

NATIONAL PARK SERVICE CAVE PALEONTOLOGY: 2002–2023

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ABSTRACT

The first published inventory of paleontological resources associated with National Park Service (NPS) caves was issued in 2001 (Santucci et al. 2001). This report documented occurrences of fossil resources within caves in 35 NPS units and the challenges of managing and protecting these paleontological resources. Many significant NPS cave paleontology discoveries have been made in the following two decades. Highlights include: the first paleontological inventory of Carlsbad Caverns National Park, which documented both Permian fossils in cavern bedrock, and bones of Quaternary megafauna; reassessments of Quaternary fossils, particularly avifauna, from rock shelters and caves of Channel Islands NP; the discovery of thousands of Pleistocene–Holocene mummified bats from a cave in Grand Canyon NP, and the identification of an American cheetah skull from Rampart Cave; documentation of extinct or locally extirpated taxa from Great Basin NP; discoveries of abundant Mississippian fossils, particularly sharks, in cave bedrock of Mammoth Cave NP and Natchez Trace Parkway; the relocation of the Port Kennedy Bone Cave site in Valley Forge National Historical Park; and an inventory of *Neotoma* middens from across the NPS. The rise of photogrammetry as an investigative technique has been key to facilitating study of in situ specimens in these challenging settings. The possibility of paleontological resources in caves is now addressed during any paleontological inventory work in NPS units. We can expect that many more cave paleontology discoveries from NPS caves will be made in the decades to come.

INTRODUCTION

Paleontological resources found in cave settings include some of the most remarkable fossils of the National Park Service (NPS). The NPS’s cave fossils were first inventoried in Santucci et al. (2001), which listed 35 parks with known paleontological resources in cave settings. These records include fossils of organisms, especially vertebrates, that entered the cave context after the cave began to form, and fossils of organisms in the cave bedrock now exposed by the same processes forming the cave. Many new discoveries have been made in the two decades since then, as well as discoveries of overlooked data. The original list of 35 NPS units now includes 60 units (Fig. 1; Table 1). Of these, 40 have paleontological resources in more “traditional” cave settings, and the other 20 have records restricted to pre-modern packrat middens found in protected rock shelters, talus voids, and other small and/or shallow features. Below are notable park reports and updates for the period 2002–2023.

NEW INFORMATION

Carlsbad Caverns National Park (New Mexico)

A paleontological resource inventory was conducted at Carlsbad Caverns National Park (NP) in 2019 by Geoscientists-in-the-Parks intern Scott Kottkamp (Kottkamp et al., 2020). This was the first time that a comprehensive inventory of fossil resources had been attempted for the park, bringing together various publications, a wealth of internal park reports and other gray literature, and other paleontological information for dozens of park caves. Many of the caves of Carlsbad Caverns NP contain Quaternary paleontological resources, primarily bones, with at least 18 extinct and 13 extralimital taxa represented (Table 2); further information on the Quaternary assemblage can be found in Kottkamp et al. (2022). The Permian bedrock of the caves, pertaining to the Capitan Reef Complex, is also extensively fossiliferous. Weathering has exposed beautifully preserved examples of Permian invertebrates, such as brachiopods with internal anatomy and articulated crinoids.

Channel Islands National Park (California)

Paleontologically notable caves of Channel Islands NP have been discussed in several publications since 2001. A San Miguel Island cave used as a barn owl roost contains a record of small vertebrates from the latest Pleistocene through the Holocene. This site has been studied for decades but continues to reveal new information. The bird record from this site was most recently summarized in Collins et al. (2018a), which documented 88 species. Mead et al. (2018) published the first report of the chorus frog *Pseudacris* from the cave, and Mychajliw et al. (2020) documented the occurrence of a metacarpal from a short-faced bear (*Arctodus simus*). This unexpected find is thought to be the result of a scavenging bird bringing a portion of a mainland bear carcass to the cave (Mychajliw et al., 2020). A similar barn owl cave roost on Santa Barbara Island, to date confined to the Holocene, has been recently documented for the NPS

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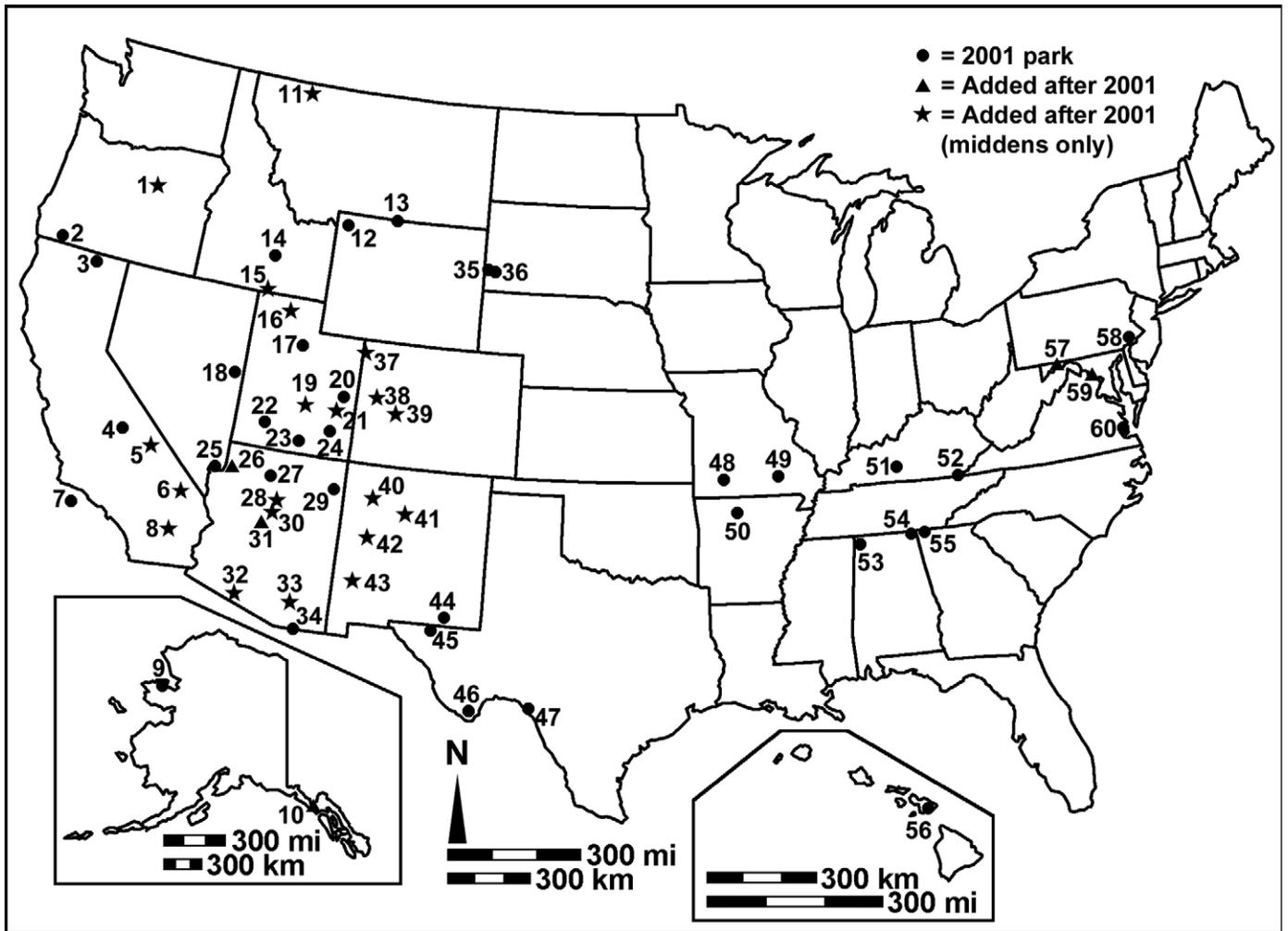


Figure 1. Map of NPS units with fossils from cave settings. The parks documented in Santucci et al. (2001) are marked with circles. Parks recognized as having pre-modern packrat middens but no other cave fossils to date are marked with stars. Other park occurrences recognized since 2001 are marked with triangles. 1. John Day Fossil Beds National Monument (NM); 2. Oregon Caves NM; 3. Lava Beds NM; 4. Sequoia and Kings Canyon National Parks (NPs); 5. Death Valley NP; 6. Mojave National Preserve (NPres); 7. Channel Islands NP; 8. Joshua Tree NP; 9. Bering Land Bridge NPres; 10. Glacier Bay NP&Pres; 11. Glacier NP; 12. Yellowstone NP; 13. Bighorn Canyon NRA; 14. Craters of the Moon NM; 15. City of Rocks NPres; 16. Golden Spike NHS; 17. Timpanogos Cave NM; 18. Great Basin NP; 19. Capitol Reef NP; 20. Arches NP; 21. Canyonlands NP; 22. Cedar Breaks NM; 23. Glen Canyon NRA; 24. Natural Bridges NM; 25. Lake Mead National Recreation Area (NRA); 26. Parashant NM; 27. Grand Canyon NP; 28. Wupatki NM; 29. Canyon de Chelly NM; 30. Walnut Canyon NM; 31. Montezuma Castle NM; 32. Organ Pipe Cactus NM; 33. Saguaro NP; 34. Coronado National Memorial; 35. Jewel Cave NM; 36. Wind Cave NP; 37. Dinosaur NM; 38. Colorado NM; 39. Curecanti NRA; 40. Chaco Culture National Historical Park (NHP); 41. Bandelier NM; 42. El Malpais NM; 43. Gila Cliff Dwellings NM; 44. Carlsbad Caverns NP; 45. Guadalupe Mountains NP; 46. Big Bend NP; 47. Amistad NP; 48. Wilson’s Creek NB; 49. Ozark National Scenic River; 50. Buffalo NR; 51. Mammoth Cave NP; 52. Cumberland Gap NHP; 53. Natchez Trace Parkway; 54. Russell Cave NM; 55. Chickamauga and Chattanooga National Military Park; 56. Haleakalā NP; 57. Potomac Heritage National Scenic Trail; 58. Valley Forge NHP; 59. Chesapeake and Ohio Canal NHP; 60. Colonial NHP.

(Collins et al., 2018b); they reported 43 bird taxa identifiable to genus or species in the pre-historic deposits. The San Miguel and Santa Barbara cave sites contribute to perhaps the richest record of Quaternary birds in the entire NPS. A summary of the paleontological resources of Channel Islands NP can be found in Tweet et al. (2020), the recent paleontological resource inventory report.

Chesapeake and Ohio Canal National Historical Park (District of Columbia–Maryland–West Virginia)

Trilobites have been informally reported in the Conococheague Limestone bedrock of a cave in the vicinity of Dam 4 within Chesapeake and Ohio Canal National Historical Park but were not observed during a 2009 visit (Clites and Santucci, 2010).

Glacier Bay National Park and Preserve (Alaska)

Reconnaissance by Kevin Allred and Wayne Howell in 2001 located several caves in Glacier Bay NP and Preserve. Among them was a vertical pit, dubbed “Ai Chi Pit”, containing an undated skull of a mink or marten (Heaton, 2002). Caves in the park so far pertain to the Silurian Willoughby Limestone (P. Burger, pers. comm., August 2023).

Table 1. A concise summary of NPS units with fossils found in cave settings. * = new since 2001; ** = *Neotoma* midden record only (not included in 2001); † = units with fossils found in deep cave settings as well as small-scale features with *Neotoma* middens

Amistad NRA	Craters of the Moon NM†	Mammoth Cave NP
Arches NP†	Cumberland Gap NHP	Mojave NPres**
Bandelier NM**	Curecanti NRA**?	Montezuma Castle NM*
Bering Land Bridge NPres	Death Valley NP**	Natchez Trace Parkway
Big Bend NP†	Dinosaur NM**	Natural Bridges NM†
Bighorn Canyon NRA†	El Malpais NM**	Oregon Caves NM
Buffalo NR	Gila Cliff Dwellings NM**	Organ Pipe Cactus NM**
Canyon de Chelly NM†	Glacier NP**	Ozark NSR
Canyonlands NP**	Glacier Bay NP&Pres*	Parashant NM*†
Capitol Reef NP**	Glen Canyon NRA†	Potomac Heritage NST*
Carlsbad Caverns NP†	Golden Spike NHS**	Russell Cave NM
Cedar Breaks NM	Grand Canyon NP†	Saguaro NP**
Chaco Culture NHP**	Great Basin NP†	Sequoia / Kings Canyon NP†
Channel Islands NP	Guadalupe Mountains NP†	Timpanogos Cave NM†
Chesapeake & Ohio Canal NHP*	Haleakalā NP	Valley Forge NHP
Chickamauga/Chattanooga NMP	Jewel Cave NM†	Walnut Canyon NM**
City of Rocks NPres**	John Day Fossil Beds NM**	Wilson’s Creek NB
Colonial NHP	Joshua Tree NP**	Wind Cave NP
Colorado NM**	Lake Mead NRA†	Wupatki NM**
Coronado NMem	Lava Beds NM†	Yellowstone NP†



Figure 2. A mummified myotis bat preserved in a Grand Canyon NP cave (NPS/ Shawn Thomas).

at least eight species (Fig. 2) (Mead et al., 2021a). This discovery documents a record of bats ranging in age from more than 43,500 YBP (C. Chambers, pers. comm., 2022) to 3,500 YBP (Mead et al., 2021a). The exquisite preservation, abundance, and taxonomic diversity of these bats will permit an unprecedented glimpse of the life and ecology of these animals from the latest Pleistocene through much of the Holocene. Second, felid remains from three caves previously identified as *Puma concolor* (mountain lion) have been reidentified as elements of the extinct North American cheetah *Miracinonyx trumani*, which has implications for the ecology of this species as being adaptable to near vertical rocky terrain and canyons like some modern large felids (Hodnett et al., 2022a).

Grand Canyon National Park (Arizona)

Caves are one of the outstanding sources of paleontological resources in Grand Canyon NP (Santucci and Tweet, 2021). The abundance and quality of the cave fossils has led to them being documented in inventories at various scales: a single cave (Rampart Cave; Carpenter, 2003); a region of the park (eastern Grand Canyon; Mead et al., 2003); and the entire park (Kenworthy et al., 2004; Mead et al., 2021a). Still, the information that can be gained from the park’s cave fossils is nowhere near being exhausted. Numerous publications have incorporated fossils from Grand Canyon NP caves over the past two decades; a full list is omitted here for brevity, but Mead et al. (2021a) provides a lengthy bibliography. Two significant events have occurred in the past few years. First, a remote cave has been found to include hundreds to thousands of mummified bats representing at

Table 2. Extinct and extralimital Quaternary vertebrate taxa found in the caves of Carlsbad Caverns NP, as determined in Kottkamp et al. (2022).

Extinct	Extralimital
Cathartidae: undetermined extinct genus	Testudinidae: <i>Gopherus</i> cf. <i>G. morafkai</i>
Cathartidae: <i>Coragyps occidentalis</i>	Sciuridae: <i>Marmota flaviventris</i>
Nothrotheriidae: <i>Nothrotheriops shastensis</i>	Sciuridae: <i>Tamiasciurus hudsonicus</i>
Soricidae: <i>Notiosorex dalquesti</i>	Cricetidae: <i>Microtus ochrogaster</i>
Molossidae: <i>Tadarida constantinei</i>	Cricetidae: <i>Microtus pennsylvanicus</i>
Felidae: <i>Miracinonyx trumani</i>	Cricetidae: <i>Neotoma cinerea</i>
Felidae: <i>Panthera atrox</i>	Leporidae: <i>Sylvilagus nuttalli</i>
Canidae: <i>Canis armbrusteri</i>	Soricidae: <i>Cryptotis parva</i>
Canidae: <i>Aenocyon dirus</i>	Soricidae: <i>Sorex cinereus</i>
Equidae: <i>Equus conversidens</i>	Soricidae: <i>Sorex merriami</i>
Equidae: <i>Equus occidentalis</i>	Soricidae: <i>Sorex monticolus</i>
Tayassuidae: <i>Platygonus</i> sp.	Soricidae: <i>Sorex palustris</i>
Camelidae: <i>Camelops hesternus</i>	Bovidae: <i>Ovis canadensis</i>
Cervidae: <i>Navahoceros fricki</i>	
Antilocapridae: <i>Capromeryx furcifer</i>	
Antilocapridae: <i>Stockoceros conklingi</i>	
Bovidae: <i>Euceratherium collinum</i>	
Bovidae: <i>Oreamnos harringtoni</i>	

Great Basin National Park (Nevada)

Great Basin NP in eastern Nevada has long been known for caves; in fact, the park was originally established as Lehman Caves National Monument in 1922. Vertebrate remains were known from the caves for decades and were among the components of the park paleontological resource inventory undertaken by Gordon Bell from 2010 to 2015. The park's caves include a variety of Quaternary remains of amphibians, reptiles, birds, and mammals. Among them are extinct taxa (rabbits *Aztlanolagus agilis* and *Brachylagus coloradoensis*), locally extirpated taxa (pika *Ochotona princeps*, pocket gopher *Thomomys talpides*, and an unidentified marten), and taxa that are much less abundant in the Snake Range at present than in the cave deposits (marmot *Marmota flaviventris*) (Bell et al., 2016).

Lake Mead National Recreation Area (Arizona–Nevada)

During the production of a paleontological resource inventory for Lake Mead National Recreation Area (Bonde et al., 2018), it was found that a cave previously reported in the literature, Catclaw Cave, is within the recreation area. This large shelter is the source of the holotype of the bighorn sheep *Ovis catclawensis* Hibbard and Wright (1956). This species is now generally considered to be a synonym of *O. canadensis* but may potentially represent a distinct subspecies within that species.

Mammoth Cave National Park (Kentucky)

The cave paleontological resources of Mammoth Cave NP have been a subject of documentation and research since Santucci et al. (2001). As of 2023, a paleontological resource inventory report was being prepared to summarize the park's paleontology. Until recently, the vast majority of fossils reported from the cave system were remains of Quaternary vertebrates. Colburn (2005) provided a detailed inventory of these finds, with a further summary in 2017. Among the notable discoveries was the recognition of a *Smilodon* fibula, the first record of this genus in the state. Although there was hope that the proboscidean noted in Santucci et al. (2001) would prove to be a Mammoth Cave mammoth, it has been identified as an American mastodon (Colburn 2005). A pair of publications in 2015 focused on bat paleontology in the park's caves. Colburn et al. (2015) determined that the bat bonebed of Bat Cave represents deposition during at least 11 flooding events between 10,800 and 2,200 years ago. Widga and Colburn (2015) focused on guano deposits in several areas, which together present a record greater than 54,000 years in duration, from the present to in excess of the limit of radiocarbon dating. Bones in the guano beds almost entirely represent bats, including locally extirpated taxa such as *Tadarida brasiliensis* (Mexican free-tailed bat) present during an interstadial.

Although fossils have long been recognized in the Mississippian-age bedrock cave surfaces in Mammoth Cave NP, it was not until recent years that a concerted effort has been made to formally document and describe them. An unprecedented diversity of Mississippian chondrichthyans and bony fish has been found since 2019, along with well-preserved echinoderms, other invertebrate fossils, enormous invertebrate burrows, and conodonts. To date more than 110 chon-

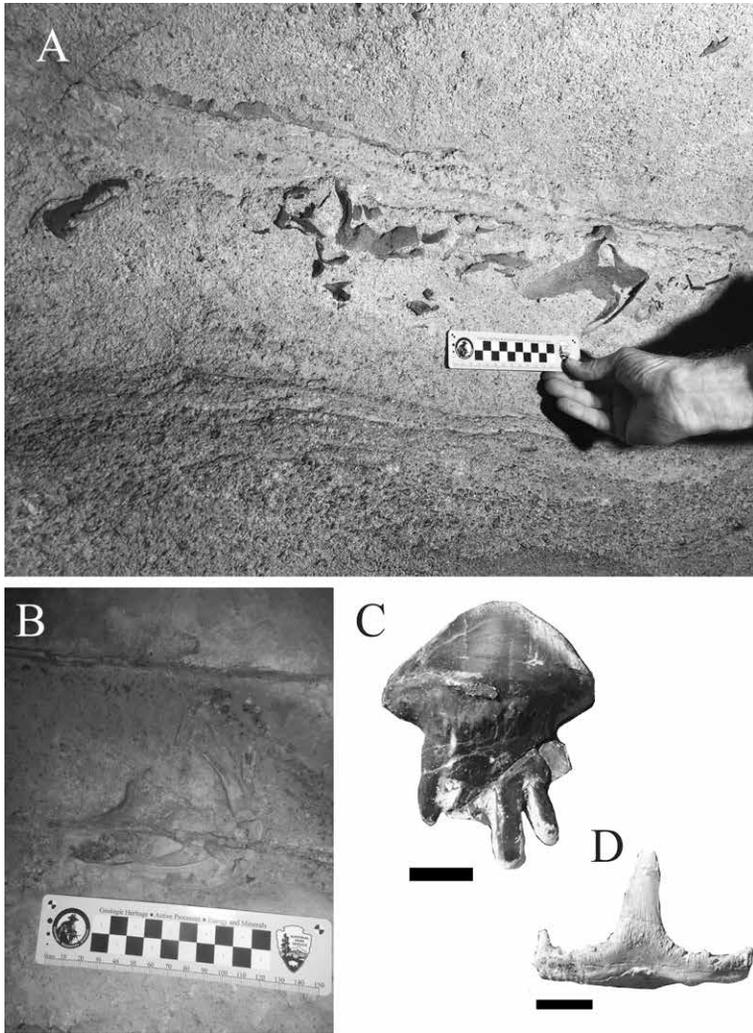


Figure 3. Samples of chondrichthyan fossils from Mammoth Cave NP. (a) The lower jaw, cranial cartilage, and teeth of the ctenacanthiform shark *Saivodus striatus* in situ of the cave wall in the Middle Mississippian Ste. Genevieve Formation (NPS/JP Hodnett); (b) The articulated upper and lower jaws, gill arches, and teeth of the ctenacanthiform *Glikmanius* sp. in situ of the cave wall in the Middle Mississippian Ste. Genevieve Formation (NP/Rickard Toomey); (c) An isolated tooth of *Polyrhizodus concavus* from the Middle Mississippian St. Louis Formation, scale 1 cm (NPS/JP Hodnett); (d) An isolated tooth of *Saivodus striatus* from the Late Mississippian Girkin Formation, scale 1 cm (NPS/JP Hodnett).

drichthyan species have been found in four Middle to Late Mississippian formations, including several that are new to science. These chondrichthyan fossils include teeth, dermal spines and denticles, and complete to nearly complete cartilaginous skeletal material, some of which are articulated (Fig. 3) (Hodnett et al., 2022b). One new taxon, the petalodont chondrichthyan *Strigilodus tollesonae*, was named in 2023 (Hodnett et al., 2023a), with others in prep.

Montezuma Castle National Monument (Arizona)

The cave paleontological resource record of Montezuma Castle National Monument was overlooked in Santucci et al. (2001), so is included here. The sinkhole known as Montezuma Well includes a cave in the Pliocene Verde Formation, which was investigated in the 1950s by Arthur Lange. Lange (1957) reported that the cave had few speleothems except for calcite that had recrystallized in molds left by decomposed twigs and other organic remains. The cave's fissure fill also includes remains of birds and small rodents (Lange, 1957).

Natchez Trace Parkway (Alabama–Mississippi–Tennessee)

During a reconnaissance survey in advance of construction, NPS associate J. P. Hodnett visited a cave within Natchez Trace Parkway and observed both bedrock fossils and Quaternary faunal remains that potentially include Pleistocene fossils. Fossils in the cave bedrock include specimens of productid and spiriferid brachiopods, crinoids, and multiple chondrichthyan taxa. These cave bedrock fossils represent a shallow Middle Mississippian marine facies, with some of the chondrichthyan taxa similar to those found at Mammoth Cave NP (Hodnett et al., 2022b). Quaternary remains include bones, teeth, and scales of fish, reptiles, birds, and small mammals. Use as a roost and/or carnivoran den is suspected. Documentation of the fossils has been published in a paleontological resource inventory (Hodnett et al., 2023b).

Parashant National Monument (Arizona)

Parashant National Monument, also known as Grand Canyon-Parashant National Monument, is geologically similar to adjacent Grand Canyon NP but much more poorly known in terms of paleontology. Resource management is complicated by joint administration; only about 20 percent of the monument is administered by the NPS, most of the rest being administered by the Bureau of Land Management. Like Grand Canyon NP, Parashant National Monument has numerous caves and rock shelters, some of which contain paleontological resources. A preliminary inventory of Quaternary fossils was produced by Jim Mead (Mead, 2003). Several years of cave inventorying and fossil collection followed, but the results have not yet been published (Tweet et al., 2021).

During the fall of 2020, Geoscientists-in-the-Parks interns Holley Flora and Summer Rose Weeks conducted a paleontological inventory at the monument; the published report (Tweet et al., 2021) is the first formally published document to refer to these cave fossils.



Figure 4. The entrance to Cumberland Bone Cave along the Great Allegheny Passage trail (J.-P. Hodnett).

Potomac Heritage National Scenic Trail (District of Columbia–Maryland–Pennsylvania–Virginia)

Although the Potomac Heritage National Scenic Trail was established in 1983, it has undergone a number of expansions. One such expansion that occurred after 2001 put the notable Cumberland Bone Cave on the Great Allegheny Passage portion of the trail, northwest of Cumberland (Fig. 4). Cumberland Bone Cave, uncovered during work on the Western Maryland Railroad in the early 1910s, is a former sinkhole that accumulated a large quantity of bones at close to the early–middle Pleistocene boundary; Withnell et al. (2020) dated peccary teeth from the site to 790 ± 53 and 722 ± 64 ka. It is comparable in many ways to Port Kennedy Bone Cave in Valley Forge National Historical Park (see below), except the site has not been buried and is still producing fossils. See Gidley and Gazin (1933) and Norden (2006) for summaries. With both Cumberland Bone Cave and Port Kennedy Bone Cave, the NPS is serendipitously associated with two of the most significant mid-Pleistocene (Irvingtonian)

vertebrate localities in the eastern United States. A monograph reviewing the Cumberland Bone Cave was in preparation in 2023 (R. Eshelman, pers. comm., 2022), and a complementary NPS report has been produced (Hodnett et al., 2023c).

Valley Forge National Historical Park (Pennsylvania)

At the time Santucci et al. (2001) was written, Port Kennedy Bone Cave was assumed to be within the boundaries of Valley Forge National Historical Park, but its location was unknown. The bone-filled fissure had been buried along with the surrounding quarry during the early 20th century and then forgotten. In the 1990s, Valley Forge NHP natural resources manager Brian Lambert initiated an effort to relocate the site. Historical research narrowed the search field (Daeschler et al., 2005), and geophysical investigation using gravity and electrical resistivity surveying in 2004 and 2006 established the location of the buried site (Hojdila et al., 2005; Baughman et al., 2006; Bechtel and Baughman, 2006). Further direct investigation of the site is not anticipated, due to asbestos-bearing quarry fill.

Wind Cave National Park (South Dakota)

Abundant Quaternary fossils have been found in the recently discovered Persistence Cave located within Wind Cave NP. Most of the fossils have not yet been formally published, except for voles (Jass et al., 2020) and a pine marten (Mead et al., 2021b, which also includes an occurrence from Wind Cave itself), but informal reports and abstracts state that the site includes both invertebrates (gastropods and insects) and vertebrates (frogs, salamanders, snakes, lizards, bats, shrews, pikas, rabbits, rodents, mustelids, bears, canids, *Bison*, and extinct horses and camels). A paleontological resource inventory was conducted at the park in 2022 by Scientists in Parks intern Theodore Herring (Herring et al., 2023).

Packrat Middens

Middens constructed by packrats/wood rats (*Neotoma* spp.) are among the most abundant paleontological resources found in caves and rock shelters and are extremely useful as “paleoecological time capsules”. An inventory of NPS packrat middens (Tweet et al., 2012) found records of 35 NPS units with ancient or modern middens, and six more have been identified since then (Carlsbad Caverns NP, Glacier NP, John Day Fossil Beds NM, Petrified Forest NP, Sequoia and Kings Canyon NPs, and Walnut Canyon NM). In many cases the sources are rock shelters rather than deep caves, but they are still of interest. Sites with modern middens only and no other cave paleontological records (Mesa Verde NP,



Figure 5. Taking photogrammetric images of a prepared specimen (the *Euceratherium* skull from Musk Ox Cave, now *Speleotherium logani*) (NPS/Vincent Santucci).

Petrified Forest NP, Pipe Spring NM) are omitted from Table 1 and Fig. 1.

Photogrammetry

Photogrammetry, a photo-documentation technique that can be used on both in situ and excavated fossils (Matthews et al., 2006; Matthews and Breithaupt, 2011; Mallison and Wings, 2014), has become a powerful tool for documenting cave fossils since 2001. This technique produces three-dimensional images of objects from multiple photos taken at various angles. The three-dimensional image can then be studied or viewed in a digital environment or printed using rapid prototyping technology to produce a physical representation of the object similar to a cast. This technique is especially useful for studying fossils that cannot be collected. One of the earliest uses of photogrammetry to document an NPS cave fossil was the modeling of a Carlsbad Caverns NP *Euceratherium* skull in October 2016 at the Smithsonian (USNM PAL 598576) (Fig. 5).

More recently, photogrammetry has been used to document two in situ shark skeletons at Mammoth Cave NP. The benefits of this kind of non-destructive documentation of fossils in a cave setting are readily apparent: caves are not ideal settings for extracting fossils, and the potential for damaging other resources is greatly reduced. Examples of online digital photogrammetric models of NPS cave fossils can be seen at:

- <https://3d.si.edu/object/3d/euceratherium-cf-sinclairi:7a5211b8-2d58-4681-ac31-3f7cb4b8302a> (Carlsbad Caverns NP *Euceratherium*)
- <https://www.nps.gov/articles/000/shark-fossil-glikmanius.htm> (Mammoth Cave NP *Glikmanius*)
- <https://www.nps.gov/articles/000/shark-fossil-saivodus-striatus.htm> (Mammoth Cave *Saivodus*)

CONCLUSIONS

Inventory and monitoring for paleontological resources, including within caves, is an important activity undertaken by the National Park Service Paleontology Program. Through these inventories the scope, significance, distribution, and management issues associated with fossils have been identified, providing important baseline paleontological resource data to inform park management in planning and decision-making. Frequently, paleontological resource inventories in parks have resulted in important new fossil discoveries, as outlined in this publication. Preservation of these cave fossils through documentation, photography, photogrammetry, and collection will enhance opportunities for scientific research, public education, and resource stewardship of this important non-renewable record of life from NPS caves.

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