunity knocked and no one was home; aspinothoracid arthrodires (Placodermi) from the Ohio Shale Formation (Upper Devonian, North America). Geobios, Memoire Special **19**:81.

Cooper, C. L. 1931. Conodonts from the Arkansas Novaculite, Woodford Formation, Ohio Shale and Sunbury Shale. Journal of Paleontology **5**:143-151.

Easterday, C. R. and L. E. Babcock. 1999. Early myriapod-like body fossil and associated walking trace from a Silurian Lagerstatte in Ohio. Geological Society of America Abstracts with Programs **31**:104.

Fagadau, S. P. 1952. Stratigraphy and paleontology of the Logan Formation in central and southern Ohio. Geological Society of America Bulletin **63**:1248-1249.

Foreman, H. P. 1963. Upper Devonian radiolaria from the Huron Member of the Ohio Shale. Micropaleontology **9**:267-304.

Foreman, H. P. 1959. A new occurrence of Devonian radiolaria in calcareous concretions of the Huron member of the Ohio Shale [Ohio-Kentucky]. Journal of Paleontology **33**: 76-80.

Grahn, Y. 1985. Llandoverian and Early Wenlockian chitinozoa from Southern Ohio and Northern Kentucky, U.S.A. Palynology **9**:147-164.

Hansen, M. C. 1994. Ohio Shale Concretions. Ohio Division of Geological Survey, Columbus, Ohio. GeoFacts 4.

Herring, D. M. 1998. Biohermal facies and asphalt in the Silurian Lilley and Bisher Formations (Clinton-Lockport) of Adams County, Ohio. American Association of Petroleum Geologist Bulletin **82**:1768.

Hoare, R. D. 1990. Mississippian rostroconch mollusks from Ohio. Journal of Paleontology **64**:725-732.

House, M. R., M. Gordon, and W. J. Hlavin. 1986. Late Devonian ammonoids from Ohio and adjacent states. Journal of Paleontology **60**:126-144.

Kenworthy, J. P. and V. L. Santucci. 2006. A preliminary inventory of National Park Service paleontological resources in cultural resource contexts, Part 1: General overview. Pages 70-76 *in* S. G. Lucas, J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. Fossils from Federal

Lands. New Mexico Museum of Natural History and Science, Albuquerque, New Mexico. Bulletin 34.

Kleffner, M. A. 1998. Wenlock conodont chronostratigraphy and sequences of the Appalachian Basin in New York, Ohio, and Tennessee. American Association of Petroleum Geologists Bulletin **82**:1769.

Kleffner, M. A. 1992. Conodonts and their implications concerning the Lockport/Salina contact in the North American Midwestern basins and arches region. Geological Society of America Abstracts with Programs **24**:319.

Kleffner, M. A. 1988. Lilley Formation, Lilley-Peebles transition unit, and Peebles Dolomite (Silurian, southern Ohio); conodont biostratigraphy and chronostratigraphy and depositional history. Geological Society of America Abstracts with Programs **20**:351.

Kleffner, M. A. 1987. Conodonts of the Estill Shale and Bisher Formation (Silurian, southern Ohio); biostratigraphy and distribution. Ohio Journal of Science **87**:78-89.

Kleffner, M. A. 1985. The Lilley Formation (Silurian, Ohio); conodont biostratigraphy and correlation with Silurian formations of the Great Lakes region. Geological Society of America Abstracts with Programs **17**:296.

Kleffner, M. A. 1984. Conodonts of the Silurian Estill Shale and Bisher Formation in southern Ohio and their bearing on the Estill-Bisher contact and depositional environment. Geological Society of America Abstracts with Programs **16**:150.

Leutze, W. P. 1958. Eurypterids from the Silurian Tymochtee Dolomite of Ohio. Journal of Paleontology **32**:937-942.

Manger, W. L. 1971. The Mississippian Ammonoids *Karagandoceras* and *Kazakhstania* from Ohio. Journal of Paleontology **45**:33-39.

Mayor, A. 2005. Fossil legends of the first Americans. Princeton University Press, Princeton, New Jersey.

Middleman, A. 1976. Trace fossils of the Logan Formation (Lower Mississippian) in northern Hocking County, Ohio. Thesis. Ohio University at Athens, Athens, Ohio.

Mills, W. C. 1922. Exploration of the Mound City Group. Ohio Archaeological and HistoricalSociety Quarterly 31:422.

Neal, M. L. and J. T. Hannibal. 2000. Paleoecologic and Taxonomic Implications of *Sphenothallus* and *Sphenothallus*-like Specimens from Ohio and Areas Adjacent to Ohio. Journal of Paleontology **74**:369-380.

Ohio Geological Survey. 2001. A brief summary of the geologic history of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. GeoFacts 23. Online. (http://www.dnr.state.oh.us/Portals/10/pdf/GeoFacts/geof23.pdf) Accessed June 2008

Orton, E. 1889. The discovery of sporocarps in the Ohio shale. American Association for the Advancement of Science, Proceedings **1889**:179.

Papazis, P. K. 2005. The widespread occurrence of agglutinated foraminifera in black shales. Geological Society of America Abstracts with Programs **37**:188.

Reynolds, M. B. 1959. Pleistocene molluscan faunas of the Humboldt Deposit, Ross County, Ohio. The Ohio Journal of Science **59**:152-166.

Roeser, E. W. 1985. A Lower Mississippian (Kinderhookian-Osagian) crinoid fauna from the Cuyahoga Formation of northeastern Ohio. Geological Society of America Abstracts with Programs **17**:702.

Slucher, E. R., E. M. Swinford, G. E. Larsen, G. A. Schumacher, D. L. Shrake, C. L. Rice, M. R. Caudill, R. G. Rea, and D. M. Powers. 2006. Bedrock geologic map of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Map BG-1. 1:500,000 scale.

Wells, J. W. 1941. Association of crinoids with *Callixylon* in the lower Ohio shale. Palaeobiologica **7**:105-110.

Williams, M. E. and J. T. Hannibal. 1984. Recent additions to the history of fossil fish collecting in the Ohio Shale. Ohio Journal of Science **84**:92-93.

Wilson, M. A. 1979. A new species of the trilobite *Brachymetopus* from the Cuyahoga Formation (LowerMississippian) of northeastern Ohio. Journal of Paleontology **53**:221-223.

## Additional References

Burke, J. J. 1979. *Diphuicrinus somersi* (Whitfield) n. comb. and *Contocrinus conspicuus* (Strimple) n. comb.; inadunate crinoid taxa previously attributed to *Graffhamicrinus*. Ohio Journal of Science 79: 28.

Carlson, E. H. 1987. Copperas Mountain: black shale facies of the Upper Devonian Ohio Shale in south-central Ohio. Geological Society of America, Boulder, Colorado. Geological Society of America Centennial Field Guide-North-Central Section Trip 99.

Claypole, E. W. 1888. Fossils from the Ohio shale. American Geologist:62-64.

Feldmann, R. M. and M. Hackathorn. 1996. Fossils of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 70.

Greber, N. 1983. Recent excavations at the Edwin Harness Mound, Liberty Works, Ross County, Ohio. Cleveland Museum of Natural History, Cleveland, Ohio. Kirtlandia 39.

Hoover, K. V. 1960. Devonian-Mississippian shale sequence in Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Information Circular.

Hyde, J. E. 1953. Mississippian formations of central and southern Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 51.

Kleffner, M. A. 1987. Conodonts of the Estill Shale and Bisher Formation (Silurian, southern Ohio); biostratigraphy and distribution. Ohio Journal of Science **87**:78-89.

McDonald, J. 1989. A collection of fossils from an Adena Mound in Athens County, Ohio, and notes on the collecting and uses of fossils by Native Americans. Unknown source.

Morningstar, H. 1922. Pottsville fauna of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Bulletin 25.

Pavey, R. R., R. P. Goldthwait, C. S. Brockman, D. N. Hull, E. M. Swinford, and R. G. Van Horn. 1999. Quaternary geology of Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Map M-2. 1:500,000 scale.

Quinn, M. J. and R. P. Goldthwait. 1985. Glacial geology of Ross County, Ohio. Ohio Division of Geological Survey, Columbus, Ohio. Report of Investigation 127.

Reynolds, M. B. 1959. Pleistocene molluscan faunas of the Humboldt deposit, Ross County, Ohio. Ohio Journal of Science **59**:152-166.

Schmidt, D. A. 2006. Paleontology and sedimentology of calcifying microbes in the Silurian of the Ohio-Indiana region; an expanded role of carbonate-forming microbial communities. Dissertation. Ohio State University, Columbus, Ohio.

## Data Sets

*Hopewell Culture National Historical Park Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

*Hopewell Culture National Historical Park Museum Collections*
1923-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by HOCU staff; status: Active.

*Midwest Archeological Center Collections*
1969-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by MWAC staff; status: Active.

# Hot Springs National Park

In 1820 the Territorial Assembly of Arkansas approved the first of several petitions to the U. S. Congress aimed at keeping the hot springs out of private hands. On April 20, 1832, President Andrew Jackson signed legislation to set aside "four sections of land including said (hot) springs, reserved for the future disposal of the United States (which) shall not be entered, located, or appropriated, for any other purpose whatsoever." This act represents the earliest example of a natural resource set aside for federal use to be retained by the Federal government in perpetuity. Administration of the park was transferred from the General Land Office to the Department of the Interior in 1849, with the reservation becoming a national park on March 4, 1921 (Shugart 2003).

## Geologic Background

Hot Springs National Park is situated in the Zigzag mountains of the Ouachita uplift, formed during a late Paleozoic orogeny associated with the Ouachita Orogenic Belt. This orogeny (mountain building event) affected an area that extends from eastern Mississippi to western Texas. Eight geologic formations are exposed in this area, predominantly of Ordovician to Mississippian age, with small Cretaceous aged igneous dikes also present (McFarland 1988; Horwitz, 2005). During the Paleozoic the southern portion of North America was covered by an extensive shallow sea. Marine plants and animals thrived in this warm environment. The area now known as HOSP was part of a large ocean basin. Sediments from the shallow shelf to the north accumulated to form the shales and sandstones that now make up this area, with these sediments cascading downward from the shelf in turbidity currents (submarine landslides). Animals and plants would become trapped in these sediments and occasionally preserved as fossils (Hanor 1990).

The NPS Geologic Resources Division conducted a geological resource scoping summary on April 23, 2007. The Arkansas Geological Survey (AGS) has preliminary geologic worksheets for all of these quadrangles, but none are published geologic quadrangle maps (National Park Service 2007). Future mapping by the AGS is planned for fall of 2008 (A. Chandler, Arkansas Geological Survey pers. comm. May 2008). The U.S. Geological Survey Folio 215 (Purdue and Miser 1923) covers the HOSP area, with excellent descriptions of geologic units, features, and processes. Croneis (1930) gives a very good stratigraphic summary of the area, with some sections referring to rock formations that outcrop within HOSP. Horwitz and Jorstad (2005) also provide stratigraphic information of HOSP online.

## Sources of Paleontological Resources

Fossils have been documented from the following geologic formations and the museum collections within HOSP. These fossils present opportunities for resource management (including field surveys, inventory, and monitoring), education, interpretation, and continued or future scientific research in the park.

### *Polk Creek Shale (Upper Ordovician)*

The rocks of the Upper (Late) Ordovician Polk Creek Shale lie conformably on the Bigfork Chert and are composed of black fissile shale with minor amounts of black chert, gray quartzite and limestone. This formation is found on the southern flank of Sugarloaf Mountain, and on the north/northwest face of North, West and Indian mountains, and is present within HOSP, although most outcrops are found in ravines and stream beds (Purdue and Miser 1923). Graptolite fossils are very common from the lower portion of the formation, and are present in the Whittington Creek bed in Whittington Park in HOSP. A small collection of Polk Creek Shale graptolites is cataloged into the HOSP park museum collection even though the fossils were apparently collected outside of the park boundaries (S. Shugart pers. comm. May 2008; Decker 1935; McFarland 1998; Croneis 1930; Hanor 1990).

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within HOSP. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Womble Shale (Middle Ordovician)*

The oldest formation exposed in the HOSP area is the Middle Ordovician Womble Shale. It does not appear that this formation is present within the park, but instead outcrops to the north and northeast (Purdue and Miser 1923). This black shale is hard and argillaceous, with interbedded lenses of limestone and sandstone. The sandstones are found in the lower portion of the formation and are dark gray, compact, fine-grained, and occasionally conglomeratic and phosphatic. The limestones are dense and blue-gray in color, and are found in the upper portion of the formation. The Womble is generally known to contain the remains of trilobites, graptolites and conodonts, although none are known from HOSP at this time (Purdue and Miser 1923; Croneis 1930; Stitt 1994; McFarland 1998).

### *Bigfork Chert (Middle-Upper Ordovician)*

Resting conformably on the Womble Shale is the Middle to Upper (Late) Ordovician Bigfork Chert. This unit consists of thinly bedded dark gray chert that is highly fractured and interbedded with thin black siliceous shale, calcareous siltstone, and dense blue-gray limestone. Chert also occurs in thin to medium beds, but is often highly fractured. Limestone is more common in northwestern exposures. This formation is present just north of the town of Hot Springs, and is exposed within the park. The Bigfork forms the center of a large anticline in the area and is bound by Sugarloaf, West, North, and Indian Mountains (McFarland 1998; Purdue and Miser 1923). Fossils are rare and fragmentary, but are not known from this unit within HOSP. The remains of radiolarians, trilobites and conodonts have been reported from the Zigzag Mountains, with sponges, brachiopods, crinoids, and graptolites also being fairly common (McFarland 1998; Henbest 1936; Croneis 1930).

### *Blaylock Sandstone (Silurian)*

The Blaylock Sandstone, which rest conformably on the Polk Creek Shale, consists of fine- to medium-grained sandstone with interbedded dark to black fissile shale. This formation is only exposed in the Trap Mountains, along the southeastern border of the Arkadelphia Quadrangle and the southwestern part of the Malvern Quadrangle. It does not appear to be present within HOSP (Purdue and Miser 1923). Outcrops are typically trending east to west, found in narrow valleys between high ridges. Fossils are very rare, with only graptolites and a few trace fossils reported from this sandstone unit, although no location data was recorded by Croneis (McFarland 1998; Croneis 1930).

### *Missouri Mountain Shale (Silurian)*

The Missouri Mountain Shale is composed of gray, green, black or red shale that is interbedded with various amounts of conglomerate, novaculite (see below) and sandstone near the base and top of the formation. The shale is soft and argillaceous, with small pyrite crystals common. In some places this shale has been metamorphosed into slate. This formation outcrops within the park and is found on the southern flank of Sugarloaf Mountain, and on the north/northwest face of North, West and Indian mountains (Purdue and Miser 1923). This formation rests conformably on the Blaylock Sandstone to the south and the Polk Creek Shale to the north. Very few identifiable fossils, other than conodonts, are known from the Missouri Mountain Shale, and none have been described from within HOSP (Barrick 1987, 1994; McFarland 1998; Croneis 1930).

### *Arkansas Novaculite (Devonian-Lower Mississippian)*

The Devonian to Lower (Early) Mississippian Arkansas Novaculite (highly siliceous and microcrystalline quartz) is subdivided into three distinguishable units. The Lower Division consists of white massive bedded novaculite with interbedded shales at the base, followed by the greenish to dark gray shales and

thinly interbeddeded dark novaculites of the Middle Division. The Upper Division is composed of think bedded calcareous novaculite (McFarland 1998; Croneis 1930). This formation is the dominant formation within the park, forming the entirety of Hot Springs Mountain, and capping Sugarloaf, West, North, and Indian mountains (Purdue and Miser 1923). The Arkansas Novaculite has long been a source of projectile points by American Indians and is also used in the manufacturing of modern whetstones. Fossils from the Arkansas Novaculite include sponge spicules, radiolarians, conodonts and spores, with none yet described from within park units (Croneis 1930; Henbest 1936; Cooper 1931, 1935; Holbrook and Stone 1978; Hanor 1990).

### *Stanley Shale Group (Upper Mississippian)*

The Arkansas Novaculite is disconformably overlain by the Hot Springs Sandstone member of the Stanley Shale Group, a hard, gray quartzite, interbedded with black shales. The Hot Springs Sandstone type section was described from sections in the vicinity of HOSP, however no formalized location has been made at this time (National Park Service 2007). It can be found on the northern flank of Sugarloaf Mountain, and on the south/southeast face of North, West and Indian mountains (Purdue and Miser 1923). An occasional thin conglomerate / breccia is found near the base of the sequence and may indicate a submarine disconformity between the Hot Springs Sandstone and the Arkansas Novaculite (McFarland 1998; Croneis 1930). Ridges of the Stanley Shale consist of greenish black to black shale, gray sandstones, with traces of chert and tuff. The fragmentary fossilized remains of plants are described by White (1936) from Gillham, Arkansas, to the southwest of HOSP near the Oklahoma border. Invertebrate fossils are known from this member in the area, but have not been described from within the park (Croneis 1930).

## Park Collections and Fossils in Cultural Resource Contexts

The only fossils currently in the HOSP collections seven specimens of graptolite colonies in Polk Creek Shale. These fossils were collected in 1961 by Stu Branson at Blakely Mountain near the Blakely Mountain dam which impounds Lake Hamilton on the Ouachita River. This is in Garland County but not within HOSP (S. Shugart, HOSP Museum Specialist, pers. comm. May 2008). Graptolite colonies have been observed in the portion of Whittington Creek running through park owned land (S. Shugart, HOSP Museum Specialist, pers. comm. July 2008).

Limestone building stones in Bathhouse Row architecture of HOSP are from Alabama and Arkansas (the latter from Batesville; M. Blaeuer pers. comm. May 2008). It is unknown as to whether they contain fossils, but the possibility exists and could be further explored. Fossiliferous building stones are common through the NPS and even within the HTLN (see LIBO and TAPR sections). Such cultural resource contexts present unique interpretive “exposures” of fossils.

## Paleontological Resource Management, Preliminary Recommendations

- T The NPS Geologic Resources Division sponsored geologic resource scoping sessions for HOSP in April 2007 (National Park Service 2007). The lack of adequate baseline paleontological resources data was identified as one of the most significant geological issues in the park and a field-based inventory was recommended. Paleontological resources are known from within the park collections and are known from the geologic formations mapped within the park.
- The park should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be

documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.

- A forthcoming (late 2008-early 2009) Geologic Resource Monitoring Manual by the Geological Society of America and NPS Geologic Resources Division includes a section on paleontological resource management.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Barrick, J. E. and J. N. Haywa-Branch. 1994. Conodont biostratigraphy of the Missouri Mountain Shale (Silurian-Early Devonian?) and the Arkansas Novaculite (Devonian), Black Knob Ridge, Atoka County, Oklahoma. Pages 161-177 in N. H. Suneson and L. A. Hemish, editors. Geology and resources of the eastern Ouachita Mountains frontal belt and southeastern Arkoma Basin, Oklahoma; Part II, Contributed papers. Oklahoma Geological Survey, Norman, Oklahoma.

Barrick, J. E. 1987. Conodonts from the Missouri Mountain Shale (Silurian-Devonian) and lower Arkansas Novaculite (Devonian), Black Knob Ridge, Oklahoma. Geological Society of America Abstracts with Programs **19**:146.

Cooper, C. L. 1935. Conodonts from the upper and middle Arkansas Novaculite, Mississippian, at Caddo Gap, Arkansas. Journal of Paleontology **9**:307-315.

Cooper, C. L. 1931. Conodonts from the Arkansas Novaculite, Woodford Formation, Ohio Shale and Sunbury Shale. Journal of Paleontology **5**:143-151.

Croneis, C. 1930. Geology of Arkansas Paleozoic area with especial reference to oil and gas possibilities. Arkansas Geological Survey, Little Rock, Arkansas. Bulletin 3.

Decker, C. E. 1935. Graptolites of the Sylvan Shale of Oklahoma and Polk Creek Shale of Arkansas. Journal of Paleontology **9**:697-708.

Hanor, J. S., B. Hanor, and E. Adams. 1981. Fire in folded rocks: the geology of Hot Springs National Park. United States National Park Service, Hot Springs, Arkansas.

Henbest, L. G. 1936. Radiolaria in the Arkansas Novaculite, Caballos Novaculite, and Bigfork Chert. Journal of Paleontology **10**:76-78.

Holbrook, D. F. and Stone, C. G. 1978. Arkansas Novaculite: A silica resource. Page 51-57 *in* K. S. Johnson and J. Russell, editors. Thirteenth Annual Forum on the Geology of Industrial Minerals. Oklahoma Geological Survey, Norman, Oklahoma. Circular 79.

Horwitz, J. and Jorstad, R. B. 2005. Online stratigraphy of Hot Springs National Park, Arkansas. Geological Society of America Abstracts with Programs **37**:300.

McFarland, J. D. 1998. Stratigraphic summary of Arkansas. Arkansas Geological Commission, Little Rock, Arkansas. Information Circular 36.

McFarland, J. D. 1988. Geological features at Hot Springs, Arkansas. Pages 263-264 *in* O. T. Hayward, editor. Geological Society of America, Boulder, Colorado. South-central section of the Geological Society of America Field Guide.

National Park Service. 2007. Geologic resource evaluation scoping summary: Hot Springs National Park. National Park Service, Geologic Resources Division, Denver, Colorado. Online. (http://www.nature.nps.gov/geology/inventory/publications/s_summaries/HOSP_scoping_summary_2007-0724.pdf). Accessed 3 June 2008.

Purdue, A. H. and Miser, H. D. 1923. Geological Atlas, Hot Springs folio. U. S. Geological Survey, Washington, D.C. Geologic Atlas Folio 215.

Repetski, J. E. and Ethington, R. L. 1977. Conodonts from graptolite facies in the Ouachita Mountains, Arkansas and Oklahoma. Pages 92-106 *in* C. G. Stone, editor. Symposium on the geology of the Ouachita Mountains, Volume I, Stratigraphy, sedimentology, petrography, tectonics, and paleontology. 7th Annual Meeting of the South-Central Section of Geological Society of America, Little Rock, Arkansas.

Shugart, S. 2003. Hot Springs National Park: a brief history of the park. Department of the Interior, National Park Service. Online. (http://www.nps.gov/hosp/historyculture/upload/Brief%20History%20of%20Bathhouse%20Row.DOC). Accessed May 2008

Stitt, J. H. 1994. Trilobites from the Collier and Womble shales and Bigfork Chert, Ouachita Mountains, Arkansas. Geological Society of America Abstracts with Programs **26**:27.

White, D. 1936. Fossil plants from the Stanley Shale and Jackfork Sandstone in southeastern Oklahoma and western Arkansas. U. S. Geological Survey, Reston, Virginia. Professional Paper 186-C.

## Additional References

Bedinger, M. S., Pearson, F. J., Reed, J. E., Sniegocki, R. T., and Stone, C. G. 1979. The waters of Hot Springs National Park, Arkansas: their origin, nature and management. U. S. Geological Survey, Reston, Virginia. Professional Paper 1044-C.

Dando, K. H. 1980. Stratigraphy and conodont paleontology of the Mazarn Shale south of Lake Ouachita, Garland County, Arkansas. Thesis. University of New Orleans, Louisiana.

Dokka, R. K., Bouma, A. H. and Stone, C. G. 2003. Mississippian and Pennsylvanian stratigraphy and tectonics of the Ouachita Orogenic Belt, Arkansas. Pages 33-62 *In* Field trip guidebook. Geological Society of America, Boulder, Colorado. Joint meeting, South-central and Southeastern sections Geological Society of America 51.

Fellowes, T. L. 1968. Geology of Hot Springs National Park and vicinity, North-central Arkansas. Geological Society of America, Boulder, Colorado. Special Paper 101.

Hass, W. H. 1956. Conodonts from the Arkansas novaculite, Stanley shale and Jackfork sandstone [Arkansas-Oklahoma]. Ardmore Geological Society, Ardmore, Oklahoma. Guidebook Ouachita Mountain, Field Conference.

Hohensee, S. R. and Stitt, J. H. 1989. Redeposited Elvinia zone (Upper Cambrian) trilobites from the Collier Shale, Ouachita Mountains, west-central Arkansas. Journal of Paleontology **63**(6):857-879.

Orr, P. J. 2005. Ecospace utilization in early Phanerozoic deep-marine environments; deep bioturbation in the Blakely Sandstone (Middle Ordovician), Arkansas, U.S.A. Geological Society of America Abstracts with Programs **37**:405.

Stitt, J. H., Rucker, J. D., Boyer, N. D., and Hart, W. D. 1994. New Elvinia zone (Upper Cambrian) trilobites from new localities in the Collier Shale, Ouachita Mountains, Arkansas. Journal of Paleontology **68**:518-523.

## Data Sets

*Hot Springs National Park Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

*Hot Springs National Park Museum Collections*
1921-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by HOSP staff; status: Active.

# Lincoln Boyhood National Memorial

Abraham Lincoln's boyhood home in Indiana was established as Lincoln Boyhood National Memorial (LIBO) on February 19, 1962. This is the farm site where Abraham Lincoln lived from 1816 to 1830, and his mother, Nancy Hanks Lincoln, is buried here. The state of Indiana transferred ownership of the historic property to the Federal government in June of 1963, which is currently composed of 81 ha (199 acres) in Spencer County, Indiana.

## Geologic Background

The LIBO area is underlain by the Brazil and Staunton formations (Pennsylvanian), of the Raccoon Creek Group. These formations consist of mostly shale and sandstone with thin beds of limestone, clay, and coal (Wier 1986). The memorial lies within the Boonville Hills physiographic section (Gray 2000), situated south of the Illinoian and Wisconsin glacial boundaries. During the Wisconsinan (Pleistocene), the tremendous volume of water carried by the Wabash River created a lake that covered much of southwestern Indiana. Depositions dating from this time are responsible for the present topography of broad aggraded valleys separated by low, rolling hills. In unglaciated areas, the soil is thin and easily eroded (Kellar 1956; Schneider 1966; Wayne 1966).

Although both the Brazil and Staunton formations contain fossils, fossils have yet to be described from within LIBO (H. Gray, stratigrapher, Indiana Geological Survey, pers. comm. June 2008; M. Capps, LIBO Chief of Interpretation and Resources, pers. comm. May 2008). Many coal strip mines in Spencer County are unreclaimed and have exposed highwalls where plant fossils have been noted (Canfield 1959; Judd 1968; Judd and Nisbet 1969; H. Gray, stratigrapher, Indiana Geological Survey, pers. comm. June 2008; C. Rexroad, paleontologist, Indiana Geological Survey, pers. comm. June 2008). The Indiana Geological Survey provides geological maps with detailed unit descriptions via their website.

Although no Pennsylvanian fossils have been reported to date, fossils are visible within the "exposures" provided by the fossil-rich Salem Limestone (Mississippian), which is informally called the "Indiana Limestone." Individual grains of the Salem Limestone are mostly microfossils (including especially foraminifera), macrofossil fragments, and whole diminutive forms of macrofossils (Rexroad 1986). The Salem Limestone is used as building stone throughout the visitor center and other structures in the park. See the park collections section below.

## Sources of Paleontological Resources

Fossils have been documented from the building stones within LIBO. These fossils present opportunities for education, interpretation, and offer a connection to the Lincoln Memorial in Washington, DC. They are further described in the "Park Collections and Fossils in Cultural Resource Context" section below.

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within LIBO. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Raccoon Creek Group (Lower-Middle Pennsylvanian)*

The Lower-Middle Mississippian Raccoon Creek Group primarily consists of sandstone and shale with minor amounts of coal, limestone, clay, and chert. The Raccoon Creek Group is divided into the Mansfield, Brazil, and Staunton formations and the group contains the oldest commercial coal-bearing unit in Indiana. Within the Mansfield Formation, which is present in Spencer County, there are seven members with only one, the Lead Creek Limestone Member, known to contain marine and plant fossils.

This member is divided into three sections: a lower dark shaly argillaceous limestone, a middle shale and siltstone, and an upper massive cherty limestone (Shaver 1986). The Lead Creek Limestone Member fossil fauna is dominated by fusulinids of the Profusulinella zone, ostracods of the Amphissites rothi zone, and a low diversity conodont fauna including five genera (Thompson and Shaver 1964; Shaver and Smith 1974; Rexroad et al. 1999, 2008).

The Brazil Formation consists of shale, sandstone, clay, and coal and contains three coal members. The lower portion of this formation is assigned to the *Amphissites rothi* ostracod zone (Thompson and Shaver 1964; Shaver and Smith 1974). LIBO is situated near the boundary between the Brazil Formation and the Staunton Formation (C. Rexroad, paleontologist, Indiana Geological Survey, pers. comm. June 2008).

LIBO is located on the Staunton Formation (H. Gray, stratigrapher, Indiana Geological Survey, pers. comm. June 2008). The three named members that compose the Staunton Formation all are known to contain fossils, although none have been noted from within LIBO boundaries. All are considered to be part of the *Amphissites centronotus* ostracod zone. The Perth Limestone Member is a gray, argillaceous and fossiliferous limestone containing sponge spicules, the ostracods *Amphissites centronotus* and *A. girtyi*, microcrinoids, and conodonts (Hamilton 1975; Lane 1981, 1982; Brown 1993; Rexroad et al. 1998). Ostracods and conodonts have been collected from the Perth Limestone Member 3.2-4.8 km (2-3 miles) south of LIBO (Shaver and Smith 1974; Rexroad et al. 1999; C. Rexroad, paleontologist, Indiana Geological Survey, pers. comm. June 2008). The Holland Limestone Member is composed of chert, limestone, and shale and clay that contain limestone pebbles (Franklin and Wanless 1944). Fossils within this member consist of the fusulinids *Fusulina wedekindellina* (St. Jean 1957), and the Weller Falls Fauna with a diversity of marine invertebrates such as foraminifera, sponges, bryozoans, brachiopods, bivalves, gastropods, cephalopods, scaphopods, rostroconchs, ophiuroids, trilobites, ostracods, and crinoids (Campbell 2002). Less than 0.8 km (0.5 miles) south of Lincoln City a railroad cut, known as “Eliza’s cut”, exposes the Holland Limestone Member (H. Gray, stratigrapher, Indiana Geological Survey, pers. comm. June 2008). The Silverwood Limestone Member is a dark-blue to gray fossiliferous limestone, with calcareous fossiliferous shales which preserve conodonts (Stanley 1982).While the fossils noted from the Raccoon Creek Group are common throughout its formations within the state, they have yet to be identified from within the LIBO area. Based on this potential for paleontological resources, future field investigations in the park may identify fossiliferous exposures of Raccoon Creek Group.

### *Carbondale Group (Middle Pennsylvanian)*

The Carbondale Group includes shales and sandstones with some laterally persistent limestone beds and five of Indiana's commercially important coal units. The group is composed of three formations: the Linton, Petersburg, and Dugger formations. The Linton Formation is found in Spencer and Warrick counties, to the west of LIBO. The Linton Formation includes six named members, two of which contain marine fossils. These include the Mecca Quarry Shale Member (Hasenmueller and Ault 1991), a gray to black evenly bedded shale, and the Velpen Limestone Member, a tan to black, dense, and argillaceous limestone (Burger et al. 1986). The Mecca Quarry Shale Member is regionally abundant in brachiopods, cephalopods, gastropods, conodonts, and fish (Rexroad 1999). The pelecypod *Dunbarella* is found within most rock exposures of the Mecca Quarry Shale Member. The Velpen contains calcareous, fossiliferous shale and finely crystalline limestone that contains the abundant remains of brachiopods, crinoid fragments and conodonts (Wade 1978; Rexroad 1999, 2001). The Carbondale Group is only exposed west of LIBO, so fossils from this unit are not expected to be found within the park.

## Park Collections and Fossils in Cultural Resource Context

No fossils are known from LIBO park collections (M. Capps, Chief of interpretation and resources, pers. comm. May 2008). However, fossil marine invertebrates (foraminifera, corals, bryozoans, mollusks and crinoids) are present and easily visible in the “Indiana Limestone” (formally the Mississippian Salem Limestone) used as building stone for the memorial and visitor center. This stone was quarried near

Bloomingon. Similar fossils occur as well within other monuments, memorials, and stone structures in the park.

The "Indiana Limestone" is an extraordinarily fossiliferous unit and an extraordinarily popular building stone throughout the United States. Many of our nation's buildings therefore display fossils from the state of Indiana. Fittingly, the Lincoln Memorial in Washington, D.C., contains Indiana Limestone blocks as does the U.S. Capitol Reflecting Pool and numerous other buildings in downtown Washington, D.C. All of these buildings display abundant and easy to recognize marine invertebrate fossils (Kenworthy and Santucci 2004). Fossils in building stones are a common example of NPS fossils found in cultural resource contexts. Kenworthy and Santucci (2006) provide an overview of this topic and examples of building stones that display fossils, including the "Indiana Limestone."

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for LIBO. Formal paleontological inventories have likewise not yet been completed. Paleontological resources are not currently known from within the geological exposures in LIBO and there are no fossils within the park's museum collections. However fossils from these formations are well known in other parts of Indiana. Fossils are visible in "exposures" of the Salem Limestone used as a building stone throughout the park. They provide a link to the Lincoln Memorial in Washington, DC, which was constructed of the same stone.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- If significant fossil resources are discovered within the park, LIBO should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited

Brown, L. M., C. B. Rexroad, and R. J. Suman. 1993. Conodonts from the Perth limestone member, Staunton Formation (Pennsylvanian, Desmoinesian), from the southeastern part of the Illinois Basin. Geological Society of America Abstracts with Programs **25**:9.

Burger, A. M. and C. E. Wier. 1986. Carbondale Group. Page 27 *in* R. H. Shaver, C. H. Ault, A. M. Burger, D. D. Carr, J. B. Droste, D. L. Eggert, H. H. Gray, D. Harper, N. R. Hasenmueller, W. A. Hasenmueller, A. S. Horowitz, H. C. Hutchison, B. D. Keith, S. J. Keller, J. B. Patton, C. B. Rexroad, and C. E. Weir, editors. Compendium of Paleozoic rock-unit stratigraphy in Indiana; A Revision. Indiana Geological Survey, Bloomington, Indiana. Bulletin 59.

Burger, A. M., C. E. Wier, and C. H. Ault. 1986. Velpen Limestone Member. Page 106 *in* R. H. Shaver, C. H. Ault, A. M. Burger, D. D. Carr, J. B. Droste, D. L. Eggert, H. H. Gray, D. Harper, N. R. Hasenmueller, W. A. Hasenmueller, A. S. Horowitz, H. C. Hutchison, B. D. Keith, S. J. Keller, J. B.

Patton, C. B. Rexroad, and C. E. Weir, editors. Compendium of Paleozoic rock-unit stratigraphy in Indiana; A Revision. Indiana Geological Survey, Bloomington, Indiana. Bulletin 59.

Campbell, M. R. 2002. Faunal patterns of Pennsylvanian silicified marine gastropoda from Indiana. Geological Society of America Abstracts with Programs **34**:117.

Canright, J. E. 1959. Fossil plants of Indiana. Indiana Geological Survey, Bloomington, Indiana. Report of Progress 14.

Franklin, D. W. and H. R. Wanless. 1944. Pennsylvanian stratigraphy of part of southern Indiana. Transactions of the Illinois State Academy of Science **37**:85.

Gray, H. H. 2000. Physiographic divisions of Indiana. Indiana Geological Survey, Bloomington, Indiana. Special Report 61.

Hamilton, M. M. 1975. The paleoecology and stratigraphy of the Perth Limestone (Pennsylvanian) and underlying shales in Warren County, Indiana. Thesis. Indiana University, Bloomington, Indiana.

Hasenmueller, W. A., and C. H. Ault. 1991. Reference and correlation of key beds in the Petersburg and Linton Formations (Pennsylvanian) in Indiana. Indiana Geological Survey, Bloomington, Indiana. Occasional Paper 57.

Judd, R. W. and J. J. Nisbett. 1969. Pennsylvanian coal ball flora of Indiana. Proceedings of the Indiana Academy of Science **78**:120.

Judd, R. W. 1968. Pennsylvanian coal ball flora of Indiana. Thesis. Ball State University, Muncie, Indiana.

Kellar, J. H. 1956. An Archaeological Survey of Spencer County, Indiana. Indiana Historical Bureau, Indianapolis.

Kenworthy, J. P. and V. L. Santucci. 2004. Paleontological resource inventory and monitoring, National Capital Region. National Park Service TIC# D-289.

Kenworthy, J. P. and V. L. Santucci. 2006. A preliminary inventory of National Park Service paleontological resources in cultural resource contexts, Part 1: General Overview. Page 70-76 *in* S. G. Lucas, J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. Fossils from Federal Lands. New Mexico Museum of Natural History and Science, Albuquerque, New Mexico. Bulletin 34.

Lane, N. G., and G. D. Sevastopulo. 1982. Growth and systematic revision of *Kallimorphocrinus astrus*, a Pennsylvanian microcrinoid. Journal of Paleontology **56**:244-259.

Lane, N. G. 1981. A nearshore sponge spicule mat from the Pennsylvanian of west-central Indiana. Journal of Sedimentary Petrology **51**:197-202.

Peppers, R. A. 1964. Spores in strata of Late Pennsylvanian cyclothems in the Illinois Basin. Illinois State Geological Survey, Champaign, Illinois. Bulletin 90.

Rexroad, C. B. 1986. Salem Limestone. Page 132-133 *in* R. H. Shaver, C. H. Ault, A. M. Burger, D. D. Carr, J. B. Droste, D. L. Eggert, H. H. Gray, D. Harper, N. R. Hasenmueller, W. A. Hasenmueller, A. S. Horowitz, H. C. Hutchison, B. D. Keith, S. J. Keller, J. B. Patton, C. B. Rexroad, and C. E. Weir, editors. Compendium of Paleozoic rock-unit stratigraphy in Indiana; A Revision. Indiana Geological Survey, Bloomington, Indiana. Bulletin 59.

Rexroad, C. B., W. J. Nelson, and P. L. Meighen. 2008. Aspects of Pennsylvanian, stratigraphy, sedimentation, and conodonts in southwestern Indiana. Geological Society of America, Boulder, Colorado. Field Guide 12.

Rexroad, C. B., L. M. Brown, and N. A. Wilke. 1999. Conodont paleontology of the Lead Creek Limestone Member of the Mansfield Formation (Pennsylvanian) in Indiana. American Association of Petroleum Geologists Bulletin **83**:1372.

Rexroad, C. B., L. M. Brown, J. Devera, and R. J. Suman. 1998. Conodont biostratigraphy and paleoecology of the Perth Limestone Member, Staunton Formation (Pennsylvanian) of the Illinois Basin, U.S.A. Palaeontologica Polonica **58**: 247-259.

Rexroad, C. B., J. A. Wade, G. K. Merrill, L. M. Brown, and P. Padgett. 2001. Conodont biostratigraphy and depositional environments of the Mecca Quarry Shale Member and the Velpen Limestone Member of the Linton Formation (Pennsylvanian, Desmoinesian) in the eastern part of the Illinois Basin, U.S.A. Indiana Geological Survey, Bloomington, Indiana. Special Report 63.

Rexroad, C. B., J. A. Wade, G. K. Merrill, and P. Padgett-Alano. 1999. Conodont biostratigraphy of the Mecca Quarry Shale Member and the Velpen Limestone Member of the Linton Formation (Pennsylvanian, Desmoinesian) in the eastern part of the Illinois Basin, USA. Geological Society of America Abstracts with Programs **31**:67.

Schneider, A. F. 1966. Physiography, Page 48 *in* A. A. Lindsey, editor. Natural Features of Indiana. Indiana Academy of Sciences, Indianapolis.

Shaver, R. H. 1986. Lead Creek Limestone Member. Page 74-75 *in* R. H. Shaver, C. H. Ault, A. M. Burger, D. D. Carr, J. B. Droste, D. L. Eggert, H. H. Gray, D. Harper, N. R. Hasenmueller, W. A. Hasenmueller, A. S. Horowitz, H. C. Hutchison, B. D. Keith, S. J. Keller, J. B. Patton, C. B. Rexroad, and C. E. Weir, editors. Compendium of Paleozoic rock-unit stratigraphy in Indiana; A Revision. Indiana Geological Survey, Bloomington, Indiana. Bulletin 59.

Shaver, R. H. and S. G. Smith. 1974. Some Pennsylvanian kirkbyacean ostracods of Indiana and midcontinent series terminology. Indiana Geological Survey, Bloomington, Indiana. Report of Progress 31.

St. Jean, J. 1957. A Middle Pennsylvanian foraminifera fauna from Dubois County, Indiana. Indiana Geological Survey, Bloomington, Indiana. Bulletin 10.

Stanley, S. G. 1982. Conodont micropaleontology and biostratigraphy of the Silverwood Limestone Member, Universal Limestone Member, and Salt Creek Limestone Lens (Desmoinesian). Thesis. Ball State University, Muncie, Indiana.

Thompson, M. L. and R. H. Shaver. 1964. Early Pennsylvanian microfaunas of the Illinois Basin. Transactions of the Illinois State Academy of Science **57**: 3.

The Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin. 2001. Toward a more uniform stratigraphic nomenclature for rock units (formations and groups) of the Pennsylvanian System in the Illinois Basin. Illinois Basin Consortium, Champaign, Illinois. Study 5.

Wade, J. A. 1978. Conodont paleontology of the Velpen Member, Linton Formation (Desmoinesian), Parke County, Indiana. Thesis. Indiana University, Bloomington, Indiana.

Wayne, W. J. 1966. Ice and land, Pages 32-36 *in* A. A. Lindsey, editor. Natural Features of Indiana. Indiana Academy of Sciences, Indianapolis, Indiana.

Wier, C. E. 1986. Raccoon Creek Group. Page 120-121 *in* R. H. Shaver, C. H. Ault, A. M. Burger, D. D. Carr, J. B. Droste, D. L. Eggert, H. H. Gray, D. Harper, N. R. Hasenmueller, W. A. Hasenmueller, A. S. Horowitz, H. C. Hutchison, B. D. Keith, S. J. Keller, J. B. Patton, C. B. Rexroad, and C. E. Weir, editors. Compendium of Paleozoic rock-unit stratigraphy in Indiana; A Revision. Indiana Geological Survey, Bloomington, Indiana. Bulletin 59.

## Additional References

Bassett, J. L. 1980. Chert resources of the Upper Patoka drainage basin. Page 89 *in* C. A. Munson, editor. Archaeological Salvage Excavations at Patoka Lake, Indiana: Prehistoric Occupations of the Upper Patoka River Valley. Indiana University, Bloomington, Indiana. Research Reports 6.

Baxter, R. W. 1950. *Peltastrobus reedae*, a new sphenopsid cone from the Pennsylvanian of Indiana. Botanical Gazette **112**:174.

Baxter, R. W. 1951. *Ankyropteris glabra*, a new American species of the *Zygopteridaceae*. American Journal of Botany **38**:440-452.

Brown, L. M. 1991. Conodont paleontology of the Providence Limestone Member of the Dugger Formation (Pennsylvanian, Desmoinesian) in the southern part of the Illinois Basin. Journal of Paleontology **65**:945-957.

Cantin M. and K. B. Tankersley. 1988. Redefinition of several Upper Mississippian and Lower Pennsylvanian chert types in southern Indiana. The 104th annual meeting of the Indiana Academy of Science, South Bend, Indiana.

Cantin, M. and C. M. Anslinger. 1985. Variations in temporal usage of Holland chert in selected areas in southwestern Indiana. The annual meeting of the Indiana Historical Society, Indianapolis, Indiana,

Collins, M. B. 1980. Fluvial deposits and archaeological interpretation, middle Salt River valley, Kentucky. Geological Society of America Abstracts with Programs **12**:222.

Cooper, C. L. 1946. Pennsylvanian ostracodes of Illinois. Illinois State Geological Survey, Champaign, Illinois. Bulletin 70.

Gray, H. H. 1978. Buffalo Wallow Group upper Chesterian (Mississippian) of southern Indiana. Indiana Geological Survey, Bloomington, Indiana. Occasional Paper 25.

Guennel, G. K. 1952. Fossil spores of the Alleghenian coals in Indiana. Indiana Geological Survey, Bloomington, Indiana. Report of Progress 4.

Gutschick, R. C. 1966. Bedrock Geology. Pages 1-3 *in* A. A. Lindsey, editor. Natural Features of Indiana. Indiana Academy of Sciences, Indianapolis, Indiana.

Hall, J. and J. M. Clarke. 1894. An introduction to the study of Paleozoic brachiopods, Part II. New York State Geologist, Annual Report **13**:749.

Jacobson, R. J., C. B. Trask, C. H. Ault, D. D. Carr, H. H. Gray, W. A. Hasenmueller, D. Williams, and A. D. Williamson. 1985. Unifying nomenclature in the Pennsylvanian System of the Illinois Basin. Transactions of the Illinois State Academy of Science **78**:1.

Maples, C. G. 1985. Paleontology, paleoecology, and depositional setting of the lower part of the Dugger Formation (Pennsylvanian; Desmoinesian) in Indiana. Dissertation. Indiana University, Bloomington, Indiana.

Oestry-Stidd, L. L. 1979. Anatomically preserved *Neuropteris rarinervis* from American coal balls. Journal of Paleontology **53**:37-43.

Reynolds, D. 1968. Union Chapel pool, Spencer County, Indiana. Page 237-241 *in* Geology and petroleum production of the Illinois basin, a symposium. Illinois Oil and Gas Association, Mt. Vernon, Illinois. Illinois and Indiana-Kentucky Geological Society.

Schweers, F. P. 1940. Some Lower Pennsylvanian foraminifers of Spencer County, Indiana. Thesis. Indiana University, Bloomington, Indiana.

Shaver, R. H., C. H. Ault, A. M. Burger, D. D. Carr, J. B. Droste, D. L. Eggert, H. H. Gray, D. Harper, N. R. Hasenmueller, W. A. Hasenmueller, A. S. Horowitz, H. C. Hutchison, B. D. Keith, S. J. Keller, J. B. Patton, C. B. Rexroad, and C. E. Weir. 1986. Compendium of Paleozoic Rock-Unit Stratigraphy in Indiana; A Revision. Indiana Geological Survey, Bloomington, Indiana. Bulletin 59.

Stafford, C. R., C. M. Anslinger, M. Cantin, and R. E. Pace. 1988. An analysis of data center site surveys in southwestern Indiana. Indiana State University, Terre Haute, Indiana. Anthropology Laboratory Technical Report 3.

Waninger, S. 2006. Early Wisconsinan (?) eolian activity along the Ohio River in southwestern Indiana. Geological Society of America Abstracts with Programs **38**:60.

White, C. A. 1884. The fossils of Indiana rocks (no. 3). Indiana Department of Geology and Natural History Annual Report **13**:107-108.

## Data Sets

### *Lincoln Boyhood Home National Memorial Paleontological Archives*

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

# Ozark National Scenic Riverways

In 1962 President John F. Kennedy endorsed the formation of Ozark National Scenic Riverways (OZAR) in south-central Missouri, with President Lyndon Johnson signing the park's enabling legislation in August of 1964. Approximately 32,375 ha (80,000 acres) of land along the Current and Jacks Fork rivers today form Ozark National Scenic Riverways. OZAR is a riverine corridor through Shannon, Carter, Dent, and Texas counties in southeastern Missouri (Stevens 1991). OZAR preserves 216 km (134 miles) of the Current and Jacks Fork rivers. This unit of the National Park Service was the first designated national scenic river. The site preserves a wide range of natural, cultural, and recreational resources.

## Geologic Background

Ozark National Scenic Riverways in southeastern Missouri comprises Mesoproterozic ("Precambrian"; see Figure 2) extrusive volcanic rocks along with Late Cambrian and Early Ordovician-aged sedimentary rocks. The volcanic granites and rhyolites were deformed and uplifted, with erosion beginning in the Mesoproterozoic and continuing through Neoproterozoic time (Kisvarsanyi 1979; Weary and Schindler 2004). The sedimentary rocks are composed of lower Paleozoic marine strata, chiefly dolomite, chert, orthoquartzite and sandstone. The Paleozoic strata are flat lying, exhibiting numerous karst features, including sinkholes, springs, and underground drainage, with 300-400 recorded caves (Santucci et al. 2001; Orndorff et al. 2006). Fossils are known within the park from both the Paleozoic bedrock and in association with the park's caves.

The Upper Cambrian within OZAR is represented by five geologic formations, dominated by dolomite, sandstone and shale. From oldest to youngest, these are the Lamotte Sandstone, Bonneterre Formation, Davis Formation, Derby-Doerun Dolomite, the Potosi Dolomite, and the Eminence Dolomite. Only the Potosi and Eminence Dolomites are exposed at the surface in the park. During the Upper (Late) Cambrian, the OZAR area was flooded by a large epicontinental sea that covered most of the midwestern United States. Due to the topography during that time, low areas were covered by the sea with areas of higher elevation remained above the water and formed islands. The youngest formation exposed within the park is the Lower (Early) Ordovician Roubidoux Formation.

The NPS Geologic Resources Division conducted a geological scoping summary on December 4-6, 2001. The USGS has been conducting geologic mapping at 1:24,000 scale of quadrangles in the OZAR and BUFF areas (KARST Project). Currently six geologic quadrangles have been mapped for OZAR by the USGS, with three more planned for FY2008-09 (Orndorff et al. 1999; McDowell and Harrison 2000; Harrison et al. 2002; Weary and Schindler 2004; Weary and Weems 2004; Weary and McDowell 2006;). One geologic quadrangle was mapped by the Missouri Geological Survey (Baker 1999). A thematic inventory on paleontological resources associated with National Park Service caves includes a discussion on fauna known from some of the more than 300-400 caves within OZAR (Santucci et al. 2001), and preliminary reports on conodont microfossils and biostratigraphy of the Roubidoux Formation have been published by USGS cooperators and their colleagues (Repetski et al. 1998, 2000b).

## Sources of Paleontological Resources

Fossils have been documented from the following geologic formations, caves, and museum collections within OZAR. These fossils present opportunities for resource management (including field surveys, inventory, and monitoring), education, interpretation, and continued or future scientific research in the park.

### *Eminence Dolomite (Upper Cambrian)*

The Eminence Dolomite is a medium- to coarse-grained, medium- to thick-bedded, dolomite that contains minor amounts of chert (Weary and Schindler 2004). Gastropods, other mollusks, and trilobites

are known from this unit, although none have been described from within park boundaries at this time. Stromatolites are documented from within the park (Bridge 1930; Rasetti 1952; Yochelson and Stinchcomb 1987; Yochelson and Nuelle 1985; Stinchcomb 1986; Weary and Schindler 2004). The Eminence Dolomite is also one of the main cave-forming units within OZAR (see below), with the majority of caves concentrated just below the Gunter Sandstone Member of the overlying Gasconade Formation (Orndorff et al, 2006).

### *Roubidoux Formation (Lower Ordovician)*

The youngest geologic bedrock formation within OZAR is the Roubidoux Formation (Weary and Schindler 2004). Dominated by dolomite (cherty dolomite, sandy dolomite, dolomitic sandstone), quartz sandstone, orthoquartzite, cherty sandstone, chert and sandstone breccia, this formation rarely contains fossils. There are occasional impressions and molds of the gastropod *Lecanospira,* brachiopods and crinoid fragments in quartz sandstones and cherts within the park. These are curated at the Smithsonian Institution and U.S. Geological Survey as described below in the Park Collections section. Stromatolite fossils are found within some of the cherts. The remains of cephalopods and trilobites are documented from this formation outside of the park (Harrison et al. 1996; Heller 1954; Weary and Schindler 2004), and conodonts are present sporadically throughout the Roubidoux including within the park (see Park Collections section below; Repetski et al., 2000b).

### *Fossils Associated with OZAR Caves (Pleistocene-Holocene)*

The extensive cave and karst features within OZAR often contain paleontological resources. As described by Santucci et al. (2001), fossils in caves can occur in two contexts: Paleozoic marine invertebrates in the carbonate rocks that make up the cave or as Pleistocene-Holocene age fossils of organisms which either died in or were transported into the caves after death. Cave fossils from OZAR were featured in a summary of fossils in NPS caves (Santucci et al. 2001). The following section is extracted from that report. Subsequent to the 2001 inventory additional fossils have been found in OZAR caves and there is excellent potential for continued fossil discovery.

> Pleistocene mammal remains have been collected from a number of the park's 300-400 caves and overhangs. Oscar "Oz" Hawksley, of Central Missouri State University, collected many of these fossils between the 1950s and 1980. Much of Hawksley's collection is now curated in the Illinois State Museum Vertebrate Paleontology Collection. American black bear (*Ursus americanus*) remains were found in a number of caves including Bat, Leather Creek, and Wind (Tucker 1984). Short-faced bear (*Arctodus simus*) bones have been found in both Round Spring Cavern and Powder Mill Creek Cave. Jaguar (*Panthera onca*) bones are known from Bat Cave. The stilt-legged deer *Sangamona* (or *Odocoileus*) has been described from Little Bluff Cave. Remains of beaver (*Castor canadensis*) and dire wolf (*Canis* (*Aenocyon*) *dirus*) were collected in Powder Mill Creek Cave (Galbreath 1964). In addition, wolf material was collected from Round Spring Cavern (B. Schubert, Curator of Vertebrates and Assistant Professor East Tennessee State University (currently), pers. comm., 2001). Portions of a giant armadillo carapace are also reported from the park's caves (C. Putnam, OZAR Resource Manager (now retired), pers. comm., 2001).

Most fossils in Shannon and Oregon counties, however, are from animal species that still occupy the area today, such as porcupine (*Erithizon dorsatum*), cougar (*Felis concolor*), and gray wolf (*Canis lupus*; Hawksley 1986; Weary and Schindler 2004). All Pleistocene vertebrate fossils from the caves of Missouri are Wisconsinan or younger (Reams 1968; Weary and Schindler 2004).

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within OZAR. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Lamotte Sandstone (Upper Cambrian)*
Clastic (composed of eroded rock fragments) deposits belonging to the Lamotte Sandstone represent the initial onlap of Cambrian seas. Distribution of this unit is somewhat erratic and some of the conglomeratic deposits at its base are probably of Neoproterozoic age, representing residuum (erosional "leftovers") and proximal fluvial (river) facies of a long-lasting erosional event that predated the marine transgression. Locally derived pebbles and boulders of silicic volcanic and plutonic rocks are the chief constituents of the conglomerate, which rests directly upon Mesoproterozoic basement rocks. Little research has been dedicated to the basal Paleozoic clastic rocks anywhere in the midcontinent; yet, they occupy an interval representative of hundreds of millions of years of geologic history. The Lamotte Sandstone is comprised of arkosic and quartzose sandstone. This unit pinches out and is on-lapped by the younger Bonneterre Formation in the vicinity of the Mesoproterozoic basement.

### *Bonneterre Formation (Upper Cambrian)*
The interbedded dolomite, limestone, and siltstone of the Bonneterre Formation conformably overlies the Lamotte Sandstone and, locally, unconformably overlies the Middle Proterozoic volcanic rocks (Weary and Schindler 2004). Sponges, hyoliths, brachiopods, gastropods, other mollusks and trilobites (Lochman 1934, 1936, 1940, 1968; Hu 1970) are known from this formation outside of the park (Lochman 1940; Stinchcomb 1975; Kurtz 1971). This formation is present only in the subsurface of the park.

### *Davis Formation (Upper Cambrian)*
The Davis Formation conformably overlies the Bonneterre Formation and is composed of shale, siltstone, sandstone, dolomite, and limestone conglomerate (Weary and Schindler 2004). The Davis shales are dark green in color, fissile, and thin- to thick-bedded. These shales compose as much as 50 percent of the formation. Limestones present are typically light-gray, fine-grained to cryptogranular, dense, and locally glauconitic. The Davis Formation contains intraformational sedimentary breccias and grainstones. Within OZAR the Davis Formation occurs only in the subsurface (Weary and Schindler 2004). Outside of OZAR boundaries, the Davis Formation contains the remains of stromatolites and trilobites within its interbedded silty dolomite and green shale (Fraunfelter 1986; Stitt 1983). Due to its unexposed nature within the park, the discovery of fossils is unlikely at this time.

### *Derby-Doerun Dolomite (Upper Cambrian)*
The Derby-Doerun Dolomite is composed chiefly of buff to brown or light-gray dolomite that is fine- to medium-grained, thin- to medium-bedded with minor amounts of chert and sparse sulfide minerals, occasionally being vuggy and porous. Siltstone and shale present are thin-bedded and interbedded with the dolomite. The Derby-Doerun Dolomite (usage of Missouri Geological Survey, 1979) originally was separated into two formations described from outcrops near mines operated by the Derby Lead Co. and the Doe Run Lead Co. in St. Francois County, Missouri (Thompson 1995; Weary and Schindler 2004). No fossils have been reported from this unit. This formation is present only in the subsurface of the park.

### *Potosi Dolomite (Upper Cambrian)*
The Potosi Dolomite is the oldest sedimentary unit exposed in the park. Potosi Dolomite is fine- to medium-grained, thick-bedded, vuggy, porous dolomite that is locally stromatolitic within the riverway exposures. The dolomite crops out at the base of bluffs along the Current River and the lower Pike Creek valley in the northeastern part of the Van Buren South quadrangle (Weary and Schindler 2004). Distinct cavern development is present at or near the contact between the Potosi and the overlying Eminence Dolomite (minor caves and other solution features). The Potosi is characteristically unfossiliferous, but is known to contain some fossilized gastropods, other mollusks, and trilobites, from localities outside of the park (Weary and Schindler 2004; Stinchcomb 1986).

### *Gasconade Dolomite (Lower Ordovician)*
The Lower Ordovician Gasconade Dolomite is divided into five units and comprises dolomite, *Cryptozoon* chert, sandstone, and orthoquartzite (silica-cemented quartz sandstone). Mollusks, including

planispiral gastropods and cephalopods, along with stromatolites are known from this formation (Stinchcomb 1975; Harrison et al. 1996; Weary and Schindler 2004; Pojeta et al. 2005). Conodont biostratigraphy suggests that there could be multiple unconformities within the basal Gasconade (Repetski et al. 2000a). Stromatolite fossils are often found in chert blocks within the regolith derived from the Gasconade Dolomite. The upper part of the Gasconade Dolomite is the main cave-forming unit in the park. Caves are concentrated just below the upper contact with the Roubidoux Formation (Orndorff et al. 2006).

## Park Collections and Fossils in Cultural Resource Contexts

Fossils from the Roubidoux Formation are the only examples of marine invertebrates from the Paleozoic bedrock and Pleistocene-Holocene fossils from the park's caves comprise the majority of fossils within OZAR museum collections. Additionally, some of these fossils were found in cultural resource contexts.

Conodonts, and a rock slab with numerous *Lecanospira* gastropod molds from the Roubidoux Formation, published from OZAR are reposited with the Paleobiology Department at the U.S. National Museum of Natural History, Washington, DC, and at the U.S. Geological Survey, Reston, Virginia (Repetski, 1998). Short-faced bear (*Arctodus simus*) remains from Round Spring Cavern in the OZAR collections are reposited at the Illinois State Museum, Research & Collections Center (ISM) (OZAR accession 292, catalog # 25484-25485). The remains of jaguar, stilt legged deer, extinct beaver, short faced bear, wolf and black bear from OZAR are also reposited at ISM (OZAR accession 309, catalog # 25516, 202 specimens). In 1961 black bear (*Ursus americanus*) remains were recovered from Bat Cave, Shannon County (at the time this cave was on private land, but is now within OZAR). While cleaning the remains a Nodena arrow point was discovered embedded in the pelvis, an example of cultural resources being found in a paleontological resource context. Kenworthy and Santucci (2006) provide an overview of NPS paleontological resources in cultural resource contexts. This specimen is now reposited at the Department of Natural Resources, Division of Geology and Land Survey, in Rolla, Missouri (OZAR accession #327, catalog #25591; B. Culpepper, OZAR Collections Manager, pers. comm. May 2008). Dire wolf (*Canis dirus*) and giant short-faced bear (*Arctodus simus*) specimens have been found within Powder Mill Creek Cave (within OZAR watershed; dire wolf - OZAR accession #325, catalog #25589; Galbreath 1964) and both specimens are curated at the ISM (B. Schubert, Curator of Vertebrates and Assistant Professor, East Tennessee State University, pers. comm., June 2008). In addition, stag moose (*Cervalces*) and Jefferson's ground sloth (*Megalonyx jeffersonii*) remains have recently been recovered from this cave and are also curated at the ISM (B. Schubert, pers. comm., June 2008).

A fossil snail and an unidentified fossil shell are curated in the Midwest Archeological Center collections from OZAR and are known from a cultural context, likely being transported to the area by humans (D. Bringelson, Archaeologist, MWAC, pers. comm., May 2008). The fossil snail (OZAR catalog # 18288) was collected during excavation of a late prehistoric feature at a site on Shawnee Creek. The object was clearly brought to this location by humans about AD 1000-1100. The fossil shell (OZAR catalog # 21361) was collected from the surface of an archaeological site in Dent County by James and Cynthia Price (M. Lynott, Archaeologist, Midwest Archeological Center, pers. comm., June 2008). Other likely locations for collections of OZAR fossil remains include Central Missouri State University (OZAR Archive Accession #323, Catalog #25587; Hawksley 1986), University of Michigan Museum of Paleontology, College of the Ozarks, and University of Missouri Columbia (B. Culpepper, OZAR Collections Manager, pers. comm. May 2008).

## Paleontological Resource Management, Preliminary Recommendations

- The NPS Geologic Resources Division sponsored geologic resource scoping sessions for OZAR in December 2001 (National Park Service 2001). Paleontological resources are known from within the park collections, the geologic formations mapped within the park, and from within the

extensive karst features of the park. There is potential for future discovery within the park's exposures of geologic units that are known to preserve fossils outside of the park.

- The park should consider future field inventories for paleontological resources to more fully document *in situ* and karst occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) and karst features for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- A forthcoming (late 2008-early 2009) Geologic Resource Monitoring Manual by the Geological Society of America and NPS Geologic Resources Division includes a section on paleontological resource management.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Baker, H. 1999. Geologic map of the Grandin SW 7.5' quadrangle. Missouri Division of Geology and Land Survey, Jefferson City, MO. OFM-99-342-GS. 1:24,000 scale.

Bridge, J. 1930. Geology of the Eminence and Cardareva quadrangles. Missouri Division of Geology and Land Survey, Jefferson City, MO. 2nd Series Volume 24. 1:62,500 scale.

Fraunfelter, G. H. 1986. Trace fossils associated with algal stromatolites in the Davis Formation (Upper Cambrian) near Leadwood, Missouri. Transactions of the Illinois State Academy of Science **79**:42.

Galbreath, E. C. 1964. A dire wolf skeleton and Powder Mill Creek cave, Missouri. Transactions of the Illinois State Academy of Science **57**:224-242.

Harrison, R. W., R. C. Orndorff, and D. J. Weary. 2002. Geology of the Stegall Mountain 7.5-Minute Quadrangle, Shannon and Carter Counties, South-central Missouri. U.S. Geological Survey, Reston, Virginia. Geologic Investigations Series Map I–2767. 1:24,000 scale.

Harrison, R .W., R. C. Orndorff, and R. E. Weems. 1996. Geology of the Fort Leonard Wood Military Reservation and adjacent areas, south-central Missouri, with contributions on Quaternary terraces by Paul E. Albertson, Dennis Mienert, and Grant Butler. U.S. Geological Survey, Reston, Virginia. Open-File Report 96–60.

Hawksley, O. 1986. Remains of Quaternary vertebrates from Ozark caves and other miscellaneous sites. Missouri Speleology **26**:67 p.

Heller, R .L. 1954. Stratigraphy and paleontology of the Roubidoux Formation of Missouri. Missouri Geological Survey, Jefferson, MO. Water Resources Reports, 2nd Series 35.

Henry, A. L. 1992. Alteration of organic matter in the Viburnum Trend lead-zinc district of southeastern Missouri. Economic Geology and the Bulletin of the Society of Economic Geologists **87**:288-309.

Hu, C. H. 1970. Ontogenies and sexual dimorphisms of two upper Cambrian trilobites. Proceedings of the Geological Society of China **13**:143-155.

Kisvarsanyi, E. B. 1979. Structure contour map of buried Precambrian basement-rock surface, Rolla 1 x 2 quadrangle and adjacent areas, Missouri. U.S. Geological Survey, Reston, Virginia. Miscellaneous Field Studies Map MF–1001–B. 1:250,000 scale.

Kurtz, V. E. 1971. Upper Cambrian *Acrotretidae* from Missouri. Journal of Paleontology **45**:470-476.

Lochman, C. 1968. *Crepicephalus faunule* from the Bonneterre Dolomite (Upper Cambrian) of Missouri. Journal of Paleontology **42**:1153-1162.

Lochman, C. 1940. Fauna of the basal Bonneterre dolomite (Upper Cambrian) of southeastern Missouri. Journal of Paleontology **14**:1-53.

Lochman, C. 1936. New trilobite genera from the Bonneterre dolomite (Upper Cambrian) of Missouri. Journal of Paleontology **10**:35-43.

Lochman, C. 1934. Fauna of the basal Bonneterre Formation of Missouri. Proceedings of the Geological Society of America:335-336.

Lyle, J. R. 1977. Petrography and carbonate diagenesis of the Bonneterre Formation in the Viburnum Trend area, southeast Missouri. Economic Geology **72**:420-434.

McDowell, R .C. and R. W. Harrison. 2000. Geologic map of the Powder Mill Ferry quadrangle, Shannon and Reynolds Counties, Missouri. U.S. Geological Survey, Reston, Virginia. Geologic Investigations Series Map I–2722. 1:24,000 scale.

National Park Service. 2001. Geologic resources evaluation scoping summary: Ozark National Riverways. National Park Service, Geologic Resources Division, Denver, Colorado. Online. (http://www.nature.nps.gov/geology/inventory/publications/s_summaries/OZAR_scoping_summary_20011210.pdf). Accessed 3 June 2008.

Orndorff, R. C., R. W. Harrison, and D. J. Weary. 1999. Geologic Map of the Eminence Quadrangle, Shannon County, Missouri. U.S. Geological Survey, Reston, Virginia. Geologic Investigations Series Map I–2653, scale 1:24,000.

Orndorff, R. C., D. J. Weary, and R. W. Harrison. 2006. The role of sandstone in the development of an Ozark karst system, south-central Missouri. Pages 31-38 *in* R. S. Harmon and C. M. Wicks. Perspectives on karst geomorphology, hydrology, and geochemistry--a tribute volume to Derek C. Ford and William B. White. Geological Society of America, Boulder, Colorado. Special Paper 404.

Pojeta, J., J. F. Taylor, and G. Darrough. 2005. *Matthevia* (Polyplacophora) invades the Ordovician; the first reported post-Cambrian occurrence. Journal of Paleontology **79**:1021-1027.

Rasetti, F. R. D. 1952. Cephalic sutures in the Upper Cambrian trilobite *Entomaspis* [Missouri]. Journal of Paleontology **26**:797-802.

Reams, M. W. 1968. Cave sediments and the geomorphic history of the Ozarks. Dissertation. Washington University, Saint Louis, MO.

Repetski, J. E., J. D. Loch, and R. L. Ethington. 1998. Conodonts and biostratigraphy of the Lower Ordovician Roubidoux Formation in and near the Ozark National Scenic Riverways, southeastern Missouri. Pages 109-115 *in* V. L. Santucci and L. McClelland, editors. National Park Service,

Paleontological Research. Geologic Resources Division, Lakewood, Colorado. Technical Report NPS/NRGRD/GRDTR-98/01.

Repetski, J. E., R. C. Orndorff, D. J. Weary, and R. L. Ethington. 2000a. Conodont biostratigraphy of the Eminence Dolomite–Gasconade Dolomite contact interval in the Missouri Ozarks. Geological Society of America Abstracts with Programs **32**:A39–A40.

Repetski, J. E., J. D. Loch, R. L. Ethington and R. I. Dresbach. 2000b. A preliminary re-evaluation of the stratigraphy of the Roubidoux Formation of Missouri and correlative Lower Ordovician units in the southern Midcontinent. Pages 103-106 *in* K. S. Johnson, editor. Platform carbonates in the southern Midcontinent, 1996 Symposium. Oklahoma Geological Survey, Norman, Oklahoma. Circular 101.

Santucci, V. L., J. Kenworthy, and R. Kerbo. 2001. An inventory of paleontological resources associated with National Park Service caves. Geological Resources Division, Lakewood, Colorado. Technical Report NPS/NRGRD/GRDTR-01/02.

Stevens, D. L. 1991. A homeland and a hinterland: The Current and Jacks Fork Riverways. Historic Resource Study, Ozark National Scenic Riverways. NPS Midwest Regional Office, Omaha, NE.

Stinchcomb, B. L. 1986. New *Monoplacophora* (Mollusca) from Late Cambrian and Early Ordovician of Missouri. Journal of Paleontology **60**:606-626.

Stinchcomb, B. L. 1975. Paleoecology of two new species of late Cambrian *Hypseloconus* (Monoplacophora) from Missouri. Journal of Paleontology **49**:416-421.

Stitt, J. H. 1983. Enrolled Late Cambrian trilobites from the Davis Formation, Southeast Missouri. Journal of Paleontology **57**:93-105.

Thompson, T. L. 1995. The stratigraphic succession in Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey, Jefferson, MO. Volume 40, 2nd Series.

Tucker, T. G. 1984. A study of Quaternary black bears (*Ursus americanus*) from Missouri Ozark caves, with special reference to the extinct sub-species, *Ursus americanus amplidens* Leidy. Missouri Speleology **24**:36.

Weary, D. J. and R. C. McDowell. 2006. Geologic Map of the Big Spring Quadrangle, Carter County, Missouri. U.S. Geological Survey, Reston, Virginia. Scientific Investigations Map 2804. 1:24,000 scale.

Weary, D. J. and J. S. Schindler. 2004. Geologic Map of the Van Buren South Quadrangle, Carter County, Missouri. U.S. Geological Survey, Reston, Virginia. Geologic Investigations Series Map I–2803 1:24,000 scale.

Weary, D. J. and R. E. Weems. 2004. Geologic Map of the Van Buren North Quadrangle, Carter, Reynolds, and Shannon Counties, Missouri. U.S. Geological Survey, Reston, Virginia. Geologic Investigations Series Map I–2802. 1:24,000 scale.

Yochelson, E. L. and B. L. Stinchcomb. 1987. Recognition of *Macluritella* (Gastropoda) from the Upper Cambrian of Missouri and Nevada. Journal of Paleontology **61**:56-61.

Yochelson, E. L. and L. M. Nuelle. 1985. *Strepsodiscus* (Gastropoda) in the Late Cambrian of Missouri. Journal of Paleontology **59**:733-740.

## Additional References


Harrison, R. W., R. Orndorff, and R. Weems. 1997. Geology of Ozark National Scenic Riverways. U. S. Geological Survey, Reston, Virginia. Fact Sheet 050-97. Online. (http://pubs.usgs.gov/fs/fs50-97/). Accessed May 2008.

Hu, C. H. 1983. The ontogenic development of two upper Middle Cambrian trilobites from the Bonneterre Dolomite, Missouri (with a discussion on the morphologic varieties of *Cedarina vale* Lochman). Chung Kuo Ti Chih Hsueh Hui Chuan Kan - Memoir of the Geological Society of China 5:275-280.

Hu, C. H. 1978. Ontogenies of four Upper Cambrian trilobites from the Bonneterre Dolomite, Missouri. Transactions and Proceedings of the Palaeontological Society of Japan, New Series 111:348-357.

McDowell, R. C., R. C. Orndorff, R. W. Harrison, R. E. Weems, D. J. Weary, J. E. Repetski, J. L. Imes, and M. J. Kleeschulte. 1998. New geologic mapping in the Ozarks of southern Missouri, USA: an approach to understanding the hydrologic framework. Pages 527-531 *in* J. V. Brahana, and others, editors. Gambling with Groundwater – Physical, Chemical, and Biological Aspects of Aquifer-Stream Relations, Proceedings volume of joint meeting, International Association of Hydrologists XXVIII Congress/American Institute of Hydrology Annual Meeting, Las Vegas, NV, USA, 27 Sept.-2 Oct., 1998, American Institute of Hydrology, St. Paul, MN.

Orndorff, R. C., D. J. Weary, and R. W. Harrison. 2006. The role of sandstone in the development of an Ozark karst system, south-central Missouri. Pages 31-38 *in* R. S. Harmon and C. M. Wicks. Perspectives on karst geomorphology, hydrology, and geochemistry--a tribute volume to Derek C. Ford and William B. White. Geological Society of America, Boulder, Colorado. Special Paper 404.

Orndorff, R. C., D. J. Weary, and S. Sebela. 2003. Geologic framework of the Ozarks of south-central Missouri. Missouri Speleology **42**:1-8.

Orndorff, R. C., D. J. Weary, and S. Sebela. 2001. Geologic framework of the Ozarks of south-central Missouri—contributions to a conceptual model of karst. Pages 18-24 *In* E. L. Kuniansky, editor. U.S. Geological Survey Karst Interest Group Workshop Proceedings, St. Petersburg, Florida. U.S. Geological Survey, Reston, Virginia. Water Resources Investigations Report 01-4011.

Orndorff, R. C., D. J. Weary, and K. M. Lagueux. 2000. Geographic information systems analysis of geologic controls on the distribution of dolines in the Ozarks of south-central Missouri, USA. Acta Carsologica **29**:161.

Orndorff, R. C., S. Sebela, D. J. Weary, R. C. McDowell, R. W. Harrison, R. E. Weems. 1999. A geologic framework in karst: US Geological Survey contributions to the hydrogeology of the Ozarks of Missouri. Pages 57-62 *in* B. F. Beck, A. J. Pettit, J. Gayle Herring: A. A. Balkema, editors. A.A. Balkema Publishers, Boston, MA. Hydrogeology and Engineering Geology of Sinkholes and Karst 7.

Repetski, J. E., R. L. Ethington, W. M. Furnish, and D. J. Kennedy. 1993. Conodonts from the Oneota and Gasconade Dolomites (Lower Ordovician) of the central midcontinent, U.S.A. Geological Society of America Abstracts with Programs , North-Central Section **25**:74-75.

Repetski, J. E., J. D. Loch, R. L. Ethington, and R. I. Dresbach. 1996. Stratigraphy of the Lower Ordovician Roubidoux Formation of Missouri and correlative units in the southern midcontinent, U.S.A. Page 33 *in* K. Johnson, editor. Platform carbonates in the southern midcontinent, Abstracts with Program. Oklahoma Geological Survey and Bartlesville Project Office, Department of Energy.

Repetski, J. E., J. D. Loch, and R. L. Ethington. 1997. Revised Lower Ordovician biostratigraphic framework for the Ozark region, midcontinent U.S.A., and implications for sequence stratigraphic interpretations. Geological Society of America Abstracts with Programs **29**:44.

Sebela, S., R. C. Orndorff, and D. J. Weary. 2003. Geologic controls in the development of caves in the south-central Missouri Ozarks. Missouri Speleology **42**:9.

Summerson, C. H. 1951. Cambrian tracks in the Lamotte sandstone. Journal of Paleontology **25**: 533.

Weary, D. J. 2006. Geologic Mapping in the Ozark National Scenic Riverways, Missouri, and vicinity. U. S. Geological Survey and National Park Service Cooperation. Geological Society of America Abstracts with Programs **38**:157.

Weary, D. J., R. W. Harrison, M. P. Wright, R. B. Jacobson, M. J. Pavich, S. A. Mahan, and D. J. Wronkiewicz. 2004. Constraints on the geological history of the karst system in southern Missouri, U.S.A. provided by radiogenic, cosmogenic and physical/chemical characteristics of doline fill. Acta Carsologica **33**:207.

Weary, D. J. and R. C. Orndorff. 2002. Physical controls on karst features in the Ozark Plateaus of Missouri, USA, as determined by multivariate analyses in a geographic information system (GIS). Acta Carsologica **30**:181.

## Data Sets

*Ozark National Scenic Riverways Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

*Ozark National Scenic Riverways Museum Collections*
1962-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by OZAR staff; status: Active.

*Midwest Archeological Center Collections*
1969-present. (museum specimens; associated specimen notes; collection records; maps; etc.). Originated by OZAR staff; status: Active.

*Central Missouri State University Museum Collections*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by OZAR staff; status: Active.

*College of the Ozarks Museum Collections*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by College of the Ozarks staff; status: Active.

*Illinois State Museum Vertebrate Paleontology Collection*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by ISM staff; status: Active.

*Smithsonian Institution National Museum of Natural History*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by NMNH staff; status: Active.

*University of Michigan Museum of Paleontology Collections*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by UMMP staff; status: Active.

*University of Missouri-Columbia Museum Collections*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by UM-C staff; status: Active.

*United States Geological Survey Collections (Reston, Virginia)*
(museum specimens; associated specimen notes; collection records; maps; etc.). Originated by USGS staff; status: Active.

# Pea Ridge National Military Park

Pea Ridge National Military Park (PERI), authorized on July 20, 1956, commemorates a pivotal 1862 Union victory over Confederate troops (including approximately 1,000 Cherokee and Choctaw-Chickasaw Indians) to maintain control of Missouri during the American Civil War. This battle was crucial to the Mississippi campaign. The military park covers 1,740 ha (4,300 acres) of rolling hills in northwestern Arkansas. Located in Benton County, the park is 7.2 km (4.5 miles) northeast of Rogers and Bentonville, Arkansas. The military park also includes a small, 23 ha (56 acre) outlying unit that is unnamed (National Park Service 2007).

## Geologic Background

The stratigraphy of the PERI area includes nearly flat-lying, relatively undeformed sedimentary strata, which were deposited in a shallow marine setting. The three primary geologic units in the park vicinity are the Mississippian-age Boone Formation, Batesville Sandstone and the Fayetteville Shale (National Park Service 2007; Clanton 1963). A sandstone unit of possible Pennsylvanian age sits atop the Fayetteville Shale (Clanton 1963). PERI is very heavily vegetated and wooded in most areas, limiting exposure of the underlying geology. However, the fossiliferous nature of these formations suggests a high potential for fossil discovery in areas of exposure (W. Manger, University of Arkansas, pers. comm., May 2008; National Park Service 2007). While all of the Mississippian units within PERI are fossiliferous, no fossils are known from within the park collections at this time. Fossils of coral and plants have been observed within the park after a rock slide occurred (K. Eads, PERI Resource Management, pers. comm., June 2008).

The NPS Geologic Resources Division conducted a geological scoping summary on April 25, 2007 (National Park Service 2007). Currently only three geologic maps have been produced for the PERI area (Adams 1905; Clanton 1963; Cintron 1962). PERI is situated mainly on the Pea Ridge 7.5' quadrangle and has a sliver on the Garfield 7.5' quadrangle to the east. Both quadrangles have been mapped at the reconnaissance level by the Arkansas Geological Survey (AGS), but never published or put into a digital format at large-scale (National Park Service 2007). Geologic maps of both the Pea Ridge and Garfield Quadrangles will be completed by the AGS in the summer of 2009 (A. Chandler, E. Doerr and S. Ausbrooks, Arkansas Geological Survey, pers. comm., May 2008).

## Sources of Paleontological Resources

### *Rock Slide Debris (Mississippian-Pennsylvanian?)*

Fossils tentatively identified as "coral" and "plant" have been observed within the park after a rock slide occurred, but none have been collected at this time (K. Eads, PERI Resource Management, pers. comm., June 2008). Angela Chandler (Arkansas Geological Survey, pers. commun., October 2008) further identified the plant fossils as *Lepidodendron*. *Lepidodendron* (or "scale tree") was a large (up to 30 m or nearly 100 ft tall) tree-like plant with distinctive diamond-shaped leaf scars. They are common plant fossils from the Mississippian and Pennsylvanian time periods. Further investigation into the provenance of these fossils is recommended. The identifications create an interesting observation. Coral (found in warm, shallow, marine waters) fossils are not typically associated with plant (terrestrial) fossils. However, until the fossils are further documented and identified, their co-ocurrence remains a mystery.

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within PERI. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park.

### *Boone Formation (Lower-Middle Mississippian)*
The Lower (Early) Mississippian St. Joe Limestone is the basal (lowest/oldest) member of the Boone Formation. It is composed of a gray coarse-crystalline bioclastic limestone with some thin calcareous shales and fossil clasts. The St. Joe is known to preserve the abundant remains of crinoids, along with rugose coral, bryozoans, brachiopods, ostracods, blastoids and conodonts (McFarland 1998; Clanton 1963). The Middle Mississippian Boone Formation is composed of fine- to coarse-grained fossiliferous limestone along with chert. Crinoids are also the most common fossil in the Boone Formation, with coral, bryozoans, brachiopods, mollusks, trilobites, conodonts, and shark material (Taylor 1968; McFarland 1998; Clanton 1963). While no fossils have yet been described from the Boone Formation within PERI, this formation is mapped in the valleys of the park and likely preserves similar fossils. The Boone Formation may have been the source of fossils discovered in the rock slide mentioned above.

### *Batesville Sandstone (Upper Mississippian)*
Unconformably above the Boone Formation is the Batesville Sandstone, which consists of fine- to coarse-grained, cream-colored to brown sandstones with thin shales. The basal Hindsville Member of the Batesville Sandstone is a crystalline, fossiliferous limestone whose beds contain brachiopods and crinoids. However, fossils are sparse in the sand facies (McFarland 1998; Clanton 1963). This formation is found within the park along the flanks of Elkhorn and Round Mountains below the Fayetteville Shale (Clanton 1963). While no fossils have yet been described from the Batesville Formation within PERI, this formation may preserve similar fossils within the park.

### *Fayetteville Shale (Upper Mississippian)*
The Fayetteville Shale consists of a black, fissile concretionary, clay shale that outcrops in the park around the flanks of Elkhorn and Round Mountains (McFarland 1998; Clanton 1963). Pyritic and silicified invertebrate fossil remains are known from this formation outside of PERI (McFarland 1998; Clanton 1963). While no fossils have yet been described from the Fayetteville Shale within PERI, this formation may preserve similar fossils within the park.

### *Potential Pennsylvanian unit(s)*
An additional sandstone unit from the park has been described in the area, but its current stratigraphic position and nomenclature has not yet been satisfactorily determined. It has been proposed that the Lower Pennsylvanian Hale Formation might be present in PERI (National Park Service 2007). Clanton (1963) makes note of "post- Fayetteville sandstones (?) of the Pennsylvanian (?) system" which he describes as a "flaggy to massive, coarse-grained, sugary textured, ripple-marked and calcareous." Alternatively, due to its stratigraphic position, it is possible that it is the Wedington Sandstone Member of the Fayetteville Shale (as mapped by Glick 1970, after Purdue and Miser 1916). It is also possible that this sandstone is from the Hale Formation of the middle sandstone of the Bloyd Formation. Clanton (1963) cites two possibilities: the lithology and plant fossils indicate a placement in the basal "Winslow Formation" (Pers. comm. to Clanton from Garner 1962). Willard (1962) and Renfroe (personal communication to Clanton 1963) attribute the sandstone to the Hale Formation on the basis of lithology, fossil and heavy mineral analysis. Future geological mapping, will be completed during the summer of 2009 by the Arkansas Geological Survey and will clarify this doubtful assignment (A. Chandler, E. Doerr and S. Ausbrooks, Arkansas Geological Survey, pers. comm., May 2008). The Wedington Sandstone, Hale Formation and Bloyd Formation are all fossiliferous, with common fossils including plants such as *Lepidodendron*, and invertebrate fossils including crinoids, bryozoans, and ammonites. Further investigations may lead to fossil discoveries in the PERI area from this unit.

### *Quaternary Deposits*
Regolith, composed mostly of weathered chert fragments and with mixed clays (most likely derived from the Boone Formation), encompass the majority of the valley fill at PERI. Prairie mounds composed of loess were noted by Clanton are thought to have been deposited during the 'Altithermal,' or the dry postglacial interval centered about 5500 years ago, during the Holocene (Quinn 1958, Clanton 1963). No fossils are reported from these deposits.

## Park Collections

No fossils are present within the park's collections (K. Byrne, HFC Curator, pers. comm., January 2008).

## Paleontological Resource Management, Preliminary Recommendations

- The NPS Geologic Resources Division sponsored geologic resource scoping sessions for PERI in July 2007 (National Park Service 2007). Paleontological resources are not currently known from within the geological exposures in PERI and there are no fossils within the park's museum collections. The provenance and identification of the fossil material observed within the park rock slide would provide important information regarding paleontological resource potential within PERI.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- If significant fossil resources are discovered within the park, PERI should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Adams, G. I. 1905. Fayetteville Folio, Arkansas-Missouri. U. S. Geological Survey Geological Atlases of the United States 119. Online. (http://txspace.tamu.edu/handle/1969.1/2952) Accessed May 2008.

Cintron, J. 1962. The geology of the Garfield Quadrangle, Benton County, Arkansas. Thesis. University of Arkansas, Fayetteville, Arkansas.

Clanton, Q. D. 1963. The geology of the Pea Ridge Quadrangle, Benton County, Arkansas. Thesis. University of Arkansas, Fayetteville, Arkansas.

McFarland, J. D. 1998. Stratigraphic summary of Arkansas. Arkansas Geological Commission Information Circular **36**:39p.

National Park Service. 2007. Geologic resources evaluation scoping summary: Pea Ridge National Military Park, Geologic Resources Division, Denver, Colorado. Online: (http://www.nature.nps.gov/geology/inventory/publications/s_summaries/PERI_scoping_summary_2007-0724.pdf) Accessed 3 June 2008.

Quinn, J. H. 1958. Plateau surfaces of the Ozarks. Proceedings of the Arkansas Academy of Sciences **11**:36-43.

Taylor, J. D. 1968. Proetid trilobite from the Boone Formation of Arkansas. Proceedings of the Arkansas Academy of Sciences **22**:102-104.

Willard, R. J. 1961. Preliminary report on the geology of the Beaver Reservoir portion of the Garfield, Beaver, and Mundell Quadrangles, Arkansas. U. S. Department of the Interior, National Park Service. Unpublished report on file.

## Additional References

Arnold, J. J. 1960. Prairie mounds and their climatic implications. Thesis. University of Arkansas, Fayetteville, Arkansas.

Brown, H. L. 1958. Loess deposits of northern Arkansas. Thesis. University of Arkansas, Fayetteville, Arkansas.

Croneis, C. 1930. Geology of the Arkansas Paleozoic area with especial reference to oil and gas possibilities. Arkansas Geological Survey, Little Rock, Arkansas. Bulletin 3.

Girty, G. H. 1915. Faunas of the Boone Limestone at St. Joe, Arkansas. U. S. Geological Survey, Reston, Virginia. Bulletin 598.

Gordon, M. 1964. Carboniferous Cephalopods of Arkansas. U. S. Geological Survey, Reston, Virginia. Professional Paper 460.

Manger, W. L. 1988. An introduction to the geology of northwestern Arkansas; field trips. Compass **65**: 242-257.

Quinn, J.H. 1961. Prairie Mounds of Arkansas. Newsletter of the Arkansas Archeological Society **2**:1-8.

Webb, G. E. 1993. Skeletal microstructure and mode of attachment in *Palaeacis* species (Anthozoa: Tabulata) from the Mississippian and Pennsylvanian of northeastern Oklahoma and northwestern Arkansas. Journal of Paleontology **67**:167-178.

## Data Sets

*Pea Ridge National Military Park Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

# Pipestone National Monument

On August 26, 1937, Pipestone National Monument (PIPE) was established to protect the historic pipestone quarries, which are considered sacred by many Native Americans. Located in Pipestone County, Minnesota, this park encompasses 120 ha (297 acres).

## Geologic Background

Pipestone National Monument is located in southwestern Minnesota, north of the city of Pipestone. Pleistocene glacial deposits overlay the Paleoproterozoic ("Precambrian" see Figure 2) Sioux Quartzite, which composes the bedrock of the monument. 30.5 m (100 ft) of the Sioux Quartzite is intermittently exposed within PIPE. This unit represents an environment that was deposited under stable conditions in an inland sea setting which occurred at the end of the Penokean orogeny (1,850 million years ago), but before the onset of Keweenawan rifting (1,000 million years ago, Morey 1984; Morey and Setterholm 1987). The rocks are dominated by orthoquartzite, but are also composed of red-colored claystones ('catlinite'), quartz-rich siltstones, and silty mudstones. The soft properties of the catlinite are favored by Native American Indians to craft ceremonial pipes and other religious items (Morey and Setterholm 1987). These quartzite rocks are, in general, highly resistant to weathering and erosion. Three distinct quartzite outcrops occur within the monument oriented in a north-south direction. Sedimentary structures present within this formation, including ripple marks, mud cracks, trough and planar cross-bedded sands, horizontal and cross-laminated sands, scour and fill deposits and mud chips, imply that these rocks were deposited in a braided stream setting (Morey 1984; Morey and Setterholm 1987). The Pleistocene glacial deposits are interpreted to be Kansan in age (Pleistocene - 410,000 to 380,000 years before present; Morey and Setterholm 1987).

Fossils are not known from either the Proterozoic or Pleistocene units. Detailed studies on the Sioux Quartzite have been conducted (Morey 1984; Morey and Setterholm 1987). However, detailed geologic maps have not yet been produced for PIPE. There is little potential for discovery of fossils within PIPE.

"Dubiofossils" have been noted in the Sioux Quartzite (M. Jirsa, Minnesota Geological Survey, pers. comm. to T. Connors, NPS Geologic Resources Division, October 2008). These round impressions have been variously interpreted as having a biogenic (organic) or abiogenic (non-organic) origin, although their actual cause remains a mystery. Further research is required to definitively identify the source of these impressions. Photos of the impressions are available from the NPS Geologic Resources Division.

## Park Collections

No fossils are known from park collections (K. Byrne, HFC Curator, pers. comm., January 2008).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for PIPE. Definitive paleontological resources are not currently known from within the geological exposures in PIPE and there are no fossils within the park's museum collections. There is some very limited potential for fossil discovery. Further research into the "dubiofossils" in the Sioux Quartzite is needed to determine their origin.
- Further research may elucidate a connection between paleontological resources and the Native American Indians in the PIPE area.
- Due to the lack of documented *in situ* fossil occurrences within the park, and the unlikelihood of extensive macrofossil discovery within the park, establishment of a paleontological resource management plan is not necessary at this time.

- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited

Morey, G. B. and D. R. Setterholm. 1987. Pipestone National Monument: the Sioux Quartzite – an early Proterozoic braded stream deposit, southwestern Minnesota. Geological Society of America Centennial Field Guide – North-central section:73-76.

Morey, G. B. 1984. Sedimentology of the Sioux Quartzite in the Fulda Basin, Pipestone County, Southwestern Minnesota. Minnesota Geological Survey, St. Paul, MN. Report of Investigation 32.

## Additional References

Corbett, W. P. 1980. Pipestone: the origin and development of a National Monument. Minnesota History **47**:83.

Dahlberg, J. C. 1982. Take another look at Minnesota rocks. Lapidary Journal **36**:66-72.

Morey, G. B. 1983. Evaluation of catlinite resources, Pipestone National Monument, Minnesota. U.S. National Park Service Research/Resources Management Report MWR-4.

Watts, W. A. and H. E. Wright. 1966. Late-Wisconsin pollen and seed analysis from the Nebraska Sandhills. Ecology **47**:202-210.

## Data Sets

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

# Tallgrass Prairie National Preserve

Tallgrass Prairie National Preserve (TAPR), in Chase County, Kansas, was established on November 12, 1996. It is the only unit of the National Park System dedicated to the rich natural and cultural history of the tallgrass prairie ecosystem. This 4,409 ha (10,894 acres) portion of the once vast tallgrass prairie is being preserved as a critical resource for the benefit, education, and enjoyment of this and future generations. Management of the preserve is accomplished through a private/public partnership between the National Park Service (the primary land manager), The Nature Conservancy (the primary landowner), and the Kansas Park Trust.

## Geologic Background

The Flint Hills physiographic region crosses east central Kansas and extends from near the Nebraska border to the north into Oklahoma to the south and is included within TAPR. Geologically the area is principally composed of alternating beds of shale and limestone. Three of the limestone beds within the park also contain chert, commonly called 'flint.' Chert is a fine grained siliceous rock usually formed in sea environments either as a chemical precipitate, or as accumulated remains of siliceous single celled organisms such as radiolaria. As the limestones erode, angular fragments of chert accumulate at the surface, giving the Flint Hills their name. The native people of the area, including the Pawnee, Osage, Wichita, and Kansa, collected this rock for use in a wide variety of tools and weapons.

The rocks of the Flint Hills were deposited during the Permian Period, about 280 million years ago. The area that is now known as Kansas was a vast shallow body of water called the Permian Sea during the early Permian Period. During this time, the climate was hot, and the surface was typically covered by a shallow tropical ocean. The limestones represent periods when the surface area was covered by shallow, tropical oceans with carbonate deposition. The shales correspond to times when mud was deposited on the ocean floor. The shallow warm seas supported a rich diversity of invertebrates, fishes, and amphibians. Many invertebrates are now preserved as fossils within the preserve, with vertebrate fossils being known from similar units outside of TAPR and surrounding areas. Many of the limestone layers create prominent benches on the hillsides with the shales forming the steep slopes between the benches. The hills themselves are created by differential erosion, where the harder, more resistant limestones and chert cap the tops of the hills, while the shale beds beneath them erode away more quickly. TAPR contains the largest diversity of both fossil genera and fossil bearing formations in the Heartland Network.

The Geologic Resources Division conducted a geological resource evaluation scoping meeting in June of 2008 with a forthcoming summary document. The Kansas Geological Survey recently completed a geologic map at 1:12,000 scale of the TAPR area (Strong City Quadrangle; Sawin 2008).

## Sources of Paleontological Resources

The lower Permian within TAPR is composed of 12 geologic formations, dominated by limestones and mudstones. Outside of the preserve, fossils are known from all of these formations, with the exception of the Stearns Shale. The stratigraphic nomenclature at TAPR is based on Zeller (1968). Most of the fossil identifications indiacted below are based on field observations by researchers including the Kansas Geological Survey (B. Sawin, Research Associate Kansas Geological Survey, pers. comm., August 2008). These fossils present opportunities for resource management (including field surveys, inventory, and monitoring), education, interpretation, and continued or future scientific research in the park. Fossils are also visible within the building stones of many historic strutures within the park. The building stone fossils are described in greater detail in the "Park Collections and Fossils in Cultural Resource Contexts" section.

### *Eskridge Shale (Lower Permian)*

The Eskridge Shale is the lowest unit exposed at TAPR and is composed of 4.3 m (14 ft) of light-gray-green mudstone, with a thin, argillaceous limestone occasionally occurring near the middle of the formation. This formation is exposed along Fox Creek at a few localities (Sawin 2008). Bivalves (*Aviculopecten*, *Myalina*, *Pseudomonotis*, *Pleurophorus*, *Marginifera*, *Septimyalina*, *Astartella*), gastropods (*Bellerophon* and *Loxonema*), and brachiopods are known from TAPR (Wells 1950, Elias 1937). Tree bark, leaves (*Neuropteris*) and other plant material have been described from this formation elsewhere (Wells 1950, Elias 1937). According to Elias (1937), the fossils known from the Eskridge Shale indicate that this unit was deposited in a shallow marine setting alternating with a near shore, nonmarine environment (Wells 1950).

### *Beattie Limestone (Lower Permian)*

The Beattie Limestone is comprised of three members: the Cottonwood Limestone, the Florena Shale, and the Morrill Limestone. The total thickness of this formation is about 6.4 m (21 ft).

The Cottonwood Limestone is a fossiliferous, massive, light-gray to yellow-white limestone that is blocky in appearance. Abundant wheat-grain-sized and shaped fusulinids (*Schubertella*, *Schwagerina*, and *Triticites*) present in the upper portion of the member are distinctive of the Cottonwood Limestone in TAPR. Other fossils, found outside the preserve, include phylloid algae (*Calcipatera cottonwoodensis* – formerly *Anchicodium*; Torres et al. 1992; Sawin and West 2005), gastropods, ostracods, and trilobites, with small crinoids, echinoid spines, brachiopods, bryozoan, and small broken shell fragments (present in the lower portion of the member) known from TAPR, although these are less common (Twiss 1988, Sawin 2008). The Cottonwood Limestone was the primary building stone used in the construction of the main ranch house at TAPR. This particular rock was quarried south of the preserve's boundary (National Park Service n.d.).

The Florena Shale is composed predominantly of a light-gray-green carbonate mudstone, dolomitic mudstone, and mudstone, with the lower 0.92-1.8 m (3-6 ft) being highly fossiliferous (Twiss 1988, Sawin 2008). Abundant fossils in TAPR exposures of the Florena Shale include fenestrate bryozoans, brachiopods (*Neochonetes*, *Meekella*, *Derbyia*, *Composita*, and productid shell fragments), echinoid spines, and crinoid columnals (Sawin 2008). Sponges, coral, gastropods, pelecypods, ammonoids, ostracods (*Cryptobairdia seminalis*, *Amphissites centronotus*, and *Knightina texana*), and trilobites also having been described from the Florena Shale elsewhere in Kansas (Costanzo and Kaesler 1987).

The Morrill Limestone, the uppermost (youngest) member, is a light-gray to yellow-brown limestone which contains thin mudstone partings. In some areas it is massive and forms a prominent outcrop, weathering irregularly to blocky, while in other areas it is inconspicuous. Fossils in the TAPR sections of the Morrill Limestone are rare, except for small skeletal fragments near the base (brachiopods and echinoderms; Twiss 1988, Sawin 2008).

### *Bader Limestone (Lower Permian)*

The Bader Limestone is about 7.9 m (26 ft) thick and is composed of three members: the Eiss Limestone, the Hooser Shale, and the Middleburg Limestone.

The lowermost Eiss Limestone varies from 3.9 to 5.5 m (13-18 ft) thick. It can be divided into an upper and lower limestone, and middle mudstone, although exposures of the middle mudstone and lower limestone are limited. Fossils are plentiful in the lower limestone and in the lower part of the middle mudstone. The lowermost limestone in TAPR is light gray, clayey, and include the fossilized remains of bivalves (*Aviculopecten*, *Acanthopecten*, *Pseudomonotis*, *Schizodus*, *Aviculopinna*, and myalinids), bryozoans (*Tabulipora*, *Rhombopora*, *Acanthocladia*, and others), brachiopods (*Neochonetes* , *Meekella*., *Derbyia*, *Composita*, *Juresania*, and *Reticulatia*), echinoid spines and plates, crinoids (columnals, plates, and ossicles), and trilobites (*Ditymopyge*). The upper limestone is a massive, vuggy when weathered, bench forming gray limestone. The upper limestone in TAPR may contain fossils (small shell fragments)

and siliceous nodules (Sawin 2008). Other fossils noted to occur in the Eiss Limestone in Kansas include foraminifera (*Tetrataxis*, *Ammodiscus*, and *Polytaxis*), echinoderms (*Protocaudina* and *Ancistrum*), conodonts (*Streptognathodus*?), and unidentified vertebrate fragments such as fish teeth and scales, and unidentified toe bones (Dietsch 1956).

The Hooser Shale is a calcareous, gray to gray green (red near the base), mudstone that is 1.5 m (5 ft) thick. The Middleburg Limestone is about 1.8 m (6 ft) thick. It is composed of an upper limestone, middle mudstone and shale, and lower limestone. The lower limestone member of the Middleburg at TAPR is light gray, massive, and fossiliferous. Fossils are dominated by bivalves (*Aviculopecten*, *Acanthopecten*, *Pseudomonotis*, myalinids), with brachiopods (productids) and occasional gastropods (*Bellerophon* and high-spired snails). The fossils, lithology, and weathering characteristics often resemble the "Easly Creek limestone" which is described below. A green mudstone followed by black, fissile shale is present above the lower limestone. The upper limestone is gray to light gray or light yellowish brown and fossiliferous (Sawin 2008).

### *Easly Creek Shale (Lower Permian)*

The Easly Creek Shale consists of a lower varicolored (green, red, and purple), calcareous mudstone that contains a limestone near its base, a prominent limestone near the middle, and an upper light-green, calcareous mudstone. The mudstone section is calcareous and fossiliferous, containing the abundant remains of broken shell fragments, bryozoans, brachiopods (*Composita*, *Derbyia*, *Neochonetes*, and productids), gastropods (*Straparollus* [*Amphiscapha*]), trilobites (*Ditomopyge*), crinoids, and burrows within TAPR. The prominent limestone, locally (and informally) referred to as the "Easly Creek limestone," is gray, silty, and fossiliferous. Algal-coated and bored bivalves (*Aviculopecten*, *Acanthopecten*, and *Pseudomonotis*) and brachiopods (*Composita*, *Derbyia*, and productids) are characteristic in the TAPR sections, with bryozoans (*Acanthocladia* and others), worm tubes (spirorbid worms attached to bivalve shells), and a few gastropods also known (Sawin 2008).

### *Crouse Limestone (Lower Permian)*

The Crouse Limestone averages 3.4 m (11 ft) thick. The lower portion of the Crouse is a gray or light-yellowish-brown, massive, bench forming limestone, containing siliceous nodules and geodes, iron deposits (limonite), and fossils. Fossils are common in TAPR near the top of the lower limestone and include high-spired gastropods, the bivalve *Permophorus* and ostracods (West and Twiss 1988). The lower section of the lower limestone is composed almost entirely of bivalves (*Aviculopecten*, *Acanthopecten*, *Pseudomonotis*, *Septimyalina* and myalinids; West and Twiss 1988; Sawin 2008). Foraminiferids, gastropods, and ostracods are known from the middle mudstone section of the Crouse elsewhere in Kansas (West and McMahon 1972a,b; West and Twiss 1988). The upper portion of the Crouse is a yellow-gray, clayey limestone that weathers into thin plates, a characteristic of this part of the formation (Sawin 2008). The upper section is noted to contain the flat-laminated stromatolites, foraminiferids, ostracods, and isolated pockets of bivalves (*Permophorus*; West and McMahon 1972a,b), but these have not been described from units within TAPR.

The massive, three level barn at TAPR is constructed predominately of Crouse Limestone that was quarried south of the preserve's boundary (National Park Service n.d.) and as such might display fossils from the Crouse Limestone. A fossil horseshoe crab (*Paleolimulus*) is known from the Crouse Limestone outside of TAPR in Pottawatomie County, Kansas (Babcock et al. 2000).

### *Funston Limestone (Lower Permian)*

The Funston Limestone averages about 6 m (20 ft) in thickness and can usually be divided into an upper and lower limestone, separated by a mudstone. The lower portion of the Funston Limestone is a very light gray to light yellow gray (sometimes nearly white), very fine grained, and finely laminated limestone. Fossil specimens vary in TAPR, with bivalves (*Aviculopecten* , *Pseudomonotis*, myalinids, and small algal-coated specimens) being most common. The middle mudstone is black to dark gray and is not noted to contain fossils. The upper limestone contains multiple mudstone layers, with the upper part being a light-

yellowish-brown to light-gray, thin, platy limestone that is rarely exposed; it contains broken shell fragments and algal-coated bivalves in the preserve. The lower portion is a gray, fossiliferous, bench forming, massive limestone that commonly crops out on the hillsides. This lower limestone in TAPR contains plentiful remains of broken shell fragments (mostly bryozoans and brachiopods), bivalves (*Aviculopecten*, and *Aviculopinna*; Sawin 2008) and burrows. In northeastern Pottawatomie County, Kansas, the Funston (commonly referred to as the "Onaga limestone" because it is quarried near Onaga, Kansas) is quarried for commercial and residential building stone, although none of the park's structures were built from this unit (Grisafe 1983). Fossil remains of elasmobranch (shark) teeth (*Xenacanthus luedersensis*) are known from the Funston in Geary County (Schultze 1985).

### *Speiser Shale (Lower Permian)*

The Speiser Shale is composed of a gray to green, calcareous, fossiliferous mudstone, that occasionally contains thin limestone layers. Fossils from the Speiser Shale within the preserve are plentiful in the upper mudstone and include bryozoans, bivalves (*Aviculopecten*, *Acanthopecten*, and myalinids), brachiopods (*Neochonetes*, *Chonetinella*, *Derbyia*, and productids), and crinoid columnals and cup plates. The middle and lower parts of the Speiser Shale are composed of varicolored (red, purple, and green) mudstone (Sawin 2008).

Fossils collected from the Speiser Shale outside of TAPR include the echinoderm *Ophiuraster burrisi,* from Butler County, Kansas (Hattin 1959). In Riley County, Kansas, to the north of TAPR, the remains of the temnospondyl amphibian *Acroplous vorax* (Hotton 1959; Coldiron 1978; Foreman 1990) were discovered. Amphibians (*Diplocaulus* , *Lysorophus* , *Acroplous vorax*, and *Trimerorhachis*) and the lungfish *Gnathorhiza* were found near the town of Bushong, Kansas, to the northeast of the preserve (Foreman and Martin1988; McAllister 1990, 1991). Elasmobranch teeth from Cowley County (Schultze 1985); and the amphibian *Diplocaulus* and fish *Gnathorhiza* from Geary County, Kansas (Foreman and Martin 1988) were also found in the Speiser Shale. Also northeast of the preserve, near the town of Eskridge, lies perhaps the richest fossil site of the Speiser Shale, known as the "Eskridge locality." This site preserves the remains of the lungfish *Gnathorhiza* (Foreman and Martin 1988), amphibians (*Diplocaulus*, *Euryodus bonneri*, *Lysorophus*, and *Acroplous vorax*) and pelycosaur reptiles.

### *Wreford Limestone (Lower Permian)*

The Wreford Limestone (12 m or 40 ft thick) is composed of three members: the Threemile Limestone, the Havensville Shale, and the Schroyer Limestone.

The Threemile Limestone is a prominent bench, or "rimrock" of gray limestone that caps many of the flat-topped hills in the southern portion of TAPR. Nodular and banded chert is more abundant in the upper and lower parts of the Threemile Limestone. Thin mudstone layers may occur within the limestone. Small shell fragments (mostly bryozoans, brachiopods, and crinoids) are common throughout the Threemile Limestone in the preserve. Near the base of this member, well-preserved fossil include crinoids, echinoid spines and plates, bryozoans, horn corals, and brachiopods (*Neochonetes*, *Meekella*, *Wellerella*, and productid spines; Lutz 1990; Sawin 2008). Other fossils known from the Threemile Limestone outside of the TAPR include brachiopods (*Composita*, *Chonetes*, *Derbyia*, *Reticulatia*; Lutz 1990; Mazzullo et al. 1997), bryozoans (*Filiramoporina kretaphilia* from Chase County, Fry and Cuffey 1976), ostracods, gastropods, foraminifera, fusulinids (?*Schwagerina*; Sanderson and Verville 1970), trilobites, and sponges (Schultze 1985).

The Havensville Shale is a light-yellowish-brown, green, and yellowish-green mudstone with interbedded, light-gray, and light-yellowish-brown clayey limestones that are fossiliferous. Within TAPR, the Havensville Shale is dominated by fossils of bryozoans, bivalves (*Aviculopecten*, *Wilkingia*, and myalinids), and brachiopods (*Composita*). Less common fossils include echinoid spines and crinoids (Sawin 2008). Outside of the preserve the remains of foraminifers, ostracods, gastropods, brachiopods (*Derbyia*, *Myalina*; Mazzullo et al. 1997), crinoids, and trilobites are also known from the Havensville Shale (Schultze 1985; Schweitzer et al. 1986; Mazzullo et al. 1997).

The upper portion of the Schroyer Limestone is a massive, gray, fine-grained, recrystallized limestone with layers of chert. Weathered blocks contain the common remains of small, broken shell fragments. The middle part of this member is a recrystallized, limonitic, orange-brown limestone that has a porous, clayey appearance. In the preserve, fossils in this middle part include algal-coated grains and an occasional brachiopod. The lower portion is a gray, fine-grained limestone containing layers of chert. Fossils in this area are predominately echinoid spines and plates, but also contain small bryozoans, brachiopods (*Composita*, *Wellerella*, chonetids, productids; Lutz 1990), and crinoids in both the limestone and chert (Sawin 2008). Sponges, corals, bryozoans, ostracods, gastropods, brachiopods (*Reticulatia*, *Composita*, *Chonetes*; Mazzullo et al. 1997), and crinoids are also known from the Schroyer Limestone elsewhere in Kansas (Schultze 1985, Schweitzer et al. 1986).

Vertebrate fossil remains from the Wreford Limestone outside of TARP include elasmobranch (shark) teeth and a fin spine (*Stemmatias* from the Threemile Limestone in Marshall County; *Serratodus* from the Havensville Shale in Morris County). An *Acanthodes* fin spine is known from the middle Havensville Shale (Geary County), with a scale known from the Threemile Limestone in Cowley County, Kansas (Schultze 1985). Actinopterygian teeth and scales from the Threemile Limestone (Pottawatomie, Cowley, Wabaunsee, Marshall counties), Havensville Shale (Cowley, Morris counties), and the Schroyer Limestone (Geary, Pottawatomie, Greenwood counties) along with a palaeoniscoid (fish) centra (Threemile Limestone, Wabaunsee County) were also described by Schultze (1985).

### *Matfield Shale (Lower Permian)*

The Matfield Shale is composed of three members: the Wymore Shale, the Kinney Limestone, and the Blue Springs Shale. This formation is 20 m (65 ft) thick. The upper portion of the Wymore Shale is composed of a light-yellowish-brown, gray, and green mudstone that contains a thin limestone. This thin limestone includes the fossilized remains of bivalves and brachiopods (*Derbyia*). The middle part is varicolored (red, purple, and green) mudstone that may contain boxwork limestone. The lower mudstone is gray, light yellowish brown and yellowish green (Sawin 2008). Stacked paleosols are present outside of TAPR in the Wymore Shale and suggest a transition from a relatively arid to a seasonally wet/dry conditions (Montgomery and Mazzullo 1997). Other fossils from outside the preserve (Riley County) include plants (*Neuropteris*), invertebrate burrows, and bivalves (*Volsellina*, *Aviculo Pecten*, *Permophorus*; Busch 1988). Another location in Riley County, Kansas, preserves the remains of marine fish (including elasmobranchs), and microsaurs (a form of amphibian) as well as coprolites (fossil dung) and enterospirae (fossilized contents of the digestive tract; McAllister 1985; Foreman and Martin 1988).

Three zones commonly exist in the Kinney Limestone, with an upper and lower limestone and a middle mudstone. The lower limestone is a light-gray to gray limestone (where thickest) and weathers to large, elongated blocks that collect on the slope below the outcrop. Fossils in this lower limestone in TAPR include bivalves, gastropods, brachiopods (*Composita* and *Derbyia*), and small crinoids. One outcrop within the preserve is unlike all other exposure in the lower limestone of TAPR. The limestone here is thicker (about 2.7 m, or 9 ft), with the lithology composed of a recrystallized gastropod coquina (a limestone composed of mostly shell and shell fragments). Fossils here are dominated by high- and low-spired gastropods with the occasional bivalves (some have been bored into by predatory gastropods; Sawin 2008).

The middle mudstone is gray to green and can include one or more calcareous zones or thin limestones. Fossils are frequent in the middle and upper portions (Moore et al. 1951). The upper limestone is a gray, fine-grained skeletal limestone. The grainy texture of this limestone is attributed to the high concentration of shell fragments (<1mm). In the upper limestone, fossils include algal blades, high-spired gastropods, brachiopods, crinoids, ostracods (characteristic of this unit) and spirorbids (worm-tubes). At some locations the skeletal fragments are almost entirely ostracods (Sawin 2008). Elsewhere in Kansas, the remains of brachiopods (*Derbyia* and *Reticulatia*), bryozoans, foraminifers, crinoids, bivalves (*Allorisma*,

*Aviculopecten*, *Myalina*, and *Septimyalina*) have been described in the Kinney Limestone (Mazzullo et al. 1997).

The Blue Springs Shale is poorly exposed within the preserve. The upper portion of this member is a gray, yellow, or yellowish-green mudstone that occasionally contains thin, irregular layers of limestone. Near the middle of the Blue Springs Shale a 0.3 m (1 ft) bed of limestone can occur. The lower part of this member is a varicolored (yellowish-green, green, red, and purple) mudstone (Moore et al. 1951, Sawin 2008). Near Manhattan, Kansas, burrows of the lungfish *Gnathorhiza* occur in the hundreds of thousands, with the greatest concentration found in a single level several meters below the Florence Limestone Member of the Barneston Limestone (Hasiotis et al. 2002). Bivalves, gastropods, brachiopods, and ostracods are described from an outcrop near Manhattan, Kansas (Busch 1988). Paleosols present in the Blue Springs shale indicate a long-term period of climatic stability existed during the Early Permian (Montgomery and Mazzullo 1997).

### *Barneston Limestone (Lower Permian)*

The Barneston Limestone is composed of three members: the Florence Limestone, the Oketo Shale, and the Fort Riley Limestone. However, in the TAPR area, only the Florence Limestone is present, capping the highest hills along the northwest edge of the preserve. In this vicinity up to 4.6 m (about 15 ft) of lower Florence Limestone is present. The Florence Limestone is a light-gray to yellow-gray limestone containing several layers of light- to dark-gray nodular chert (Sawin 2008). Fossils are common, with platy algal fragments, fusulinids (*Pseudoschwagerina texana* and *Pseudofusulina moranensis*; Thompson 1954, Sanderson and Verville 1988), bryozoans, bivalves (*Permophorus*), gastropods (*Bellerophon*), brachiopods (*Derbyia*, *Reticulatia*, *Composita*, and *Meekella*), echinoid spines and crinoids present in other outcrops outside of TAPR (Busch 1988; Twiss and Underwood 1988; Mazzullo et al. 1997).

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within TAPR. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park with the exception of the nonfossiliferous Stearns Shale.

### *Stearns Shale (Lower Permian)*

The Stearns Shale is about 3.7 m (12 ft thick), and is composed of a nonfossiliferous, varicolored (green, red, purple, and gray), calcareous mudstone that may contain clayey calcilutites (fine-grained limestones), thin limestone beds or boxwork limestone (Twiss 1988; Sawin 2008).

### *Blue Rapids Shale (Lower Permian)*

The Blue Rapids Shale is composed of a gray, green, and light-yellowish-brown, calcareous mudstone that may contain a thin limestone layer in the lower part of the unit (Sawin 2008). Outside of TAPR, in Riley County, Kansas, three stacked paleosol profiles, or ancient soil horizons, are present in the Blue Rapids Shale (McCahon and Miller 1993). Tetrapod material (*Clepsydrops* and *Cricotus*) originally reported in 1897 from Cowley County, Kansas, appears to be from the Blue Rapids Shale (Foreman and Martin 1988). Similar fossils are not yet documented from within TAPR.

## Park Collections and Fossils in Cultural Resource Contexts

Fossils are not present in the TAPR collections (T. Roop, TAPR Chief of Maintenance and Cultural Resources, pers. comm. June 2008). The Cottonwood Limestone, known to contain the abundant remains of fusulinids and other marine invertebrates, was the primary building stone used in the construction of the main ranch house at TAPR. This particular rock was quarried south of the preserve's boundary (National Park Service n.d.). Fossils in building stones are a common example of NPS fossils that are found in cultural resource contexts. Within the HTLN, both LIBO and TAPR are known to preserve such

fossils. Kenworthy and Santucci (2006) provide an overview of this topic and include examples of building stones that display fossils.

## Paleontological Resource Management, Preliminary Recommendations

- The NPS Geologic Resources Division sponsored geologic resource scoping sessions for TAPR in June 2008. Extensive fossil resources are known from within the park and are even visible within building stones of many of the park's historic structures. Paleontological resources are not known from within the park collections. There is excellent potential for continued fossil discovery within the park.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- The park should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future.
- A forthcoming (late 2008-early 2009) Geologic Resource Monitoring Manual by the Geological Society of America and NPS Geologic Resources Division includes a section on paleontological resource management.
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited


Babcock, L. E., D. F. Merriam, and R. R. West. 2000. *Paleolimulus*, an early limuline (Xiphosurida), from Pennsylvanian-Permian Lagerstätten of Kansas and taphonomic comparison with modern *Limulus*. Lethaia **33**:129-141.

Busch, R. M. 1988. Minor T-R units in the Lower Permian Chase Group, northeast Kansas. Pages 17-24 *in* O. T. Haywood. Geological Society of America Centennial field Guide – South-central Section, Boulder, Colorado.

Coldiron, R. W. 1978. *Acroplous vorax* Hotton (Amphibia, Saurerpetontidae) restudied in light of new material. American Museum, New York City, NY. Novitates 2662.

Costanzo, G. V. and R. L. Kaesler. 1987. Changes in Permian marine ostracode faunas during regression, Florena Shale, northeastern Kansas. Journal of Paleontology **61**:1204-1215.

Cuffey, R. J. and W. B. Hall. 1985. Species-level bryozoan assemblages within the Lower Permian Wreford Megacyclothem of Kansas, Oklahoma, and Nebraska. The Lethaia Foundation, Blackwell Publishing, Boston, MA. International Congress on Carboniferous Stratigraphy and Geology 9.

Cuffey, R. J. and A. H. Simonsen. 1980. Auxiliary constructional roles of delicate ramose and fenestrate bryozoans in the Waulsortian-like chalky-limestone mud-bank facies in the Wreford Limestone (Lower Permian; Kansas). Geological Society of America Abstracts with Programs **12**:223.

Dietsch, H. A. 1956. Paleoecology of the shale in the Eiss Limestone member of the Bader Limestone Formation (Lower Permian) Chase County, Kansas. Thesis. University of Kansas, Lawrence, KS.

Elias, M. K. 1937. Depth of deposition of the Big Blue (Late Paleozoic) sediments in Kansas. Geological Society of America Bulletin **48**:403.

Foreman, B. C. 1990. A revision of the cranial morphology of the Lower Permian temnospondyl amphibian *Acroplous vorax* Hotton. Journal of Vertebrate Paleontology **10**:390-397.

Foreman, B. C. and L. D. Martin. 1988. A review of Paleozoic tetrapod localities of Kansas and Nebraska. Pages 133 -145 *in* Regional Geology and Paleontology of Upper Paleozoic Hamilton quarry area in southeastern Kansas. Kansas Geological Survey, Lawrence, KS. Guidebook Series 6.

Fry, H. C. and R. J. Cuffey. 1976. *Filiramoporina kretaphilia* – a new genus and species of bifoliate tubulobryozoan (Ectoprocta) from the Lower Permian Wreford Megacyclothem of Kansas. The University of Kansa, Lawrence, KS. Paleontological Contributions Paper 84.

Fry, H. C. and R. J. Cuffey. 1975. Bifoliate cryptostome bryozoans in the Werford Megacyclothem (Lower Permian) in Kansas. Geological Society of America Abstracts with Programs **7**:61.

Grisafe, D. A. 1983. Geology and characteristics of building limestones of Kansas. Pages 91-112 *in* Proceedings of 18th Forum on Geology and Industrial Minerals. Indiana Geological Survey, Bloomington, Indiana. Occasional Paper 37.

Hasiotis, S. T. 2002. Burrows of the lungfish *Gnathorhiza* within paleosols of the Lower Permian (Wolfcampian) of eastern Kansas: a unique paleoenvironmental setting and justification for a new ichnotaxon. Geological Society of America Abstracts with Programs **34**:212.

Hattin, D. E. 1959. An occurrence of *Ophiuraster burrisi* Miller. Journal of Paleontology **33**:1125-1128.

Hotton, N. 1959. *Acroplous vorax*, a new and unusual Labyrinthodont Amphibian from the Kansas Permian. Journal of Paleontology **33**:161-178.

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., J. A. Spielmann, P. M. Hester, J. P. Kenworthy, and V. L. Santucci, editors. America's Antiquities (Proceedings of the 7th Federal Fossil Conference). New Mexico Museum of Natural History & Science, Albuquerque, New Mexico. Bulletin 34.

Lutz, A. B. 1990. The distribution of the brachiopods *Wellerella* and *Enteletes* in the Lower Permian Werford Megacyclothem (Nebraska, Kansas, and Oklahoma). Geological Society of America Abstracts with Programs **22**:14.

Mazzullo, S. J., C. S. Teal, and C. A. Burtnett. 1997. Outcrop stratigraphy and depositional facies of the Chase Group (Permian, Wolfcampian) in Kansas and Southeastern Nebraska. Kansas Geological Survey, Lawrence, KS. Technical Series 6.

McAllister, J. A. 1991. A new species of *Gnathorhiza* (Dipnoi) from the Permian of Kansas. Journal of the Pennsylvania Academy of Science **64**:197.

McAllister, J. A. 1990. An unusual bone assemblage from the Permian of Kansas. Journal of Vertebrate Paleontology Abstracts with Programs **10**:34A.

McAllister, J. A. 1985. Reevaluation of the formation of spiral coprolites. The University of Kansas, Lawrence, KS. Paleontological Contributions Paper 114.

McCahon, T. J. and K. B. Miller. 1993. Paleosols in the Blue rapids Shale (Lower Permian) of northcentral Kansas. Pages 6-1 to 6-7 *in* Second International Paleopedology Symposium: field excursions, August 13-20, 1993. Kansas Geological Survey, Lawrence, KS.

Montgomery, M. W. and S. J. Mazzullo. 1997. Analysis of paleosols in Chase Group strata (Lower Permian), south-central Kansas. American Association of Petroleum Geologist Bulletin **81**:1353.

Moore, R. C., J. M. Jewett, H. C. O'Connor, and R. K. Smith. 1951. Geology, Mineral Resources, and Ground-Water Resources of Chase County, Kansas. Kansas Geological Survey, Lawrence, KS. Report 11.

Pachut, J. F. and R. J. Cuffey. 1999. Stratigraphic and geographic bryozoan abundance gradients in the calcareous shales of the Wreford Megacyclothem. The University of Kansas, Lawrence, KS. Paleontological Contributions Number 10.

Pachut, J. F. and R. J. Cuffey. 1998. Stratigraphic and geographic (onshore-offshore) bryozoan abundance gradients in the Wreford Megacyclothem (Lower Permian) of Kansas. Geological Society of America north-central section Abstracts with Programs **30**: 66.

Sanderson, G. A. and G. J. Verville. 1970. Morphologic variability of the genus *Schwagerina* in the lower Permian Wreford limestone of Kansas. Palaeontology **13**:175-183.

Sawin, R. S. 2008. Surficial Geology of the Tallgrass Prairie National Preserve, Chase County, Kansas. Kansas Geological Survey, Lawrence, KS. M-119A. 1:12,000 scale.

Sawin, R. S., and R. R. West. 2008. Lithology and paleontology of the stratigraphic units cropping out at the Tallgrass Prairie National Preserve, Chase County, Kansas. Kansas Geological Survey, Lawrence, KS. Open-file Report 2008-15.

Sawin, R. S., and West, R. R., 2005, Paleoecology of the Permian (Wolfcampian) Phylloid Alga *alcipatera* from an *In Situ* Occurrence in Kansas, U.S.A.: Kansas Geological Survey, Lawrence, KS. Current Research in Earth Sciences, Bulletin 251. Online. (http://www.kgs.ku.edu/Current/2005/sawin/index.html).

Schultze, H. P. 1985. Marine to onshore vertebrates in the Lower Permian of Kansas and their paleoenvironmental implications. The University of Kansas, Lawrence, KS. Paleontological Contributions Paper 113.

Schultze, H. P. 1980. Fossil vertebrates in the Speiser Shale, Lower Permian of Kansas. Transaction of the Kansas Academy of Sciences **83**:120.

Schweitzer, P. N., R. L. Kaesler, and G. P. Lohmann. 1986. Ontogeny and heterochrony in the Ostracode *Cavellina coryell* from the Lower Permian rocks in Kansas. Paleobiology **12**:290-301.

Thompson, M. L. 1954. American Wolfcampian fusulinids. University of Kansas, Lawrence, KS. Paleontological Contributions, Protozoa, Article 5.

Torres, A. M., West, R. R., and Sawin, R. S. 1992. *Calcipatera cottonwoodensis*, a new membranous Late Paleozoic calcareous alga. Journal of Paleontology **66**: 678-681.

Twiss, P. C. 1988. Beattie Limestone (Lower Permian) of eastern Kansas. Pages 35-41 *in* O.T. Haywood, editor. Geological Society of America Centennial Field Guide – South-central Section.

Twiss, P. C. and J. R. Underwood. 1988. Barneston Limestone (Lower Permian) of eastern Kansas. Pages 25-28 *in* O.T. Haywood, editor. Geological Society of America Centennial Field Guide – South-central Section.

Wells, J. D. 1950. A study of the Eskridge Shale. Transactions of the Kansas Academy of Sciences **53**:535-543.

West, R. R. and P. C. Twiss. 1988. The Crouse Limestone in north-central Kansas; Lateral changes and paleoecological analysis. Pages 29-34 *in* O.T. Haywood, editor. Geological Society of America Centennial field Guide – South-central Section.

West, R. R. and E. C. McMahon. 1972a. Significance of lower Crouse fossil assemblages. Pages 91-95 *in* Stratigraphy and depositional environments of the Crouse Limestone (Permian) in north-central Kansas. Kansas State University, Department of Geology, Manhattan, KS. Prepared for the Sixth Annual Meeting of the Geological Society of America, South-Central Section April 6-8, 1972.

West, R. R. and E. C. McMahon. 1972b. Primary study of Crouse fossil assemblages. Geological Society of America Abstracts with Programs **4**:299.

Zeller, D. E. 1968. The stratigraphic succession in Kansas. Kansas Geological Survey, Lawrence, KS. Bulletin 189.

## Additional References

Beede, J. W. 1901. Fauna of the Permian of the Central United States: Part I. Transactions of the Kansas Academy of Science **17**:185-189.

Carr, T. R. 1998. Report to United States Department of Interior, National Park Service: Petroleum Geology and Oil and Gas Operations in Chase County with Emphasis on the Tallgrass Prairie National Preserve. Kansas Geological Survey, Lawrence, KS. Open-file Report 98-46.

Mandel, R. D. 2006. Geomorphology, Quaternary Stratigraphy, and Geoarcheology of Fox Creek Valley, Tallgrass Prairie National Preserve, Northeast Kansas. Kansas Geological Survey, Lawrence, KS. Open-file Report 2006-29.

Moore, R. C., C. G. Lalicker, and A. G. Fischer. 1952. Invertebrate Fossils. McGraw-Hill Book Company, Inc, New York.

Reichman, O. J. 1991. Konza Prairie: A Tallgrass Natural History. University Press of Kansas, Lawrence.

Sawin, R. S. and J. R. McCauley. 2004. Geologic Map of the Historic Ranch Headquarters and School House Areas, Tallgrass Prairie National Preserve, Chase County, Kansas. Kansas Geological Survey, Lawrence, KS. Open-file Report 2004-34 (Revised July 2008).

Schoewe, W. 1949. The Geography of Kansas, Part II, Physical Geography. Kansas Academy of Science Transactions **52**:261.

Williams, R. B. 1975. Ancient life found in Kansas rocks: An introduction to common Kansas fossils. Kansas Geological Survey, Lawrence, KS. Educational Series I.

Wind, F. H. 1974. Biostratigraphy and paleoecology of conodonts of the Chase Group, lower Permian, of Kansas. Geological Society of America Abstract with Programs 6:552.

## Data Sets

*Tallgrass Prairie National Preserve Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

# Wilson's Creek National Battlefield

On April 22, 1960, Wilson's Creek National Battlefield Park was established. The park was redesignated as Wilson's Creek National Battlefield (WICR) on December 16, 1970. WICR commemorates the Battle of Wilson's Creek; the first major American Civil War engagement west of the Mississippi River. Located southwest of Springfield, Missouri, this park encompasses 958 ha (2,368 acres).

## Geologic Background

The stratigraphy of the WICR area includes nearly flat-lying, relatively undeformed sedimentary strata, which were deposited in a shallow marine setting. The three primary geologic units in the park vicinity are the Mississippian-age undifferentiated Burlington-Keokuk Limestone, the Elsey Limestone, and the Reeds Formation (M. Siemens, Missouri Department of Natural Resources Geologist, pers. comm., July 2008). While all of the Mississippian units within WICR are potentially fossiliferous, no fossils exist within the park collections at this time. Fossils of bivalves, coral and crinoids have been observed within the park, although their geologic provenance is currently unknown although the Burlington Limestone may preserve some of these fossils (G. Sullivan, WICR Chief of Resources and Facilities Management, pers. comm., May 2008). Future field investigations could determine which of the following units preserve the observed fossils.

The NPS Geologic Resources Division has not yet conducted a geological scoping summary for WICR. Currently four geologic maps have been produced for the WICR area (Walker 1961; Thomson et al. 1981; Work and Robertson 1991; Wedge 2001); ). WICR is situated on the Republic 7.5' quadrangle.

## Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following geologic units within WICR. However, future field investigations within the park may yield fossils from one or more (or none) of the following geologic units. Fossils are documented from these units outside of the park. The Burlington Limestone is a likely source of the observed fossils within the park, although further investigation or documentation is needed to confirm this.

### *Burlington-Keokuk Limestone (Lower Mississippian)*

The undifferentiated rocks of the Burlington-Keokuk Limestone are a light- to medium-gray, medium- to coarsely- crystalline massive bedded, crinoidal limestone with isolated nodules and discontinuous beds of white to light-gray fossiliferous chert. The main fossils in the Burlington-Keokuk Limestones are crinoids. Less abundant fossils include the brachiopods *Tetracamera subtrigona*, *Delthyris similis*, *Chonetes illiniosensis*, *Pseudosyrinx keokuk*, *Torynifera pseudolineata*, *Buxtonia*, *Dictyoclostus*, *Linoproductus*, *Marginirugus, Echinoconchus alternatus*, and the crinoid *Cleiothyridina obmaxima* (M. Siemens, Missouri Department of Natural Resources Geologist, pers. comm., July 2008; Wedge 2001). There are three caves reported within the Burlington Limestone of WICR. Fossilized marine invertebrates have been identified from within the Burlington Limestone just outside of the cave entrances. These fossils remain *in situ* and there are currently no collections of these paleontological resources (Santucci et al. 2001; G. Sullivan, WICR Chief of Resources and Facilities Management, pers. comm. May 2008).

### *Elsey and Reeds formations (Lower Mississippian)*

The Elsey Limestone Formation is a finely to medium-crystalline, light-gray to brown limestone with light-gray to white chert with brown mottles, that occurs as ellipsoidal nodules, discontinuous beds and nodular massive beds. Common fossils in this unit include the numerous coarsely crystalline crinoidal lenses that are widespread in the limestone and the chert (M. Siemens, Missouri Department of Natural Resources Geologist, pers. comm., July 2008; Wedge 2001). The Reeds Formation (also called the Reed

Springs Formation) consists of brown to dark-gray chert (Wedge 2001). A fossil seed plant (*Pyonoxylon shumatei*) was described from this formation in Greene County (Cribbs 1940).

### *Pleistocene deposits*

While no Pleistocene deposits have yet to be described from WICR, three caves have been identified from the Burlington Limestone within the park (Santucci et al. 2001). It is unknown what age the caves are, and no fossils other than the fossils from the Mississippian limestone are known at this time. In southwestern Greene County 10.5 km (6.5 miles) from WICR, a cave with fossil remains was discovered during road construction in 2001. This cave, the Riverbluff Cave Site, preserves the remains of thousands of trackways, coprolites (dung), hair, and numerous bones of extinct Pleistocene fauna. The remains of mammoths, short-faced bears, horses, peccaries, birds, reptiles, and rodents have been discovered, some of which are new species (Forir and Ciampaglio 2004, 2005). Park staff may want to take this find into consideration should any new development take place that could uncover karst systems that may contain fossilized remains.

## Park Collections

Fossils are not reposited within park collections (G. Sullivan, WICR Chief of Resources and Facilities Management, pers. comm., May 2008).

## Paleontological Resource Management, Preliminary Recommendations

- Geologic resource scoping sessions, sponsored by the NPS Geologic Resources Division, have not yet been held for WICR. Paleontological resources are known from the bedrock in the park but are not contained within park collections. While the exact provenance of the fossils is unsure, the Burlington Limestone is the likely source. Field observations can confirm this hypothesis.
- Park staff should be encouraged to observe exposed cliffs, other erosional bedrock, rivers and streams (especially during times of low water levels) for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g. pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place. Except for permitted scientific research, paleontological resources should remain *in situ* unless they are subject to imminent threats by artificially accelerated natural processes or human impacts.
- If significant fossil resources are discovered within the park, WICR should consider future field inventories for paleontological resources to more fully document *in situ* occurrences of fossils. The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future
- Contact the NPS Geologic Resources Division for paleontological resource management or interpretation assistance.

## Literature Cited

Cribbs, J. E. 1940. On a new species of fossil seed plant from the Reed Springs Formation of southwestern Missouri. Proceedings of the Missouri Academy of Science **5**:92.

Forir, M. and C. Ciampaglio. 2005. The Riverbluff Cave site of Green County, Missouri. Page 49 in L. D. Agenbroad and R. L. Symington, editors. Quaternary International, Pergamon Elsevier Science, Tarrytown, NY. World of Elephants 2 - Selected papers from the 2nd Congress, Mammoth Site of Hot Springs, 2nd World of Elephants Congress 169-170.

Forir, M. and C. Ciampaglio. 2004. The Riverbluff Cave paleontological site and its importance as an educational tool. Geological Society of America Abstracts with Programs **36**:419-420.

Thomson, K. C. and others. 1981. Geology of the Brookline, Republic, Springfield, and Nixa Quadrangles, Missouri. Missouri Division of Geology and Land Survey, Jefferson City, MO. OFM-81-46-GI. 1:62,500 scale.

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, Colorado. Technical Report NPS/NRGRD/GRDTR-01/02. TIC# D-2231.

Walker, R. 1961. Geology of the Republic Quadrangle, Greene and Christian Counties, Missouri. Missouri Geological Survey and Water Resources, Jefferson City, MO. Unpublished geologic map #SP-6105.

Wedge, W. K. 2001. Geologic map of the Springfield, Missouri 30' X 60' Quadrangle. Missouri Division of Geology and Land Survey, Jefferson City, MO. OFM-01-398-GS. 1:100,000 scale.

Work, D. M. and C. E. Robertson. 1991. Geologic map of the Republic Quadrangle, Greene and Christian Counties, Missouri. Missouri Division of Geology and Land Survey, Jefferson City, MO. Unpublished geologic map #SP-9101.

## Additional References

Banner, J. L. and J. Kaufman. 1994. The isotopic record of ocean chemistry and diagenesis preserved in non-luminescent brachiopods from Mississippian carbonate rocks, Illinois and Missouri. Geological Society of America Bulletin **106**:1074-1082.

Fay, R. O. 1960. Ptychoblastus, a new Mississippian blastoid from Missouri. Journal of Paleontology **34**: 1198-1201.

Galbavy, K. M. 1989. A field guide to the fossils of Greene County, Missouri. Thesis. Southwest Missouri State University, Springfield, MO.

Ghosh, B. and W. J. Meyers. 1991. Regional variation in microdolomite content of crinoids from the Mississippian Burlington-Keokuk Formation, Iowa, Illinois and Missouri. Geological Society of America Abstracts with Programs **23**:64

McLeod, J. D. 1973. Fossils of the Warsaw Limestone. Earth Science **26**: 243-247

Thompson, T. L. 1986. Paleozoic succession in Missouri; Part 4, Mississippian System. Missouri Geological Survey, Jefferson City, MO. Report of Investigations 70.

Robertson, C. E. 1967. The Elsey Formation and its relationship to the Grand Falls chert. Missouri Geological Survey and Water Resources, Jefferson City, MO. Report of Investigations 62.

Rovey, C. W., K. R. Evans, K. L. Mickus, J. F. Miller, T. G. Plymate, K. C. Thomson. 2003. Impact origin of the Weaubleau-Osceola structure in southwestern Missouri. Geological Society of America Abstracts with Programs **35**:339.

Weller, S. 1895. The succession of fossil faunas at Springfield, Missouri. American Journal of Science **49**:185-199

## Data Sets

*Wilson's Creek National Battlefield Paleontological Archives*
5/1985–present. (hard copy data; reports; electronic data; photographs; maps; publications). Originated by Santucci, Vincent; status: Active.

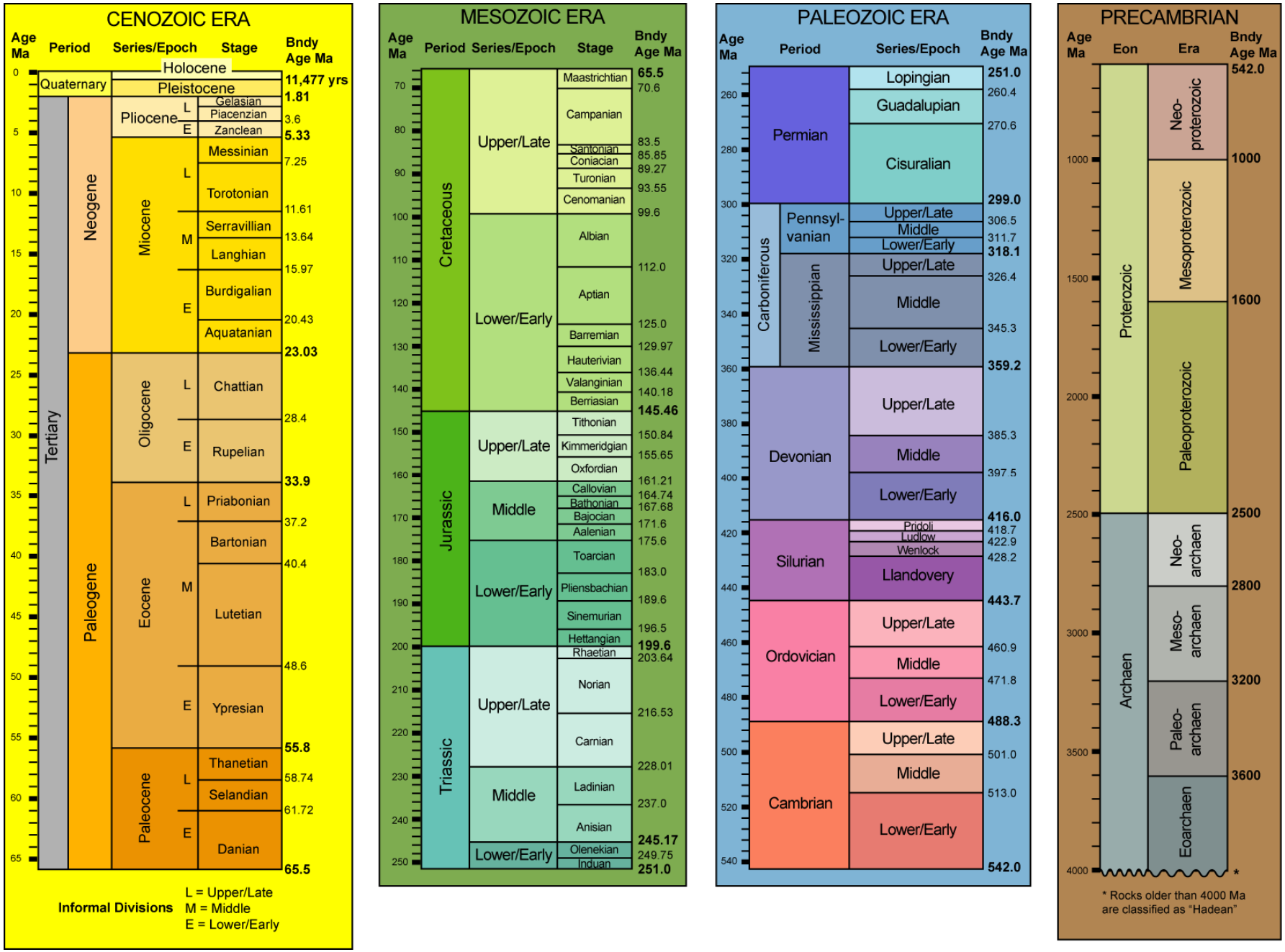



**Figure 2.** Geologic Time Scale. *Ma = Millions of years old. Bndy Age = Boundary Age.* Colors are USGS standard colors found on geologic maps. Modified from 1999 Geological Society of America Time scale (www.geosociety.org/science/timescale/timescl.pdf). Boundary dates and additional information from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

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-66 October 2008

**National Park Service**
**U.S. Department of the Interior**

**Natural Resource Program Center**
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov