Research put into action: How a fossil inventory informed paleontological resource monitoring efforts preceding road construction at Theodore Roosevelt National Park

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ABSTRACT

Theodore Roosevelt National Park (THRO) in western North Dakota comprises badlands that surround the Little Missouri River in three separate units. Established initially as a national memorial park in 1947 and redesignated as a national park with its current boundaries in 1978, THRO was founded for its connection to its namesake, the United States president, and continues to memorialize Roosevelt's ideals of stewardship with its management of its diverse cultural and natural resources. The badlands in the park expose the highly fossiliferous Paleocene-age Bullion Creek and Sentinel Butte Formations that have been investigated extensively outside of the park's boundaries but not as much within them. Following a survey between 1994 and 1996 and later paleontological discoveries in the park, a Paleontological Resource Inventory was conducted during 2020 and 2021 to gauge these resources within THRO and determine best management and protection practices. This inventory was put to the test in monitoring for fossil resources preceding two road construction projects in the park: on the South Loop Road in 2021 and the Buck Hill Road in 2023. The inventory gave information as to what paleontological resources were to be encountered during construction, including known fossil occurrences and localities within and surrounding the project area. Results of monitoring included the discovery of new paleontological material, including bird material and well-preserved angiosperm fossils around the South Loop Road, and a potentially high-yield vertebrate site including choristodere (an extinct aquatic reptile), bowfin, and turtle material near Buck Hill Road. These instances demonstrate the importance of paleontological resource inventories as a foundation for resource monitoring preceding construction projects.

INTRODUCTION

Theodore Roosevelt National Park (THRO) , located in western North Dakota, was established in 1947 as a national memorial park and redesignated as a national park with its current boundaries in 1978. It memorializes President Theodore Roosevelt's ideals of stewardship of natural resources in the area where those ideas first took hold, where he had hunted bison and had a ranch (KellerLynn 2007; Salcido 2022). THRO manages cultural, historic, and natural resources present within the park's boundaries over its 70,446 acres across its three units (Figure 1): the South Unit near the town of Medora, which holds the largest area of land; the North Unit, approximately 40 miles to the north near the town of Watford City; and the much smaller Elkhorn Ranch Unit between the two. While the primary focus of natural resource management was intended to be on the plants and wildlife, the badlands within THRO's borders also contain significant terrestrial fossils in rocks of the Bullion Creek and Sentinel Butte Formations (Figure 1).

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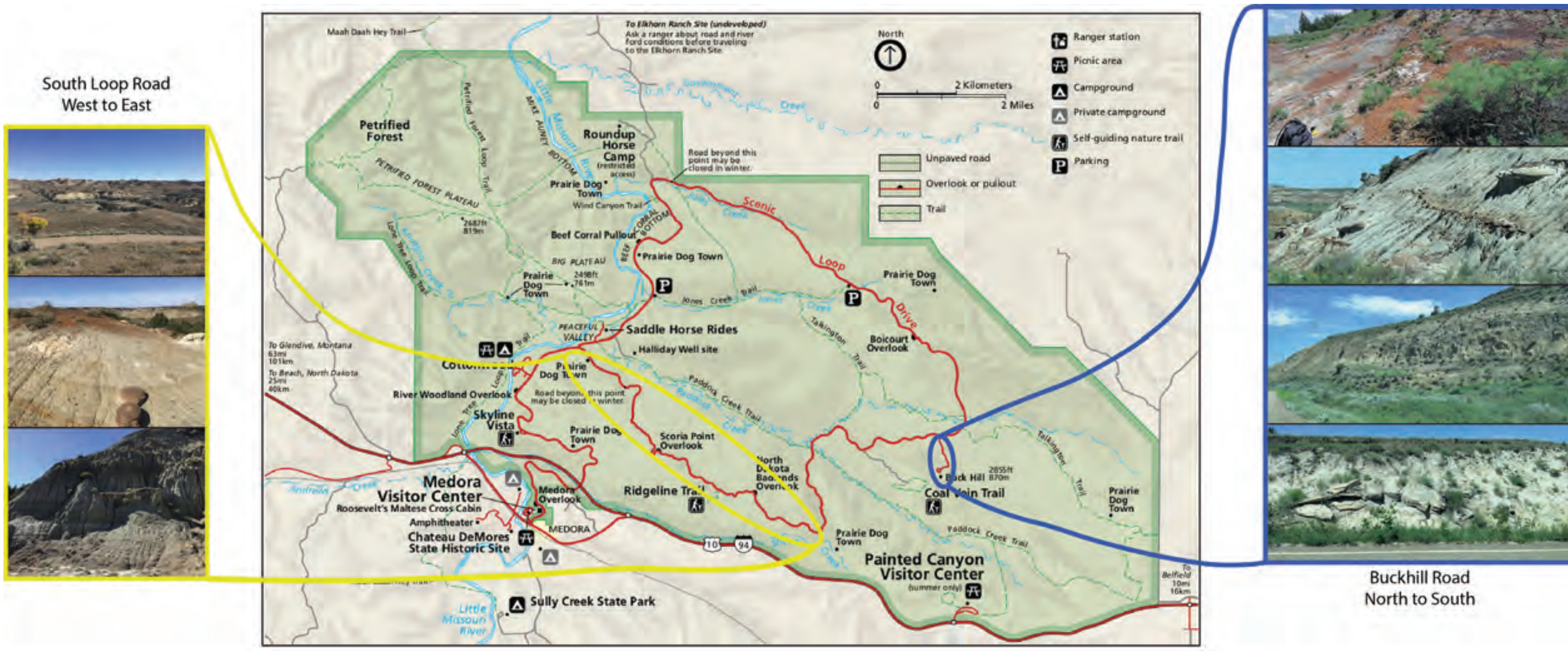


FIGURE 1. Map of THRO's South Unit with areas of recent mitigation highlighted, along with associated scenery. Edited from an NPS map with photos from Charles Salcido and from Murphey and Munson (2021), the latter (images left of the map) courtesy Paul C. Murphey, Paleo Solutions.

GEOLOGICAL AND PALEONTOLOGICAL BACKGROUND

THRO is located within the Williston Basin, a deposition basin that covers several hundred thousand square miles of North America including South Dakota, Montana, and portions of southern Canada (Royse 1970; Biek and Gonzalez 2001; KellerLynn 2007; Salcido 2022). The badlands that are the lowest section of the park's rock layers are from material shed from the Rocky Mountains and deposited during the middle to late Paleocene approximately 60 million years ago (Jacob 1976; Cherven 1978; Hartman and Kihm 1995), after the extinction of the non-avian dinosaurs 66 million years ago and before the climate phenomenon known as the Paleocene-Eocene Thermal Maximum approximately 55 million years ago in which there was a 5–8°C average global temperature increase (Biek and Gonzalez 2001; KellerLynn 2007). Deposition continued until about 30 million years ago when regional uplift changed the area from a basin to an area where streams began to erode and cut down existing rock. The last material deposited dates from the Pleistocene (better known as the "Ice Ages," starting approximately 2.6 million years ago) and the Holocene (the present). Pleistocene deposits include evidence of cyclic periods of glacial advancement and retreat in the North Unit (Biek and Gonzalez 2001; KellerLynn 2007; Salcido 2022). Because of this history of erosion, the rocks best exposed on the surface in THRO, and especially in the South Unit, are the middle-to-late Paleocene Bullion Creek Formation and the subsequent Sentinel Butte Formation of the Fort Union Group, which are highly paleontologically productive according to the Bureau of Land Management's rating (BLM 2016).

The Bullion Creek Formation is a highly fossiliferous fluvial and lacustrine formation. It consists of grey claystone and siltstone, lignite, and yellow siltstone and sandstones (Figure 2A) (Clayton and Moore 1977; Erickson 1982; Wallick 1984). Grey claystone and siltstone deposition represent a floodplain, lignite is a type of coal formed from the remains of plant material and represents swampy environments, and yellow siltstone and sandstones represent crevasse splay and levee deposition. The environment during the time of Bullion Creek Formation deposition has been interpreted as a low-relief coastal plain with a dynamic system of rivers, streams, ponds, lakes, and swamps (Hoganson and Campbell 2002; Salcido 2022). This formation is overlain by the Sentinel Butte Formation, marked by the red HT Butte clinker bed that resulted from ignited lignite that was hot enough to partially melt the rock surrounding it, giving the rock a reddish color. The Bullion Creek Formation is exposed in the South Unit and the Elkhorn Ranch Unit.

The Sentinel Butte Formation also is a highly fossiliferous fluvial and lacustrine formation. It is similar in rock types to the Bullion Creek Formation, including sandstones, siltstones, and claystones, but is a lighter color with somber

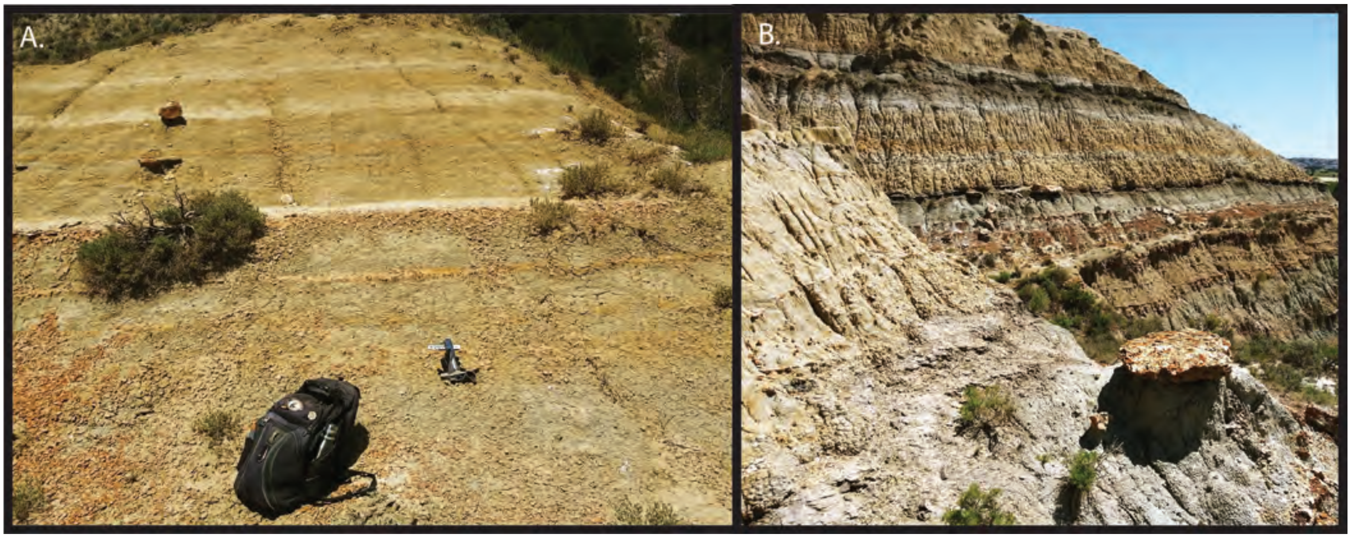


FIGURE 2. Examples of the main rock units in THRO: (A) Bullion Creek Formation and (B) Sentinel Butte Formation (Salcido et al. 2022).

grey to brown rocks (Figure 2B) (Brown 1948; Royse 1967; Cherven 1973, 1978; Daly, Groenewold, and Schmit 1985; Forsman 1985; Kihm and Hartman 1991). Often, this similarity causes confusion between the two rock units, but the Sentinel Butte Formation has fewer lignite, limestone, and linear sand bodies. Instead, it has greater amounts of tabular sandstone, a prevalent petrified wood horizon near its base, and a widespread bentonite (a clay made from weathered volcanic ash) deposit that is up to 8 m thick in the North Unit. The weathering slopes of the Sentinel Butte Formation are also much steeper than those of the Bullion Creek Formation. The Sentinel Butte Formation is exposed in the South Unit and the North Unit.

The depositional environments of the Bullion Creek Formation and the Sentinel Butte Formation were generally similar to one another, with rivers and lakes. However, tabular sandstones in the Sentinel Butte Formation indicate greater sinuosity in its streams, and delta progradation from the Bullion Creek Formation to the Sentinel Butte Formation indicates a large deltaic complex in the latter (Wallick 1984; Daly, Groenewold, and Schmit 1985).

There are various fossils found within the Bullion Creek and Sentinel Butte Formations that depict a warm, wet terrestrial environment (Figure 3). Among the most abundant are fossil plants, including remnants of petrified wood as tree stumps or fragments (Figure 3A); fossil leaf impressions; fossilized fruit bodies; fossilized seeds; and lignite, which is the remains of plant material as a form of coal (Hinds 1983; Kittle et al. 2005; Crane 1990). Fossil invertebrates include mollusks, such as freshwater bivalves and gastropods (Figure 3B and 3C); insects; and ostracods (seed shrimp) (Hartman, Roth, and Kihm 1993; Hoganson and Campbell 2002). Fossil vertebrates include fish such, as bowfins, pikes, and gars; amphibians, such as the salamander *Piceoerpeton*; reptiles, such as turtles (including soft-shell and hard-shell turtles); crocodilians (genera such as *Borealosuchus*); choristoderes (amphibious reptiles that are similar to crocodilians, e.g., *Champsosaurus*) (Figure 3D); birds; and mammals, including members of extinct groups such as *Titanoides* (a black bear-sized herbivore), *Phenacodus* (an ungulate relative), and *Plesiadapis* (a primate relative) (Hoganson and Campbell 2002; Kihm, Krause, and Hartman 2004; Hoganson, Person, and Gould 2011; Salcido 2022). Trace fossils (indirect remains of organisms typically representing behavior such as feeding or movement), including fossil feces (known as coprolites), feeding marks, worm burrows, and fossil footprints, have also been found in THRO (Hoganson and Campbell 2002; Salcido 2022).

While there are rock units younger than the prior two described within the park, there is much less of them exposed in comparison. The Late Paleocene to Early Eocene Golden Valley Formation is not present as *in situ* ("in place") rock beds within THRO; rather, it exists as erosional remnants of the resistant Taylor bed from the formation's Bear Den Member in the park (Salcido 2022). From the time of uplift and the shift to greater erosion after approximately 30 million years ago, there are unnamed gravel deposits. The Quaternary is represented by the Pleistocene Coleharbor Group and the postglacial Oahe Formation. The Coleharbor Group includes grains from as large as a boulder to as fine as silt and clay.

FIGURE 3. Examples of fossils found in THRO. (A) A petrified wood stump in life position eroding into smaller pieces. (B) A freshwater bivalve fossil. (C) A high-coiled gastropod fossil (Salcido et al. 2022). (D). A display in the THRO Visitor Center highlighting vertebrate fossils such as the gharial-like choristodere *Champsosaurus* (the skeleton) and a turtle shell beneath it. NATIONAL PARK SERVICE / JUSTIN TWEET

The Oahe Formation is composed of mostly yellow, brown-to-red, or grey non-bedded coarse silt and fine sand that is mainly wind-blown (Salcido 2022).

PALEONTOLOGICAL RESOURCE INVENTORY

THRO's Paleontological Resource Inventory began in the summer of 2020 with the hiring of two paleontological assistants (Charles Salcido and Patrick Wilson) via the Geological Society of America Geoscientists-in-the-Parks program (now the Scientists-in-Parks program). The program provided funding for an extensive survey of the park to be conducted between the South Unit and the North Unit. With the occurrence of the Covid global pandemic, the summer 2020 field work was delayed and shortened to only one month, but was still productive with 46 new localities recorded over 1.99 km^2 of the park (predominantly within the South Unit). The second summer (2021), one assistant (Charles Salcido) returned with a focus on the North Unit and Bullion Creek outcrops and the closed portion of the southern side of the Scenic Loop Road (referred to hereafter as the South Loop Road) of the South Unit, and recorded 112 new localities over 7.07 km^2 (Salcido 2022).

The purpose of the inventory was to provide information to THRO staff to manage paleontological resources ahead of repair and construction projects within the park that could cause ground dis–turbance. Accordingly, it was specifically requested that a survey of the South Loop Road be done during the second summer to provide preliminary monitoring work for a repair and construction project later that year. Since then, there have been two construction projects within the park for which survey teams used the inventory as a preliminary source of information for monitoring. Because of this, new significant paleontological localities have been documented around these projects and have been properly managed.

During the monitoring, fossil localities were considered either "significant" or "not significant." Non-significant localities included fossils that were either highly fragmented, very common in collections, or had very little material. Fossils that were considered very common in collections included invertebrate fossils such as bivalves and gastropods, and petrified wood fragments that can be found throughout the park and cannot be attributed to a more specific family- or genus-level taxon of fossil plant. Significant localities generally included well-preserved material that could be identified at a more specific family or genus taxonomic level and were not commonly found in collections. Fossils fitting these latter criteria would generally be vertebrate fossils; well-preserved plant fossils, such as plant/leaf impressions, seeds, or fruits; and trace fossils.

EXAMPLES OF INVENTORY USED FOR PALEONTOLOGICAL MONITORING

South Loop Road Project

The project area was in the South Unit of the park along approximately six miles of the southern portion of the South Loop Road. Large-scale rehabilitation work had not been performed on the Scenic Loop Road in 20 years and this area has succumbed to landslides and other damage over time. The construction project aimed to provide long-term, sustainable access for future visitor use. However, based on the Paleontological Resource Inventory, it became apparent that potentially scientifically significant paleontological resources might be encountered during construction. Because of this, surveys were conducted to provide an inventory of paleontological resources within the project area (one conducted during the park-sponsored inventory and one conducted afterwards by the private firm Paleo Solutions) and collect all scientifically important paleontological resources discovered.

Preceding Construction

The preliminary monitoring and survey work on the South Loop Road was done mainly in the last weeks of the summer of 2021 during the Paleontological Resource Inventory, though some localities had been noted around that area during the summer of 2020. Within one mile of the project area, there were a total of 18 fossil localities recorded from both the Bullion Creek and Sentinel Butte Formations. Most of the project area was in the Sentinel Butte Formation, with the Bullion Creek Formation cropping out only in the northwestern section of the project area or in local valleys. Three localities were recorded from the Bullion Creek Formation while the rest were from the Sentinel Butte Formation. The three Bullion Creek Formation localities included gastropods (including the genus *Campeloma*) and bivalves of whose quality of preservation ranged from poor to good. No vertebrate material was found in this formation in the project area. Only one Bullion Creek Formation locality in the immediate project area had fossil bivalves and gastropod fragments in generally good condition.

The remaining 15 localities were from the Sentinel Butte Formation and contained different fossils. In the larger area, 12 localities included fossil material such as petrified wood stumps; gastropods (including the genus *Campeloma*); bivalves; fish bones (including a jaw fragment and an operculum) and scales (genus *Amia*, the bowfin fish); turtle shell fragments; crocodilian teeth;

choristodere teeth and vertebra; and miscellaneous vertebrate bone and limb fragments. Fish material occurred in a thin (approximately 6-cm thick), black (indicating carbon-rich) layer of rock (Figure 4A). In the immediate project area, there were three localities from the Sentinel Butte Formation that included bivalves, long-bone elements from a reptile, and fish vertebrae. Like the fish bones found in the larger area within one mile of the project, the fish vertebrae here were found in a thin, black layer of rock (Salcido 2022).

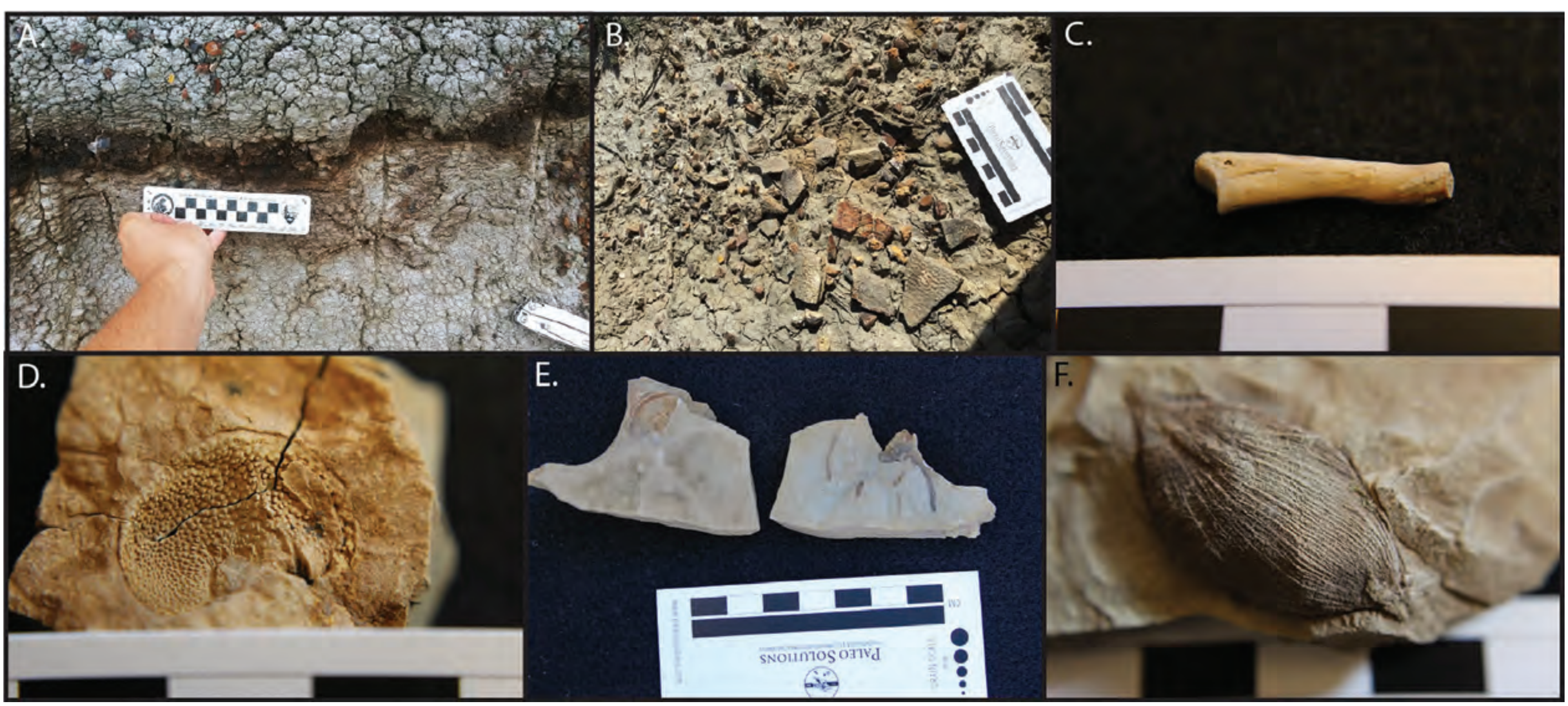
During Construction

Monitoring of the South Loop Road construction project was conducted a few months later in September 2021 by Paleo Solutions and reported as the Theodore Roosevelt National Park, South Unit Loop Road Reconstruction (Murphey 2021). The Paleo Solutions survey team undertook a literature review and records search before surveying, using the results from the THRO Paleontological Resources Inventory including noting the previously recorded fossil localities mentioned above and revisiting them within the project area.

The Paleo Solutions survey team's revisit of the four previously recorded localities that were within the immediate vicinity of the construction project yielded additional material. The one Bullion Creek Formation locality yielded ten gastropods, five bivalves, some shell fragments of gastropods, and hundreds of shell fragments of bivalves. The revisits to the three Sentinel Butte Formation localities yielded a claw and distal lateral hypoplastral process of a soft-shelled turtle, a proximal ulna of a bird, a proximal phalanx and phalanx fragment of a reptile, and indeterminate turtle shell fragments (Figure 4B and C) (Murphey 2021).

In terms of new fossil localities, the report by Paleo Solutions recorded one new significant fossil locality and four non-significant fossil occurrences. The one significant fossil locality was from the Sentinel Butte Formation and yielded two *Nyssidium articum* fruits (Figure 4D and E), five *Porosia verrucosa* (seeds or leaves) (Figure 4F), and four leaves and plant fragments from undetermined angiosperms. All of these were collected due to their exceptional preservation or because they were associated with the exceptionally preserved materials. The non-significant fossil occurrences contained the following: one locality with more than 15 bivalve fragments from the Bullion Creek Formation; one locality with more than 50 poorly preserved plant impressions on bedding planes from the Sentinel

FIGURE 4. Fossils collected during the South Loop Road monitoring efforts. (A) Carbon-rich layer with Amia fossils that was within 1 mile of the project area (Salcido et al. 2022). (B) Various turtle and reptile fossils from the site revisit near the project area. (C) Avian proximal ulna recovered from the site revisit near the project area. (D–F) Well-preserved plant fossils that were recovered during construction. (D, E) *Porosia verrucosa,* a fruit body. (F) *Nyssidium arcticum,* a fossil seed. B–F FROM MURPHEY AND MUNSON (2021), COURTESY PAUL C. MURPHEY, PALEO SOLUTIONS



Butte Formation; one locality with hundreds of petrified wood fragments from the Sentinel Butte Formation; and one locality with hundreds of bivalve and gastropod shell fragments from the Sentinel Butte Formation (Murphey 2021).

Following the discovery of these fossil localities and the revisit of previously documented localities, a few recommendations were made to park management. They included: factoring in the fossil resources in future projects involving ground-disturbing actions and those that increase public access to rock outcrops with these resources; having trails and similar recreational uses avoid scientifically significant fossil localities if possible; and, for the construction project itself, screenwashing a bulk sample of matrix from vertebrate fossil localities for potential small vertebrate fossils, and monitoring ground disturbances during construction on significant fossil localities to continue collection of additional fossils (Murphey 2021).

BUCK HILL ROAD PROJECT

Preceding Construction

THRO contracted Charles Salcido, one of the investigators from the Paleontological Resource Inventory, to do a preliminary report around Buck Hill Road for the Buck Hill Road Reconstruction Project and provide an inventory of paleontological resources around the project area, collect all scientifically important specimens, and provide management and mitigation recommendations. The Buck Hill Road Reconstruction Project in the South Unit aims to reconstruct most of the 0.7-mile road that leads from the Scenic Loop Road to the Buck Hill Overlook. Much like the Scenic Loop Road, Buck Hill Road has not had major reconstruction work in many years, has areas predominantly covered in dirt, and has pavement damaged from wear. The purpose of the reconstruction project is to ensure long-term sustainable access to the Buck Hill Overlook and Buck Hill Trail, both popular sites for visitors. The Buck Hill Road cuts through exposures of the Sentinel Butte Formation across a change of approximately 57 m in elevation. The field survey was conducted in June 2023.

No major localities were recorded within the immediate project area during the prior THRO Paleontological Resource Inventory, only some south of the Buck Hill Overlook and far from the Buck Hill Road. However, in surveys dating from 1994–1996 by the North Dakota Geological Survey (NDGS) there were localities noted within a mile of the larger Buck Hill area and a few within the immediate project area (Salcido 2022). One locality of note from these surveys, found by John Hoganson of NDGS, recorded salamander vertebrae and a coprolite in a carbonaceous mudstone.

The present field survey was conducted within 100 yards on either side of the Buck Hill Road Project area and was pedestrian, with only safely accessible areas investigated. Like the prior survey by Paleo Solutions for the South Loop Road, all fossils observed were documented, recorded, and divided into either significant or non-significant fossil localities. The field survey resulted in one new significant fossil locality and three new non-significant fossil occurrences.

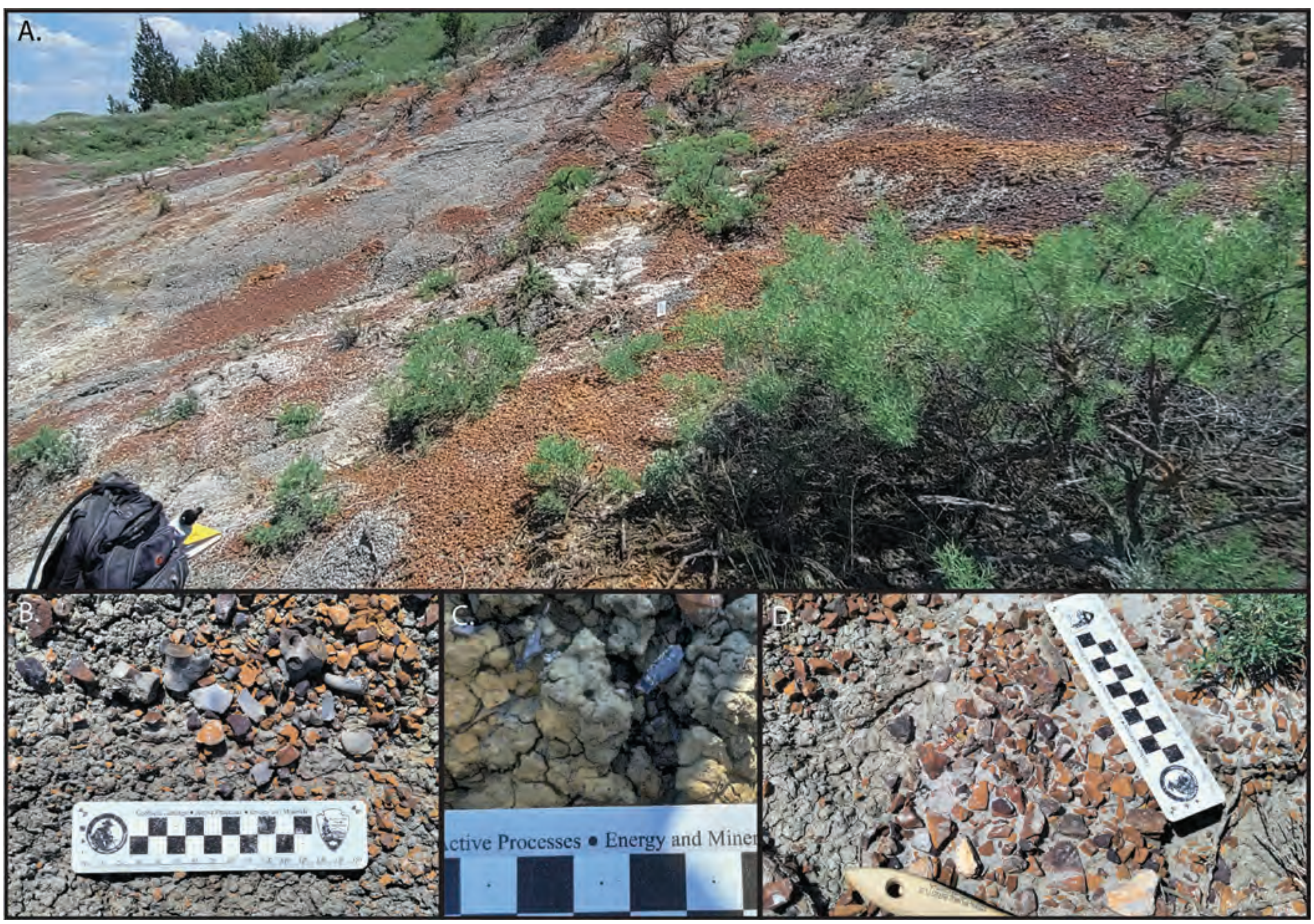
Two of the non-significant fossil occurrences had unidentifiable fossil plant impressions along the bedding plane at two different elevations of the Sentinel Butte Formation outcrop along the road. The third non-significant fossil occurrence had numerous bivalve and gastropod shells and shell fragments along with a single indeterminate vertebrate bone fragment (likely the fragment of a joint) and a single fish vertebra within two parallel layers separated by approximately a meter in elevation. Although this occurrence included vertebrate material, there was very little material found and was thus considered non-significant. However, it was noted that while there was not an abundance of vertebrate fossil material in this layer, caution was recommended in case more material was found during ground disturbance in that section of road.

The significant fossil locality was laterally extensive (Figure 5), with the fossil-bearing bed occurring on both sides of the road yielding numerous shell fragments of bivalves and gastropods; choristoderes (champsosaurs) in the form of vertebrae that included the spinous processes, bone fragments, a rib fragment, and an ungual (Figure 5B); fish material (likely the bowfin genus *Amia*), including vertebrae, mandible fragments (Figure 5C), an operculum fragment, an otolith, and numerous bone fragments; turtle shell and bone fragments (Figure 5D); and a partial crocodilian tooth. Different areas of the rock yielded different amounts of these vertebrate fossils. The vertebrate material was collected with the exception of some turtle material that was left because it was going into the rock and the survey was not cleared to do an excavation. However, an excavation was recommended by the investigator. Additionally, it was recommended that a bulk sample be taken from the area of the fish material to be screen-washed to find any micro-vertebrate fossil material. It was recommended that this locality be monitored after construction due to the abundance of vertebrate material, ease of access, and proximity to park visitors.

CONCLUSION

The THRO Paleontological Resource Inventory has proven to be very useful as a reference preceding future construction projects within the park. It will allow investigators to understand what fossils are likely to be encountered in construction projects, revisit sites noted from the inventory that are within the area of those projects, and develop proper plans and procedures for mitigation and management of fossil materials encountered. Such uses of a paleontological resource inventory are applicable to other areas of the National Park System that contain paleontological resources, of which there are many (Santucci 2017; Santucci, Tweet, and Connors 2018; Tweet and Santucci 2022). Because of this, it would be useful for these parks to have a paleontological resource inventory on hand for surveyors to better manage and protect such resources, as occurred with the South Loop Road and Buck Hill Road projects.

FIGURE 5. The significant fossil locality from the Buck Hill Road survey and fossils found. (A) General area of the locality, which stretches from the backpack to the background. (B) Choristodere vertebra and other bone fragments. (C) Amia mandible fragment and some bone fragments coming out of a carbon-rich layer. (D) Turtle site with various turtle shell fragments coming out of the rock.



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