Chapter 12. Grand Canyon National Park Paleontological Resources Management and Protection

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Introduction
Paleontological resources are an integral part of Grand Canyon National Park (GRCA). As stated in the park’s foundation statement, one of the purposes of GRCA is to preserve and protect Grand Canyon’s unique geologic, paleontologic, and other natural and cultural features for the benefit and enjoyment of the visiting public. Furthermore, paleontological resources are considered a fundamental resource, warranting primary consideration during planning and management, contributing to the park’s significance, and helping achieve the park’s purpose (NPS 2017).

The foundation document also highlights fossil resources of particular interest, such as the diverse invertebrate and vertebrate trace fossils in the Coconino Sandstone, Precambrian stromatolites, Pleistocene vertebrate fossils found in cave deposits, and the large assemblages of marine invertebrate fossils in the Redwall Limestone, Surprise Canyon Formation, and Kaibab Formation. While it is known that GRCA contains an extremely diverse and complete fossil record, visitor use trends and site conditions for heavily visited fossil localities are lacking. The foundation statement supports the development of this paleontology inventory report and paleontological resource protection plan in order to preserve paleontological resources and support the park’s purpose (NPS 2017).

In previous years, there have been a few dedicated paleontologists studying fossil tracks, cave fossils, vertebrates, and other fossil resources found at GRCA; however, they are often outside researchers who do not work directly for the NPS. During the 2019 Paleontology Inventory, GRCA preserved and protected paleontological resources by building a park-based team and partnering with paleontologists from the NPS Geologic Resources Division. Therefore, 2019 has been an important year that demonstrated that establishing a team of dedicated paleontologists can greatly advance the knowledge and protection of fossil resources in NPS units and provide valuable outreach opportunities for the public.

GRCA Paleontological Resource Inventory
The inventory of paleontological resources is one of the most fundamental resource management activities that can be undertaken by a park. Baseline paleontological resource inventories help
identify the scope, significance, distribution, and resource management issues associated with fossils. The information gained through the inventory of park fossils enables park management to incorporate this information into park planning, programming, and decision-making.

Paleontological resource inventories are specifically identified in Section 6302 of the Paleontological Resources Preservation Act of 2009 (16 USC 470aaa–1), in Section 4302 of the Federal Cave Resources Protection Act of 1988 (16 USC 4301), and in NPS policy. The NPS Paleontology Program provides assistance to parks, including GRCA, by documenting and preserving paleontological resource information in the NPS Paleontology Archives and Library.

Between 1970 and 2010, most of the paleontology related activities undertaken at GRCA were primarily related to research and collecting by outside academic paleontologists and geologists working in the park. Jim Mead and students from the Quaternary Studies Program at Northern Arizona University coordinated paleontological research and collecting at Rampart Cave and other caves in GRCA (Mead 1981; Mead and Van Devender 1981; Mead and Phillips 1982; Mead et al. 2003; Carpenter 2003). In 2001, an inventory of paleontological resources associated with NPS caves, including those in GRCA, was undertaken by the NPS Geologic Resources Division (Santucci et al. 2001). This work later led to a GRCA-focused inventory of cave paleontological resources (Kenworthy et al. 2004). A more comprehensive inventory of paleontological resources at GRCA was included in a report documenting the fossils of the Southern Colorado Plateau Inventory and Monitoring Network in 2009 (Tweet et al. 2009). Between 2012 and 2018 a trans-boundary and collaborative project known as the Greater Grand Canyon Landscape Assessment (GGCLA) was undertaken to assess cave resources, including cave fossils, in and around the park. This project was expanded to include a Resource Condition Assessment (RCA) for the cave resources evaluated in the GGCLA project (Stortz 2018).

A number of paleontology interns were hired at GRCA after Deanna Greco was hired as the GRCA Physical Science Program Manager in 2010. Cassi Knight, Jeff Dobbins, James Super, Robyn Henderek, and Anne Miller served as Geoscientists-in-the-Parks (GIP) paleontology interns at GRCA and assisted with a variety of paleontological resource inventory projects. The work completed by these paleontology interns, along with their field notes, are incorporated into the GRCA museum and resource management archives.

In preparation for GRCA’s centennial in 2019, the NPS Paleontology Program (Vincent Santucci) initiated communication with GRCA staff (Jeanne Calhoun) in early 2018 proposing the development of a park specific paleontological resource inventory for GRCA in conjunction with the park’s centennial. This proposal was met with support from GRCA leadership and is the basis for this report.

In addition to the publication of this paleontology resource inventory report, GRCA staff conducted several surveys to document fossil localities as part of the second ever NPS PaleoBlitz (the first was conducted at CHIC in 2016). A few stratigraphic units at GRCA were the focus of these PaleoBlitz activities; Chinle Formation, Moenkopi Formation, Kaibab Formation, Coconino Sandstone, and Bright Angel Shale. Paleontologists Adam Marsh and Bill Parker from Petrified Forest National Park

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(PEFO) assisted in surveying the Mesozoic strata. JP Hodnett, program coordinator for the Maryland-National Capital Park and Planning Commission (M-NCP) Dinosaur Park (MD) and National Fossil Day coordinator, conducted surveys for vertebrate material in the Kaibab Formation on the North and South Rims. The GRCA Paleontology Team (Mark Nebel, Anne Miller, Diana Boudreau, Klara Widrig, and Jered Hansen) conducted targeted surveys of, primarily, the Coconino Sandstone and, to a lesser degree, the Kaibab and Toroweap Formations and the Bright Angel Shale, throughout the 2019 season, and discovered a number of previously unknown track localities (Figure 12-1). Each survey used a combination of field notebooks, paper locality forms, and digital data collection devices leveraging the ArcGIS Online and Collector technologies to physically and digitally collect locality and site information, setting the stage for faster and more efficient data entry for future paleontology surveys.

Figure 12-1. The GRCA paleontology team documenting a new fossil track locality in the Coconino Sandstone during the 2019 PaleoBlitz (Left to Right: Klara Widrig, Anne Miller, Diana Boudreau, and Jered Hansen) (NPS/MARK NEBEL).

GRCA Paleontological Resource Monitoring
The monitoring of in situ paleontological resources is another important resource management tool for the NPS. Paleontological resource monitoring enables the long term assessment of fossil stability
through the use of a variety of techniques (Santucci and Koch 2003; Santucci et al. 2009). Monitoring strategies may be developed for each fossil locality to consider the site specific variables, either natural or anthropogenic, which may threaten the paleontological resources and their values. Paleontological monitoring prescriptions are developed to determine the site specific monitoring activities such as 1) how frequently to monitor the fossil locality; 2) which monitoring methods are to be used; 3) when conditions warrant the collection of fossils from the locality; and other considerations.

The most common technique to monitor paleontological sites is repeat photography. GRCA archives contain many images of known fossil sites, many of which would benefit from monitoring. Many of these images have recently been linked to the paleontology geodatabase for ease of access and ability to spatially analyze paleontology site and locality data. Recreating these images would allow GRCA staff to assess the vulnerability of those sites due to natural or anthropogenic effects. Photogrammetry is another great option for monitoring. By taking a series of photographs and stitching them together to create 3D models, it is possible to preserve large specimens, such as trackways, to establish a baseline condition. However, neither of these techniques are quantitative in nature. Miller et al. developed a methodology, based on paleontological sites from GRCA, that uses clearly defined indices to quantitatively identify high-priority sites for monitoring (2018). Both quantitative and qualitative methods should be utilized to monitor paleontological resources.

There are a number of natural processes, environmental conditions, and other natural factors beyond human management that affect the stability of paleontological sites at GRCA. Fossils are primarily affected by weathering and erosion, particularly at GRCA where unvegetated outcrops and seasonal climate are common. Freeze-thaw cycles contribute to increased fracturing and monsoonal precipitation can increase rates of erosion. Winds transporting sediments can also gradually abrade fossils already exposed. Fossils found near creeks and streams at GRCA are threatened by flash flood activity that could abrade exposed fossils or wash fossils out of geologic context and deeper into the canyon. Sudden geologic processes, such as rock falls, may also reveal, cover, or damage fossil resources. Biological activity, such as lichen growth, plant growth, or trampling by deer, elk, or bighorn, could impact the visibility or quality of those fossils.

In addition to natural processes, anthropogenic or human caused impacts, both intentional and unintentional, can lead to degradation of fossil sites. Unintentional harm could be done by individuals that are not aware of the fossils or those who don’t understand that their actions negatively impact fossil stability. Despite the fossil protection provided by the Paleontological Resources Preservation Act (PRPA), fossils are still intentionally disturbed, removed, or vandalized. Due to these impacts, determining the monitoring plan for a fossil site should factor in ease of public access, visitor use near or at the site, potential for any ground disturbing activities, such as trail maintenance or construction work, and other factors that may contribute to theft or vandalism (Miller et al. 2018: Table 4).

**GRCA Paleontological Resource Protection**

Paleontological resources are threatened by natural processes such as erosion, as well as anthropogenic impacts, such as unauthorized collecting and vandalism. These threats impact the
fossils’ inherent scientific and educational value, as removing fossils from their geologic context impairs scientists’ ability to accurately understand a fossil’s significance in the geologic record. For resource management and protection, patrols of known paleontological sites and resources should be conducted to identify any indirect or direct human or natural impacts.

In 2009, the Paleontological Resources Preservation Act (PRPA) was signed into law as part of the Omnibus Public Land Management Act of 2009. New paleontology legislation is currently being drafted by an interagency coordination team including representatives from the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), National Park Service (NPS), and U.S. Fish & Wildlife Service (FWS) within the Department of the Interior (DOI). This legislation will provide guidance related to fossil inventories, monitoring, public education, research and collecting permits, curation, and criminal prosecution on DOI lands. For more information regarding this act, visit https://www.nps.gov/subjects/fossils/fossil-protection.htm.

**History of Paleontological Resource Protection at GRCA**

Fossil theft and vandalism at GRCA have not been frequently reported. Few incident reports have been filed regarding paleontology theft and vandalism. However, anecdotal evidence from Law Enforcement Officers (LEO) in South Rim, Inner Canyon, and North Rim districts indicate that damage to fossils may occur more frequently than the incident report records show (Figures 12-2 and 12-3). Most fossil incidents occur within the Canyon District, because more fossils are exposed in that district.

![Figure 12-2](image)

*Figure 12-2.* Track blocks have been chiseled out and removed from the Coconino Sandstone along Hermit Trail (left). Individuals have attempted to remove other trackways (solid blue oval), but did not complete the task, leaving behind chisel marks (dashed red oval) (NPS/VINCENT SANTUCCI).
Figure 12-3. A nail was used by a visitor attempting to pry this brachiopod fossil from the Kaibab Formation (NPS/VINCENT SANTUCCI).

The first record of fossil vandalism was in 1946. Superintendent Harold Bryant saw threats to park resources, including fossils, and compiled a list including abused signs, interpretive displays, trees, shrubbery, and graffiti, as well as noting damaged or stolen binoculars and a fossil specimen from the Yavapai Observation Station (now renamed Yavapai Geology Museum). Bryant’s efforts emboldened staff to prevent, as he called them, “such vicious acts of destruction.” In addition, this was the start of littering fines and proactive measures to lessen harm to park resources (Anderson 2000).

More recently, there have been continued reports of fossil theft and vandalism. In 2007 or 2008, law enforcement investigated a report of a fossil track block that was stolen off of North Kaibab Trail. During Spring Break of 2017, the Fossil Fern Exhibit along South Kaibab Trail at Cedar Ridge and fern impressions surrounding the exhibit were heavily vandalized (Figures 12-4 and 5). Most of the damage involved scratching rocks and the plexiglass covering the exhibit. Part of the plexiglass was broken, exposing the fossils housed inside the exhibit. Fossil specimens may have been removed from the area by visitors, but this has not been confirmed.
Figure 12-4. Scratch marks on the Fossil Fern Exhibit structure along the South Kaibab Trail in 2017 (NPS/ANNE MILLER).

Figure 12-5. Photographs from 2013 (A) and 2017 (B) of the same fossil fern impressions near the exhibit showing vandalism that occurred during Spring Break in 2017 (NPS).

On May 20, 2019 two individuals were caught collecting approximately 13.5 kg (30 lbs.) of specimens from the fossil beds along the western Rim Trail (Figure 12-6). They were reported by a visitor, and law enforcement responded in time to apprehend the individuals. The couple appeared to be avid rock collecting hobbyists and used small hammers and picks to collect specimens. All fossil specimens were confiscated and are being held as evidence.
Figure 12-6. Rock and fossil specimens found in suspect's backpack after GRCA law enforcement apprehended them removing specimens from park land in 2019 (NPS).

Paleontological Resource Protection Recommendations
Canyon Rangers, law enforcement, and GRCA staff should be attentive during their regular duties for individuals attempting to take or deface specimens. Many well-preserved specimens are close to the main trails in the park and are therefore at a higher risk of damage or theft due to ease of access. Regular patrols should be conducted near heavily visited paleontological localities.

Fossil theft and vandalism trainings can better prepare staff to identify, report, and manage fossil theft and vandalism incidents. For more information on Paleontology Resource Protection trainings, contact Vincent Santucci (vincent_santucci@nps.gov). Regular training of LEOs and interpretive staff can help reduce the number of fossil theft or vandalism incidents. However, active recruitment of paleontological research scientists should also be considered a management strategy.

If fossil specimens are found during regular patrols by staff or visitors, follow these steps:

- Do not collect, remove, or disturb the fossils without consulting the Chief of Resources or individual responsible for paleontological resources at GRCA.
- Record locality information, including, but not limited to, geographic location, nearest trail or natural feature, GPS coordinates, and description of fossil within the rock.
• Take photos of the fossil specimen itself with a scale, a wider view of the fossil in the surrounding rock, and images looking up trail, down trail, and/or with identifiable landmarks in frame. Use an item for scale in each photo (e.g., another hiker, backpack, water bottle, coin).

• Reach out to individuals responsible for paleontological resources at GRCA to notify them of the resource and provide them with the associated information.

GRCA Paleontological Resource Research and Permits

Internal Permits
Several internal blanket permits were issued to past Chiefs of Resources to facilitate study and interpretation of geological and paleontological resources within the park. Permit GRCA-2011-SCI-0034 was issued to Deanna Greco to facilitate a paleontological inventory of Grand Canyon National Park with Geoscientists-in-the-Parks (GIP) interns Jeff Dobbins and James Super. Judy Helmich was issued permit GRCA-2003-SCI-0085 that allowed interpretive staff to collect specimens while in the field to use in their programs. Both of these permits are now expired.

On October 18, 2019, the GRCA Paleontology Program received a programmatic Categorical Exclusion (CE) (PEPC 90271) to guide ongoing paleontology work in the Park. The CE describes routine, ongoing paleontology inventory and monitoring work and resource mitigations for performing this work.

Previous Research Permits
Jim Mead and Mary Carpenter were issued permit GRCA-1999-SCI-0001 for their project “Late Pleistocene Vertebrate Communities in the Lower Grand Canyon, Arizona: Rampart and Muav Caves.” This work supported Mary Carpenter’s thesis (Carpenter 2003) and an abstract (Carpenter and Mead 1999).

John Foster was issued permit GRCA-2009-SCI-0032 in an attempt to relocate historic trilobite quarry locations. The permit was for in situ research only. He was unsuccessful in relocating the Cameron-Walcott quarry site, but the McKee Quarry was relocated in 2009. His findings were published in the Museum of Northern Arizona bulletins (Foster 2011).

Jessica Metcalfe was issued permit GRCA-2013-SCI-0001 for her dissertation project, “Late Pleistocene Paleoeology of the Colorado Plateau.” The overall goal of this study was to reconstruct late Pleistocene paleoecology on the Colorado Plateau using isotopic analysis to examine feeding and migratory patterns. No collections were made as part of this project, which instead relied on GRCA and MNA museum collections (Metcalfe 2018).

Permit GRCA-2017-SCI-0054 was issued to Stephen Rowland for the study of fossil trackways in the Supai Formation. Research was focused on a trackway along the Bright Angel Trail, which may represent the oldest vertebrate trackway in the park. A paper on this trackway is currently in peer review.
Anne Miller was issued permit GRCA-2017-SCI-0059 for her Master’s thesis at Northern Arizona University “Ichnology of the Bright Angel Shale Formation, Grand Canyon, AZ: Indicators for Middle Cambrian Paleoecology.” This research is still ongoing.

A complete list of paleontology research permits issued in Grand Canyon National Park from 1999 to 2019 can be found in Appendix 12-A.

**Current Permits**

Permit GRCA-2019-SCI-0002 was issued to Vincent Santucci for the Grand Canyon National Park 2019 Paleontological Resource Inventory and PaleoBlitz. All field activities related to this report were authorized by this permit. Field activity is focused on the documentation and assessment of paleontological localities; however, surface collection of exceptional specimens is permitted.

**GRCA Paleontological Resource Curation and Museum Collections**

Museum collections at GRCA are stored at 2C Albright Avenue, Grand Canyon, Arizona, 86023. This storage facility was completed in 1999. It contains 6,000 ft² (557 m²) of climate-controlled storage and houses over 1.6 million objects. Items are cataloged using the Interior Collections Management System (ICMS), version 8.20.48.3660 as of April 29, 2019.

**Scope of Paleontological Collections**

Grand Canyon National Park’s paleontology collection includes a total of 13,428 catalog numbers. Of these, the vast majority were found within the park. Specimens collected from outside the park were once brought into the collections for teaching, research, exhibit, or other purposes, with the majority being from Arizona. This practice was discontinued in 1978, when the service’s management policies stated “a scope of collection statement, in which the limits of museum collection are detailed, must be prepared and approved for every park.” Fossils from other NPS units that remain in the GRCA collections include: 12 specimens from Harpers Ferry Center, one of which was returned to the Harpers Ferry Center museum storage facility; 38 specimens from Lake Mead National Recreation Area (LAKE); 45 specimens from Petrified Forest National Park (PEFO); and 239 specimens from Grand Canyon-Parashant National Monument (PARA). Most of the non-GRCA fossils are from areas in the vicinity of the park in northern Arizona. It should be noted that some Grand Canyon fossil specimens come from lands formerly part of GRCA, but now within the Havasupai Indian Reservation, which may lead to some confusion, because the original locality information may report that they are from the park. With 2,857 cataloged specimens, brachiopods are the most common fossil type in the collection, followed by mammals (2,177), trilobites (1,438), and bivalves (1,006). When considering the rock unit of origin, the greatest number of fossils in the collection were found in Quaternary deposits (4,994 catalog numbers), followed by the Kaibab Formation (3,302) and the Bright Angel Shale (1,669).

At least 167 fossil taxa have been named from specimens (holotypes, syntypes, etc.) collected within the modern boundaries of GRCA (Appendix A). An additional 13 taxa are based on specimens potentially collected within GRCA, but the provenance information is too vague to know for certain (Appendix B) (Tweet et al. 2016). Four holotype specimens are stored in a locked cabinet separate from the rest of the paleontology collections for added security.
Notable Contributors to Paleontological Collections

Paleontological Collections in Outside Repositories
Numerous GRCA specimens are housed at outside institutions. The exact number of these institutions will probably never be known. There are several reasons for this. Among the most important factors are the following: the Grand Canyon region has long been a popular area for geological and paleontological field trips; undocumented collecting frequently occurred before the permitting system was implemented; the park boundaries have changed several times; standards for reporting locality information were formerly more relaxed, so that fossils collected from within GRCA are undoubtedly lost behind provenance information limited to “Grand Canyon” or “Arizona”; provenance information has been partially or entirely lost when material from smaller collections has been absorbed by other institutions; and many fossil specimens are easily accessible, portable, and therefore prone to illegal collecting. Because of these and other factors, it would not be surprising to find a small quantity of Grand Canyon fossils in any large paleontological collection.

A list of institutions containing GRCA specimens has been compiled from the literature. This list is based on mentions of definite GRCA specimens in specific collections (particularly type and figured specimens). This is not an exhaustive list. Contact information is provided in Appendix D.

- Academy of Natural Sciences of Drexel University (ANSP, formerly the Academy of Natural Sciences of Philadelphia; Philadelphia, Pennsylvania)
- American Museum of Natural History (AMNH; New York, New York)
- Brigham Young University (BYU; Provo, Utah)
- California Academy of Sciences, including material from the former collections of Stanford University (CAS; San Francisco, California)
- Carnegie Museum of Natural History (CMNH; Pittsburgh, Pennsylvania)
- Cincinnati Museum Center, including material from the former collections of the University of Minnesota (CMC; Cincinnati, Ohio)
- Columbia University (CU; New York, New York)
- Field Museum of Natural History (FMNH; Chicago, Illinois)
- Harvard University Herbaria (HUH; Cambridge, Massachusetts)
- Lake Mead National Recreation Area (LAKE; Boulder City, Nevada)
- Lund University (UL; Lund, Sweden)
- Museum of Comparative Zoology (MCZ; Harvard, Massachusetts)
- Museum of Northern Arizona (MNA; Flagstaff, Arizona)
• Natural History Museum of Los Angeles County, including material from the former collections of the California Institute of Technology and University of California at Los Angeles (LACM; Los Angeles, California)
• Raymond Alf Museum (RAM; Claremont, California)
• Smithsonian National Museum of Natural History (USNM; Washington, D.C.)
• University of Arizona Laboratory of Paleontology (UALP; Tucson, Arizona)
• University of California Museum of Paleontology (UCMP; Berkeley, California)
• University of Notre Dame (UND; Notre Dame, Indiana)
• University of Tübingen (Eberhard Karls University) (UT; Tübingen, Germany)
• Western Archeological and Conservation Center (WACC; Tucson, Arizona)
• Yale Peabody Museum (YPM; New Haven, Connecticut)

USNM houses significant material from GRCA, including the holotypes of 138 of the 167 fossil species named from GRCA material. Notable non-holotype specimens include a complete vampire bat skull (Desmodus stocki) found in Rampart Cave (USNM V 25478). The Smithsonian also houses the GRCA collections of Charles Doolittle Walcott, Charles Gilmore’s track collections, David White’s fossil plants, and Rampart Cave collections.

Photographic Archives
The GRCA Museum Collection maintains an image index database of historical photos related to paleontology in the park. This collection includes 247 photos, the oldest of which is an 1858 portrait of J. S. Newberry, the first geologist to describe fossils from Grand Canyon. Other notable geologists and paleontologists in the image database include David White, John Merriam, George Hesemann, Edwin McKee, and Charles Doolittle Walcott. Many of the photographs in the database document fieldwork and ichnofossils throughout the canyon. As such, they are useful for relocating historic sites and providing comparative photos for site monitoring and management. The oldest of these field photographs was taken in 1913, by Francois Matthes, and documents vertebrate tracks in the Coconino Sandstone. In 1930, a series of photographs of ichnofossils in the Coconino Sandstone were taken by George Grant. Civilian Conservation Corps (CCC) projects in the late 1930s were well documented via photography. These projects included the construction of the Fossil Fern Exhibit on the South Kaibab (Yaki) Trail, construction of trilobite exhibits near Indian Garden, and work at Rampart Cave. The CCC project at Rampart Cave was photographed by Michael Bobko and includes photographs of sloth dung filling the cave and the CCC crew excavating fossil bones. Kaibab fossils within the Museum Collection were also extensively photographed in the 1930s.

The image index database also includes a handful of photographs from outside the park. Photos of dinosaur tracks near Moenkopi, Cameron, and Tuba City can be found in the archives. Two photos of modern animal tracks in a sand dune north of Kanab, UT, were added for comparison with fossil trackways. Other notable photos include petrified wood from PEFO and a human skeleton at Willow Beach photographed during the CCC expedition to Rampart Cave. Western portions of GRCA were
once within the boundary of Lake Mead National Recreation Area (LAKE), so additional archival items may be found within LAKE’s archives.

**Digital Archives**

3D models produced by photogrammetry techniques are an excellent way to make fossils available to the general public and remote researchers. A total of 15 photogrammetry models have been created from GRCA specimens using this technique. Two models can be found on the Smithsonian 3D Digitization webpage. Both specimens were originally from GRCA and are now housed at USNM.

In April 2019, a project with Geology and Photogrammetry Specialist Jack Wood (GRD) was initiated to digitize additional museum specimens to display as online 3D models for National Fossil Day. These models have been uploaded to the National Park Service Geologic Resource Division Sketchfab page (https://sketchfab.com/grd_nps/models), GRCA photogrammetry series website (https://www.nps.gov/articles/series.htm?id=A9E62040-AC6F-A6D7-BE564A036F1D6146), and photos and files associated with each 3D model have been archived on IRMA. For a complete list of specimens with photogrammetry 3D models see Appendix 12-B.

Very few photographic records exist for fossils within the collections. Although it would be a lengthy undertaking, photographing each item in the collection would be extremely useful for archival and research purposes. It would also be valuable to digitize more museum objects via 3D photogrammetry. This would make the museum collections far more accessible to visitors and researchers, the vast majority of whom do not have the opportunity to tour or visit the museum collection.

**Outreach**

The GRCA Museum Collection is a storage and research facility that is open to the public by appointment only. All tours of the collections must be requested in advance. Museum curators normally give 50 to 60 tours each year. The main audiences for these tours are school groups, park staff, and members of other affiliated organizations, such as Xanterra and the Grand Canyon Conservancy. A yearly art exhibition is held in mid-September, where the museum hosts a three-hour open house to display the art collection.

**GRCA Paleontological Resource Interpretation, Education, and Outreach**

The fossils preserved in the rock layers of GRCA are an integral part of explaining the geologic history of the canyon to the public. Their presence helps scientists better understand past depositional environments and how the landscape and lifeforms of this region have changed over time. There are many ranger-led programs, self-guided hikes, brochures, booklets, and educational programs at GRCA that focus on fossils and paleontological resources. All of the programs, handouts, and available resources are compiled here to better prepare interpretation and education staff. While most events are localized to the South Rim, any large interpretive event or program that is developed by the park should extend to the North Rim, Desert View, and Inner Canyon districts as often as possible. This can be accomplished by distributing flyers, cards, stickers, posters, or by adapting programs for use at these other locations.
Current Long Range Interpretive Plan
There is no current or proposed long range interpretive plan for paleontology at GRCA.

Current Paleontological Interpretive Programs

Ranger-Led Programs

Fossil Walk—Summer Only
The Fossil Walk program takes visitors on a journey back in time to discover what fossils can tell us about this part of the continent 270-million-years ago. Visitors join a Park Ranger for a hike along the western Rim Trail from Bright Angel Trailhead to visit the fossil beds preserved in the Kaibab Formation. Fossils are abundant in this area including *Meekella* and productid brachiopods, crinoid stem segments, stick and lacy bryozoans, burrows, horn corals, and sponges. This locality is also very close to the rim, providing an excellent opportunity to discuss other fossiliferous units in the canyon and the significance of the fossil record.

Geo-Glimpse—Year-Round
This 20-minute ranger-led program explains how Grand Canyon formed while exploring the canyon rim near Yavapai Geology Museum. Although fossils are not a central part of this program, paleontological topics are woven into the geologic history of the Grand Canyon to better understand paleoenvironments and the canyon we see today. A 45-minute version of this program is offered spring to fall as a Geo-Walk Ranger Program.

Junior Ranger Family Program—Summer Only
During summer months, in Grand Canyon Village on the South Rim, special family-friendly programs are offered with youth and Junior Rangers in mind. Two of these programs, Family Adventure Hike and Natural Wonders, highlight the paleontological resources found within the layered rocks of Grand Canyon. Family Adventure Hike guides individuals down the Hermit Trail for a two-hour hike to explore the canyon’s resources first hand. Natural Wonders is a 30-minute Park Ranger presentation on the historic El Tovar Hotel Canyon-side porch.

Evening Programs—Summer Only
Evening programs presented by Park Rangers cover a wide variety of topics. Occasionally, programs discuss paleontology and geology of GRCA.

Self-Guided Hikes

Trail of Time Geology Walk—South Rim, Year-Round
The Trail of Time is a self-guided walking timeline trail along the South Rim that prompts visitors to understand the complex and long geologic history of Grand Canyon without having to leave the rim (Figure 12-7). Examples of each of the major rock layers are displayed along the trail, some of which contain fossil resources such as stromatolites, trace fossils, and invertebrate body fossils. A number of wayside signs explain paleontological concepts such as evolution, deep time, depositional environments, and erosion of past fossil-bearing strata. A Trail of Time companion booklet was compiled to provide visitors with a more in-depth interpretive experience. Self-guided materials for school groups or other larger groups are also available for teachers who could not schedule a ranger-led field trip.
Figure 12-7. Entrance portal along the Trail of Time near the Grand Canyon Headquarters building (NPS/DIANA BOUDREAU).

Widforss Trail—North Rim, April through October
The Widforss Trail provides access to many views of the canyon along the North Rim. The interpretive brochure available at the trailhead or Visitor Center provides visitors with paleontology information at stops 2 and 9. Stop 2 encourages visitors to examine the fossils preserved in the Kaibab Formation beneath their feet including crinoids and other small marine creatures (Figure 12-8). Stop 9 identifies the cliff forming Coconino Sandstone from a particularly scenic overlook. Visitors are informed of the wealth of fossil tracks preserved in this prominent geologic unit and the brochure includes an image of fossil vertebrate tracks.
Figure 12-8. Crinoid stems, stick and lacy bryozoans, and shell fragments from exposures of the Kaibab Formation can be found along the rim of the canyon (NPS/DIANA BOUDREAU).

Curriculum-Based Programs

Ranger-Led Field Trips—Spring and Fall

Each year the Environmental Education Branch of Grand Canyon National Park offers many ranger-led field trips for grades 3–12. Students from Arizona, and across the world, sign up for these free, curriculum-based programs. “Stories in Stone” is a two-and-a-half-hour trip focused on teaching introductory geology and paleontology, how fossils form, how to interpret ancient environments, and the importance of field work and making observations. “Grand Canyon Rocks” is a similar field trip to “Stories in Stone”, but it includes more exercises related to geology rather than paleontology. “Dynamic Earth” is a five-hour field trip that combines the information presented in these two programs. During each of these field trips, students fill out a journal with guiding questions and exercises to introduce new geologic and paleontological terms and concepts (Figure 12-9).
Figure 12-9. Students identify fossils in the Kaibab Formation at the fossil beds during the “Stories in Stone” field trip (NPS/RONNIE COLVIN).

Classroom Ranger Visits—Winter Only
During the winter months, Park Rangers make classroom visits to nearby schools in Arizona and surrounding states to educate students about a variety of topics, including paleontology and geology of GRCA.

Distance Learning—Year-Round
These programs are available year-round to classrooms or anyone with an internet connection. One of the distance learning programs is the “Ancient Life Program” which aims to teach 3rd–5th grade students about fossils. This program introduces students to the National Park Service, orients them to the geographic location of GRCA, familiarizes students with examples of GRCA fossils and rock units that contain fossils, relates rock types to depositional environments, explains environmental change over geologic time, and introduces students to the vast amount of time represented by the rock layers in the Grand Canyon. Students also better understand fossil bias in the rock record by playing a card game in which students are either turned into fossils or not, depending on the cards they are dealt.
Junior Paleontologist Program—Year-Round
This nationwide program targets kids age 5–12 and encourages them to explore, learn about, and protect fossil resources in National Parks, including those at Grand Canyon. The NPS Geologic Resources Division can provide Junior Paleontologist Activity Program supplies including activity booklets, badges, posters, and other fossil-related educational resources. Contact Vincent Santucci for more details (vincent_santucci@nps.gov).

Grand Canyon Field Institute and School Programs
There are a number of outside companies that offer guided trips into the canyon, such as the Grand Canyon Field Institute that is run by the park’s non-profit partner, Grand Canyon Conservancy. Some of these guided trips take time to educate their groups on the geology and fossil resources found within the park.

Canyon Field School is a partnership between the Grand Canyon Conservancy and the National Park Service and offers unique opportunities for youth to experience the great outdoors at Grand Canyon National Park. They offer overnight camps that center around scientific discovery and learning at Grand Canyon National Park.

National Fossil Day Event
National Fossil Day is an annual event that takes place nationwide on Wednesday of the second full week in October, which is also Earth Science Week. Grand Canyon National Park has hosted a National Fossil Day event on the South Rim for the past five years (Figure 12-10). In the past, Park Rangers have led a fossil walk program, scheduled fossil themed games and activities for kids, hosted a Q&A session with fossil experts, remotely toured the Kaibab Formation fossil beds and interacted with rangers and fossil experts using “Facebook Live”, and presented a fossil themed evening program focused on National Fossil Day and GRCA fossil resources. The NPS Geologic Resources Division can assist the park with planning for National Fossil Day activities and provide Junior Paleontologist Activity Program supplies including activity booklets, badges, posters, and other fossil-related educational resources. Contact Vincent Santucci for more details (vincent_santucci@nps.gov).
The 2019 National Fossil Day Celebration was a larger event compared to previous years, as an opportunity to commemorate the park’s 100th anniversary (Figure 12-11). In 2019, Grand Canyon National Park hosted a number of outside researchers and partners on the South Rim on September 27 and 28. The festivities started off with a mini Paleontology Symposium on Friday, September 27, 2019. Four guest speakers shared their research on GRCA paleontology and specimens from the museum were on display during the symposium (Figure 12-12). During the National Fossil Day Celebration on September 28, visitors could participate in ranger-led programs to the fossil beds, create fossil-themed crafts during children’s activities at the Yavapai Geology Museum, and were even able to ask paleontologists questions virtually through a special Facebook Live event. Twelve partner organizations participated with informational booths at the Grand Canyon Visitor Center plaza, including a green-screen photobooth provided by the American Geosciences Institute (Figure 12-13). A welcome ceremony for the event took place at the Mather Amphitheater with guest speakers Bruce MacFadden (President of the Paleontological Society) and Vincent Santucci (NPS Senior Paleontologist), Science and Resource Management’s Chief of Resources, Jeanne Calhoun, and an Arizona State Greeting for the National Fossil Day event (Figure 12-14). The National Fossil Day Celebration was capped by a special paleontology evening program given by NPS Senior Paleontologist and Paleontology Program Coordinator Vincent Santucci. For more in-depth information on the National Fossil Day Celebration, refer to the 2019 Paleontology Project After Action Report (Boudreau 2020).
Figure 12-11. NPS paleontologists and educators who assisted with the 10th Annual National Fossil Day activities and programs on the South Rim of Grand Canyon National Park on September 28, 2019. Left to right (front): Jeremy Childs, Jennifer Glennon, Anne Miller, Hazel Wolfe, Celia Dubin, Kevin Garcia, John-Paul Hodnett, Vincent Santucci, Mary Carpenter, Jim Mead, Joel Despain, Adam Blankenbicker, Chris Symons, Jason Kenworthy, and Justin Tweet. Left to right (back): Grace Lilly, Janet Gillette, David Gillette, Tom Olson, Richard McMichael, Don Weeks, Anne Scott, Eleanour Snow, Andy Grass, Sequoyah McGee, Robyn Henderek, Sandy Croteau, Erin Eichenberg, Diana Boudreau, Sherman Mohler, Mary Ontiveros, Doug Wolfe, Maria Rodriguez, Veronica Colvin, Joel Kane, and Bryan Maul (NPS/MICHAEL QUINN).
Figure 12-12. Advertisement for the four speakers at the Paleontology Symposium on Friday September 27, 2019 at the Shrine of the Ages (NPS).
Figure 12-13. Advertisement for the National Fossil Day Celebration event at the South Rim of Grand Canyon National Park (NPS).
Figure 12-14. Speakers at the Welcome Ceremony at Mather Amphitheater at the National Fossil Day Celebration on September 28, 2019. Left to right: Jeanne Calhoun, Ronnie Colvin, Bruce MacFadden, and Vincent Santucci (JOHN-PAUL HODNETT).

Below are some statistics concerning visitation during the National Fossil Day Celebration:

- Approximately 110 visitors attended the Paleontology Symposium on Friday, September 27, 2019
- 85 visitors attended the Paleontology Evening Program given by Vincent Santucci on Saturday, September 28, 2019
- Ask-A-Scientist social media livestream reached 7,617 individuals, a maximum of 104 individuals viewed simultaneously, and 116 viewers submitted comments or questions
- Fossil Bed social media livestream event reached 23,788 individuals, over double the viewership compared to last year which reached 10,756 individuals. This livestream peaked at 290 viewers and received 116 comments and questions.

A number of new interpretive materials were developed specifically for the 2019 National Fossil Day event. Interpretation and education staff designed a portable pop-up exhibit, highlighting fossils from GRCA with paleo environments, to use for events hosted at GRCA, such as National Fossil Day, or for classroom ranger visits (Figure 12-15). This pop-up exhibit was unveiled on September 27, 2019,
and was on display at the Grand Canyon Visitor Center for two months following the event. A set of nine GRCA fossil-themed trading cards and National Fossil Day informational postcards were also developed for distribution at fossil events.

**Figure 12-15.** A large pop-up exhibit highlighting Grand Canyon National Park fossils was developed for the 2019 National Fossil Day Celebration at Grand Canyon (NPS/DIANA BOUDREAU).

**Interpretive Signs and Exhibits**

**Permanent Signs and Exhibits**

*South Rim*

There are a number of fossil interpretive signs on the South Rim in Grand Canyon Village. The largest concentration of paleontological interpretation is at the Yavapai Geology Museum. There is a small wall case that contains real and replica fossil specimens, such as brachiopods, stromatolites, trilobites, worm burrows, and a cast of a dragonfly wing. Many interpretive signs within the museum explain past depositional environments at Grand Canyon and have models of fossils from the canyon, including a trilobite with tracks, brachiopods, and *Chelichnus* tetrapod trackway (Figure 12-16). A cast of the Shasta Ground Sloth skull and dung are on exhibit in the main lobby of the Grand Canyon Visitor Center. A regularly scheduled program about the formation of the Grand Canyon titled “The Canyon World” plays in the Science on the Sphere exhibit at the Grand Canyon Visitor Center and highlights the fossil record.
The Rim Trail between the Grand Canyon Visitors Center and the Yavapai Geology Museum is void of interpretive signage; however, traveling west along the Rim Trail from the Yavapai Geology Museum, visitors explore the “Trail of Time.” See the Trail of Time section above for more information. The Rim Trail is often bordered by a small stone wall that contains large chunks of petrified wood. Most notable is the section of wall across from Verkamp’s Visitors Center (Figure 12-17); it also has two large sections of petrified wood placed by the entrance ramp.
A number of other localities on the South Rim expose the public to GRCA’s rich fossil assemblage. Bright Angel Lodge has a historic geology fireplace designed by Mary Colter (Figure 12-18A). Visitors can see stromatolites and a coiled nautiloid embedded in the rock fireplace. In the central courtyard of GRCA Headquarters, a few track blocks have been placed in the benches and stone floor (Figure 12-18B). In the main lobby, a small exhibit, compiled by a previous GIP, contains paleo environment images, fossil specimens, and an explanation of the fossil history of GRCA. These are examples of paleontological resources in cultural contexts; see Kenworthy and Santucci (2006) for further information on similar occurrences.

![Figure 12-18. A. The geology fireplace in the Bright Angel Lodge designed by Mary Colter exhibits geology and paleontology of the Grand Canyon (NPS/MICHAEL QUINN). B. Fossil trackway slab used as building material for a bench in the Grand Canyon Headquarters courtyard. (NPS/DIANA BOUDREAU).](image)

**North Rim**

The North Rim has one interpretive sign that outlines the paleoenvironments of the Kaibab, Coconino, Hermit, and Supai formations. The sign is located along a paved path between the North Rim Lodge and Bright Angel Point, providing an opportunity for visitors to read about past depositional environments of the canyon. Visitors can also learn about erosion, geologic time, and lack of Mesozoic strata and dinosaurs in the park on an interpretive sign at Point Imperial.

**Desert View**

There is no paleontological signage at Desert View. However, a coiled nautiloid that was found in the Kaibab Formation during the construction of the Desert View Watchtower was placed in a small glass wall case with other cultural and historic artifacts on the 2nd floor of the watchtower with a small descriptive label (Figure 12-19).
Figure 12-19. A coiled nautiloid found in the Kaibab Formation during construction of the Desert View Watchtower on display at Desert View (NPS/SALLY CARTTAR).

Canyon District
Most of the paleontological interpretation within the canyon district occurs via ranger programs. However, interpretive staff are planning to restore and add interpretive signage to the historic Fossil Fern Exhibit along the South Kaibab Trail at Cedar Ridge. For more information on this exhibit see the Historic Interpretive Sites section.

Future Signs and Exhibits
There are a few ongoing projects to update and add to paleontological interpretation at Grand Canyon. A proposed wayside exhibit for the fossil beds site would provide visitors with information for that site year-round, however there are concerns about fossil theft and vandalism at the site. Staff also plan to restore the historic Cedar Ridge CCC Fossil Fern Exhibit along the South Kaibab Trail, produce an interactive fossil component for the GRCA park app, and develop a mini program to display at the Grand Canyon Visitor Center’s “Science on the Sphere”. Construction on the Maswick South Lodging Complex began in 2019 and each of the four new lodging buildings will be named for fossils (Trilobite, Shasta, Fern, and Burrow). Xanterra plans to incorporate paleontological interpretive and outreach elements into the construction and landscaping of these buildings.
Historic Interpretive Sites

*Cedar Ridge CCC Fossil Fern Exhibit*
Located along the South Kaibab Trail at Cedar Ridge approximately 2.4 km (1.5 mi) down trail, the CCC Fossil Fern Exhibit resides at the edge of a cliff (Figure 12-20). During the construction of the South Kaibab Trail (formerly called the Yaki Trail) in the 1930s, trail workers uncovered well-preserved fossil ferns in the Hermit Formation. Recognizing their importance, the trail crew constructed an exhibit case to display and protect the well-preserved fossil plant materials. Since that time, little has been done to maintain and protect this exhibit. Therefore, the paleontology, interpretation, and outreach staff will work along with volunteers to rebuild this historic site in future years.

![Image of Fossil Fern Exhibit](image1)

*Figure 12-20.* Fossil Fern Exhibit at Cedar Ridge on South Kaibab Trail in the 1930s (A) and in the spring of 2019 (B) (NPS).

“Lost” *Trilobite Exhibit*
A trilobite exhibit was built near Indian Garden in 1935 along the Bright Angel Trail by the CCC. There are no indicators on the trail today that this site ever existed. A team from the Museum of Western Colorado relocated one quarry using historic images in 2011 (Foster 2011). This exhibit was developed near a known fossil locality along the Tonto Trail. A total of three quarries were excavated; however, only the third quarry proved suitable for an exhibit. Unfortunately, the exhibit case did not protect the fossils from water and erosional processes. The Bright Angel Shale is very friable in nature, which caused the overlying shales to fall on top of the exhibit, obscuring the fossil trilobites. Noticing this threat to fossil resources, the park superintendent requested the exposed fossils be removed from the exhibit before it was completely buried. These specimens are now housed in GRCA museum collections. The location of the trilobite quarries is not entirely known by GRCA staff.

Interpretive Handouts, Site Bulletins, Books, and Brochures

Interpretive Staff Training and Resources

Paleontology Trainings

No formal paleontological training is provided to seasonal or permanent interpretive staff. However, Ronnie Colvin, Interpretive Park Ranger, provides a “Fossil 101” training upon request for incoming interpretive staff with an interest in fossils and paleontology. There are also teacher workshops available upon request that are taught by Ronnie Colvin and the Education Branch staff (Figure 12-21). In addition, interpreters and others interested in paleontological training may contact the park paleontologist to explore participating in field work.

Figure 12-21. Teacher workshop at the fossil beds site along the Rim Trail (NPS).

Paleontological Interpretation Resources

There are a number of tools and resources available for the interpretive staff. A cache of fossil specimens from GRCA are available for use in public programs and outreach events. The education and interpretation department has a few items located within the park. These specimens were deaccessioned from the museum collections and made available to the interpretation division.
Contact GRCA Museum Specialists Kim Besom (x7766) or Colleen Hyde (x7769) for more information. In previous years, a collection permit was provided for the interpretation staff to acquire more educational materials; however the permit has since expired and should be updated if more materials are needed.

As technology advances, examples of fossil resources are also available in digital forms. During the 2019 paleontology inventory, a number of important museum specimens were imaged to create 3D models which could then be 3D printed or viewed online as interactive models. See Appendix 12-B for a detailed list of available 3D specimens. Contact Vincent Santucci (vincent_santucci@nps.gov) or GRCA Museum Specialists Kim Besom (x7766) and Colleen Hyde (x7769) for more information.


All paleontology programs developed by Park Rangers should instruct visitors on how to be paleontologically aware while in the park. The following topics should be highlighted when mentioning fossils in interpretive programs:

- When paleontologists survey for fossils, an important tool is a geologic map. Paleontological resources are more common in certain geologic units, so knowing where those units are exposed is important for a successful survey. Other field paleontology tools include small picks and brushes, appropriate glues and consolidants, GPS, camera, topographic maps, and appropriate First Aid and safety equipment. It might be helpful to provide examples of these items for visitors during an interpretive talk, if available.

- If fossils are found in the park by a visitor, they should photograph it, note the coordinates, and notify a ranger of where the resource was found, but most importantly they should leave the fossil where they found it. It is extremely important for scientific and resource management purposes for original location information to be preserved. Visitors should be informed that park fossils are non-renewable resources that are protected by federal law (Paleontological Resources Preservation Act, 2009).

**GRCA Paleontological Resource Data Management**

GRCA has been a focal point of paleontology research even before its designation as a National Park 100 years ago, leading to a wealth of data and resources that need to be properly managed. In addition, the Paleontological Resources Preservation Act (PRPA) mandates the management of fossils and associated data using scientific principles and expertise. Information regarding paleontological resources at GRCA, such as field notes, publications, and paleontology locality datasheets, are managed within the Park’s internal network. Field data collected at paleontological sites and localities are maintained within a geospatial database. NPS Paleontology Archives and Library has a copy of all these files. These databases and archives have been fully updated as part of the 2019 Paleontology Inventory.
**GRCA Paleontology Archives**
GRCA maintains a paleontology archive and library to organize all documents related to paleontology resources at the park. Items such as field notes, publications, historic photos, maps, research permits, and museum collection documents can be found within the archives.

Due to the sensitive nature of paleontological resources, paleontology archives are restricted access only. To request access to information within the archives, contact Mark Nebel (mark_nebel@nps.gov) or Anne Miller (anne_miller@nps.gov).

**NPS Paleontology Program Archives (WASO)**
The National Park Service Paleontology Program (WASO) maintains a copy of all digital and hardcopy field notes, sketches, photographs, maps, reports, publications, and lists of archived fossil specimens at GRCA (Santucci et al. 2018). This ensures the safety of paleontological resource data in the event either GRCA or WASO archives are lost. To request access to materials in the WASO Paleontology Archives contact Vincent Santucci (vincent_santucci@nps.gov) or Justin Tweet (justin_tweet@nps.gov).

E&R Files
E&R files (from “Examination and Report on Referred Fossils”) are unpublished internal USGS documents. For more than a century, USGS paleontologists identified and prepared informal reports on fossils sent to the survey by other geologists, for example to establish the relative age of a formation or to help correlate beds. The system was eventually formalized as a two-part process including a form sent by the transmitting geologist and a reply by the survey geologist. Sometimes the fossil identifications were incorporated into publications, but in many cases this information is unpublished. These E&R files include documentation of numerous fossil localities within GRCA, including from L. F. Noble’s and Edwin McKee’s work. Extensive access to the original files was granted to the NPS by the USGS beginning in 2014 (Santucci et al. 2014).

**McKee and Walcott Archives**
Paleontological research has a long history at GRCA. Two individuals, Edwin McKee and Charles Walcott, were heavily involved in recording and studying fossils in the canyon and created extensive archives. The McKee Archives, housed at USGS in Denver, include hand drawn stratigraphic columns, specimen lists, and correspondence with outside researchers. The Walcott Archives, housed at the Smithsonian Institute, are almost entirely composed of his field notes and sketches from 1930. To request access to these archives, contact Vincent Santucci (vincent_santucci@nps.gov), Justin Tweet (justin_tweet@nps.gov), Mark Nebel (mark_nebel@nps.gov), or Anne Miller (anne_miller@nps.gov).

**Geospatial Database**
Earle E. Spamer originally created, for his own personal and professional use, a Paradox database in the 1980s to track published data, and some unpublished theses, on paleontological resources of the Grand Canyon region and their related taxonomy. This database was later migrated to an Access database format that was presented by Spamer to the National Park Service (NPS) in 2003.
GRCA GIS Program Manager Mark Nebel and Geologist Steve Rice initially developed a spatial paleontology geodatabase for GRCA in 2011, adapting and significantly modifying the framework of Spamer’s Access database, specifically for use at GRCA. The primary motivation for this effort was the imminent arrival, after many years without a paleontology program, of two Geoscientists-in-Parks (GIP) paleontology interns at GRCA. This initial GRCA geodatabase consisted of a single point feature class for paleontology localities. This was the primary database used and populated by a series of GIP interns at GRCA from 2011 into 2017.

Beginning in early 2017, GRCA Paleontology (Anne Miller) and GIS (Mark Nebel) staff recognized many shortcomings of the existing database and the need for development of a more comprehensive and systematic paleontology geodatabase for tracking data on paleontological resources in the park. After more than a year of development, including a needs assessment, database schema design, development, and field testing, the new GRCA paleontology geodatabase was deployed for park use in 2019. This database was accompanied by the development and testing of new field forms. GIS layer files (.lyr) have also been developed to provide a consistent map symbology for all feature classes in the geodatabase. This geodatabase can be adapted for use at other NPS units. For more information, contact Mark Nebel (mark_nebel@nps.gov).

The GRCA paleontology geodatabase is an ESRI file geodatabase that currently contains five feature classes (Paleontology Localities, Sites, Photopoints, Survey Lines, and Survey Polygons) and two related geodatabase tables (Paleontology Photos and Collected Specimens) (Figure 12-22). Photograph files are managed separately through a GRCA internal file system. All features in the paleontology database and all photographs have unique record IDs and are subject to naming conventions.

![Figure 12-22. Screenshot from ArcCatalog showing the structure of the GRCA Paleontology geodatabase (NPS).](image-url)
A **PaleontologyLocality** is a contiguous fossiliferous area (polygon) of a known minimum extent, based on field observations, and characterized by a unique geographic location, geology, and fossil assemblage. “In Context” **PaleontologyLocality** polygons include fossils that are in place within bedrock (“In Situ”), or situated loose on underlying bedrock of the formation from which the fossils are directly derived. Minor weathering out or local transport may have occurred. “Float” **PaleontologyLocality** polygons include fossils that are out of context, i.e., derived from a geologic formation different from that on which they are situated or located, having been transported to their current location.

A **PaleontologySite** point can be either a **PaleontologyLocality** discovery point, a specific fossil or fossil assemblage to be noted or monitored, or a fossil specimen collection point. **PaleontologySite** features are always within a **PaleontologyLocality**.

**PaleoPhotopoints** are points that represent the locations from which **PaleontologyLocality** photographs are taken, including photos of representative fossils, outcrop or outcrop-scale photos, and photos of setting or location. They are referenced to a **PaleontologyLocality** (as opposed to a **PaleontologySite**), but do not need to be within a locality polygon (Figure 12-23). Photographs provide scientific documentation of the resource and provide a baseline for monitoring their condition over time. Photographs are hot-linked in the geodatabase, so that they can be viewed directly from an ArcGIS map application connected to the GRCA network file system.

**Figure 12-23.** Screenshot from ArcMap showing an example of a Paleontology Locality with associated Sites and Photopoints (NPS).
**PaleontologySurvey** (line and polygon) features delineate areas where systematic paleontology surveys have been undertaken.

**PaleoPhotos** and **CollectedSpecimen** geodatabase tables record any photographs or collected specimens, respectively, that are associated with the Localities, Photopoints, and Sites, as appropriate, and are linked to the respective features via geodatabase relationship classes. Photographs are hot-linked to their respective **PaleoPhotopoints** via the GRCA network file system.

The geodatabase was designed initially to be compatible with Trimble GPS data collection devices, data dictionaries, and workflows. GRCA is currently developing and migrating to new protocols that leverage the ArcGIS Online and Collector software environments and GNSS data collection devices. The GRCA Paleontology geodatabase, definitions, protocols, naming conventions, and schema, field forms, etc. are evolving documents. To obtain the most current version of these documents contact Mark Nebel (GIS Program Manager; mark_nebel@nps.gov).

The following evolving GRCA paleontology documents are available upon request:

1. Geodatabase Documentation (.docx)
2. Geodatabase Schema and Domains (.xlsx)
3. Paleontology Field Form and Guide (.docx or .pdf)

**Conclusions**

As illustrated in the many chapters of this paleontological resources inventory report and the after-action report (Boudreau 2020), 2019 has been an important year in establishing a comprehensive baseline for paleontological resource stewardship and science at Grand Canyon National Park. Collectively, the paleontology-focused projects undertaken and accomplishments achieved at GRCA during 2019 represents the largest collaborative effort for paleontology in National Park Service history. This unprecedented work will help guide and inform future paleontological resource planning and activities for other NPS areas. In addition, the concurrence of this 2019 project with the celebration of GRCA’s centennial, 10th anniversary of National Fossil Day, and the Department of Interior’s final rulemaking for the Paleontological Resources Preservation Act (2009) bolstered each management action and supports continued affirmative paleontological resource management and stewardship within the park.

Despite the paleontology program at Grand Canyon being understaffed for many decades, great strides have been made, building upon 150 years of dedicated individuals who observed, recorded, preserved, and promoted the paleontological resources found within the Grand Canyon. In recent years, the park’s paleontology projects have been primarily accomplished through the supervision of Geoscientists-in-the-Parks interns and as collateral duties by physical science or GIS staff members, with guidance and assistance from the WASO NPS Paleontology Program. The establishment of a committed, multi-disciplinary team for the 2019 paleontology project provided an opportunity for the development of goals and projects to advance the paleontological knowledge of the park on behalf of science, public education, and resource stewardship. The GRCA Paleontological Resource Inventory provides the essential foundation for current and future park leaders to ensure that the non-renewable
paleontological resources at GRCA will continue to be monitored, conserved, and protected into the future.

**Literature Cited**


## Appendix 12-A. GRCA Paleontology Research Permits 1999–2019

### Appendix Table 12-A-1. List of paleontological research permits issued from 1999 to 2019.

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<th>Investigator(s)</th>
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<td>2019</td>
<td>Vincent Santucci, Anne Miller, Justin Tweet, Mark Nebel</td>
<td>Grand Canyon National Park Paleontological Resource Inventory and Paleoblitz</td>
<td>In Progress</td>
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Appendix 12-B. GRCA Photogrammetry 3D Models

3D photogrammetry models can be viewed on the National Park Service Geologic Resource Division Sketchfab page (https://sketchfab.com/grd_nps/models) or GRCA photogrammetry series website (https://www.nps.gov/articles/series.htm?id=A9E62040-AC6F-A6D7-BE564A036F1D6146).

All photos and files associated with each 3D model have been archived on IRMA and within the GRCA and WASO paleontology archives.

Appendix Table 12-B-1. GRCA specimens which have been documented as 3D photogrammetry models.

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<td>Oreamnos harringtoni</td>
<td>Harrington’s Goat Skull</td>
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