National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Theodore Roosevelt National Park

Paleontological Resource Inventory (Public Version)

Natural Resource Report NPS/THRO/NRR—2022/2385

ON THE COVER
A skeleton of the extinct aquatic reptile *Champsosaurus* recovered from Theodore Roosevelt National Park (THRO) and on display at the park's visitor center (NPS/JUSTIN TWEET).

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Contents

Contents (continued)

Page

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Photographs

Page

Appendices

Page

Executive Summary

Theodore Roosevelt National Park (THRO) in western North Dakota was established for its historical connections with President Theodore Roosevelt. It contains not only historical and cultural resources, but abundant natural resources as well. Among these is one of the best geological and paleontological records of the Paleocene Epoch (66 to 56 million years ago) of any park in the National Park System. The Paleocene Epoch is of great scientific interest due to the great mass extinction that occurred at its opening (the Cretaceous–Paleogene extinction event), and the unusual climatic event that began at the end of the epoch (the Paleocene–Eocene Thermal Maximum, an anomalous global temperature spike). It is during the Paleocene that mammals began to diversify and move into the large-bodied niches vacated by dinosaurs. The rocks exposed at THRO preserve the latter part of the Paleocene, when mammals were proliferating and crocodiles were the largest predators. Western North Dakota was warmer and wetter with swampy forests; today these are preserved as the "petrified forests" that are one of THRO's notable features.

Despite abundant fossil resources, THRO has not historically been a scene of significant paleontological exploration. For example, the fossil forests have only had one published scientific description, and that report focused on the associated paleosols ("fossil soils"). The widespread petrified wood of the area has been known since at least the 19th century and was considered significant enough to be a tourist draw in the decades leading up to the establishment of THRO in 1947. Paleontologists occasionally collected and described fossil specimens from the park over the next few decades, but the true extent of paleontological resources was not realized until a joint North Dakota Geological Survey–NPS investigation under John Hoganson and Johnathan Campbell between 1994–1996. This survey uncovered 400 paleontological localities within the park representing a variety of plant, invertebrate, vertebrate, and trace fossils. Limited investigation and occasional collection of noteworthy specimens took place over the next two decades.

In 2020, a new two-year initiative to further document the park's paleontological resources began. This inventory, which was the basis for this report, identified another 158 fossil localities, some yielding taxa not recorded by the previous survey. Additional specimens were collected from the surface, among them a partial skeleton of a choristodere (an extinct aquatic reptile), dental material of two mammal taxa not previously recorded at THRO, and the first bird track found at the park. The inventory also provided an assessment of an area scheduled for ground-disturbing maintenance. This inventory is intended to inform future paleontological resource research, management, protection, and interpretation at THRO.

THRO's bedrock geology is dominated by two Paleocene rock formations: the Bullion Creek Formation and the overlying Sentinel Butte Formation of the Fort Union Group. Weathering of these formations has produced the distinctive banded badlands seen in THRO today. These two formations were deposited under very different conditions than the current conditions of western North Dakota. In the Paleocene, the region was warm and wet, with a landscape dominated by swamps, lakes, and rivers. Great forests now represented by petrified wood grew throughout the area. Freshwater mollusks, fish, amphibians (including giant salamanders), turtles, choristoderes, and crocodilians

abounded in the ancient wetlands, while a variety of mammals representing either extinct lineages or the early forebearers of modern groups inhabited the land. There is little representation of the next 56 million years at THRO. The only evidence we have of events in the park for most of these millions of years is isolated Neogene lag deposits and terrace gravel. Quaternary surficial deposits have yielded a few fossils, primarily bison. Wood and charcoal have also been reported.

Although paleontological investigations have been limited to date, a small number of specimens are currently maintained at several institutions, primarily the North Dakota Geological Survey's paleontological collections at the North Dakota Heritage Center & State Museum. Among reposited specimens are the holotype or name-bearing specimens of two taxa: the fern spore *Azolla stanleyi* and the freshwater bivalve *Eupera missouriensis*.

The great extent of paleontological resources at THRO promises to be a challenge for management. The park exhibits some of its fossils at the visitor center, but the petrified wood is by far the best known to the public (a portion of the South Unit is known as the Petrified Forest, for example). Recommendations for management, research, protection, and interpretation are provided in this report.

Acknowledgments

Paleontological resource inventory projects, such as the one presented here, are a combined effort of multiple individuals with a diverse background of knowledge and experience. For this project, we want to recognize the support of the staff of THRO including THRO Park Archivist Megan Klosterman, THRO District Interpreter Amy McCann, THRO Park Ranger Grant Geis, and THRO Education Technician Jenna Streffon (now at Shenandoah National Park). We also want to recognize Tim Connors of the NPS Geological Resources Division for creating the geologic and paleontologic resource potential maps utilized in this report. Jim Wood (GRD) acted as peer review coordinator. Darrin Pagnac (South Dakota School of Mines and Technology), Anine Rosse (NGPN), and Ed Welsh (Badlands National Park) provided reviews.

In addition to NPS personnel, we thank North Dakota Geological Survey Geologist Emeritus John Hoganson and Former Governor's Mansion and Camp Hancock Site Supervisor Johnathan Campbell, whose survey of THRO in 1994–1996 demonstrated the need for a full inventory of paleontological resources within THRO and the development of a resource management plan. Becky Barnes (North Dakota Geological Survey; NDGS) and Katy Brooke (Friends of NDGS Paleo) joined Charles for microsampling in the North Unit in 2021. Edward Murphy (State Geologist, NDGS) gave permission for the use of Figure 9. Hongshan Wang and Steven Manchester of the Florida Museum of Natural History and Rudolph Serbet of the University of Kansas provided information about specimens in their collections. Silvia Ascari, John Munson, Paul Murphey, and Madeline Weigner of Paleo Solutions documented sites in the South Unit Loop Road construction project area and supplied us with data. Additional thanks go out to several staff in the NPS Denver Service Center including Madelyn Ruffner, Wesley Wills, Tracy Cudworth, and Matthew Loscalzo for recognizing the importance of assessing paleontological resources as part of pre-construction environmental planning for the South Unit Loop Road construction project. Finally, we extend our appreciation to Theodore Roosevelt IV (great-grandson of the 26th President of the United States), Howard Ehrlich (Theodore Roosevelt Association), and Sharon Kilzer (Theodore Roosevelt Center) for assistance with historical research related to Theodore Roosevelt and his observations on fossils.

Dedication

We dedicate this report to Pete Hart and Wendy Hart Ross, father and daughter, who both served as Superintendents of Theodore Roosevelt National Park and both supported paleontological investigations during their tenures to document the abundance and distribution of fossil resources on park lands.

Pete Hart served at the park from 1990–1995 and presided during a pivotal time in NPS when natural resource management was brought into focus as a priority. He oversaw development and completion of the park's Resource Management Plan, pursued multiple scientific research projects, and enabled the first comprehensive field investigations of paleontological resources by John Hoganson and Johnathan Campbell, beginning in 1994. This seminal work established a culture of science to inform stewardship of park resources that has been a key element of planning and operations since.

Wendy Hart Ross served as Superintendent from 2014–2021, amid a challenging period of budget shortfalls and high staff turnover. Despite these limitations, Wendy inspired her staff to lead, charging them to pursue big ideas and develop tools through scientific investigation, to engineer solutions that could be a "model" for other parks. Wendy authorized the first ever General Agreement with the North Dakota Geological Survey, sanctioning collaboration to improve fossil resource management. She supported a wide array of external and park-sponsored research and youth involvement in natural resource programs, including the Geoscientists-in-the-Parks proposals that enabled this paleontological inventory. Her efforts have established ongoing expectations for development of best management practices through science.

Pete and Wendy represent a continuum of thought, a perception of need, and an insight that much remains to be learned about Theodore Roosevelt National Park. Their leadership and pursuit of knowledge has greatly benefited park program management and policy development aimed at preservation through understanding. Specific to paleontology, their work has resulted in acquisition of extensive information pertaining to the prehistory of park lands relative to effective management of fossil resources in context of existing geomorphology, landscape ecology, visitor use, cultural resources, and park infrastructure.

Thank you, Pete and Wendy.

Photo 1. Pete Ross (left) and Wendy Hart Ross (right).

Introduction

Theodore Roosevelt National Park (THRO), located in western North Dakota, preserves portions of the badlands surrounding the Little Missouri River, including locations directly connected to Theodore Roosevelt's ranching ventures of the 1880s. THRO was first established as Theodore Roosevelt National Memorial Park on April 25, 1947, and was redesignated as a national park on November 10, 1978. The boundaries of the park have changed multiple times: June 10, 1948; June 12, 1948; March 24, 1956; November 6, 1963; and November 10, 1978. Theodore Roosevelt Wilderness Area was designated within the park's North Unit on November 10, 1978 as well. THRO encompasses 28,508.84 ha (70,556.89 acres), all but 168.84 ha (417.22 acres) of which are under federal administration. The wilderness area within THRO encompasses 12,108 ha (29,920 acres).

THRO is composed of three units. The largest is the South Unit, in central Billings County adjacent to the community of Medora on the south (Figure 1). Most of the remaining land area is in the North Unit in south-central McKenzie County, 59 km (37 miles; distances are straight lines) north of the South Unit (Figure 2). Between the two is the 88 ha (218 acres) Elkhorn Ranch Unit in northwestern Billings County, 24 km (15 miles) north of the South Unit and 36 km (22 miles) southwest of the North Unit. The largest nearby community is Dickinson, North Dakota, which is about 40 km (25 mi) east of the South Unit. Watford City, North Dakota, is about 19 km (12 mi) north of the North Unit. Williston, North Dakota is about 59 km (37 mi) north-northwest of the North Unit. All three units are linked by the Little Missouri River and are surrounded by the Little Missouri National Grassland, the largest grassland in the U.S. Forest Service. The grassland was formerly part of Custer National Forest and is seen as such in older references.

Although THRO is most famous for its connection to Theodore Roosevelt, the three units of the park contain much more. People have lived and traveled through here for thousands of years, leaving behind a rich record of cultural resources. Several American Indian tribes are culturally affiliated or traditionally associated with THRO. Despite the name "badlands", many species of plants and animals inhabit the park. Bison are a notable attraction. The scenic badlands vividly display the effects of weathering and erosion, and host the abundant paleontological resources discussed in this report. The organisms preserved as fossils show a much different past setting: a warm, wet, swampy landscape with abundant trees and reptiles and few familiar birds and mammals.

Figure 1. Park map of the South Unit of THRO north of I-94 in and near Medora, North Dakota (NPS).

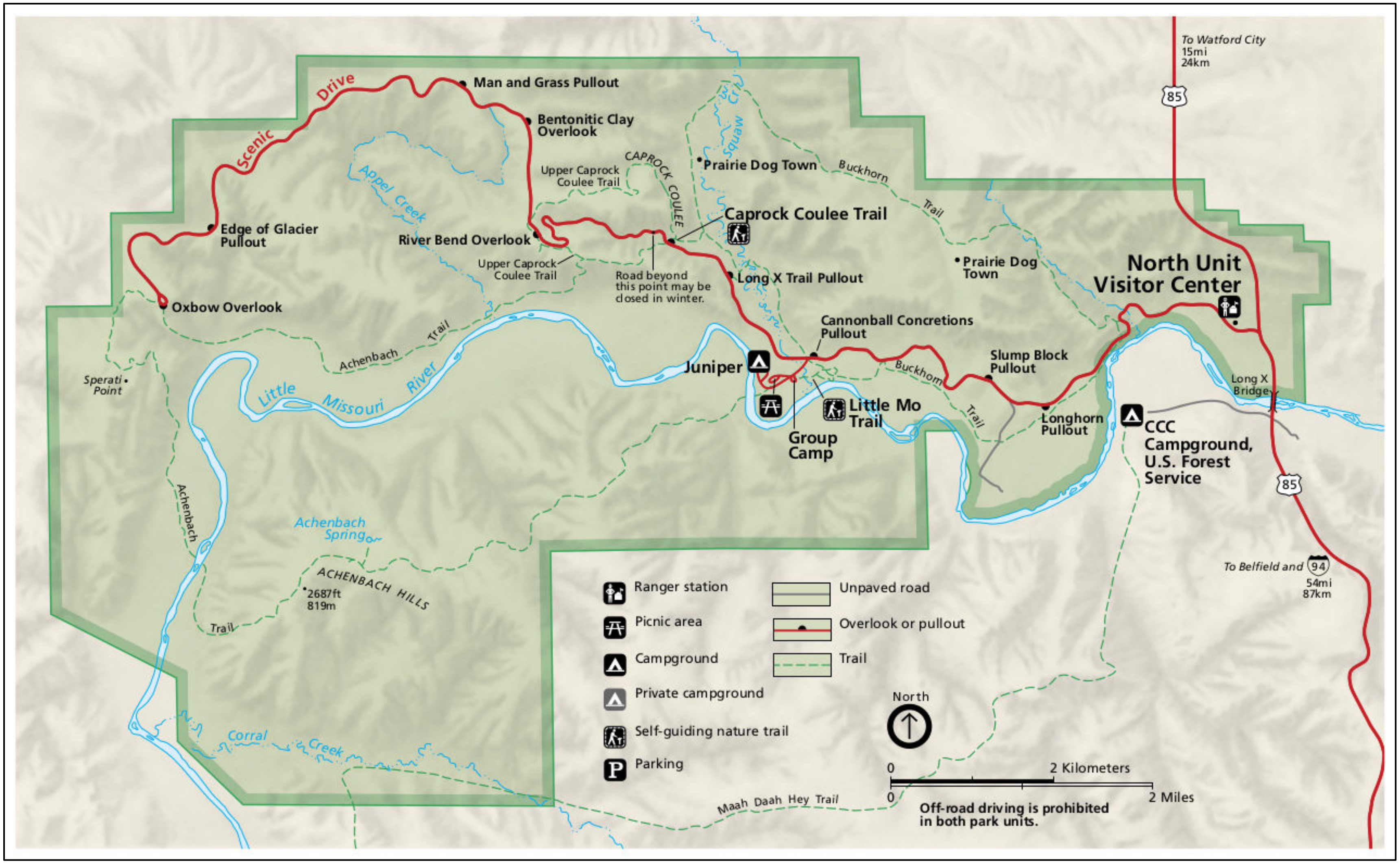


Figure 2. Park map of the North Unit of THRO west of highway 85 and south of Watford City, North Dakota (NPS). Much of the North Unit is wilderness and requires a permit to access.

The following brief history of THRO is drawn from the park website's description of the establishment of the park (https://www.nps.gov/thro/learn/historyculture/park-history.htm). Theodore Roosevelt National Park is one of five units in the National Park System to honor the 26th President of the United States. Shortly after Theodore Roosevelt's death in 1919, proposals were accepted to establish a memorial in his honor. These proposals included national parks, monuments, wildlife refuges, scenic roads, and state parks. Medora was selected as a good candidate for the park by a committee led by Sylvane Ferris, who was a close friend of Roosevelt during his Dakota cattle ranching days.

In 1924 and 1925, the Little Missouri Badlands were explored by two parties: one was a small group of 40 participants and the other was a larger group of federal, state, regional officials, news media, and other interested parties. These groups developed an early plan for the park that would include 2,030 square miles. However, in 1928 Roger Toll, Superintendent of Rocky Mountain National Park, proposed the establishment of a small national monument instead of a national park to National Park Service Director Stephen T. Mather, reporting that "A national park does not seem to be justified." This proposal was a small setback for the creation of THRO.

After Toll's report, additional studies, proposals, and counter-proposals took place. In the 1930s, drought, overgrazing, and crop failures seized the region and forced many homesteaders to sell their land across the Great Plains. In western North Dakota, most of the land was purchased for leased grazing and rehabilitation. Much of this land is now part of the Little Missouri National Grasslands, but a portion was earmarked for the establishment of a park. In 1934 the Civilian Conservation Corps, National Park Service, Resettlement Administration, and the State of North Dakota signed a cooperative agreement to start a Roosevelt Regional Park Project with the intent for the project to become a state park. In 1935, the North and South Units of the Roosevelt Regional Park were designated the Roosevelt Recreation Demonstration Area (RDA). Development of buildings, roads, picnic areas, campgrounds, and trails was done by the Works Projects Administration and Emergency Relief Administration. These projects ended in 1941.

After the North Dakota state government rejected the RDA as a state park, the land was approved for inclusion into the National Park System in 1942. However, NPS officials resisted the establishment of a new park. William Lemke, North Dakota Representative, championed the fight for a national park, but it was not until 1946 that the RDA was officially transferred to the United States Fish and Wildlife Service as the Theodore Roosevelt National Wildlife Refuge. Some legislators felt that the area lacked the necessary qualities to merit the designation as a national park.

On April 25, 1947, President Harry Truman signed PL-38, establishing the South Unit and Elkhorn Ranch as Theodore Roosevelt National Memorial Park. In June 1948 the North Unit was added to the park. The park gained recognition for its diverse cultural and natural resources, and on November 10, 1978, President Jimmy Carter signed Public Law 95-625 that elevated Theodore Roosevelt Memorial Park to Theodore Roosevelt National Park and placed 12,108 ha (29,920 acres) of the park under the National Wilderness Preservation System. To this day THRO continues to honor and memorialize Theodore Roosevelt's enduring ideals of stewardship of our nation's resources.

This report provides detailed information on the paleontological resources of THRO, including the history of paleontological work on the lands now within the park, geologic units, taxonomic groups, localities, museum collections, research, interpretation, and management and protection. In addition to the main body of text, there are six appendices: Appendix A, tables of paleontological species arranged by stratigraphy; Appendix B, museum collections data; Appendix C, contact information for repositories; Appendix D, paleontological resource law and policy; Appendix E, paleontological locality data; and Appendix F, a geologic time scale.

Significance of Paleontological Resources at THRO

Paleontological resources, or fossils, are any evidence of past life preserved in geologic context. THRO's rocks represent approximately six million years of deposition from the end of the Paleocene Epoch and more recent sediments from the Pleistocene to Holocene (see "Geologic History" below). The end of the Paleocene represents the beginning of one of the major climatic events in the Cenozoic: the Paleocene–Eocene Thermal Maximum (PETM), a thermal spike of perhaps 5–8 °C (9–14 °F) that lasted 200,000 years (McInerney and Wing 2011). Understanding how plants and animals reacted to and changed due to this climatic event can help predict how modern animals will react and change to current climate changes. Therefore, the paleontological resources at THRO, dating to just before this event, could be vital data for understanding the PETM. THRO is one of only a handful of NPS units to preserve part of this time frame; the only other park that has a significant terrestrial record from the Paleocene is Big Bend National Park in Texas, at nearly the same longitude as THRO but at a significantly different latitude.

The primary paleontological resources at THRO pertain to two geologic formations, the Bullion Creek Formation and the overlying Sentinel Butte Formation. These formations contain complex depositional environments, such as low-relief coastal plains with river, swamps, rainforests, and crevasse splays. Previous surveys in the park showed that these formations were very fossiliferous with approximately 40 sites per square mile. Most of the 400 fossil localities recorded in the 1994–1996 survey were invertebrate and/or plant localities and relatively little material was collected. Further survey work done for this report in 2020–2021 documented 158 localities over 9.1 km^2 (3.5 mi^2) of the park.

There is currently a large discrepancy between the fossils known from the Bullion Creek and Sentinel Butte Formations throughout western North Dakota and what has been positively identified and collected from these formations in the park. Robust samples of plant, invertebrate, and vertebrate taxa have been reported from these formations outside of THRO, but many of these taxa have not yet been reported from within THRO. There is a high potential for these formations to produce scientifically significant material with additional surveys, monitoring, and the completion of an extensive paleontological resource inventory. Sites near THRO with fossils from the Bullion Creek and Sentinel Butte Formations have yielded taxa not yet identified from the park, so increased paleontological work in the park is likely to yield more taxa. The 2020–2021 paleontological resource survey has added two mammalian taxa (represented by tooth and jaw fragments) and one avian ichnotaxon (represented by fossil footprints) to the park's record. Additional taxa may be found after samples have been processed for microfossils (particularly microvertebrate remains such as small teeth, which are important for the study of fossil mammals).

Purpose and Need

The NPS is required to manage its lands and resources in accordance with federal laws, regulations, management policies, guidelines, and scientific principles. Those authorities and guidance directly applicable to paleontological resources are cited below in Appendix D. Paleontological resource inventories have been developed by the NPS to compile information regarding the scope, significance, distribution, and management issues associated with fossil resources present within parks. This information is intended to increase awareness of park fossils and paleontological issues to inform management decisions and actions that comply with these laws, directives, and policies. Options for paleontological resource management are locality-specific, and may include no action, surveys, site monitoring, cyclic prospecting, stabilization and reburial, shelter construction, excavation, closure, patrols, and alarm systems or electronic surveillance. See Appendix D for additional information on applicable laws and legislation.

Project Objectives

This park-focused paleontological resource inventory project provides information to THRO staff for formulating management activities and procedures to comply with related laws, regulations, policy, and management guidelines. Additionally, this project will facilitate future research, proper curation of specimens, and resource management practices associated with the non-renewable paleontological resources at THRO. The objectives of the paleontological resource inventory project include:

- Determining the scope, significance, distribution, and management issues associated with fossil resources present within THRO.
- Locating, identifying, and documenting paleontological resource localities through field reconnaissance and archival research, using photography, GPS data, and standardized forms.
- Relocating and assessing historic fossil localities.
- Assessing collections of THRO fossils maintained within the park collections and in outside repositories.
- Documenting current information on faunal assemblages and paleoecological reconstructions.
- Interviewing park staff to gather information on the current status of paleontological resources, to aid in formulating plans for management, ideas for interpretation, and recommendations for future planning and actions.
- Conducting a thorough search for relevant publications, unpublished geologic notes, and outside fossil collections from THRO.

History of Paleontological Work at THRO

The Little Missouri Badlands were frequently referred to as Pyramid Park in the late 19th and early 20th centuries (e.g., Winser 1883). The name "Pyramid Park" both reflected the character of the terrain and was more appealing for marketing than "badlands". Abundant petrified wood was one of the prominent features of Pyramid Park (e.g., Winser 1883; Hauge 1884; Wheeler 1895; Campbell et al. 1915) (Figure 3). Winser (1883) reproduced part of an article written by the same author in 1882, which included this description of Pyramid Park (Winser 1883:133):

> *"We also chipped off specimens of petrified wood, full of sparkling, silicious crystals, from the mammoth tree trunks turned to stone, which crop out from the sides of the conglomerate mounds, showing that, in ages long remote, a stately forest grew on these grassy plains."*

It is not clear if any of the early reports can be specifically attributed to lands within THRO, because "Pyramid Park" included a broad area centered on the stretch of badlands between Sully Springs on the east and Medora/Little Missouri on the west and south of the Northern Pacific Railroad, as depicted in Campbell et al. (1915: sheet 9). However, these citations do clearly show that the presence of petrified wood was widely known by the late 19th century.

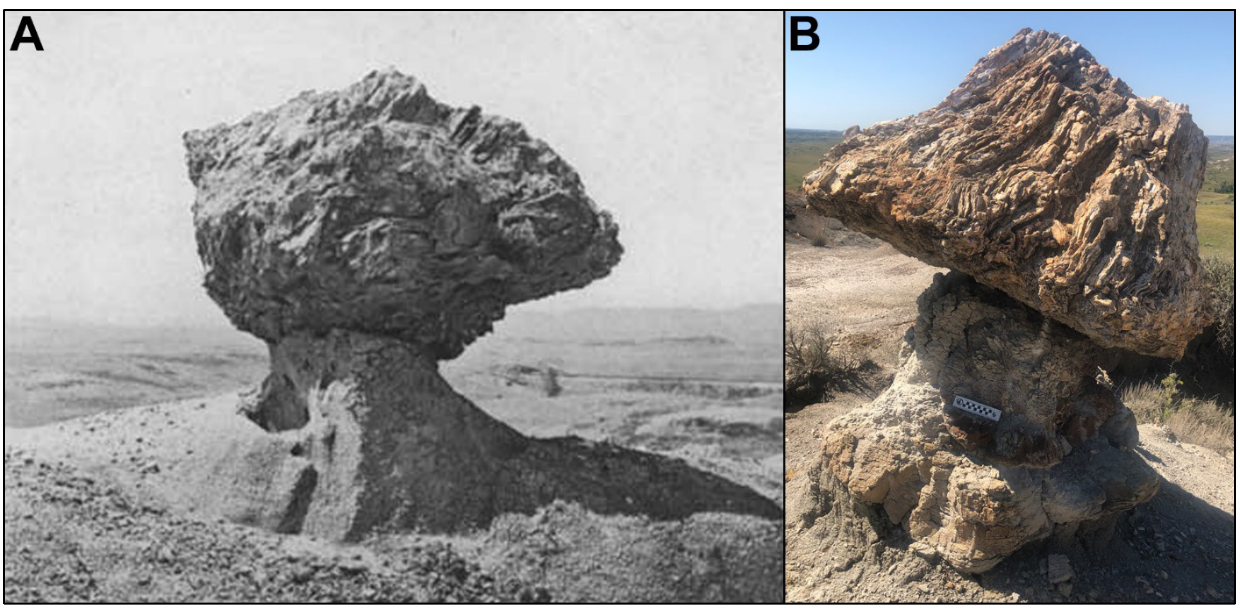


Figure 3. A. A stump protecting a pedestal in Pyramid Park (Figure A of Plate VI in Campbell et al. 1915). The original caption reads "A. Silicified stump in Pyramid Park, N. Dak. A remnant of one of the big trees of the Fort Union forest, now a mass of stone resting on a pedestal of soft clay. Photograph by Haynes, St. Paul, Minn." What may be the same photo is used in a collage image in Wheeler (1895). **B.** Similar features can be found today in THRO (NPS/PATRICK WILSON).

Roosevelt himself was aware of the presence of fossils in the lands around his property. In *Hunting Trips of a Ranchman*, he mentioned (Roosevelt 1885:64–65):

> *"Last spring one pair [of plains plovers] nested in a broken piece of Bad Lands near my ranch, where the ground is riven and twisted into abrupt, steep crests and deep canyons. The soil is seemingly wholly unfitted to support bird life, as it is almost bare of vegetation, being covered with fossil plants, shells, fishes, etc.—all of which objects, by the way, the frontiersman, who is much given to broad generalization, groups together under the startling title of 'stone clams.'"*

Petrified wood was considered a notable feature of the prospective park commemorating Theodore Roosevelt's time in the Little Missouri region from the first proposals in the early 1920s to the establishment of Theodore Roosevelt National Memorial Park in 1947. In a 1928 Congressional discussion, rancher Carl Olson made the following statement (Various 1928:20):

> *"The greater portion of them [tourists] are merely the traveling tourists. This petrified forest is the drawing card, and they come with the idea that the petrified forest is all that we have to show them. If they have time to see the petrified forest they think they have seen the Bad Lands. Several made a 4-hour trip to the petrified forest, and I presume the largest number of my guests referred to have spent the four hours to visit the petrified forest and to have a meal or two."*

In 1938, a guidebook to North Dakota put out by the Works Progress Administration (Federal Writers of the Works Progress Administration 1938) called attention to petrified wood in the descriptions of North and South Roosevelt Regional State Parks (the precursors to the North Unit and South Unit of THRO). After Theodore Roosevelt National Memorial Park had been created but without the petrified forest area now in the South Unit, North Dakota politician William Lemke specifically and successfully pushed to include this area in 1948 (Harmon 1986).

Although the area's petrified wood had been widely publicized beginning in the late 1800s, the geology of THRO was not described in any detail before the park was established. A few brief accounts exist from the pre-park period (Allen 1875; Tarr 1898, 1900; Hibbard 1906; Douglass 1909) but provide very generalized information and/or focus on areas outside of THRO. Perhaps the most intriguing of these reports from a paleontological standpoint is that from Earl Douglass, best known for his later discovery of the famous Carnegie Quarry of Dinosaur National Monument. He visited the area in 1905 and noted the presence of plant and invertebrate fossils in the "Fort Union" beds around Medora, but focused on younger vertebrate sites to the south and east of the South Unit of THRO. He did, though, visit the site of Theodore Roosevelt's Maltese Cross Cabin (as shown by his reference to the cabin having been "removed to the Portland Exhibition"; it is now installed near the South Unit's Visitor Center) (Douglass 1909). Douglass also took care to differentiate a potentially confusing point of nomenclature: there is both a "Little Missouri Bad-lands", which includes what is now THRO, and a "Little Bad-lands" of younger, White River Group rocks southwest of Dickinson (the White River Group is more famous as the primary rocks of Badlands National Park in South Dakota).

The first detailed descriptions of THRO geology were two publications by Wilson Laird (Laird 1950, 1956) that review the South Unit and the North Unit, respectively. These reports focused on the bedrock of the park, the Little Missouri River, formation of landforms, and the notable sedimentary features of the park (the clinker and sandstone concretions). However, Laird (1950) also described the numerous petrified stumps in the South Unit of the park, then identified as the redwood *Sequoia*. This is the first mention of the park's paleontological resources in the scientific literature. There are some publications from the 1960s and 1970s that included fossils from within park boundaries (Jain and Hall 1969; Bickel 1976). The park's fossil wood was documented in unpublished internal reports in this time frame as well (Berg and Brophy 1963; Coffin 1984). Fastovsky and McSweeney (1991) studied the Petrified Forest Plateau of the South Unit of the park and gave a detailed description of the petrified wood in THRO. The emphasis of this publication was on the paleosols in Petrified Forest Plateau and their influence on modern soil material. Paleontological research has been extensive in areas near the park, particularly the Wannagan Creek Quarry just west of the South Unit (Erickson 1991, 1999, 2012), which shows the potential for discoveries in THRO itself.

The first extensive study of the paleontological resources of the park was a 1994–1996 joint North Dakota Geological Survey (NDGS)–NPS survey led by John Hoganson and Johnathan Campbell of the NDGS. This survey covered both the North and South Units and recorded 400 sites (233 in the South Unit and 167 in the North Unit) in 26 km^2 (10 mi^2). Collection of fossil specimens was minimal during the survey. Some of what was collected is on display at the South Unit's interpretive center. The rest of the specimens are currently housed at the North Dakota Heritage Center. Publications on the survey were produced by the NDGS between 1994 and 2002 (Hoganson 1994; Hoganson and Campbell 1997, 1998, 2002). This survey established the significance of the paleontological resources in THRO and emphasized the need for further surveys of these resources. Santucci and Tweet completed an oral history interview with Hoganson concerning the survey in June 2020.

Since the NDGS–NPS survey, paleontological resources have become a more recognized component of THRO. Biek and Gonzalez (2001) wrote a geological assessment of the park with notes on the fossiliferous horizons of the Petrified Forest Plateau and the petrified wood horizons in the lower portion of the Sentinel Butte Formation exposure in the park. The park has approved 14 research permits involving geology or paleontology from outside institutions including the University of Wisconsin (2003–2004) and Yale University (2007 and 2010). Since then, publications on the paleontological resources of THRO have been reviews including a geological resource evaluation (GRE) report (KellerLynn 2007) and the Northern Great Plains Inventory & Monitoring Network paleontological resources summary report (Tweet et al. 2011). Between 2017 and the 2020–2021 park inventory there were three field collections of paleontological resources within the park in association with the NDGS. These specimens are catalogued in THRO fossil collections.

There are two fossil taxa holotypes that originate from within THRO boundaries. One is *Azolla stanleyi*, a species of fern palynomorph described by Jain and Hall (1969) from the South Unit. The sampling of *Azolla stanleyi* was a part of a larger description of palynomorphs from Paleocene and Eocene rocks in other parts of North Dakota and Montana. The other is *Eupera missouriensis*, a species of bivalve from the North Unit of the park described in Bickel (1976). The publication of

Eupera missouriensis was part of a larger study of Williston Basin mollusks that began in 1971 and included 130 localities in eastern Montana and western North Dakota (Bickel 1977).

Summary of 2020–2021 Paleontological Survey

The THRO Paleontological Resources Inventory project formally began in the summer of 2020 with the hiring of Charles Salcido and Patrick Wilson, two 12-week paleontology assistants hired through the Geological Society of America Geoscientists-in-the-Parks program (now Scientists in Parks). This program helped to provide funding for extensive survey work to be completed in the park. The initial plan was to divide the survey work between the main two units of THRO, beginning with the South Unit the first summer and followed by a survey of the North Unit in 2021. Due to unforeseen circumstances originating with the SAR-CoV-2 global pandemic, the summer 2020 field survey work was delayed for eight weeks. This greatly reduced the thoroughness of the survey completed in the South Unit. However, the paleontology assistants were able to document 46 new localities in 1.99 km^2 (0.77 mi^2) of THRO and revisit three previously recorded localities.

Photo 2. Charles Salcido (left) and Patrick Wilson (right) documenting a locality, July 2020 (NPS/JENNA STREFFON).

During the second summer (2021), one assistant (Charles Salcido) focused on the North Unit and the Bullion Creek outcrops and the then-closed portion of the Scenic Loop Road of the South Unit. Salcido covered 7.07 km^2 (2.73 mi^2) of the park with 112 new localities documented and two previously recorded localities revisited. Material was also collected with assistance from the NDGS from significant sites recorded during the 2020 survey. Overall, the two paleontology assistants documented 158 localities over 9.1 km^2 (3.5 mi^2). The 2020 field work was performed under permit THRO-2020-SCI-0012, and the 2021 field work was performed under THRO-2021-SCI-0015, with associated microvertebrate sampling performed under permit THRO-2021-SCI-0019.

Geology

Geologic History

THRO is located near the center of the Williston Basin. This depositional basin covers several hundred thousand square miles of the North American craton (Figure 4). The Williston Basin underlies North Dakota, South Dakota, and Montana in the United States, as well as southern portions of Manitoba and Saskatchewan in Canada (Zhou et al. 2008). The basin was formed by subsidence that began in the Ordovician (KellerLynn 2007; Zhou et al. 2008). Sediments in the Williston Basin record an unusually complete rock record including several major transgression/regression cycles (sea level rise and fall). More than 4,900 m (16,000 ft) of sediment are preserved in the basin with most of the sediments originating from shallow marine settings and a few from terrestrial environments (KellerLynn 2007). The early structural history of the basin itself is mostly unknown because there are no surficial exposures of Precambrian or lower Phanerozoic rocks in the basin. The Williston Basin has become an important economic resource because of its immense oil and gas reserves (KellerLynn 2007; Zhou et al. 2008).

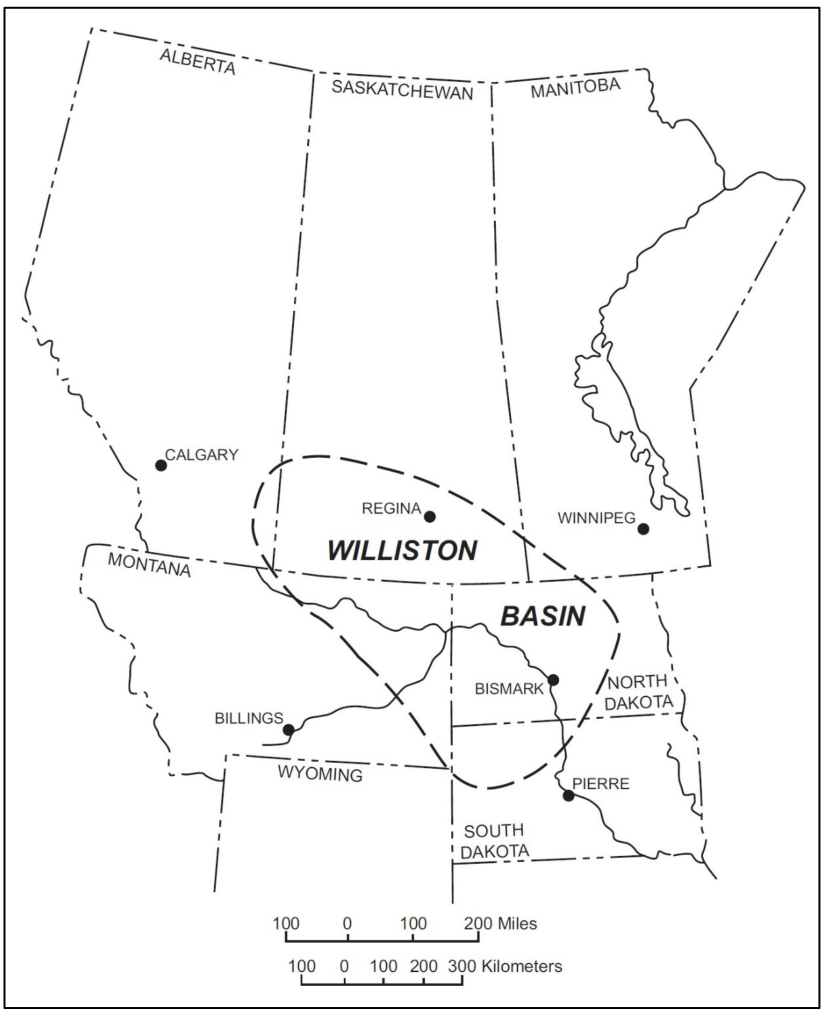


Figure 4. Index map of the Williston Basin (Figure 1 in Pitman et al. 2001).

One of the major transgression/regression cycles recorded in the Williston Basin is the transgression of the Western Interior Seaway during the Cretaceous, just before the deposition of the Fort Union Group rocks that make up the badlands of THRO (KellerLynn 2007). This shallow northwest–southeast trending continental seaway connected the Arctic with the Gulf of Mexico several times throughout its history and was hundreds of kilometers or miles in width (Figure 5) (KellerLynn 2007). At the end of the Cretaceous, the Western Interior Seaway retreated (KellerLynn 2007), with a last transgressive pulse in North Dakota during the Paleocene sometimes called the Cannonball Sea (e.g., Cherven 1978). The end-Cretaceous retreat of the seaway is coincident with the Laramide Orogeny (mountain-building event). This orogenic event is responsible for the creation of the modern Rocky Mountains. During the orogeny, the Rocky Mountains shed hundreds of cubic miles of sediment onto the Great Plains. This sediment was carried eastward by streams and created thick clastic wedges from the Late Cretaceous to the Oligocene (KellerLynn 2007).

Figure 5. Late Cretaceous (Campanian) map of the Western Interior Seaway. Figure 1 in Sampson et al. (2010). CC by 4.0 (https://creativecommons.org/licenses/by/4.0).

The Paleocene formations of the Little Missouri Badlands are composed of material shed from the Rocky Mountains during their uplift. These sediments form the Fort Union Group in North Dakota, Montana, and Wyoming. There is some debate over the exact depositional environment of the Fort Union Group (Laird 1950; Fastovsky and McSweeney 1991), but the general consensus is a low-lying swamp with water-loving trees and other plants (KellerLynn 2007). In addition to the sediments shed from the Rocky Mountains, volcanic activity associated with the Laramide Orogeny to the west added ash to the sediments. This ash accumulated in standing water and, after being partially broken down, became the bentonitic "blue beds" that can be seen in THRO (KellerLynn 2007). This silica-rich volcanic ash affected the groundwater chemistry by adding a source of silica, which contributed to the preservation of silicified plant fossils (KellerLynn 2007).

The Paleocene–Eocene Thermal Maximum (PETM), a short-lived thermal spike of perhaps 5–8 °C (9–14 °F), occurred around 56 Ma (million years ago) (McInerney and Wing 2011), shortly after the deposition of the Fort Union Group. As global climatic trends shifted toward more arid conditions after the PETM, sediment deposition in the Williston Basin area continued with the Golden Valley Formation and White River Group, deposited 55–30 Ma (Clayton et al. 1980; KellerLynn 2007). Regional uplift changed the area from a depositional basin to a place where streams cut down into the existing rock, producing long-term weathering and erosion that has largely erased evidence of deposition between the Oligocene and Pleistocene. The only remnants of Neogene material are unnamed terraced gravel deposits (KellerLynn 2007).

The last units to be deposited in the Williston Basin, excluding modern deposition, are Pleistocene in age and record a period of glacial advancement and retreat (Laird 1956; KellerLynn 2007). Current evidence and interpretation indicate that only the North Unit was directly affected by continental glaciation (KellerLynn 2007). Aside from glacial erratics in the North Unit (Biek and Gonzalez 2001), there is little evidence of glaciation within the park. However, glaciation drastically changed regional drainage (Laird 1956; Trimble 1990; KellerLynn 2007). Prior to the Pleistocene, the ancestral Little Missouri River, as part of the Missouri River system, flowed northeastward to Hudson Bay, but glaciation blocked this route and caused the system to join the Mississippi River (Trimble 1990; KellerLynn 2007). As a result, the grade of the rivers in the basin increased and downcutting accelerated. This erosion led to numerous mass wasting events and features, including two types of rotational slumping seen in THRO (KellerLynn 2007). Some of the most spectacular landslides can be seen in the North Unit of the park (KellerLynn 2007).

Geologic units exposed at THRO include, from oldest to youngest, the Bullion Creek Formation (Fort Union Group, middle–upper Paleocene), the Sentinel Butte Formation (Fort Union Group, upper Paleocene), erosional remnants of the Golden Valley Formation (upper Paleocene–lower Eocene), unnamed Neogene-age gravels, the Coleharbor Group (Pleistocene), and the Oahe Formation (post-glacial Pleistocene–Holocene) (Figures 6–8) (Biek and Gonzalez 2001; KellerLynn 2007). In the referenced maps, the Quaternary units are divided by depositional mode rather than formation. For reference, Biek and Gonzalez attribute Qt1 through Qt4 to the Coleharbor Group and Qal, Qf1, Qf2, Qmp, Qoal, and apparently Qls to the Oahe Formation. All of the geological formations are fossiliferous within the park (Table 1).

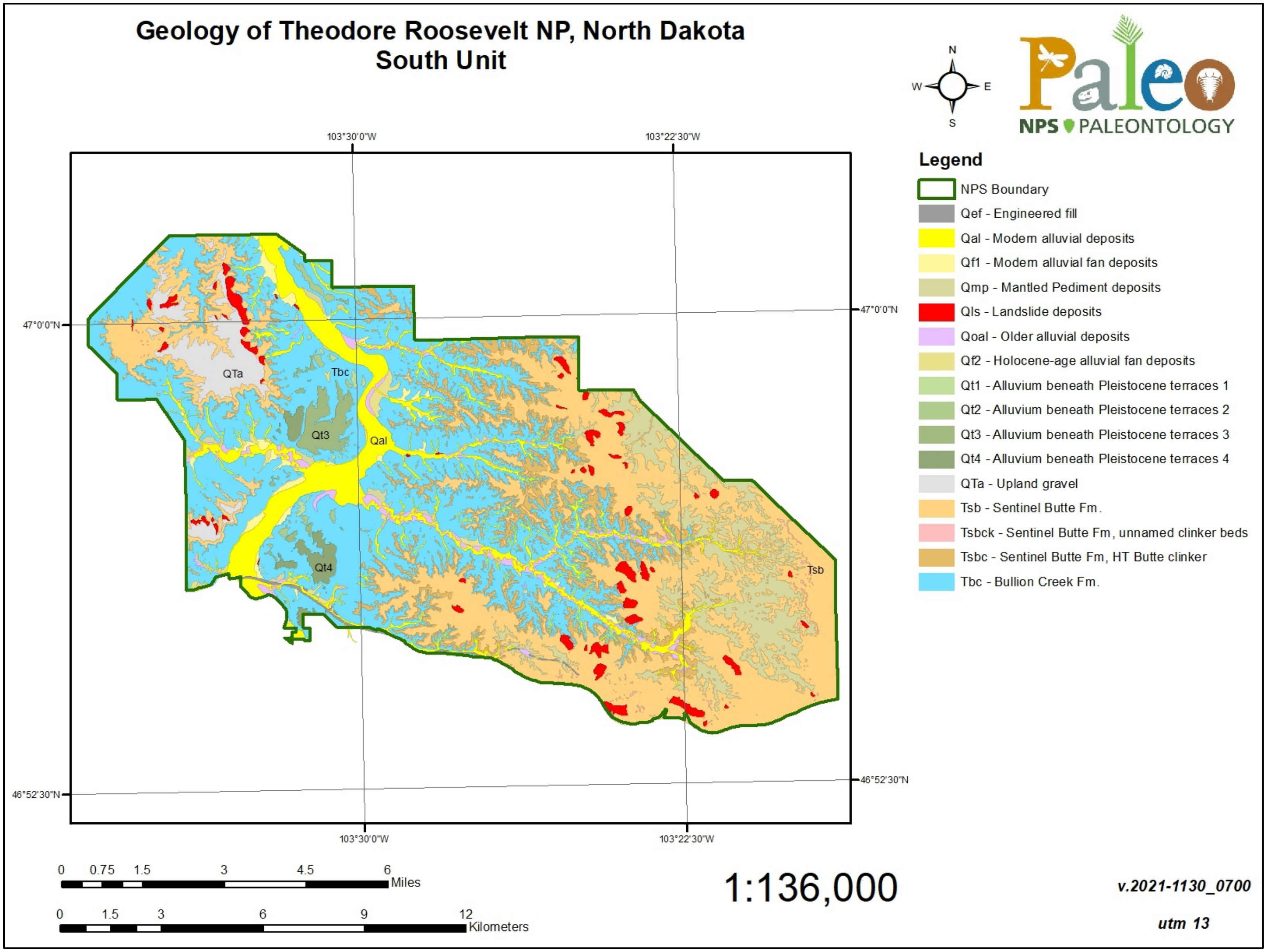


Figure 6. Geologic map of the South Unit of THRO, derived from Biek and Gonzalez (2001), digitized by the NPS Geologic Resources Inventory (GRI). Digital map data is available at: https://irma.nps.gov/DataStore/Reference/Profile/1044330.

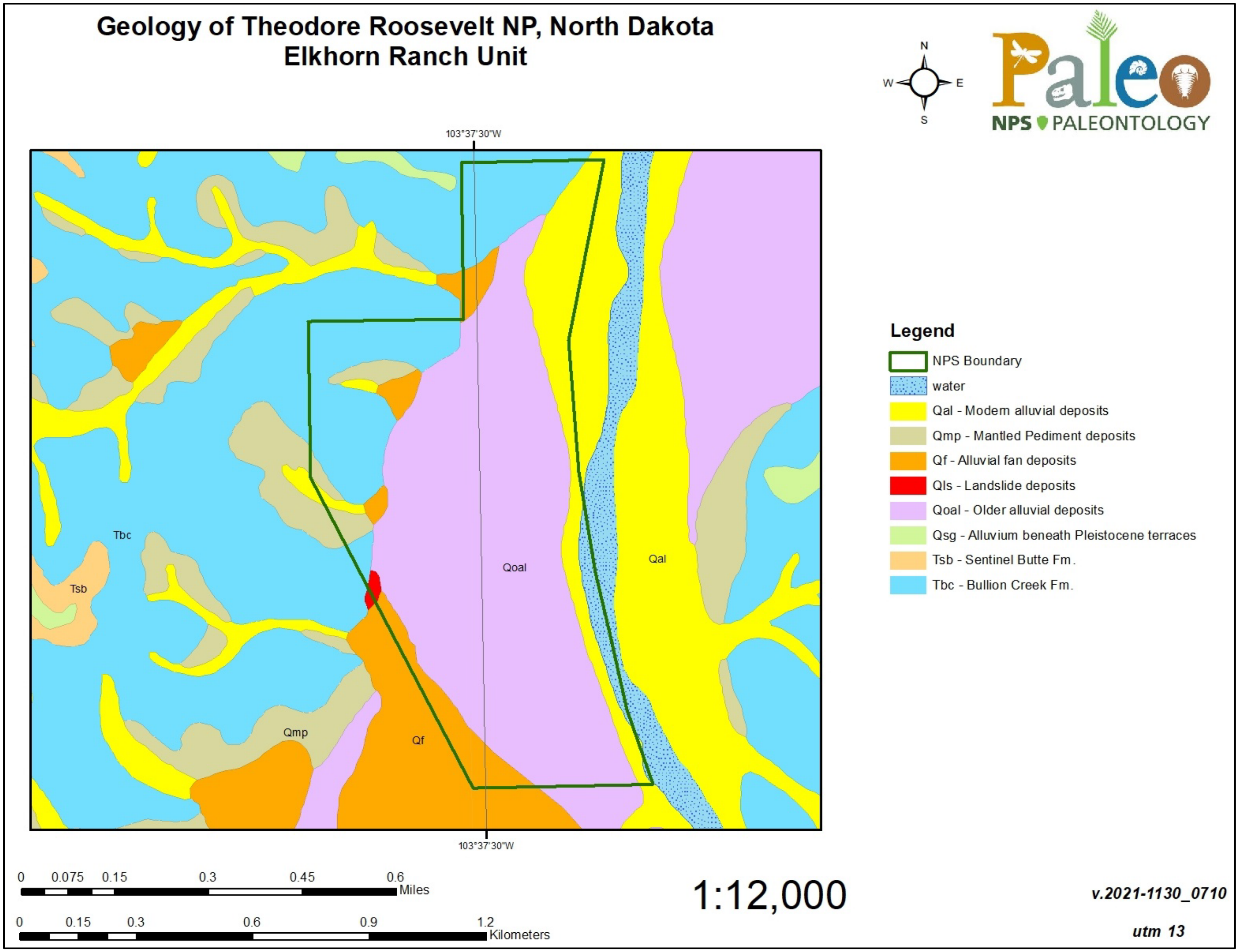


Figure 7. Geologic map of the Elkhorn Ranch Unit of THRO, derived from Gonzalez (2004a, 2004b, 2004c, 2004d), digitized by the NPS GRI. Digital map data is available at: https://irma.nps.gov/DataStore/Reference/Profile/2258957.

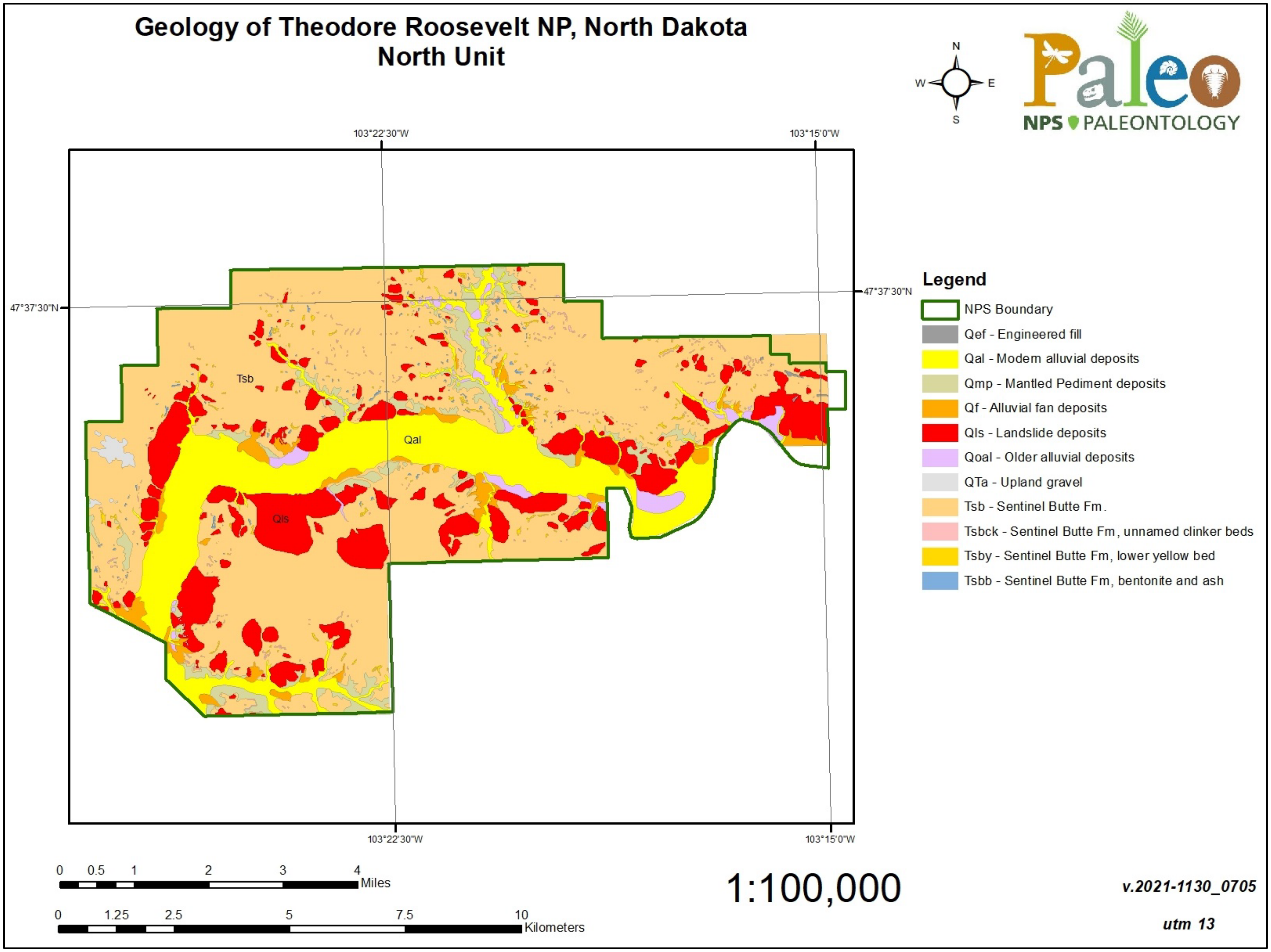


Figure 8. Geologic map of the North Unit of THRO, derived from Biek and Gonzalez (2001), digitized by the NPS GRI. Digital map data is available at: https://irma.nps.gov/DataStore/Reference/Profile/1044328.

Table 1. Summary of THRO stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in the Northern Great Plains Network paleontological resource summary (Tweet et al. 2011).

Formation	Age	Fossils Within THRO	Depositional Environment
Oahe Formation	latest Pleistocene–Holocene	Charcoal and bison bones	Eolian, fluvial, mass wasting, floodplain, engineering fill
Coleharbor Group	Pleistocene	Wood fragments and bison bones	Glacial, fluvial, lacustrine, eolian
Unnamed gravels	Neogene and/or Pleistocene	None in situ; reworked petrified wood	Stream deposits
Golden Valley Formation	late Paleocene–early Eocene	Fragments of twigs, roots, and branches	Swamp or marsh; hiatus in deposition
Sentinel Butte Formation	late Paleocene	Lignite coal, petrified wood (some with traces made by insects or birds), leaves, seeds, palynomorphs, bivalves, gastropods, ostracodes, beetles, bony fish, salamanders, turtles (one with bite marks), choristoderes, crocodilians, birds, mammals, invertebrate burrows, bird tracks, and coprolites	River, lake, and swamp; ash source 400 km (250 mi) away
Bullion Creek Formation	middle–late Paleocene	Lignite coal, leaves, seeds, petrified wood, bivalves, gastropods, ostracodes, bony fish, turtles, choristoderes, crocodilians, invertebrate burrows, and coprolites	River, lake, and swamp

Stratigraphic Nomenclature

The USGS is responsible for nation-wide standardization of stratigraphic units. However, this broad scale cannot always account for localized areas of different lithology. For example, the North Dakota Geological Survey (NDGS) treats the Fort Union stratigraphic interval differently than the USGS. The USGS prefers to treat the Fort Union interval as a formation, divided into members, whereas in North Dakota it has long been described as the Fort Union Group, divided into formations. In addition, the NDGS and USGS systems use different names for the rocks beneath the Sentinel Butte Formation or Member. Of interest for THRO, the unit directly beneath the Sentinel Butte Formation is called the Bullion Creek Formation in the NDGS system, but is called the Tongue River Member in the USGS system. The Bullion Creek name was introduced in 1977 to account for irregularities in the Ludlow and Tongue River Formations within the Fort Union Group. These irregularities were due to poor descriptions and lack of defined type sections for correlations (Clayton et al. 1977). Clayton et al. (1977) created the Slope and Bullion Creek Formations within the Fort Union Group in North Dakota to clarify unique lithologies that were originally assigned to the Tongue River Formation. It is important to highlight this change in stratigraphic nomenclature because much of the stratigraphic work done within THRO predates or coincides with the description of the Bullion Creek Formation and some relevant publications use the USGS terminology (Kihm and Hartman 2004; Belt et al. 2005).

Because the intent of this report is to assess paleontological resources within THRO, arbitrating differences of stratigraphic usage are outside of the scope of this project. The remainder of this report will use the modern NDGS nomenclature, which includes the Bullion Creek Formation and excludes the Tongue River Formation (Figure 9).

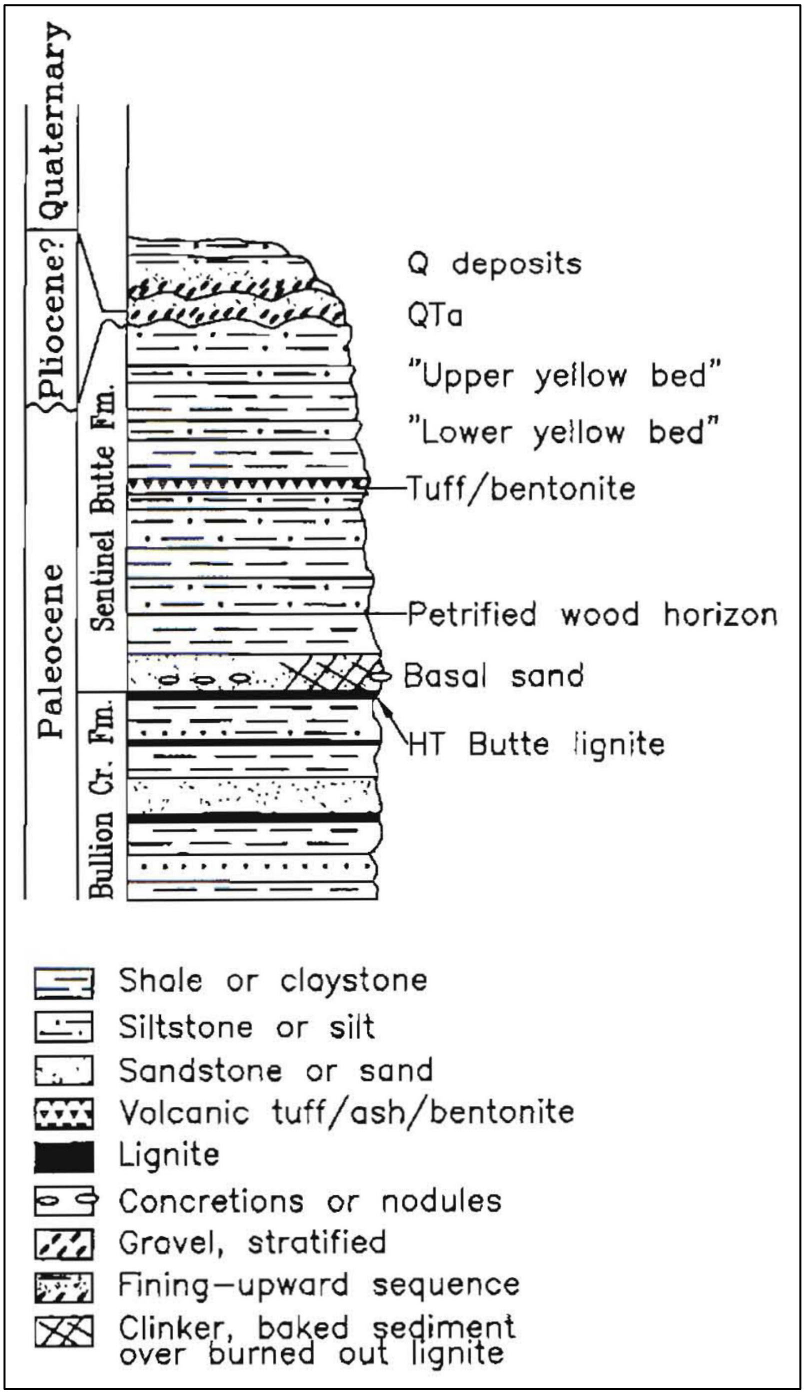


Figure 9. Chart of stratigraphic nomenclature used by the North Dakota Geological Survey and adopted in this document (COURTESY NORTH DAKOTA GEOLOGICAL SURVEY; BIEK AND GONZALEZ 2001: FIGURE 2).

Geologic Formations

Fort Union Group: Bullion Creek Formation (Paleogene: middle–upper Paleocene)

Description: The Bullion Creek Formation consists of gray claystone and siltstone, lignite, and yellow siltstone and sandstones (Figure 10) (Hoganson and Murphy 2003; KellerLynn 2007). Gray claystone and siltstone deposition represent a floodplain. Lignite deposition is derived from swampy environments where abundant plant material partially decomposed and was slightly compacted by overlying sediments. Yellow siltstone and sandstones represent crevasse splay and levee deposition. Altogether, the depositional environment of the Bullion Creek Formation is interpreted as a low-relief coastal plain with rivers, lakes, ponds, swamps, and rainforests (Laird 1950; Fastovsky and McSweeney 1991; KellerLynn 2007). The Bullion Creek Formation is exposed in the South Unit and Elkhorn Ranch Unit of THRO, varying in thickness from 60 to 180 m (200 to 600 ft) (Hoganson and Campbell 1997; KellerLynn 2007). The top of the Bullion Creek Formation is marked by the HT Butte clinker bed (Biek and Gonzalez 2001; KellerLynn 2007).

Figure 10. A typical exposure of weathering Bullion Creek Formation, with a rounded profile and color banding; TRS21-039 (NPS/CHARLES SALCIDO).

Some of the lignite beds found throughout the Bullion Creek and Sentinel Butte Formations in THRO have been ignited via natural processes and burned hot enough to partially melt the surrounding rock (Biek and Gonzalez 2001; KellerLynn 2007). The resulting rock has been colloquially called "scoria," which is a type of iron-rich extrusive igneous rock. A more appropriate term for the burned lignite deposits in THRO is "clinker," because the altered rocks lack the igneous origin necessary to be called scoria. Clinker will be used in the remainder of this report. The Bullion Creek Formation and other parts of the Fort Union Group are regarded as belonging to the Tiffanian North American Land Mammal Stage (Lofgren et al. 2004), most of the second half of the Paleocene (approximately 61 to 56 million years ago).

Fossils found within THRO: The fossils reported from this formation in the park include plants (*Cercidiphyllum* sp. and indeterminate petrified wood and plant material), invertebrates (freshwater bivalves, gastropods, and ostracodes), vertebrates (bowfin *Amia* sp., gar *Lepisosteus* sp., turtle *Protochelydra* sp., choristodere *Champsosaurus* sp., and crocodilian *Borealosuchus* sp.), and trace fossils (worm burrows and coprolites) (Hoganson and Campbell 1997; KellerLynn 2007; 2020–2021 field inventory); see Appendix A for a complete list.

Fossils found elsewhere: There are numerous fossil taxa described from this formation outside of the park boundaries. Fossil taxa include plants (numerous species), mollusks, arthropods, fish, amphibians, reptiles, birds, mammals, and ichnotaxa (Erickson 1991, 1999, 2012). Many of these taxa were reported from the nearby Wannagan Creek Quarry, just outside of the South Unit's boundaries (Erickson 1991, 1999, 2012).

Fort Union Group: Sentinel Butte Formation (Paleogene: upper Paleocene)

Description: Overlying the HT Butte clinker is a basal sandstone that marks the base of the Sentinel Butte Formation, the upper unit of the Fort Union Group (Biek and Gonzalez 2001; Hoganson and Campbell 2002). The Sentinel Butte Formation has similar lithology to the Bullion Creek Formation with sandstones, siltstones, and claystones but is lighter in color, with somber gray to brown rocks laid down in fluvial and lacustrine environments (Figure 11) (Cherven 1973, 1978; Hoganson and Campbell 2002). However, some beds in the Sentinel Butte Formation have similar coloration as Bullion Creek Formation, leading to confusion of these two formations. Overall, within the Sentinel Butte Formation there are fewer lignites, limestones, and linear sand bodies than are found in the Bullion Creek Formation (Biek and Gonzalez 2001). Tabular sandstones in the Sentinel Butte Formation are more laterally extensive and more abundant than in the Bullion Creek Formation, indicative of higher sinuosity streams (Cherven 1973, 1978). These features, along with the delta progradation of the Bullion Creek Formation to the Sentinel Butte Formation, indicate a large deltaic complex in the Cannonball Sea of the Paleocene (Cherven 1978). The formation is exposed in both the North Unit, where it has a maximum thickness of 214 m (700 ft), and the South Unit, where it has a maximum thickness of 91 m (300 ft). Within the Sentinel Butte Formation there are a few beds of note. One in the lower portion of the formation above the basal sandstone has an extensive petrified wood bed that includes stumps in growth position. Another noteworthy bed is a widespread bentonite deposit called the Sentinel Butte Ash that is up to 8 m (25 ft) thick in the North Unit (Royse 1967, 1970; Jacob 1973; Biek and Gonzalez 2001; Hoganson and Campbell 2002). Above the bentonite bed is a bright yellow sandstone containing abundant freshwater mollusk fossils (Biek and Gonzalez 2001).

Figure 11. The Sentinel Butte Formation at this location shows a combination of yellow Bullion Creek Formation-like beds and gray beds (NPS/CHARLES SALCIDO).

<u>Fossils found within THRO</u>: The fossils reported from this formation in the park include several taxa of ferns, conifers, and angiosperms; invertebrates, principally freshwater bivalves and gastropods, with undetermined beetles and ostracodes; vertebrates, among them bowfin *Amia* sp., pike *Esox* sp., gar *Lepisosteus* sp., salamander *Piceoerpeton* sp., turtles *Protochelydra* sp. and *Plastomenus* sp., choristoderes *Champsosaurus* sp. and "*Simoedosaurus*" sp., alligatoroids and crocodilians, a bird, and mammals represented by *Plesiadapis* sp., *Titanoides* sp., and indeterminate probable cimolestan and condylarth material; and ichnofossils represented by worm burrows and a bird track (Jain and Hall 1969; Bickel 1976; Hoganson and Campbell 1997; KellerLynn 2007; 2020–2021 field inventory; 2021 South Unit Loop Road survey).

<u>Fossils found elsewhere</u>: As with the Bullion Creek Formation, there are numerous fossil taxa known from the Sentinel Butte Formation that have not yet been found in THRO, although not as many as for the older formation. Fossil taxa include fossil plants, invertebrates (including mollusks and arthropods), fish, amphibians, reptiles, mammals, and invertebrate trace fossils (Brown 1948; Royse 1970; Nichols and Ting 1975; Crane et al. 1990; Kihm and Hartman 1991; Hartman and Kihm 1992; Hoganson 1997; Kays 1999; KellerLynn 2007).

Golden Valley Formation (Paleogene: upper Paleocene–lower Eocene)

Description: The Golden Valley Formation is not present as coherent beds within THRO, but erosional remnants of the resistant Taylor bed from the formation's Bear Den Member are present (Hoganson and Campbell 1997; Biek and Gonzalez 2002). The Taylor bed is composed of silicified siltstone and freshwater limestone and originates at the contact between the Bear Den Member and the overlying Camels Butte Member of the Golden Valley Formation (Hickey 1977). When present within the park, blocks of the Taylor bed are typically between 0.3 m (1 ft) and 0.6 m (2 ft) thick and around 3 m^2 (10 ft^2) in area (KellerLynn 2007). If the Bear Den Member were present in the park, it would conformably occur between the Taylor bed and the Sentinel Butte Formation. The Bear Den Member closely resembles the Sentinel Butte Formation and is interpreted to be the result of paleosol formation on top of Sentinel Butte Formation sediments (Biek 1995; Biek and Murphy 1997). The Taylor bed at the top of the member is thought to roughly correspond to the Paleocene–Eocene boundary (Clechenko et al. 2007), approximately 56 Ma. According to geologic maps produced for this project (see above), there are no exposures of in situ Golden Valley Formation rocks in THRO.

Fossils found within THRO: There are very few fossils from the Golden Valley Formation within park boundaries. Reported fossils within THRO are indeterminate plant fragments of twigs, roots, and branches (Hoganson and Campbell 1997; KellerLynn 2007), and root or stem casts (Biek and Gonzalez 2001).

Fossils found elsewhere: There are 118 fossil taxa described from this formation outside of the park boundaries. Fossil taxon groups include fossil plants, invertebrates, fish, amphibians, reptiles, mammals, and ichnotaxa (Jepsen 1963; Hickey 1977). The vertebrate and invertebrate taxa are found in the Camel Butte Member of the formation overlying the Taylor bed. Because the Camel Butte Member is not preserved in the park, it is unlikely that taxa from the member will be found in THRO.

Unnamed Gravel Deposits (Neogene and/or Pleistocene)

Description: Within park boundaries there are numerous unnamed terrace gravel deposits. These sand and gravel deposits, with occasional well-cemented pebble and cobble material, were deposited by streams and are less than 1.5 m (5 ft) thick (KellerLynn 2007). The gravel deposits have been correlated to other deposits in the region and are currently thought to pre-date Pleistocene glaciation, which places them as early Pleistocene or Neogene in age (KellerLynn 2007). However, the exact age or age range of these deposits are still unknown.

Fossils found within THRO: Petrified wood is reportedly present (KellerLynn 2007). It would not be surprising if most or even all of this wood had been reworked from older formations. Petrified wood is common in the older units and is a durable material that can withstand the process of reworking, whereas gravel deposits are generally poor for preserving fossils because they are produced by high-energy deposition.

Fossils found elsewhere: There are no fossils reported from the gravel deposits outside the park.

Coleharbor Group (Quaternary: Pleistocene)

Description: The Coleharbor Group includes a range of grain sizes from as large as boulders to as small as fine silt and clay, with deposition during the Pleistocene (Bickley 1972). It lies unconformably across older units; the contact can be identified by the change from the gray-to-grayish-brown sand and silt of the Sentinel Butte Formation to the gravel of the Coleharbor Group. The group averages 30–45 m (98–147 ft) in thickness in some areas, can be seen in all units of THRO, and covers a large area outside of the park as well. Gravel lithology includes granite, basalt, and carbonates sourced from or near the Canadian Shield, and gravels can be hard to differentiate from gravels in other units. The upper 2.0 to 2.5 m (6.5 to 8.0 ft) are dirty gray because of the presence of organic material. The deposits are mostly glacial in origin with minor amounts of fluvial, lacustrine, and eolian deposition (Bickley 1972). Quaternary deposits in THRO are composed of unconsolidated alluvium beneath Pleistocene terraces, Holocene terraces, modern floodplains, fans, undifferentiated alluvium and eolian deposits overlying pediment surfaces, landslide material, and glacial erratics (limited to the North Unit) (Biek and Gonzalez 2001). The age of glacial erratics is uncertain due to evidence of glaciation being largely removed, only leaving behind widely scattered boulders (Biek and Gonzalez 2001). However, recent studies suggest a pre-Wisconsinan age (Biek and Gonzalez 2001; Fullerton et al. 2004). Alluvial deposits from the Pleistocene are found on top of plateaus, mesas, buttes, ridges, and benches flanking the Little Missouri River valley cut through both Sentinel Butte Formation and Bullion Creek Formation strata (Biek and Gonzalez 2001).

Fossils found within THRO: The fossils reported from this group in the park include wood fragments of late Pleistocene age (24,000 years; KellerLynn 2007) and bison fossils (Hoganson and Campbell 1997; M. Klosterman, THRO archivist, pers. comm., 2020).

Fossils found elsewhere: The Coleharbor Group and Oahe Formation have only been distinguished in the past 50 years, and are not strictly Pleistocene and Holocene, so for convenience they are treated here together. Fossils reported from the Quaternary deposits in western North Dakota include sloths (*Megalonyx jeffersoni*), rodents (*Ondatra zibethicus*), carnivorans (*Taxidea*), proboscideans (mammoths and mastodons), perissodactyls (*Equus*), and artiodactyls (*Bison* and camels) (Hay 1924; Baker 1967; Hoganson and Campbell 2002; Huber and Hill 2003; Hoganson and McDonald 2007; Hoganson 2010).

Oahe Formation (Quaternary: uppermost Pleistocene–Holocene)

Description: The youngest geologic unit exposed in THRO is the Oahe Formation, which is mostly composed of yellow, brown to red, or gray non-bedded coarse silt and fine sand (Bickley 1972). It is mainly eolian in origin (loess). Most of the sediments in THRO are associated with fluvial deposits (Biek and Gonzalez 2001). The Oahe Formation is postglacial in age (Clayton et al. 1976), meaning it incorporates a time span including the latest Pleistocene and Holocene. Deposits are found in every unit of THRO on flat to gently rolling uplands and valley bottoms, with thickness controlled by wind direction and strength. The formation is divided into three members: the Mallard Island Member, the Aggie Brown Member, and the Riverdale Member (Bickley 1972). The Mallard Island Member is marked by the deposition of yellow loess. The Aggie Brown Member marks the change from a spruce woodland environment to a prairie grass environment. The Riverdale Member is marked by 4,000 years of gray loess deposition followed by a series of alternating stable and unstable hillslope episodes (Bickley 1972). Mapped Holocene deposits in THRO include Holocene terraces, modern floodplains, fans, undifferentiated alluvium and eolian deposits overlying pediment surfaces, and landslide material (Biek and Gonzalez 2001). There is also poorly sorted unconsolidated colluvium from mass wasting of bedrock and sediments noted by Biek and Gonzalez (2001), but these sediments have not been mapped because they would unduly cover the underlying bedrock formations.

Fossils found within THRO: The fossils reported from this formation in the park include late Pleistocene and middle Holocene charcoal (Kuehn 1993) and bison material (Hoganson and Campbell 1997; Tweet et al. 2011; M. Klosterman, pers. comm., 2020).

Fossils found elsewhere: See above, under “Coleharbor Group”.

Taxonomy

See Appendix A for full lists of taxa. Locality data for fossil sites can be found in Appendix E.

Fossil Plants

While numerous plant species have been collected from the Bullion Creek and Sentinel Butte Formations, little fossil plant material has been collected from THRO. Additionally, the small amount of material collected has not been thoroughly studied. There currently are 43 plant specimens held in THRO's on-site collections.

Because lignite is a form of compressed peat, which is in turn composed of plant remains, the rocks of THRO are in part composed of plant fossils (Figure 12), although lignite is not often considered in these terms. Petrified wood (Figures 13 and 14) is the most abundant recognizable plant fossil found within the park's boundaries (Hoganson and Campbell 1997). Petrified wood is present in both the Bullion Creek Formation and the Sentinel Butte Formation with a notable abundance in the lower part of the latter formation. One site of note is the Petrified Forest Plateau area of the South Unit which has fossil tree stumps found in growth position (Hoganson and Campbell 1997). Hoganson and Campbell (1997) reported that petrified wood was so abundant that it was impractical to map, so they limited documentation to unusual sites. During the 2020–2021 survey, petrified wood localities were documented if they were represented by stumps and/or large logs that were in situ or close to their layer of origin. There were 51 such sites, with 30 in the South Unit and 21 in the North Unit. The 2021 survey noted a petrified forest in the North Unit that had approximately 52 fossil tree stumps and logs with all but 11 in growth position. Logs in the South Unit are concentrated in one layer of the Bullion Creek Formation and three or four layers in the Sentinel Butte Formation. The North Unit has four or five such layers in the Sentinel Butte Formation.

Figure 12. Thin beds of lignite (thin dark layers) in the Sentinel Butte Formation; TRS-006 (NPS/CHARLES SALCIDO).

Figure 13. Three large sections of petrified logs with Charles Salcido for scale; TRS20-021, Sentinel Butte Formation (NPS/PATRICK WILSON).

Figure 14. Petrified wood fossils are typically small fragments; a large section of wood like this at TRS20-021 (Sentinel Butte Formation) can weather into innumerable fragments (NPS/PATRICK WILSON).

The identification of the taxon or taxa represented by the wood is uncertain. In an unpublished report, Berg and Brophy (1963) quoted an identification of *Sciadopitys* (umbrella pine) by B. F. Kukachka of the Forest Products Laboratory (Madison, Wisconsin). Coffin (1984), another unpublished report, instead identified wood as the podocarp conifer *Dacrydium*. Fastovsky and McSweeney (1991) referred to additional unpublished identifications that indicated a second, different type of podocarp conifer and the flowering plant *Cercidiphyllum* (katsura). Paleobotanist Steven Manchester identified wood that they sent as taxodiacean. Taxodiaceae is no longer in use, and almost all of the members are now assigned to the cypress family Cupressaceae (except, coincidentally, *Sciadopitys*).

Other plant material is present but poorly known at THRO. A few non-wood taxa were reported in Fastovsky and McSweeney (1991), including the horsetail *Equisetum* and the flowering plants *Cercidiphyllum* and *Platanus*. The 1994–1996 survey found a handful of sites with leaves, seeds, or other non-wood specimens, among them katsura seeds and foliage of ferns and the conifer *Metasequoia*. Leaves were observed at several localities during the 2020–2021 inventory (Figure 15). The North Dakota Geological Survey has numerous leaf fossils from the Fort Union Group that can be used as a comparative reference collection if well-preserved specimens are found in THRO.

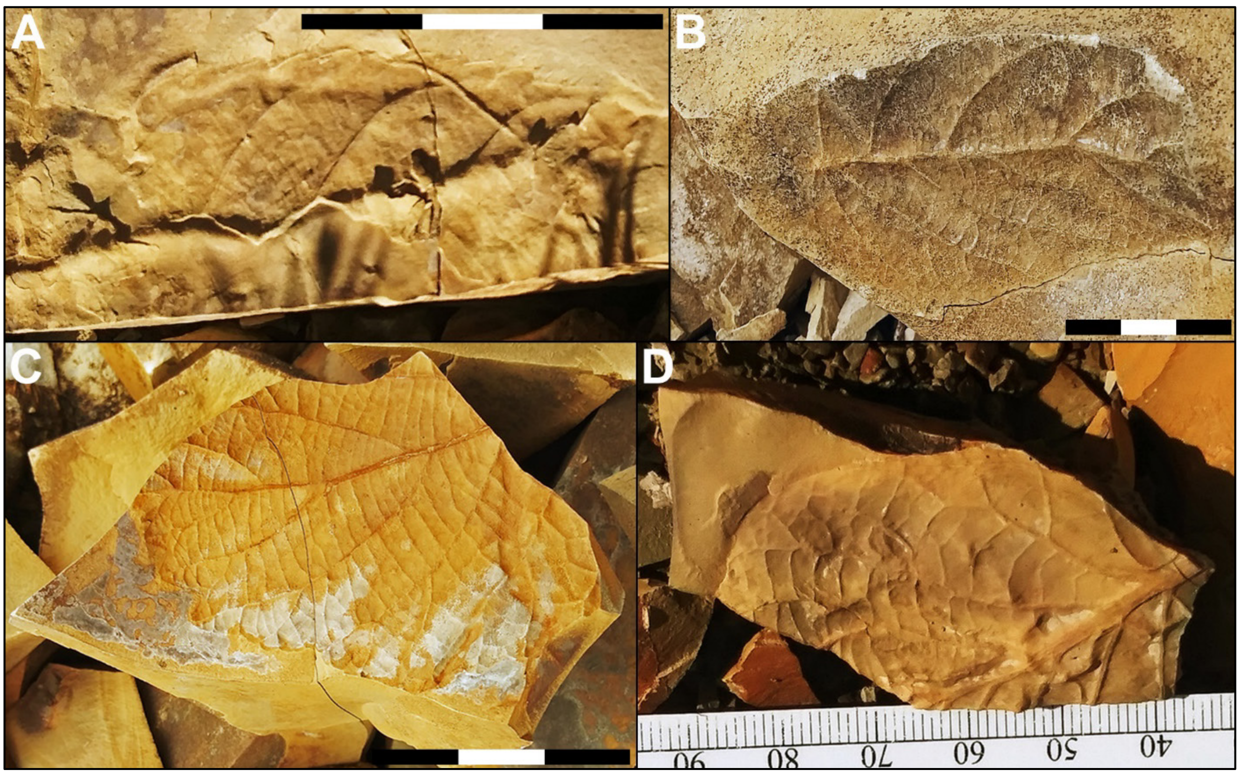


Figure 15. A variety of angiosperm leaves from the Sentinel Butte Formation in the North Unit of THRO (NPS/CHARLES SALCIDO). **A** is from TRN21-034, **B** and **C** are from TRN21-046, and **D** is from TRN21-045. Scale bars are 3 cm (1.2 in) each, divided into 1 cm (0.4 in) segments.

Although the collection of plant specimens on-site is small and mostly unidentified, some collections at outside repositories contain identifiable taxa, such as the type specimen of a palynomorph taxon, the fern spore *Azolla stanleyi* (Jain and Hall 1969).

Fossil Invertebrates

Phylum Mollusca: Class Bivalvia (clams, oysters, etc.)

Freshwater bivalves are among the most common fossils found at THRO, present in both the Bullion Creek Formation and Sentinel Butte Formation. Bivalves observed in the field include unionids (freshwater mussels) such as *Plesielliptio* (Hoganson and Campbell 1997) and sphaeriids (pill clams) such as *Eupera* (Bickel 1976) and *Sphaerium* (Hoganson and Campbell 1997). Park records include specimens catalogued in two families: Mytilidae and Veneridae. It is likely that the mytilid and venerid identifications are either mistakes due to general similarities of certain freshwater and marine forms, or represent outdated or imprecise taxonomy (for example, someone translating "mussel" as Mytilidae or "clam" as Veneridae while cataloging). Mytilidae and Veneridae are primarily marine groups. Unionids can resemble saltwater mussels (including mytilids), and sphaeriids can resemble tiny venerids (marine clams). Hoganson (1994 field notes) identified the THRO specimens catalogued as Mytilidae as freshwater clams. The park specimens assigned to Mytilidae and Veneridae are only identified to the family level. The species *Eupera missouriensis* is based on a fossil from THRO (Bickel 1976). The type specimen of *E. missouriensis* is in the collections of the Smithsonian (USNM PAL 220078). The species can be found in the Sentinel Butte Formation. Bivalves and gastropod mollusks (see below) are abundant fossils at THRO, but are often poorly preserved and/or fragmented, sometimes forming thin shell beds (Figure 16). Associated specimens are occasionally found (Figure 17).

The paleontological collection at THRO currently has one catalog number (THRO 3079) for two specimens collected from the Sentinel Butte Formation and identified as brachiopods. Brachiopods are shelled invertebrates that look similar to bivalves but represent a distinct phylum. The identification appears to be a mistake; photographs including the specimens show clusters of what appear to be bivalve shells (J. Tweet, pers. obs.).

Figure 16. Weathering bivalves in a shell-rich horizon; TRS21-013, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

Figure 17. An associated but fragmented freshwater bivalve in the field; TRS21-002, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

Phylum Mollusca: Class Gastropoda (snails)

Freshwater gastropods have been documented at many localities in THRO in both the Bullion Creek Formation and Sentinel Butte Formation. Hoganson and Campbell (1997) reported the genera *Campeloma*, *Lioplacodes*, and *Viviparus*. There is one catalogued gastropod specimen confirmed from THRO. This specimen is from the Sentinel Butte Formation but remains unidentified. Small gastropods resembling modern freshwater gastropods can be seen in the field. Several general forms can be distinguished based on coil steepness (Figure 18).

Figure 18. Various gastropods, Sentinel Butte Formation (NPS/CHARLES SALCIDO). **A.** A high-coiling example; TRN21-019. **B.** An intermediate example; TRN21-003. **C.** A low-coiling example; TRN21-003. Scale is 1 cm (0.4 in).

Phylum Arthropoda: Class Insecta

Hoganson and Campbell (1997) reported finding a single beetle fossil.

Phylum Arthropoda: Class Ostracoda (seed shrimp)

There are numerous mentions of ostracodes from the Bullion Creek and Sentinel Butte Formations in the NDGS inventory. However, there are no catalogued ostracode specimens in the collections at THRO. Ostracodes, minute crustaceans, are generally microscopic and would not be apparent to the casual viewer. Instead, they would be sampled along with other microfossils as part of a bulk sample.

Fossil Vertebrates

Vertebrate fossils are found occasionally at THRO (Figure 19). There are reports of a number of vertebrate taxa from different classes. Taxonomic classes represented include Osteichthyes, Amphibia, Reptilia, Aves, and Mammalia. Vertebrate fossil taxa have been found in the Bullion Creek Formation, the Sentinel Butte Formation, the Coleharbor Group, and the Oahe Formation. The paleontological collection at THRO contains five vertebrate fossils of unknown taxonomic class which have either been recovered from the Sentinel Butte Formation or are derived from an unknown unit.

Figure 19. Vertebrate material in the field, including choristodere vertebrae; TRS21-044, Bullion Creek Formation (NPS/CHARLES SALCIDO).

Class Osteichthyes

There are three families and genera of bony fish currently represented at THRO. Amiidae is represented by *Amia* sp. (a bowfin), Esocidae is represented by *Esox* sp. (a pike) (Figure 20), and Lepisosteidae is represented by *Lepisosteus* sp. (a gar) (Hoganson and Campbell 1997; KellerLynn 2007; 2020–2021 survey). *Amia* and *Lepisosteus* have been found in the Bullion Creek Formation and the Sentinel Butte Formation, but *Esox* has only been reported from the Sentinel Butte Formation. Specimens of *Amia* and *Lepisosteus* are held at the NDGS paleontological collections. The museum collection at THRO includes fossil fish but they are indeterminate beyond the class level, except for some *Amia* sp., *Esox* sp., and *Lepisosteus* sp. material collected during 2020 and 2021.

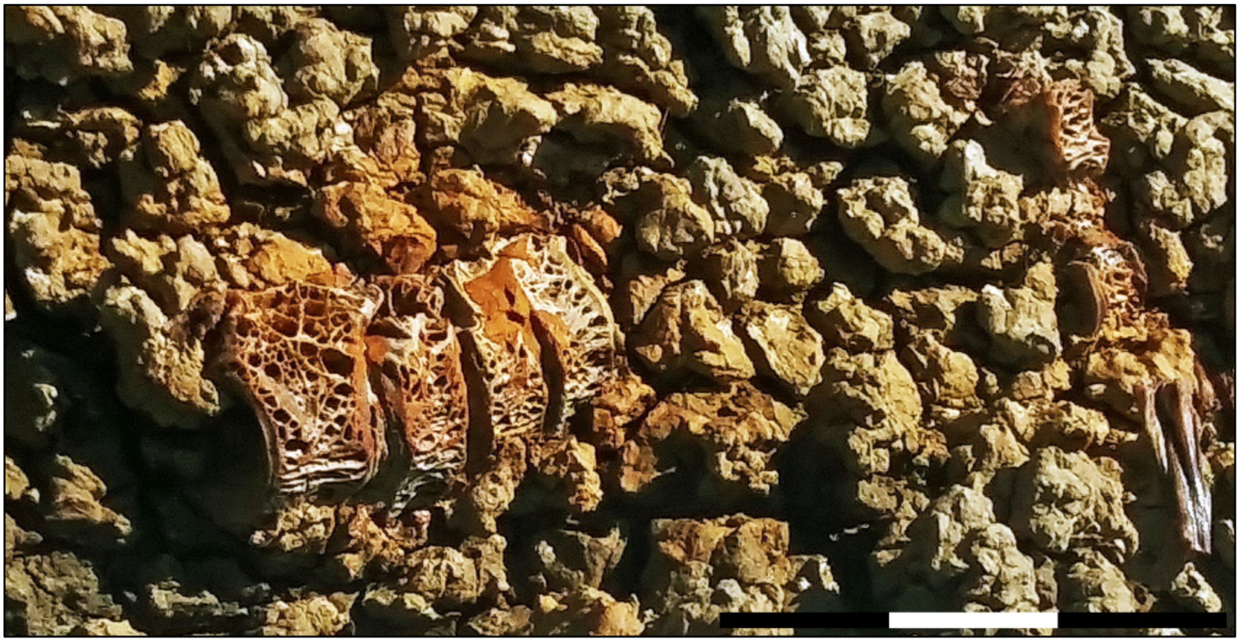


Figure 20. *Esox* vertebrae; TRS20-028, Sentinel Butte Formation (NPS/CHARLES SALCIDO). Scale is 3 cm (1.2 in) with 1 cm (0.4 in) segments.

Class Amphibia

There is only one family of amphibian fossils reported from THRO, Scapherpetontidae of the order Urodela (salamanders), which is represented by one taxon, *Piceoerpeton* sp., from the Sentinel Butte Formation (Figure 21). (Hoganson and Campbell 1997). Specimens of *Piceoerpeton* sp. are catalogued in the NDGS paleontological collections.

Figure 21. A *Piceoerpeton* vertebral centrum, TRN21-006, Sentinel Butte Formation (NPS/CHARLES SALCIDO). Scale is 3 cm (1.2 in) with 1 cm (0.4 in) segments.

Class Reptilia

THRO has a diverse assemblage of reptile fossils. Orders reported from the park include Testudines (turtles), Choristodera (champsosaurs), and Crocodilia (alligators and crocodiles). There are two genera of turtles reported from the park: *Protochelydra* sp. (a snapping turtle; Family Chelydridae) and *Plastomenus* sp. (a softshell turtle; Family Trionychidae). *Protochelydra* sp. has been found in both the Bullion Creek Formation and Sentinel Butte Formation while *Plastomenus* sp. is only reported in the latter (Hoganson and Campbell 1997). Turtle shell fragments are common vertebrate fossils at THRO (Figure 22).

Figure 22. A typical isolated fragment of turtle shell (note the textured surface); TRS21-010, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

There are two genera of choristodere in the park (*Champsosaurus* sp. and "*Simoedosaurus*" sp.) and at least two crocodilian taxa (*Borealosuchus* sp. and a small alligatoroid; a museum specimen of a crocodilian identified as *Leidyosuchus gigas* is presumably *Borealosuchus* with "*gigas*" accidently applied from *Champsosaurus gigas*) (Hoganson and Campbell 1997; KellerLynn 2007). Choristoderes are extinct aquatic reptiles. In the Fort Union Group, there are two distinct forms. *Champsosaurus* with its long slender rostrum (snout or muzzle) resembled a gharial without osteoderms (bony armor). A form with a much shorter face has usually been assigned to the European genus *Simoedosaurus*, but recently the North American species has been assigned to a new genus, *Kosmodraco* (Brownstein 2022). Regardless of the name, the short-faced choristodere may have had a lifestyle similar to the modern alligator gar. The "*Leidyosuchus gigas*" specimen and two *Champsosaurus* sp. specimens are catalogued in THRO's on-site collections while other reptilian fauna are catalogued at the NDGS paleontological collections. However, a nearly complete *Champsosaurus* sp. skeleton and a *Protochelydra* sp. carapace cataloged in the NDGS paleontological collections are on display at the THRO interpretive center. Choristodere vertebrae (Figures 19 and 23) and crocodilian osteoderms and teeth (Figure 24) are encountered occasionally, and several choristodere skeletons have been found in THRO (Figure 25).

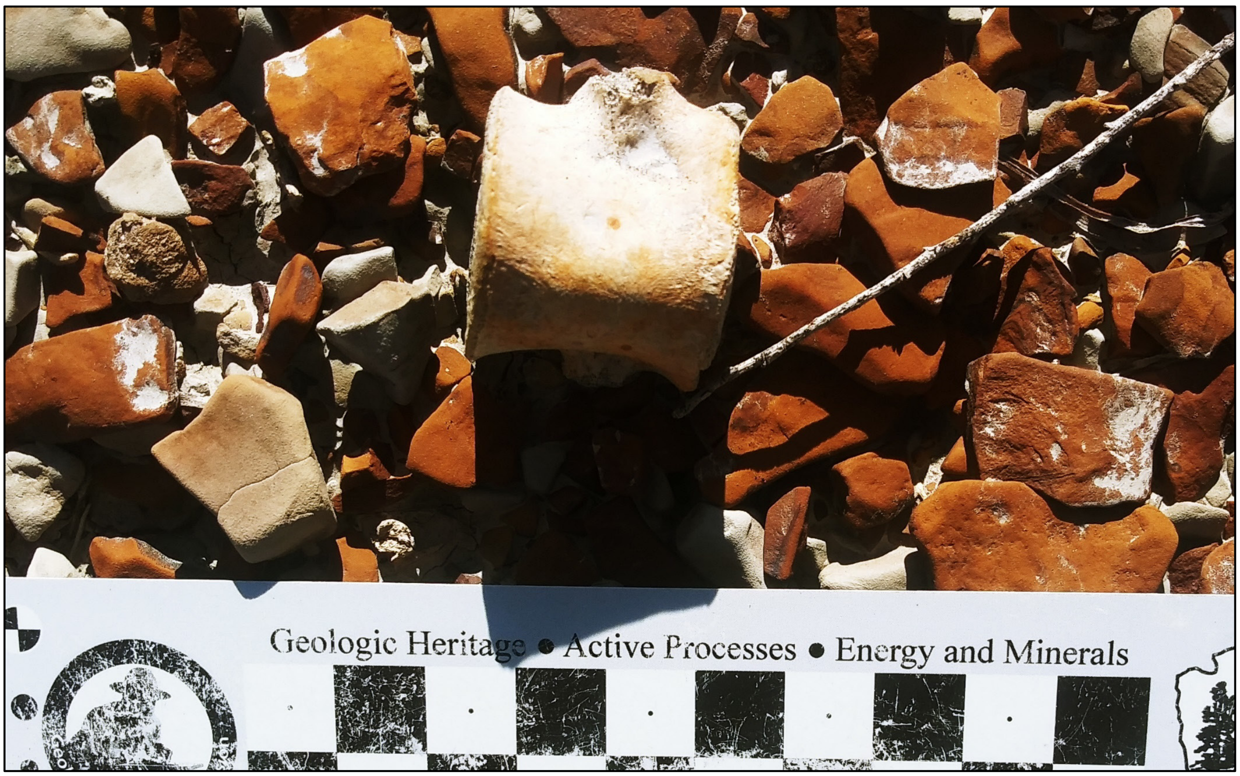


Figure 23. A choristodere vertebral centrum in the field; TRN21-015, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

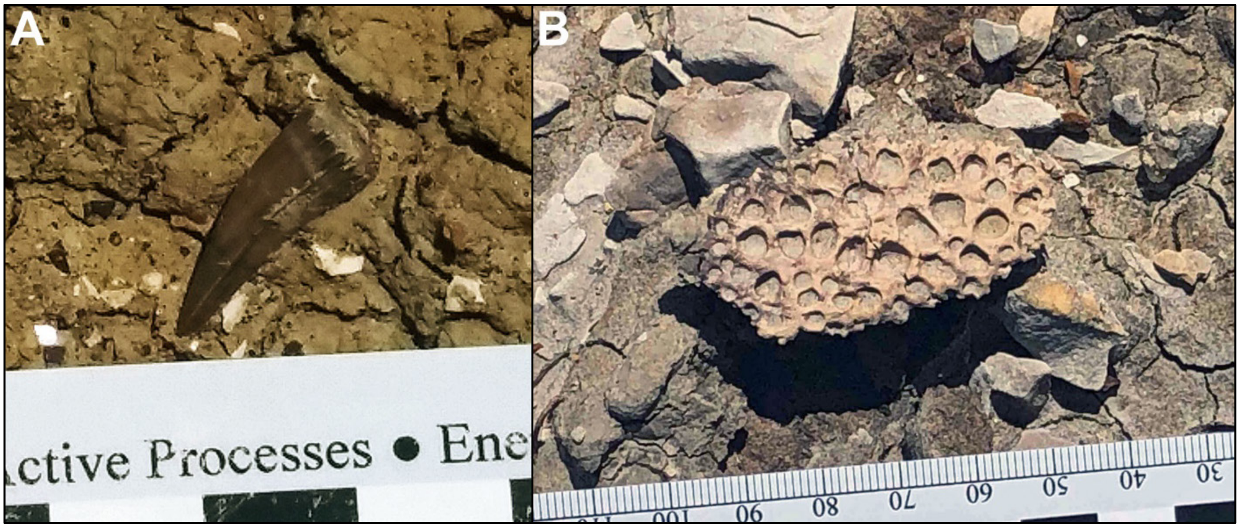


Figure 24. A. A crocodilian tooth; TRN21-019, Sentinel Butte Formation (NPS/CHARLES SALCIDO). **B.** A crocodilian osteoderm; TRS20-009, Sentinel Butte Formation (NPS/PATRICK WILSON).

Figure 25. A partial choristodere skeleton from TRN21-035 (Sentinel Butte Formation), predominantly vertebrae and limb fragments (NPS/CHARLES SALCIDO).

Class Aves

The survey of the South Unit Loop Road by Paleo Solutions in September 2021 recovered avian material from one site and the 2021 field inventory located a bird track specimen within the park (see below). Five bird taxa have been reported outside of THRO in rock units that are also found in the park. Four of the bird taxa have been found at the nearby Wannagan Creek Quarry (Erickson 1991).

Class Mammalia

Mammal fossils reported from THRO can be separated into those from Paleocene-aged rock units and those from Quaternary deposits. The Paleocene rocks of THRO have four fossil mammal taxa, as well as indeterminate mammal material: the pantodont *Titanoides* sp. (a bear-like herbivore), the primate-like *Plesiadapis* sp., and unidentified specimens that appear to represent an indeterminate cimolestan (diverse non-placental small- to medium-sized mammals) (Figure 26A) and the condylarth *Phenacodus* (an early ungulate, species possibly *P. grangeri* or *P. magnus*; C. Salcido, pers. obs.; Figure 26B), representatives of now-extinct lineages. All of these specimens are from the Sentinel Butte Formation. The Quaternary deposits of THRO have yielded fossils of *Bison*. *Bison* remains have been found in both the Coleharbor Group and the Oahe Formation. All of these mammal genera are catalogued in THRO's on-site collection, with the exception of *Plesiadapis*, which is catalogued at the NDGS paleontological collection. THRO's on-site collection also holds an indeterminate mammal fossil from the Sentinel Butte Formation. Most mammal specimens from the Paleocene rocks of THRO are represented by microfossils (i.e., bone fragments and teeth) with the exception of the *Titanoides* sp. which is represented by a partial skeleton.

Figure 26. A. A lingual (tongue side) view of a cimolestan jaw fragment with tooth; TRN21-005, Sentinel Butte Formation. **B.** A condylarth (*Phenacodus grangeri* or *P. magnus*?) molar and premolar observed in the field; TRN21-048, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

There is great potential for additional finds within THRO. Three dozen other fossil mammal taxa have been reported from the Bullion Creek and Sentinel Butte Formations from outcrops outside of THRO's boundaries. Among the mammal taxa are representatives of the groups Metatheria (marsupials and relatives), Multituberculata (extinct rodent-like forms), Cimolesta, Condylarthra, Leptictida (extinct early placental mammals or close relatives), Primates, Carnivoramorpha (dogs, cats, and their relatives), and Eulipotyphla (hedgehogs, moles, shrews, and relatives) (Holtzman 1978; Kihm et al. 1993; Kihm and Hartman 2004; Erickson 2012). It is possible that these fossil taxa could be found within the park's boundaries as well, particularly at microvertebrate sites. While there are mammal taxa reported from the Golden Valley Formation, these occurrences are from the Camel Butte Member of the formation, which is not present in the park.

Ichnofossils

Several types of trace fossils have been found in THRO. During the 1994–1996 survey, coprolites (fossil feces) were found in the Bullion Creek Formation, and a turtle with bite marks and features made on wood by insects or birds were found in the Sentinel Butte Formation (Hoganson and

Campbell 1997; Hoganson field notes). During the 2021 inventory, worm burrows were found in both formations and a bird footprint was recorded from the Sentinel Butte Formation (Figure 27). There have been four ichnotaxa reported in the rock units of THRO outside of the park's boundaries. Three of these ichnotaxa have been reported from the nearby Wannagan Creek Quarry (Erickson 1991).

Figure 27. A stone with a bird footprint, indicated by arrow; TRN21-033, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

Other Fossils

This category includes those groups that do not fall under the other categories, such as fungi and hard structures ("shells", cysts, etc.) of various microorganisms that are not plants or animals. There have been no fossil taxa in this category recorded at THRO. Overall, only two genera of fungal spores have been collected from the Bullion Creek Formation (Hickey 1977; Erickson 1991). Without intensive screen washing of various localities and sediments, it is unlikely that fungal spores will be located and documented from the park.

Fossil Localities

Paleontological Localities Within THRO

Several hundred paleontological localities have been documented in THRO, almost all identified during either the 1994–1996 NDGS–NPS survey or the 2020–2021 survey. The 1994–1996 survey documented 400 sites, 233 in the South Unit (77 in the Bullion Creek Formation, 155 in the Sentinel Butte Formation, and one in Quaternary deposits) and 167 in the North Unit (166 in the Sentinel Butte Formation and one with both Sentinel Butte Formation material and Quaternary material). The 2020–2021 survey documented 158 sites, 103 in the South Unit (33 in the Bullion Creek Formation and 70 in the Sentinel Butte Formation) and 55 in the North Unit (all in the Sentinel Butte Formation). Listed below are details about some of the significant localities documented during the two surveys. Additional details and maps can be found in the restricted-access sensitive version of this report. Specific locality information can be requested from THRO Resource Management Division.

Notable South Unit Localities

TRS40: This locality was recorded by John Hoganson and Johnathan Campbell on June 6, 1995. The fossils identified at this locality include unionid clams, possible pill clams, snails, and possible ostracods. Hoganson reported in his field notes that this locality was one of the best invertebrate sites they found in this area.

TRS67: This locality was recorded by Hoganson and Campbell on June 12, 1995. The fossils identified at this locality include unionid clams, freshwater snails, turtle fragments, and choristodere rib fragments. Hoganson reported in his field notes that this locality was one of the best in the area.

TRS101: This locality was recorded by Hoganson and Campbell on June 15, 1995. The fossils identified at this locality include unionid clams and freshwater *Campeloma* snails. Hoganson reported in his field notes that this is an important invertebrate site because of the excellent level of preservation.

TRS102: This locality was recorded by Hoganson and Campbell on June 15, 1995. The fossils identified at this locality include choristodere fragments. Hoganson reported in his field notes that this site had cranial elements and should be excavated. He and Campbell returned to excavate the site October 23–24, 1995. Collections documentation shows that the additional material is small fragments of cranial elements identified as *Champsosaurus* sp.

TRS127: This locality was recorded by Hoganson and Campbell on September 11, 1995. The fossils identified at this locality include *Metasequoia* leaves, other plant fragments, unionid clams, freshwater snails (*Campeloma* and *Lioplacodes*), and ostracodes. Hoganson reported in his field notes that this is an important site because of the level of preservation and lateral extent of the fossil bearing layer.

TRS146: This locality was recorded by Hoganson and Campbell on September 12, 1995. The fossils identified at this locality include unionid clams, freshwater snails, salamander vertebrae, and coprolites.

TRS155: This locality was recorded by Hoganson and Campbell on September 13, 1995. The fossils identified at this locality include leaves, unionid clams, and freshwater snails. Hoganson observed in his field notes that the leaves at this site were well preserved and the bed was laterally extensive.

TRS224: This locality was recorded by Hoganson and Campbell on September 22, 1995. The fossils identified at this locality include material belonging to unionid clams, freshwater snails, fish (*Amia* and *Lepisosteus*), possibly salamanders, turtles (trionychids and others), choristoderes, crocodiles, and alligators. Hoganson reported in his field notes that this site is extremely significant due to the diversity of vertebrate and invertebrate material. He also noted that some plant debris and coprolites were present as well. A bulk sample from this site was taken for screen washing by Hoganson and Campbell. The area of the site was revisited and redocumented in summer 2020 as TRS20-038 through -040 with additional float material collected (Figure 28). The area of the site is still productive and is significant.

TRS233: This locality was recorded by Hoganson and Campbell on October 3, 1995. They initially observed two partial champsosaur skeletons and made plans to excavate later. They revisited the site in October 1996, whereupon a third champsosaur was found, along with reed impressions, unionid clams, snails, fish bones and scales, and crocodilian remains. A *Champsosaurus* from the site was excavated and prepared and is now mounted in the visitor center (see cover).

Hoganson's field notes mentioned several other South Unit localities of potential significance. These include TRS90, TRS173, TRS175, and TRS201 in the Bullion Creek Formation and TRS13, TRS21, TRS22, TRS159, TRS222, and TRS225 in the Sentinel Butte Formation. TRS13, TRS90, and TRS225 include vertebrate fossils, while TRS21, TRS22, TRS173, and TRS201 are noted for their invertebrate fossils.

TRS20-011: This locality was recorded by Charles Salcido and Patrick Wilson on July 13, 2020. The fossils identified at this locality include fish and turtle specimens and a crocodilian osteoderm. There was still bone going into the rock and it is recommended to have another team excavate and screen wash the material. Clint Boyd identified that the crocodilian osteoderm recovered may be of alligatoroid affinity.

TRS20-017: This locality was recorded by Salcido and Wilson on July 16, 2020 (Figure 29). The fossils identified at this locality include many turtle specimens. The site is extensive, possibly continuing into TRS20-018 with numerous turtle specimens including shell fragments, partial limbs, and partial vertebrae of different sizes. It is recommended to pursue further excavation into this extensive turtle bed.

TRS20-019: This locality was recorded by Salcido and Wilson on July 16, 2020. The fossils identified include abundant bivalves and gastropods in an organic-rich layer (Figure 30). Due to fossil abundance, the assistants recommend that a sample of this locality be taken for screen washing and the site monitored due to frequent traffic from park visitors.

Figure 28. A teleost fish vertebra observed at TRS20-038/TRS224, Bullion Creek Formation (NPS/PATRICK WILSON).

Figure 29. A general view of TRS20-017; Sentinel Butte Formation (NPS/PATRICK WILSON).

Figure 30. Charles Salcido at TRS20-019; Bullion Creek Formation (NPS/PATRICK WILSON).

TRS20-025, TRS20-026, TRS20-027: The localities were recorded by Salcido and Wilson on July 21, 2020. Fossil material includes bivalves, fish teeth, and crocodilian teeth in a continuous carbonaceous shale layer across the localities (Figure 31). The paleontology assistants recommend that a sample be taken from this layer for screen washing.

TRS20-028: The locality was recorded by Salcido and Wilson on July 21, 2020 (Figure 32). The fossils include fish vertebrae (Figure 20) and bone fragments. The vertebrae included four elements that were in articulation. The paleontology assistants recommend this locality as high priority for excavation.

TRS21-005: This locality was recorded by Salcido on May 20, 2021 (Figure 33). Fossils identified include bivalve shell fragments, a possible vertebrate osteoderm, and a fish vertebra. The site has highly fragmented invertebrate material but also includes small vertebrate material and could be a viable microsite for screen washing.

Figure 31. TRS20-025, Sentinel Butte Formation (NPS/PATRICK WILSON).

Figure 32. TRS20-028, with Jenna Streffon (NPS); Sentinel Butte Formation (NPS/PATRICK WILSON).

Figure 33. A general view of TRS-005; Bullion Creek Formation (NPS/CHARLES SALCIDO).

TRS21-024: This locality was recorded by Salcido on June 8, 2021. Fossils identified include some gastropod fragments and choristodere remains that include vertebrae, limb fragments, and pelvic girdle fragments (Figure 34). Most of the collected material was found as float with more possible material in the organic layer. TRS21-024 may need to be revisited in the future to see if it is still productive.

Figure 34. Choristodere fossils at TRS21-024, Bullion Creek Formation (NPS/CHARLES SALCIDO).

TRS21-053: This locality was recorded by Salcido on July 19, 2021. Fossils identified include turtle shell fragments, a possible choristodere tooth, a crocodilian tooth, and limb elements. Some limb elements are still going into the rock. It is recommended that another team investigate and possibly do screen washing to get a better idea of the faunal assemblage.

TRS21-055: This locality was recorded by Salcido on July 20, 2021. Fossils identified include *Amia* (including operculum [gill covering] and jaw fragments) in an organic layer (Figure 35) and bivalves below it. This organic layer may be continuous and could contain more fish fossils.

Figure 35. An organic layer at TRS21-055, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

Notable North Unit Localities

TRN62: This locality was recorded by Hoganson and Campbell on June 14, 1996. The fossils identified at this locality include unionid clams, freshwater snails, turtle shell, and crocodile bones. Hoganson reported in his field notes that this would be an excellent field exhibit area. Additionally, Hoganson and Campbell collected a bulk sample for screen washing. Additional float material was collected in the summer of 2021 when the site was redocumented (Figure 36; TRN21-019). This prepared it for an assessment of significance, amount of ground disturbance needed, and amount of material that could be collected for further screen washing.

Figure 36. Float bone fragments and gastropods at TRN61/TRN-019; Sentinel Butte Formation (NPS/CHARLES SALCIDO).

TRN144: This locality was recorded by Hoganson and Campbell on September 4, 1996. The fossils identified at this locality include gar scales, fish vertebrae, turtle shells, choristodere ribs and gastralia, crocodilian teeth and osteoderms, and mammal teeth and jaws. The variety of material from this site elevates its significance. Hoganson reported in his field notes that this site would be an excellent candidate for bulk sampling and screen washing for microfossil specimens. Additional float material was collected in the summer of 2020 when the paleontology assistants redocumented the site (Figure 37; TRN20-002) to prepare it for an assessment of significance, amount of ground disturbance needed, and amount of material that could and should be collected for further screen washing. The summer of 2021 involved a return for microsite excavation (Figure 38; TRN21-053) in association with the NDGS which obtained three 1-gallon bag samples for screen washing and float material which included turtle shell fragments, crocodilian osteoderms and bone fragments, and a partial toothless mammal dentary.

Hoganson's field notes mentioned several other North Unit localities of potential significance. These include TRN6, TRN16, TRN54, TRN57, TRN99, TRS111, and TRN119, all in the Sentinel Butte Formation.

Figure 37. Jenna Streffon (NPS) at TRN144/TRN20-002/TRN21-053; Sentinel Butte Formation (NPS/PATRICK WILSON).

Figure 38. Becky Barnes (North Dakota Geological Survey) and Katy Brooke (Friends of NDGS Paleo) at TRN21-053 before microsampling (NPS/CHARLES SALCIDO).

TRN21-006: This locality was recorded by Salcido on June 3, 2021. Fossil material identified include bivalve, salamander, turtle, choristodere, and crocodilian fossils. Most of the material is crocodilian including teeth, limb elements, rib elements, vertebral elements, osteoderms, and skull bones. There appears to be three sizes of crocodilian material in this assemblage (C. Boyd, pers. obs.). Salamanders are represented by one centrum (the cylindrical body of a vertebra) affiliated with *Piceoerpeton* (Figure 21). Turtle material is represented by shell fragments. Choristoderes are represented by an isolated centrum. Material is spread over a large area with one notable float field. Salcido recommends that the float field is further investigated along with the area near the sandstone outcrop.

TRN21-012: This locality was recorded by Salcido on June 10, 2021. Fossil material identified include turtle and choristodere. Turtle material includes carapace material, shell fragments, an ungual, and a vertebra. Further turtle carapace material is still within the vertical wall of the locality (Figures 39 and 40). Choristodere material is represented by vertebrae from a layer approximately 0.5 m (~1.5 ft) above it. TRN21-013 likely contains the same layer and it contains crocodilian material. Salcido recommends that another team return to excavate the remaining turtle material and investigate the layer further (to the TRN21-013 area) to get more insight into the faunal assemblage of the area.

Figure 39. The turtle layer at TRN21-012; Sentinel Butte Formation (NPS/CHARLES SALCIDO).

Figure 40. TRN21-012, Sentinel Butte Formation (NPS/CHARLES SALCIDO).

TRN21-032: This locality was recorded by Salcido on June 29, 2021. Fossil material includes mollusk fragments, fish scales, vertebrate limb fragments, turtle shell fragments, and a crocodilian osteoderm. All collected material was surface float except for one larger limb fragment that was in situ. Salcido recommends some monitoring of the area of the vertebrate limb fragment and a possible screen wash of sediment from the area with fish scales. The layer may continue to be productive further eastward.

TRN21-033: This locality was recorded by Salcido on June 29, 2021. Fossil material includes petrified wood, a turtle shell fragment float, and trace fossils such as a fossil bird footprint (Figure 27). The trace fossil origination site should be monitored at times to find any other unique trace fossils such as the footprint.

TRN21-035: This locality was recorded by Salcido on June 30, 2021. Fossil material includes various parts of a choristodere skeleton including tail, limbs, ribs, sacrum (fused hip vertebrae), and skull (Figure 25). All the float material was collected but more material was still present in situ and goes into the rock (Figure 41). The remaining in situ material was covered with a protective plaster jacket and then covered with large rocks to avoid detection. Salcido strongly recommends that this specimen is revisited for complete excavation. Point of note: it is stratigraphically high, just above the Sentinel Butte Ash layer.

Figure 41. A general view of TRN21-035; Sentinel Butte Formation (NPS/CHARLES SALCIDO).

TRN21-048: This locality was recorded by Salcido on July 12, 2021. Fossil material includes bivalve fragments and mammal teeth. Two condylarth mammal teeth were collected as float from this site (Figure 26B). Due to frequent use of the trail by park visitors, it is recommended by Salcido that hiking interpreters and trail managers keep watch of this site for any other mammal material that may appear.

Elkhorn Ranch Unit Localities

Although the Elkhorn Ranch Unit is much smaller than the other two units of THRO, it too has fossiliferous rocks. Blake McCann conducted a survey of these areas on October 6, 2021 and found bivalve and gastropod shells (Figure 42). He suspects that other types of fossils are likely there as well.

Figure 42. Bivalve shell fragments from the Bullion Creek Formation of the Elkhorn Ranch Unit; note the pearlescent appearance, indicating preserved shell material (NPS/AMY MCCANN).

Paleontological Localities Near THRO

Wannagan Creek (Bullion Creek Formation): Work at the Wannagan Creek Quarry began in 1970 by Bruce Erickson for the Science Museum of Minnesota. Crews from the museum excavated and collected at the site on an annual basis until 1996, followed by another six years of post-quarry work (Erickson 2012). The overall thickness of the fossil-bearing layer was only 60 cm (24 in) thick (Erickson 1982) and has produced fossils of at least 115 taxa including numerous plants, invertebrates, and vertebrates, notably more than 100 individuals of the crocodilian *Borealosuchus* *formidabilis* (Erickson 2012). The main sediment type of this locality is a lignitic, silty clay. The site is located in the Bullion Creek Formation and lies approximately 5.7 km (3.5 mi) northwest of the South Unit of THRO. This is by far the most notable site located near THRO.

<u>NDGS Medora Dig Site (Sentinel Butte Formation)</u>: The NDGS's public dig site near Medora is located just outside of the South Unit on Theodore Roosevelt Medora Foundation property. Fossils were first found here in 2004 during an inspection of an abandoned oil well site by Darrell Nodland, an inspector for the Oil and Gas Division of the North Dakota Industrial Commission. John Hoganson of the NDGS took interest in the site for the survey's nascent public fossil dig program, and with the cooperation of the Foundation the NDGS began annual public digs at the site in 2005. Fossils are found in a layer of dark lignite-rich mudstone less than 5 cm (2 in) thick in the Sentinel Butte Formation, about 6.5 m (20 ft) above the base of the formation, representing deposition shifting from a swampy setting to a pond setting over time. Numerous plant, invertebrate, and vertebrate taxa have been found here, as well as trace fossils (Hoganson et al. 2011). Digs have taken place every year except for 2013. Similar sediment sequences have been found within the South Unit of THRO which have also been productive.

Cultural Resource Connections

There are many ways for paleontological resources to have connections to cultural resources. Examples of paleontological resources in cultural contexts include, but are not limited to: fossils used by people for various purposes, such as petrified wood used for tools, spear points, and other artifacts, or fossil shells picked up as charms or simply because they looked interesting; associations of prehistoric humans with paleontological resources, such as kill sites of mammoths, prehistoric bison, and other extinct animals; incorporation of fossils into cultural records, such as fossils in American Indian lore, "tall tales" of mountain men, and emigrant journals; and fossils in building stone. Kenworthy and Santucci (2006) presented an overview and cited selected examples of National Park Service fossils found in cultural resource contexts.

The Midwestern Archaeology Center (MWAC) holds two THRO fossil specimens in their collections. These are the only two fossils to be reported with a cultural context: THRO 2428 and THRO 2435. Both specimens were collected from Elkhorn Ranch by D. Taylor in 1959. THRO 2428 is listed as a "fossil/concretion resembling a tobacco pipe bowl" (Figure 43). It is likely this specimen is an altered *Equisetum* stem but further identification is needed. THRO 2435 is listed as a "piece of sandstone bearing fossil leaf impression" (Figure 44). This specimen does not have enough detail preserved to assess taxonomy at this time, beyond establishing it as a partial angiosperm leaf.

The Fish and Wildlife Service used petrified wood to bolster the foundation of the Peaceful Valley Ranch bunkhouse during the 1940s (Public Lands History Center 2017).

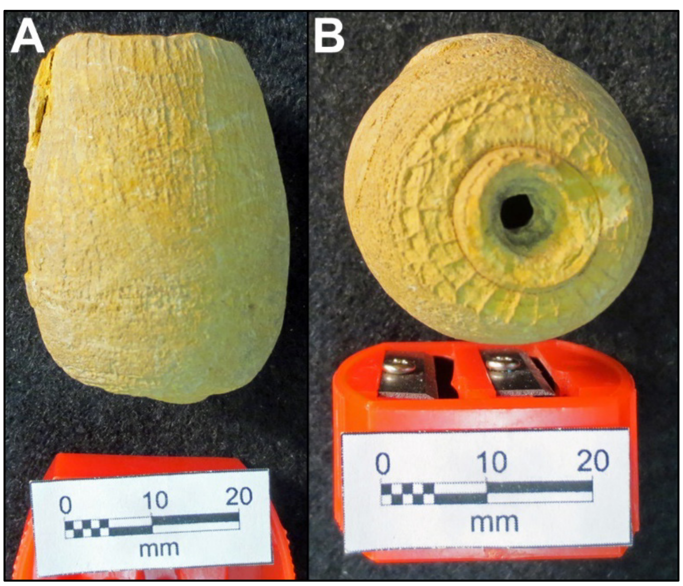


Figure 43. Two views of THRO 2428 (**A, B**) found in 1959 by D. Taylor at Elkhorn Ranch (NPS/JUSTIN TWEET).

Figure 44. THRO 2435 found in 1959 by D. Taylor at Elkhorn Ranch (NPS/JUSTIN TWEET).

Museum Collections and Paleontological Archives

Museum Collections and Curation

THRO's park collection is located at the Medora Visitor Center in Medora, North Dakota. This collection is curated and maintained by park staff. While collection of paleontological resources has not been a priority for the park, there are significant paleontological collections at the park and at the North Dakota Heritage Center (North Dakota Geological Survey collections) in Bismarck, North Dakota. This section will describe these collections as well as other material housed in outside collections across the United States.

Park Collections

Following the resource summary by Tweet et al. (2011) and before the 2020–2021 inventory, three new specimens were catalogued into THRO collections, bringing the collection to 58 catalog numbers collections representing 1,199 elements (see Appendix Table B-1). There are two catalog numbers from Quaternary deposits (probably from the Oahe Formation), three from the White River Formation, 41 from the Sentinel Butte Formation, and three from the Bullion Creek Formation. The geologic units represented are all found within THRO except for the White River Formation, which is exposed in the region.

Among the fossil taxa in the THRO catalog, plant fossils make up most of the collection with 26 catalog numbers and most are unidentified with little information on their collection (including locality data, collection data, and taxonomic data). Other catalogued taxa include bivalves (9, including one catalog number for specimens misidentified as brachiopods), gastropods (1), reptiles (5), fish (3), mammals (6), unidentified vertebrates (5), unidentified animals (1), and unknown organisms (2). The three new catalog numbers of fossil taxa previously mentioned include two partial *Champsosaurus* skeletons (THRO 7829 with 856 elements and THRO 7831 with 26 elements) and a partial skeleton of *Titanoides* (THRO 7830 with 90 elements) in 2018 and 2019.

Nineteen catalog numbers were reported as coming from the South Unit, three from the North Unit, and two from the Elkhorn Ranch Unit. Eight of the catalog numbers include specimens that came from outside of THRO or are lacking detailed geographic and stratigraphic data: THRO 1185 is from the Wannagan Creek Quarry just outside of the park; THRO 7422 was collected within the park by a visitor without proper permitting; and THRO 1670, THRO 2145, THRO 2190, THRO 3078, THRO 3195, and THRO 3196 are donations from outside of the park. Of the donations to the park collection, THRO 1670, THRO 3195, and THRO 3196 are from White River Group sediments. THRO 1670 is identified as an emydid turtle and was donated by Hank Brown from Dickinson. This specimen was collected from the Little Badlands near Heart, North Dakota. THRO 3195 and THRO 3196 are identified to the family Merycoidodontidae (also known as oreodonts, somewhat pig-like herbivores that flourished in the middle Cenozoic). Further examination of these specimens may refine this classification down to a genus. THRO 2145, THRO 2190, and THRO 3078 were gifts to the park by individuals who found the specimens nearby but outside park boundaries. THRO 2145 and THRO 3078 come from the Sentinel Butte Formation. THRO 2190, an elk specimen, is from Quaternary deposits but has been deaccessioned and given to the Rocky Mountain Elk Foundation.

For reasons that are unclear, a number of plant fossils (THRO 1061, THRO 1064, THRO 3059–3066, 3071, and 3192) and vertebrate fossils (THRO 3076–3078) are also described in the THRO catalog as cubichnia, which are traces left by organisms resting or otherwise pausing on a soft sediment surface. This identification seems to be a mistake, perhaps a misunderstanding of what "cubichnia" means (misapplying it to fossil impressions?) that propagated.

The THRO interpretive center displays some of the specimens from the THRO collection on display, as well as several specimens from the NDGS–NPS survey that are catalogued with the North Dakota Geological Survey collection and which were recovered within park boundaries. Displays include a turtle (NDGS 856), a block with snails (NDGS 961) and unionacean bivalves (NDGS 961), a bivalve (NDGS 962), and a partial skeleton of *Champsosaurus gigas* (NDGS 963) (Figure 45) (Tweet et al. 2011). There is currently a general repository agreement between THRO and NDGS with a long-term plan to use NDGS as a repository for new specimens from the park.

Figure 45. Display in the Medora Visitor Center including a *Champsosaurus*, clam, turtle, and piece of petrified wood, photographed June 2019 (NPS/JUSTIN TWEET).

North Dakota Geological Survey Collections

In 1994, Roger Andrascik, then the Resource Management Specialist at THRO, contacted NDGS to see if they would be interested in conducting a study of the paleontological resources in the North and South Units of the park (Hoganson and Campbell 1997). NDGS paleontologists John W. Hoganson and Johnathan Campbell conducted the field survey of 26 km^2 (10 mi^2) and all material recovered during the field seasons was cataloged into the NDGS's North Dakota State Fossil Collection (e.g., NDGS 856, a turtle, *Protochelydra* cf. *zangerli*) in the North Dakota Heritage Center, Bismarck, North Dakota (Tweet et al. 2011). Fossils recovered from THRO during this survey are represented by more than 150 accession numbers and include plants (including silicified peat, leaves, amber, and other plant fossils), bivalves, gastropods, ostracods, fish, amphibians, turtles, crocodilians (alligators and crocodiles), choristoderes, and trace fossils (coprolites). The accession numbers include all specimens collected from a given locality. Most of these specimens were collected from the Sentinel Butte Formation in the South Unit. Some of these specimens are on display in the Medora Visitor Center as previously mentioned, while the rest are housed at the North Dakota Fossil Collection in Bismarck, North Dakota (Tweet et al. 2011).

The NDGS has done field work in the park more recently as well (i.e., the three new catalog numbers in THRO collections). Some of the material that NDGS has from the park is still uncatalogued and in preparation (C. Boyd and B. McCann, pers. obs.). There is a long-term agreement between the two parties in the works to use the North Dakota State Fossil Collection as a repository for future THRO material. The specimens collected during this inventory will be reposited in this collection.

Collections in Other Repositories

Most of the specimens housed in outside repositories were collected from THRO with permission but prior to rigorous permitting. In some instances, the institution that collected the specimens may have transferred them to another institution to better fit the collections needs. Due to the age of most of the collections, this list is as comprehensive as the authors can effectively establish but is not necessarily exhaustive. In addition, due to the portability of petrified wood, it is likely that many private individuals have wood from the park, collected illegally.

The Smithsonian Institution's United States National Museum of Natural History (USNM) is a repository for many fossil specimens found in national parks and on public land (Santucci et al. 2018). For THRO, the Smithsonian holds both the holotype and paratype of the freshwater clam *Eupera missouriensis* (USNM PAL 220078 and USNM PAL 220079), which were found in the Sentinel Butte Formation of the North Unit (Bickel 1976). USNM PAL 220078 and USNM PAL 220079 are the only specimens known to be housed at USNM.

The Florida Museum of Natural History (FLMNH) is supposed to be the repository for the holotype slide for megaspore *Azolla stanleyi* (FLMNH slide 242-3), which was found in the Sentinel Butte Formation of the South Unit of THRO (Jain and Hall 1969; Hoffman and Stockey 1994). Initially the paleobotanical collections from THRO held at FLMNH were reposited in the University of Minnesota Paleobotanical Collections, but were loaned to the FLMNH in 1990 and formally transferred in 2000 (H. Wang, Florida Museum of Natural History paleobotany collections manager, pers. comm., May 2021). Slide 242-3 was loaned to Hoffman and Stockey in 1994 for their research, but there is no documentation about the return of the slide, and it has not been located in FLMNH collections. There are no other specimens in FLMNH collections known to have derived from the same locality (H. Wang, pers. comm., May 2021).

The University of Kansas (KU; Lawrence, Kansas) has three palynomorph slides collected from THRO by R. Jain. These specimens are 027448, 027449, and 027450. Currently, KU has these slides catalogued as unidentified from the Miocene. Per Rudolph Serbet (KU Biodiversity Institute, Division of Paleobotany collections manager, pers. comm., May 2021), the slides were probably donated to paleobotanist Thomas Taylor in the 1970s and now are part of the teaching collection. They contain various pollen and spores. No other information appears to exist.

Harr and Ting (1977) reported on plant fossils found in silicified peat in North Dakota. Although they focused on localities outside of THRO, several of the other localities appear to have been in or near THRO based on their map. The repository for their material is Bays Mountain Park in Kingsport, Tennessee (Harr and Ting 1977).

Yale University has conducted two field seasons for two different projects, one for the years 2007 and one for 2008. The 2007 project noted no recovered fossil samples, and its focus was collecting rock samples from the bentonite layer in the North Unit. However, the 2008 project was intended to collect vertebrate fossils from the North Unit and South Unit of the park with emphasis on the South Unit area near the Wannagan Creek area. The project was intended to run from 2008 to 2010, but it was cancelled after the first year due to unfavorable results from the initial reconnaissance. The Investigator's Annual Report for 2008 reported finding no vertebrate fossils and collecting no invertebrate or plant fossils, corroborated by the electronic database at the Yale Peabody Museum, which does not list fossils from this field season. The permit stated that specimens would remain the property of the National Park Service and would be cared for by the Yale Peabody Museum under a long-term loan agreement. It was not stated if this loan agreement is still ongoing.

In the 2003 field season, University of Wisconsin–Madison was given a scientific research and collecting permit. This purpose was to collect ash and bentonite samples for geologic age dating and chemical fingerprinting. The investigators on the permit were not specifically looking for paleontological resources, and the Investigator Annual Report for the permit reported collecting no fossils.

Several reports, published and unpublished, have been made on petrified wood from the park (Berg and Brophy 1963; Coffin 1984; Fastovsky and McSweeney 1991). The disposition of samples of petrified wood (especially thin sections) from these studies is not stated. For reference, the institutions of the lead authors at the time of their reports were: North Dakota State University, Fargo, North Dakota (Berg and Brophy 1963); Loma Linda University, Loma Linda, California (Coffin 1984); and the University of Rhode Island, Kingston, Rhode Island (Fastovsky and McSweeney 1991).

Type Specimens

There are currently three known type specimens from THRO. Two of these are holotypes and one is a paratype. The holotype and paratype of the freshwater bivalve *Eupera missouriensis* were found in the Sentinel Butte Formation of the North Unit of THRO (Bickel 1976). These specimens are catalogued with the USNM as USNM PAL 220078 and USNM PAL 220079. The *E. missouriensis* type specimens were collected in the early–mid 1970s.

The other known holotype specimen is the holotype megaspore of *Azolla stanleyi* from the Sentinel Butte Formation of the South Unit (Jain and Hall 1969). As discussed in the previous section, the type specimen, on a slide originally held at the University of Minnesota as slide 242-3, was part of a collection that was loaned to the Florida Museum of Natural History in 1990 and formally transferred in 2000, but the slide itself was loaned to researchers in 1994 and apparently has not been returned.

Archives

NPS Paleontology Archives

All data, references, images, maps and other information used in the development of this report are maintained in the NPS Paleontology Archives and Library. These records consist of both park-specific and service-wide information pertaining to paleontological resources documented throughout the NPS. If any resources are needed by THRO staff, or additional questions arise regarding paleontological resources, contact the NPS Senior Paleontologist and Paleontology Program Coordinator Vincent Santucci, vincent_santucci@nps.gov. Park staff are also encouraged to communicate new discoveries to the NPS Paleontology Program, not only when support is desired, but in general, so that this information can be incorporated into the archives. A description of the Archives and Library can be found in Santucci et al. (2018).

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 current NPS areas, usually predating the establishment of the NPS unit in question and frequently unpublished or previously unrecognized. Extensive access to the original files was granted to the NPS by the USGS beginning in 2014 (Santucci et al. 2014). No E&R files have been found for THRO to date.

Photographic Archives

Photographic archives are managed by the THRO Collections at the Medora Visitor Center in Medora, North Dakota.

Park Paleontological Research

Current and Recent Research

Since the 1990s, 14 permits have been issued for projects at THRO that were either paleontological in focus, or a geological project with paleontological significance. They are listed below in chronological order by project (note that some projects that spanned multiple years were issued multiple permits).

- THRO1993AIUW, principal investigator David Kuehn of Texas A&M University, project "*Stratigraphic Investigations in the South Unit of Theodore Roosevelt National Park - Phase II (Final)*", issued for 1993.
- THRO1994AKGB, principal investigator John Hoganson of the North Dakota Geological Survey, project "*Theodore Roosevelt National Park Paleontological Inventory*", issued for 1994; this project was continued in 1995 under THRO1995AMSM and in 1996 under THRO1996ARQG.
- THRO1995AMSH, principal investigator Robert Biek of the North Dakota Geological Survey, project "*Geologic Maps of Theodore Roosevelt National Park*", issued for 1995; this project was continued in 1996 under THRO1996ARQA.
- THRO-2000-009, principal investigator David Kuehn, project "*Research into the Age and Morphology of Selected Late Quaternary Soils in Theodore Roosevelt National Park, North Dakota*", issued for 2000.
- THRO-2003-SCI-0001, principal investigator Elizabeth Leslie of the University of Wisconsin–Madison, project "*Development of a temporally constrained stratigraphic framework for the Late Paleocene in Western North Dakota*", issued for 2003–2004.
- THRO-2007-SCI-0003, principal investigator Daniel Peppe of Yale University, project "*Collaborative Research: High-resolution calibration of the Maastrichtian to Paleocene of the western U.S.: Integration of geochronology, magnetostratigraphy, and paleontology*", issued for 2007.
- THRO-2008-SCI-0001, principal investigator Walter Joyce of Yale Peabody Museum of Natural History, project "*Fossil Vertebrates of the Williston Basin: Diversity, Phylogeny, and Responses to Environmental Change*", issued for 2008–2010; activity only occurred in 2008, due to unfavorable results from initial reconnaissance.
- THRO-2018-SCI-0014, principal investigator Clint Boyd of the North Dakota Geological Survey, project "*Collection of a champsosaurid (Sauropsida: Choristodera) specimen at risk of loss to erosion*", issued for 2018.
- THRO-2020-SCI-0012, principal investigator Clint Boyd of the North Dakota Geological Survey, project "*Paleontological inventory of Theodore Roosevelt National Park*", issued for 2020; this project was continued in 2021 under THRO-2021-SCI-0015. This inventory report was supported by these permits.

- THRO-2021-SCI-0019, principal investigator Clint Boyd of the North Dakota Geological Survey, project "*Microvertebrate Sampling and Collection of Specimens from Significant Paleontological Sites Identified by 2020 Paleontological Survey of Theodore Roosevelt National Park*", issued for 2021.

In addition, there was a cancelled project of relevance:

- THRO-2010-SCI-0005, principal investigator John D. W. Fielding of North Dakota State University, project "*Packrat Middens as Paleoclimate Indicators of Western North Dakota*", issued for 2000.

Paleontological Research Permits

See the National Park Service Natural Resource Management Reference Manual DO-77 section on Paleontological Resource Management, subsection on Scientific Research and Collection (https://irma.nps.gov/DataStore/Reference/Profile/572379). NPS Management Policies 2006, section 4.8.2.1 on Paleontological Resources, states that

> *The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit.*

Any collection of paleontological resources from an NPS area must be made under an approved research and collecting permit. The NPS maintains an online Research Permit and Reporting System (RPRS) database for researchers to submit applications for research in NPS areas. Applications are reviewed at the park level and either approved or rejected. Current and past paleontological research and collecting permits and the associated Investigator's Annual Reports (IARs) are available on the RPRS website (https://irma.nps.gov/RPRS/). Additional information on NPS law and policy can be found in Appendix D.

Interpretation

Current Long Range Interpretive Plan

THRO does not include paleontological resources in its current long-range interpretive plan. However, there are plans to include paleontological resources into the next update of the plan. At the time this report was drafted, THRO holds a collection of fossils found in the park as described above, and some part may be suitable for an interpretive collection. The collection is predominantly plants and mollusk shells from the Paleocene rocks and is primarily used for school groups. A more detailed identification of the plant and vertebrate specimens in the collection and a description of their significance would make this collection more useful for staff. Training of interns and park staff includes some information on paleontology from a presentation given by a professor from Dickinson State University (this professor is no longer with the university).

Recommended Interpretive Themes

I. General Paleontological Information

The following interpretation topics include a section instructing visitors how to be paleontologically aware while in the park. The ranger will provide the visitor with information on why fossils are important, how paleontologists look for fossils, what to do if fossils are found, and reminders to be aware that fossils exist and should be respected within park boundaries.

- Fossils are non-renewable resources that possess scientific and educational information and provide insight into what Earth was like thousands and even hundreds of millions of years ago.
- When paleontologists survey for paleontological resources, the most important tool for planning 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 search. Other tools that a paleontologist takes into the field include a field notebook for recording data and observations, small picks and brushes, consolidants to stabilize fossils, GPS, camera, topographic maps, and appropriate First Aid and safety equipment. These tools insure not only that fossils are collected safely, but also that associated information about the surrounding rocks is recorded. While a fossil itself is important, the information associated with it is at least as important and is easily lost during collection. It might be helpful to provide examples of these items for visitors when giving an interpretive talk.
- If fossils are found in the park by a visitor, the visitor should photograph it 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 locational information to be preserved. Visitors should be informed that park fossils are protected by law.

II. Fossils of THRO

- A program could be developed to educate the public on what types of fossils are present in THRO and what they tell scientists about Earth’s dynamic history. The goal of this program is to increase visitors’ understanding of local geology and paleontology. Therefore, information regarding fossils from the vicinity of THRO can be included.

III. Further Interpretation Themes

THRO should be sure to promote their paleontological resources and provide additional opportunities or programs for visitors to learn about fossils on National Fossil Day, celebrated annually on Wednesday of the second full week in October (National Earth Science Week). For more information on this event visit: https://www.nps.gov/subjects/fossilday/index.htm. The NPS coordinates the National Fossil Day partnership and hosts fossil-focused events across the country. Conducting one or more paleontology-focused activities on this day would be a perfect opportunity to not only increase public awareness about paleontological resources in THRO, but also connect with other parks and museums who are also participating in this national event. The NPS Geologic Resources Division can assist with planning for National Fossil Day activities and provide Junior Paleontologist Program supplies including activity booklets, badges, posters and other fossil-related educational resources (https://www.nps.gov/subjects/fossils/junior-paleontologist.htm).

Resources for Interpreting Geology and Paleontology

THRO's interpretive center has an exhibit showcasing some of the fossils found in the park including a *Champsosaurus*, a turtle, petrified wood, and some mollusks. These specimens were found during the 1994–1996 paleontological resources survey by John Hoganson and Johnathan Campbell, and an exhibit was made not long after (Hoganson and Campbell 1997). There are plans to update this exhibit.

Two opportunities for interpreting geology and paleontology are available to visitors exploring the park, a relatively new wayside in the North Unit and a trailhead sign in the South Unit at Buck Hill. The North Unit site reviews the geology of the area visible from the wayside. Paleontology is included by detailing what fossils can be found in the rock units discussed in the wayside, but it is a minor component. The sign at Buck Hill explains similar concepts in that area.

At the time of this report, there is one permanent interpreter at THRO and one education technician seasonal intern. Hiring a permanent interpreter who has a background related to geology or paleontology is recommended to help expand the interpretation and presentation of the geological and paleontological resources of the park.

Paleontological Resource Management and Protection

National Park Service Policy

Paleontological resources are non-renewable remains of past life preserved in a geologic context. At present, there are 423 official units of the National Park System, plus national rivers, national trails, and affiliated units that are not included in the official number. Of these units, 283 are known to have some form of paleontological resources. Paleontological resources are mentioned in the enabling legislation of 18 units. Fossils possess scientific and educational values and are of great interest to the public; therefore, it is exceedingly important that appropriate management attention be placed on protecting, monitoring, collecting, and curating these paleontological specimens from federal lands. In 2009, the Paleontological Resources Preservation Act (PRPA) was signed into law as part of the Omnibus Public Land Management Act of 2009. The new paleontology-focused legislation includes provisions related to inventory, monitoring, public education, research and collecting permits, curation, and criminal/civil prosecution associated with fossils from designated DOI lands. More information on laws, policies, and authorities governing NPS management of paleontological resources is detailed in Appendix D. Paleontological resource protection training is available for NPS staff through the NPS Geologic Resources Division (GRD). GRD is also available to provide support in investigations of paleontological resource theft or vandalism.

As of the date of this publication, 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) is in the processes of developing Department of Interior (DOI) final regulations for PRPA. Draft DOI regulations were published in the Federal Register in December 2016 and were available for 60 days to allow for public comment. The interagency team has reviewed public comments provided for the draft regulation and have drafted the final regulation. The final regulation has completed surnaming by the DOI Solicitor's Office and each of the four bureau directors. The final regulation has been forwarded for final review by DOI Assistant Secretaries. For more information regarding this act, visit https://www.nps.gov/subjects/fossils/fossil-protection.htm.

2006 National Park Service Management Policies (section 4.8.2.1) state

> *… Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of*

a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.

The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.

All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

Fossils have scientific, aesthetic, cultural, educational, and tourism value, and impacts to any of these values impairs their usefulness. Effective paleontological resource management protects fossil resources by implementing strategies that mitigate, reduce, or eliminate loss of fossilized materials and their relevant data. Because fossils are representatives of adaptation, evolution, and diversity of life through deep time, they have intrinsic scientific values beyond just the physical objects themselves. Their geological and geospatial contexts provide additional critical data concerning paleoenvironmental, paleogeographic, paleoecologic, and other conditions that together allow for a more complete interpretation of the physical and biological history of the earth. Therefore, paleontological resource management must act to protect not only the fossils themselves, but to collect and maintain other contextual data as well.

In general, losses of paleontological resources result from naturally occurring physical processes, by direct or indirect human activities, or by a combination of both. These processes or activities influence the stability and condition of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). The greatest loss of associated contextual data occurs when fossils are removed from their original geological context without appropriate documentation. Thus, when a fossil weathers and erodes from its surrounding sediments and geologic context, it begins to lose significant ancillary data until, at some point, it becomes more a scientific curiosity than a useful piece of scientific data. A piece of loose fossil "float" can still be of scientific value. However, when a fossil has been completely removed from its original context, such as an unlabeled personal souvenir or a specimen with no provenance information in a collection, it is of very limited scientific utility. Similarly, fossils inadvertently exhumed during roadway construction or a building excavation may result in the loss or impairment of the scientific and educational values associated with those fossils. It is not necessary to list here the natural and anthropogenic factors that can lead to the loss of paleontological resources; rather it is sufficient to acknowledge that anything which disturbs native sediment or original bedrock has potential to result in the loss of the paleontological resources that occur there, or the loss of the associated paleontological resource data.

Cave localities are in a distinct class for management due to the close connection with archeological resources and unique issues affecting cave resources. See Santucci et al. (2001) for additional discussion of paleontological resources in cave settings.

Management strategies to address any of these conditions and factors could also incorporate the assistance of qualified specialists to collect and document resources rather than relying solely on staff to accomplish such a large task at THRO. Active recruitment of paleontological research scientists should also be used as a management strategy.

Baseline Paleontology Resource Data Inventories

A baseline inventory of paleontological resources is critical for implementing effective management strategies, as it provides information for decision-making. This inventory report has compiled information on previous paleontological research done in and near THRO, taxonomic groups that have been reported within THRO boundaries, and localities that were previously reported. This report can serve as a baseline source of information for future research, inventory reports, monitoring, and paleontological decisions. The Paleontological Resource Inventory and Monitoring report for the Northern Great Plains Network completed by Tweet et al. (2011) and the references cited within were important baseline paleontological resource data sources for this THRO-specific report.

Paleontological Resource Monitoring

Paleontological resource monitoring is a significant part of paleontological resource management, and one which usually requires little to implement beyond time and equipment already on hand, such as cameras and GPS units. Monitoring enables the evaluation of the condition and stability of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). A monitoring program revolves around periodic site visits to assess conditions compared to a baseline for that site, with the periodicity depending on factors such as site productivity, accessibility, and significance of management issues. For example, a highly productive site which is strongly affected by erosion or unauthorized collection, and which can be easily visited by park staff, would be scheduled for more frequent visits than a less productive or less threatened site.

A monitoring program is generally implemented after an inventory has been prepared for a park and sites of concern have been identified, with additional sites added as necessary. Because each park is different, with different geology and paleontology among other factors, ideally each park that has in situ fossils or significant accumulations of reworked fossils would have its own monitoring protocol to define its monitoring program. Data accumulated via monitoring is used to inform further management decisions, such as the following questions: Is the site suitable for interpretation and education? Does the site require stabilization from the elements? Is collection warranted? Is there a need for some form of law enforcement presence?

Collection is recommended to be reserved for fossils possessing exceptional value (e.g., rare or high scientific significance) or at immediate risk of major degradation or destruction by human activity and natural processes. Therefore, paleontological resource monitoring is a more feasible potential management tool. The first step in establishment of a monitoring program is identification of localities to be monitored, as discussed previously. Locality condition forms are then used to evaluate factors that could cause loss of paleontological resources, with various conditions at each locality rated as good, fair, or poor. Risks and conditions are categorized as Disturbance, Fragility, Abundance, and Site Access. "Disturbance" evaluates conditions that promote accelerated erosion or mass wasting resulting from human activities. "Fragility" evaluates natural conditions that may influence the degree to which fossil transportation is occurring. Sites with elevated fragility exhibit inherently soft rapidly eroding sediment or mass wasting on steep hillsides. A bedrock outcrop that is strongly lithified has low fragility. "Abundance" judges both the natural condition and number of specimens preserved in the deposits as well as the risk of being easily recognized as a fossil-rich area by non-paleontologists, which could lead to unpermitted collecting. "Site Access" assesses the risk of a locality being visited by large numbers of visitors or the potential for easy removal of large quantities of fossils or fossil-bearing sediments. A locality with high access would be in close proximity to public use areas or other access (along trails, at roadcuts, at beach or river access points, and so on).

Each of the factors noted above may be mitigated by management actions. Localities exhibiting a significant degree of disturbance may require either active intervention to slow accelerated erosion, periodic collection and documentation of fossil materials, or both. Localities developed on sediments of high fragility naturally erode at a relatively rapid rate and would require frequent visits to document and/or collect exposed fossils in order to prevent or reduce losses. Localities with abundant or rare fossils, or high rates of erosion, may be considered for periodic monitoring in order to assess the stability and condition of the locality and resources, in regard to both natural processes and human-related activities. THRO is vulnerable to landslides and other earth movements that may both bury known paleontological sites and expose previously unknown paleontological resources (Figures 46–48). Evaluations of fresh landslides should include inspection for newly revealed fossils. Localities that are easily accessible by road or trail would benefit from the same management strategies as those with abundant fossils and by occasional visits by park staff, documentation of in situ specimens, and/or frequent law enforcement patrols. Further information on paleontological resource monitoring can be found in Santucci and Koch (2003) and Santucci et al. (2009).

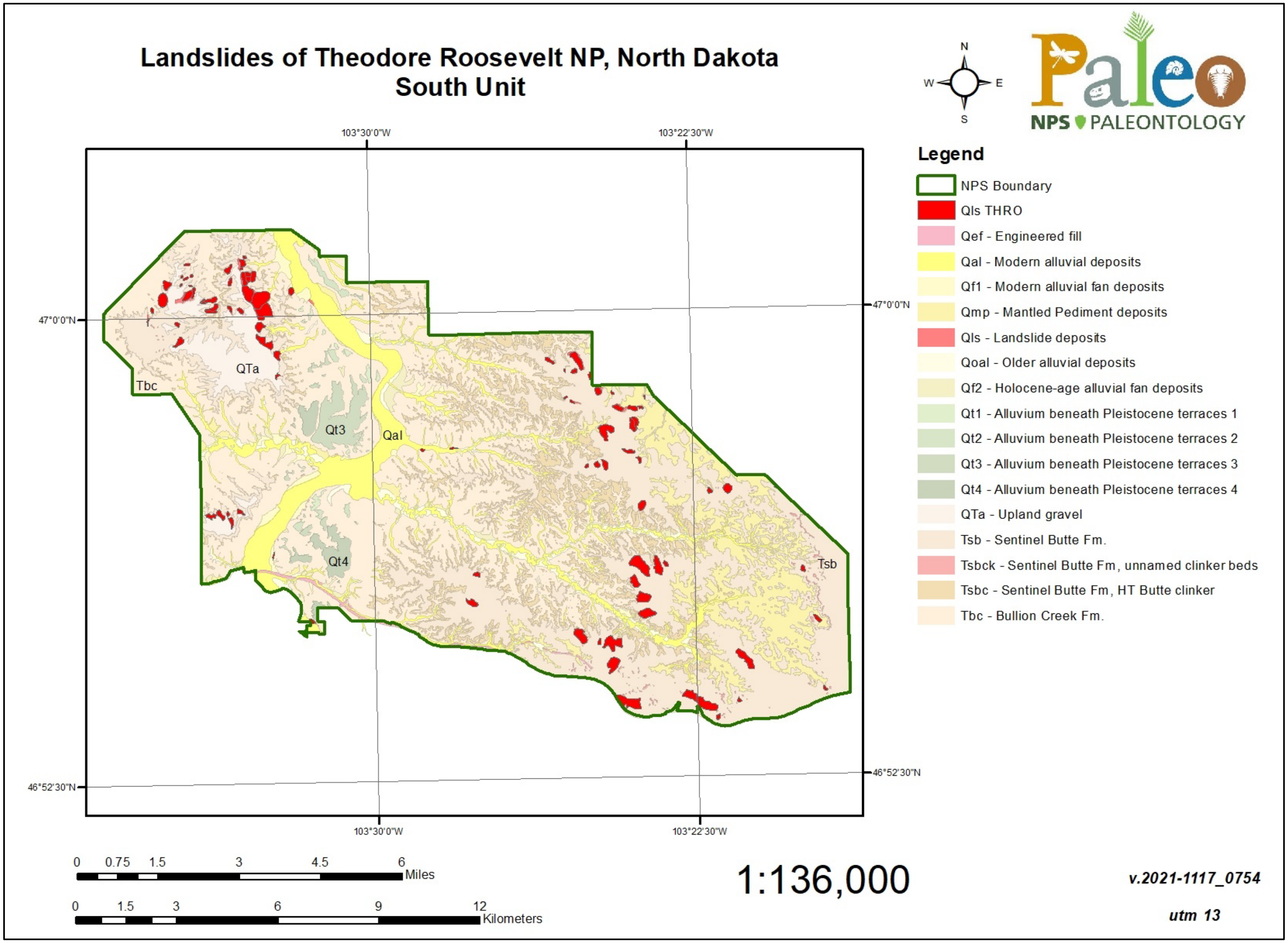


Figure 46. Geologic map of the South Unit of THRO (see also Figure 6) with landslides highlighted; landslide data supplied by the North Dakota Geological Survey.

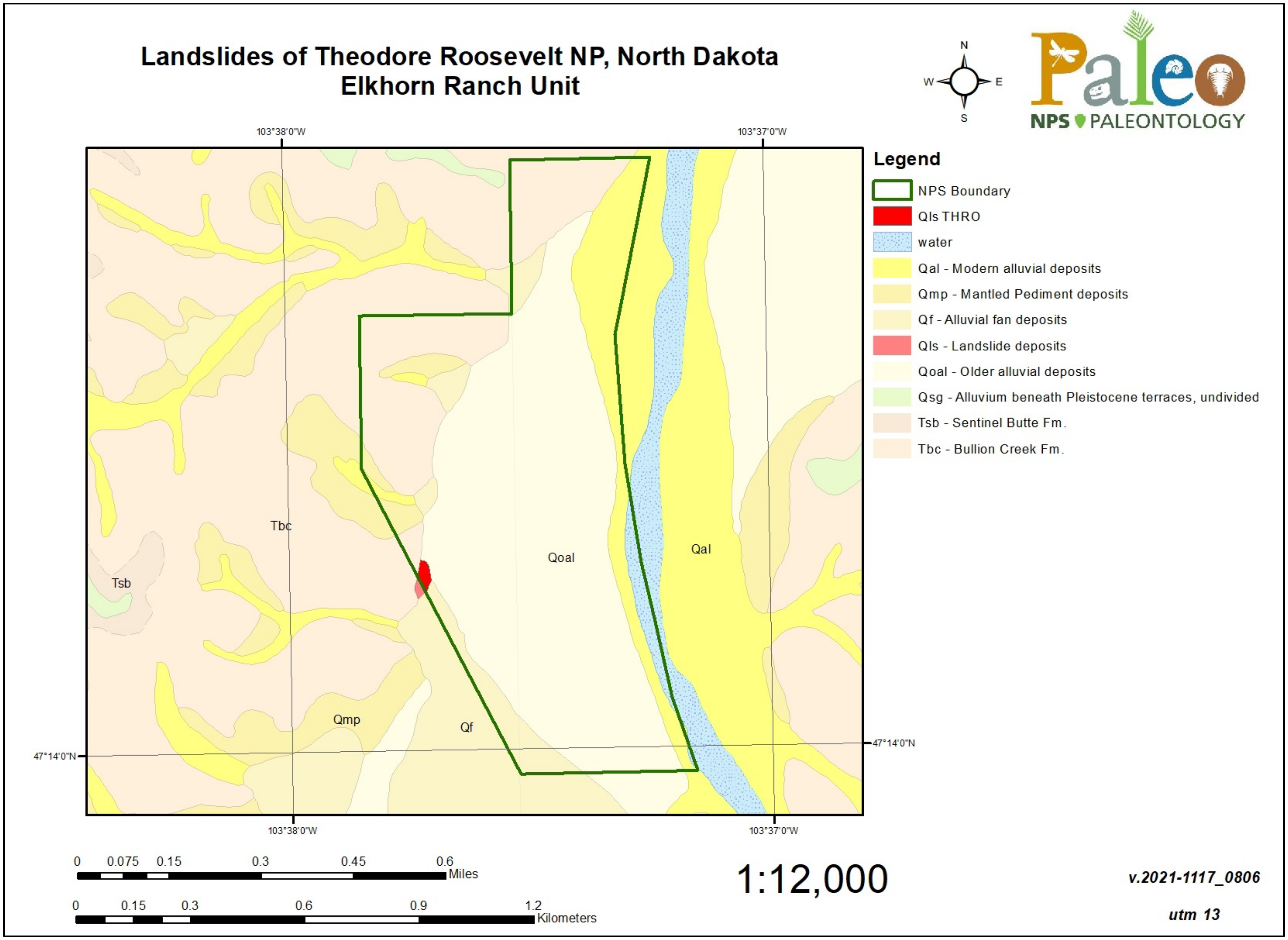


Figure 47. Geologic map of the Elkhorn Ranch Unit of THRO (see also Figure 7) with landslides highlighted; landslide data supplied by the North Dakota Geological Survey.

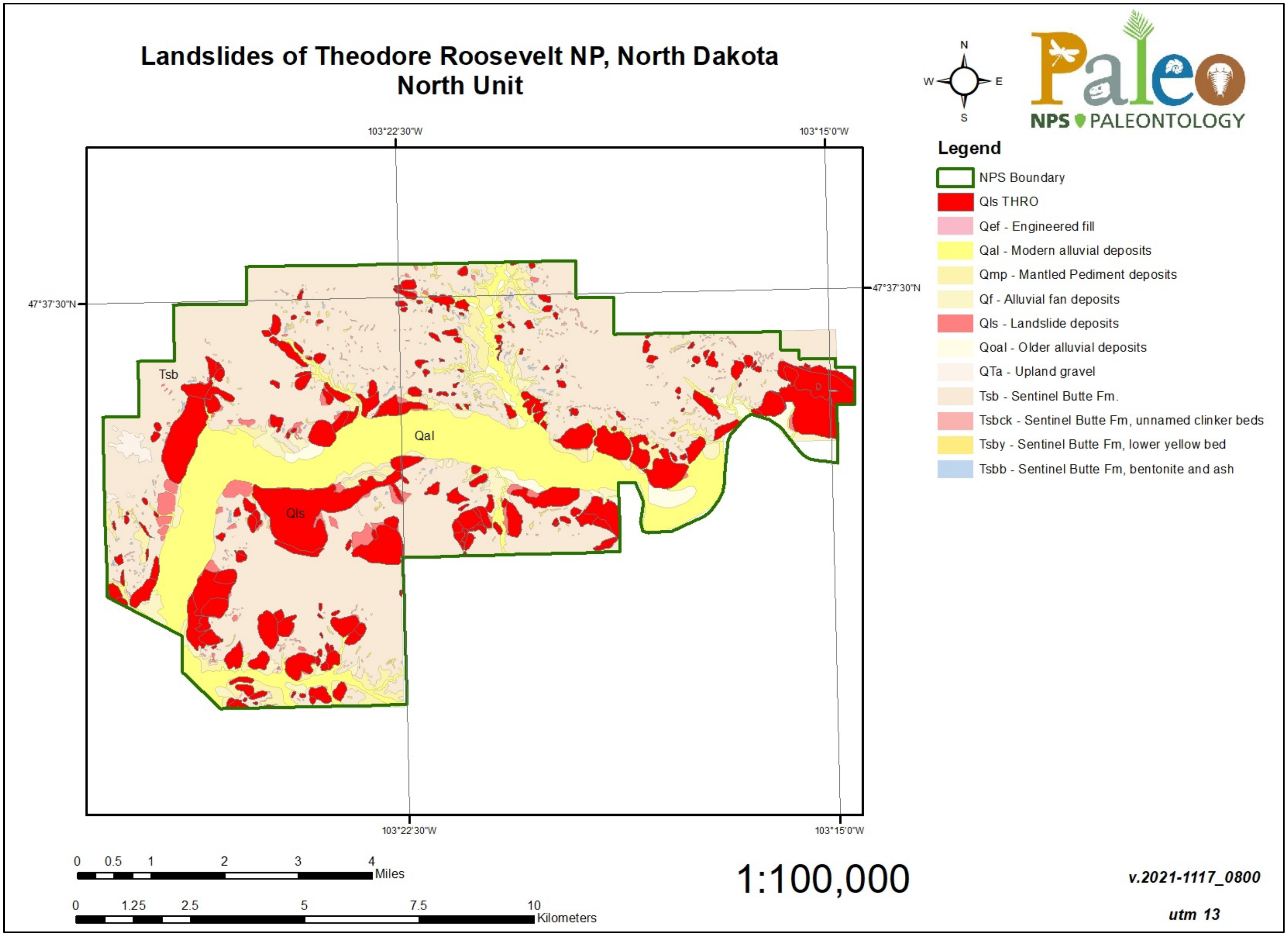


Figure 48. Geologic map of the North Unit of THRO (see also Figure 8) with landslides highlighted; landslide data supplied by the North Dakota Geological Survey.

South Unit Loop Road Construction Project Paleontological Resource Assessment

Park infrastructure work at THRO supplies a case study for paleontological monitoring in conjunction with a park road construction project. During the second year of the THRO Paleontological Resource Inventory (2021), the team was briefed on planned construction along the THRO South Unit Loop Road. This loop road is one of the oldest sections of road in the park and has been impacted by landslides, unstable slopes, and other factors over time. Therefore, a road rehabilitation project has been initiated to restore access, improve safety, and enable visitors to experience the park. The NPS Paleontology Program participated in pre-construction planning with the Denver Service Center (DSC).

Because the footprint of the proposed South Unit Loop Road construction overlaps portions of the park with previously documented fossil localities, the paleontological resource inventory team undertook some focused surface surveys of fossils along the area of proposed disturbance. More than a dozen new or previously documented fossil localities occur along the road construction corridor including sites documented in both the Paleocene Sentinel Butte and Bullion Creek Formations of the Fort Union Group. Based on this concentration of fossil localities situated along the road construction corridor, NPS Senior Paleontologist Vincent Santucci recommended to the park and DSC staff that a pre-construction assessment for paleontological resources should be undertaken, as well as for monitoring and mitigation to occur during construction ground disturbance activities.

DSC obtained funding to support the paleontological resource assessment at THRO and sent out a request for proposals in order to contract the work. Paleo Solutions, headquartered in Los Angeles, California, was awarded the contract. Paleontological resource locality information for the area around the South Unit Loop Road was provided to Paleo Solutions Vice President and Paleontology Program Manager Paul Murphey.

A Paleo Solutions field team undertook a pedestrian surface survey at THRO in late September 2021 and identified one new significant fossil locality (SFL) and four new non-significant fossil occurrences (NFO), and also revisited TRS21-050 (considered an NFO) and TRS20-041, -042, and -042b (collectively an SFL) (Tables 2 and 3) (J. Munson and P. Murphey, Paleo Solutions, pers. comm., October and November 2021). The two SFLs, both in the Sentinel Butte Formation, produced very well-preserved plants and vertebrate fossils, with specimens collected from both sites (see Appendix B).

Santucci has reviewed the draft paleontological resource assessment summary and will forward the recommendation to the park and DSC that paleontological resource monitoring and mitigation should be undertaken during the construction project ground disturbance. Significant fossil specimens collected during the pre-construction assessment will be curated into THRO collections.

Table 2. Summary of Significant Fossil Localities and Non-Significant Fossil Occurrences discovered during the South Unit Loop Road survey.

Field #	ID	Significance	Collected?	Formation
F210922-80-01 (TRS21-050)	Bivalvia undet.: 100+ shell fragments; Gastropoda undet.: 10+ shell fragments	Non-Significant	No	Bullion Creek
F210922-80-02	Bivalvia undet.: 10–15+ shell fragments	Non-Significant	No	Bullion Creek
F210922-80-03	Plantae undet.: 50+ plant impressions along bedding plane	Non-Significant	No	Sentinel Butte
F210923-72-01	Plantae undet.: petrified wood, hundreds of fragments from pebble- to boulder-sized	Non-Significant	No	Sentinel Butte
F210923-72-02	Bivalvia undet.: 100+ shell fragments; Gastropoda undet.: 100+ shell fragments	Non-Significant	No	Sentinel Butte
F210923-72-03 (TRS20-041, 042, 042b)	cf. Trionychoidea: ungual and distal lateral hypoplastral processes; Testudines undet.: shell fragments; cf. Reptilia: proximal phalanx and phalanx fragment; cf. Aves: proximal ulna	Significant	Yes—Surface Collection	Sentinel Butte
F210923-80-01	*Nyssidium arcticum*: 2 fruit; *Porosia verrucosa*: 5 seed or leaf; Angiospermopsida undet.: poorly preserved leaves and plant fragments	Significant	Yes–Surface Collection	Sentinel Butte

Table 3. Significant Fossil Localities discovered during the South Unit Loop Road survey and recommendations for additional work (formal fossil identifications have not been completed, so field identifications are provided).

Field #	Fossils Recorded	Additional Mitigation Recommendations	Formation
F210923-72-03	cf. Trionychoidea – claw (ungual), distal lateral hypoplastral processes; cf. Aves – proximal ulna; cf. Reptilia – proximal phalanx, phalanx fragment; Testudines undet. – shell fragments	Screenwash bulk matrix sample of at least 4 five-gallon buckets (~160 pounds) to test for the presence of small vertebrate fossils. If additional small vertebrates are found, collect and wash additional matrix and monitor site during construction	Sentinel Butte
F210923-80-01	*Nyssidium arcticum* – fruit; *Porosia verrucosa* – seed or leaf; Angiospermopsida undet. – poorly preserved leaves and plant fragments	Monitor ground disturbance during construction to collect additional fossils	Sentinel Butte

Foundation Documents and Resource Stewardship Strategies

Foundation documents and Resource Stewardship Strategies are two types of park planning documents that may contain and reference paleontological resource information. A foundation document is intended to provide basic guidance about a park for planning and management. It briefly describes a given park and its purpose, significance, fundamental resources and values, other importance resources and values, and interpretative themes. Mandates and commitments are also identified, and the state of planning is assessed. Foundation documents may include paleontological information and are also useful as a preliminary assessment of what park staff know about their paleontological resources, the importance they place on these resources, and the present state of these non-renewable resources. A foundation document for THRO has been published (NPS 2014).

A Resource Stewardship Strategy (RSS) is a strategic plan intended to help park managers achieve and maintain desired resource conditions over time. It offers specific information on the current state of resources and planning, management priorities, and management goals over various time frames. An RSS has not yet been published for THRO. However, there is a Natural Resource Condition Assessment for THRO (Amberg et al. 2014) that covers paleontology in some detail.

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at or beneath the land surface (Evans 2016). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the age and lowercase letters indicating the formation's name. The American Geosciences Institute website (https://www.americangeosciences.org/environment/publications/mapping) provides more information about geologic maps and their uses. The NPS Geologic Resources Inventory (GRI) has been digitizing existing maps of NPS units and making them available to parks for resource management.

Geologic maps are one of the foundational elements of a paleontological resource management program. Knowing which sedimentary rocks and deposits underlie a park and where they are exposed are essential for understanding the distribution of known or potential paleontological resources. The ideal scale for resource management in the 48 contiguous states is 1:24,000 (maps for areas in Alaska tend to be coarser). Whenever possible, page-sized geologic maps derived from GRI files are included in paleontological resource inventory reports for reference, but park staff are encouraged to download GRI source files from IRMA. The source files can be explored in much greater detail and incorporated into the park GIS database. Links to the maps digitized by the GRI for THRO can be found in IRMA at https://irma.nps.gov/DataStore/Reference/Profile/1044329. In addition to a digital GIS geologic map, the GRI program also produces a park-specific report discussing the geologic setting, distinctive geologic features, and processes within the park, highlighting geologic issues facing resource managers, and describing the geologic history leading to the present-day landscape of the park. A scoping summary for THRO was published in 2004 (NPS 2004) and a GRI report was completed in 2007 (KellerLynn 2007) and can be found in IRMA at https://irma.nps.gov/DataStore/Reference/Profile/652350. The entire THRO GRI project can be found in IRMA at https://irma.nps.gov/DataStore/Reference/Profile/2171431.

Paleontological Resource Potential Maps

Paleontological resource potential maps are included in this report (Figures 49–51). The maps show the distribution of geologic units within a park that are known to have yielded fossils within the park (colored green on the maps), have not yielded fossils within the park but are fossiliferous elsewhere (yellow), or have not yielded fossils (red). This map gives a quick indication of areas where fossils may be discovered, which in turn can provide suggestions for areas to survey or monitor, or areas where the discovery of fossils may be of concern during work that disturbs the ground (road work, building construction, etc.).

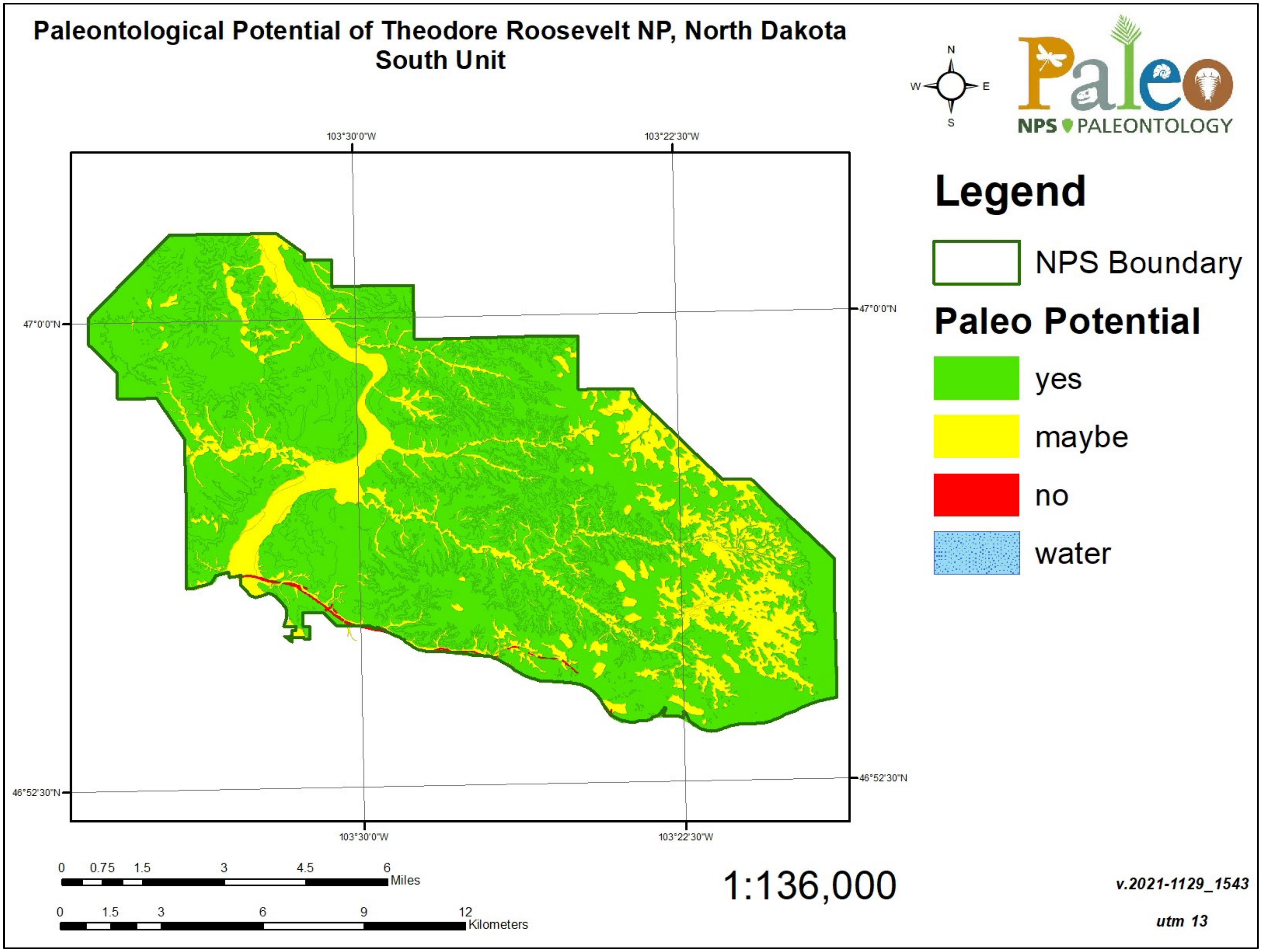


Figure 49. Map indicating paleontological potential of geologic map units in the South Unit of THRO (NPS/TIM CONNORS). The Bullion Creek and Sentinel Butte Formations have yielded fossils within THRO. Quaternary deposits within THRO are potentially fossiliferous.

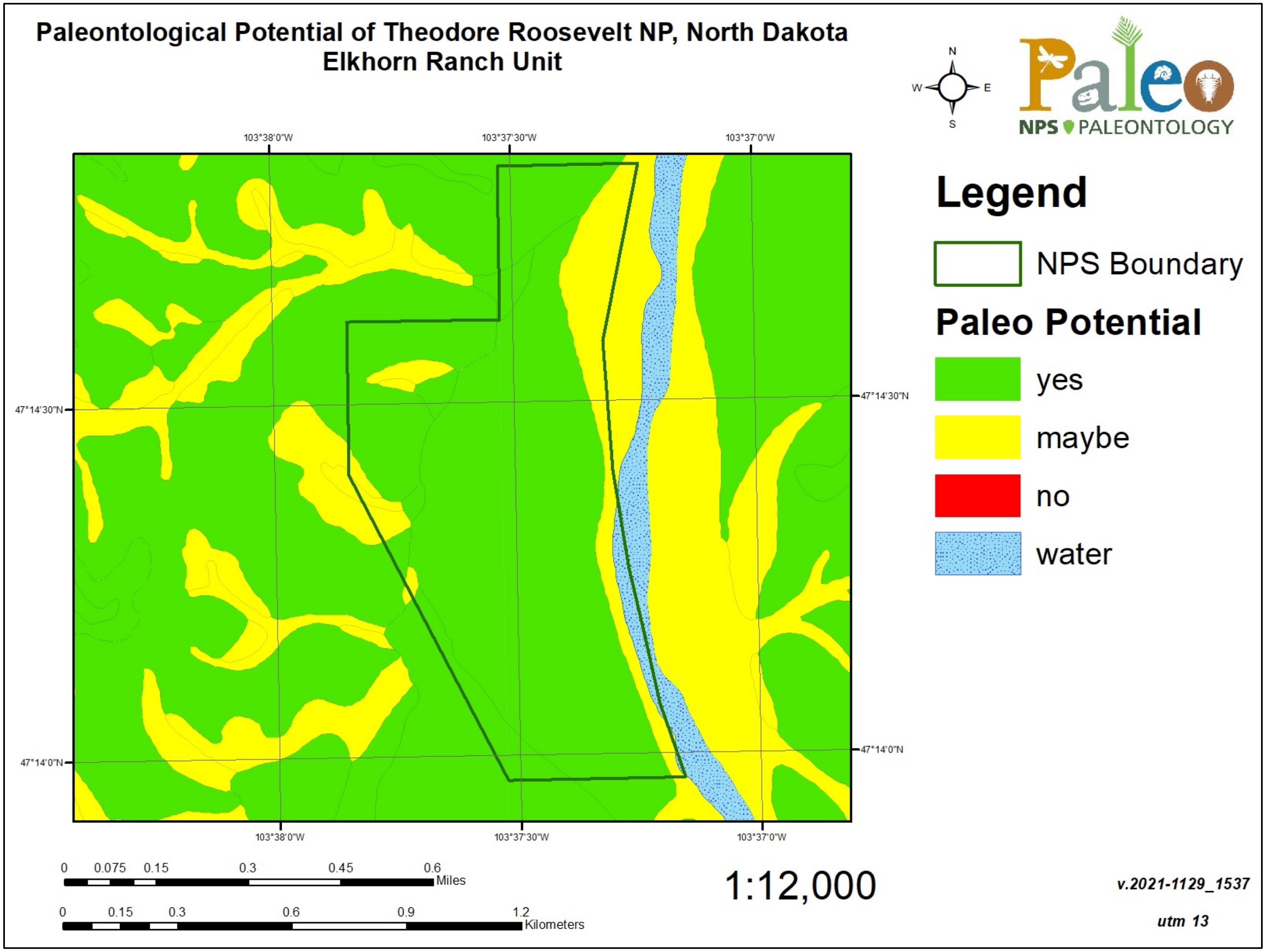


Figure 50. Map indicating paleontological potential of geologic map units in the Elkhorn Ranch Unit of THRO (NPS/TIM CONNORS). The Bullion Creek and Sentinel Butte Formations have yielded fossils within THRO. Quaternary deposits within THRO are potentially fossiliferous.

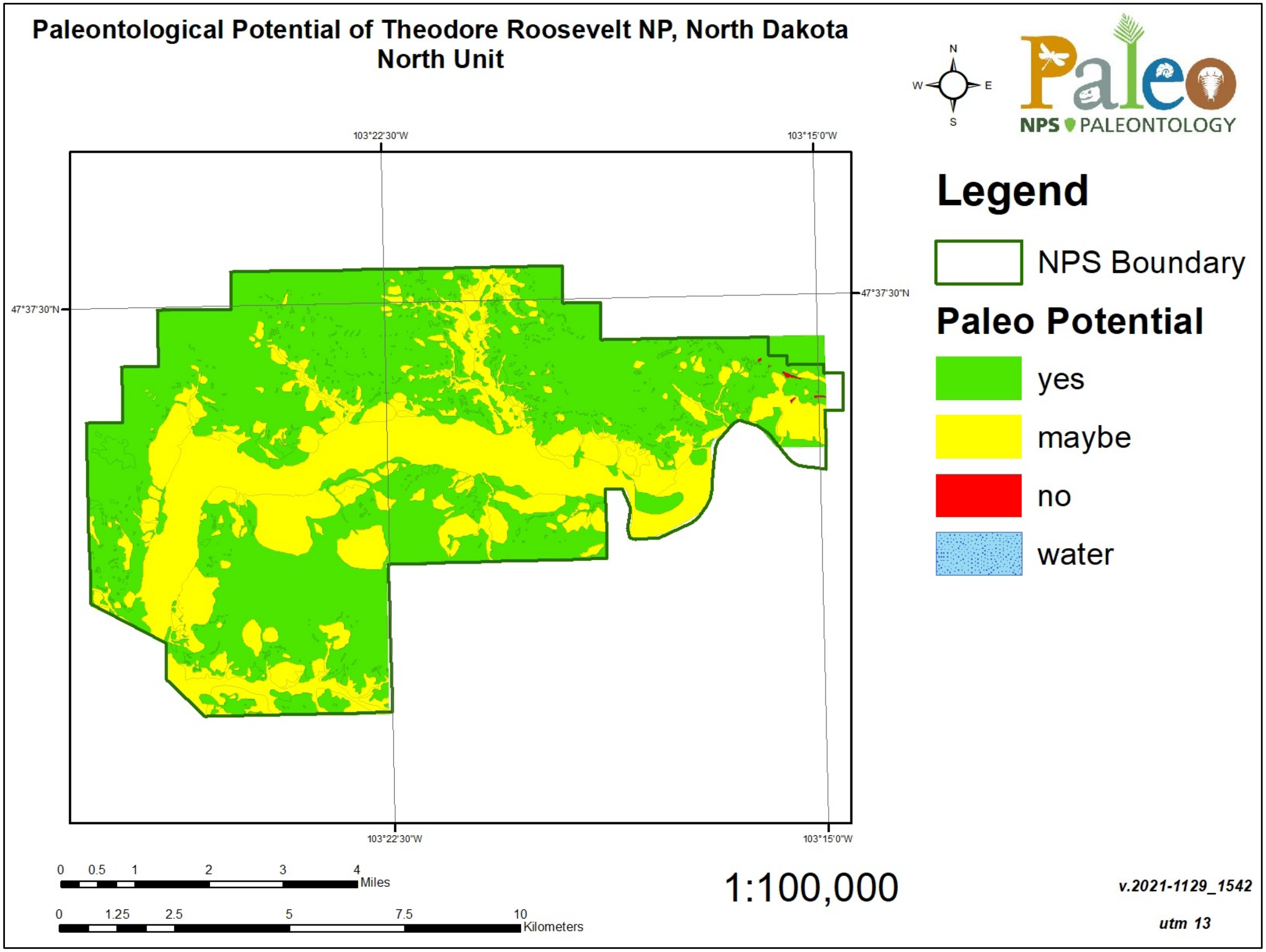


Figure 51. Map indicating paleontological potential of geologic map units in the North Unit of THRO (NPS/TIM CONNORS). The Bullion Creek and Sentinel Butte Formations have yielded fossils within THRO. Quaternary deposits within THRO are potentially fossiliferous.

Paleontological Resource Management Recommendations

The paleontological resource inventory at THRO has documented rich and previously unrecognized paleontological resources from within park boundaries. This report captures the scope, significance, and distribution of fossils at THRO as well as provides recommendations to support the management and protection of the park's non-renewable paleontological resources.

- THRO staff should be encouraged to observe exposed rocks and sedimentary deposits for fossil material while conducting their usual duties. To promote this, staff should receive guidance on recognizing common local fossils and basic documentation of fossils and localities. When opportunities arise to observe paleontological resources in the field and take part in paleontological field studies with trained paleontologists, staff should take advantage of them, if funding and time permit.
- THRO staff should photo-document and monitor any occurrences of paleontological resources that may be observed in situ. Fossils and their associated geologic context (surrounding rock) should be documented but left in place unless they are subject to imminent degradation. A Geologic Resource Monitoring Manual published by the Geological Society of America and NPS Geologic Resources Division (GRD) includes a chapter on paleontological resource monitoring (Santucci et al. 2009). Santucci and Koch (2003) also present information on paleontological resource monitoring.
- Because THRO has abundant fossils and rapid erosion, it may be useful to establish a collecting permit for one or more experienced park staff members. This would allow a faster response to significant finds. To be considered for this, an interested staff member should either undergo more advanced training on documentation and collection or have previous experience.
- Fossil theft is one of the greatest threats to the preservation of paleontological resources and any methods to minimize these activities should be utilized by staff. Any occurrence of paleontological resource theft or vandalism should be investigated by a law enforcement ranger. When possible the incident should be fully documented and the information submitted for inclusion in the annual law enforcement statistics.
- A citizen science program may be helpful to address resource protection issues. For example, Badlands National Park (BADL) has an established system for visitor site reporting (see Kottkamp et al. 2020 for more details). THRO is similar to BADL in having large areas of well-exposed fossiliferous rocks, so a similar program may be useful.
- Fossils found in a cultural context should be documented like other fossils but will also require the input of an archeologist or a cultural resource specialist. Any fossil which has a cultural context may be culturally sensitive as well (e.g., subject to NAGPRA) and should be regarded as such until otherwise established. The Geologic Resources Division can coordinate additional documentation/research of such material.
- The park may fund and recruit paleontology interns as a cost-effective means of enabling some level of paleontological resource support. The Scientists in Parks Program (formerly

Geoscientists-in-the-Parks) is an established program for recruitment of geology and paleontology interns.

- The petrified forests of THRO, a noted feature of the park, have only been described scientifically in Fastovsky and McSweeney (1991), which focused on the associated paleosols. Many aspects of the forests remain to be described. Further description of the forests would be valuable both scientifically and for management and interpretation.
- A study of microvertebrate localities may yield valuable information on Paleocene mammals, which are currently poorly known in THRO at this time.
- Fresh landslides should be evaluated for newly exposed paleontological resources.
- The park could address some of the recommendations in this report through collaboration with the NDGS paleontologist and/or the paleontology faculty at the South Dakota School of Mines and Technology in Rapid City, South Dakota. The faculty may be willing to schedule a field training exercise for paleontology students to assist with identified monitoring, microvertebrate locality sampling/screen washing, and other tasks. Such exercises would also be opportunities for park staff to learn about paleontological field procedures.
- Contact the NPS Paleontology Program for technical assistance with paleontological resource management issues.

If fossil specimens are found by THRO staff, it is recommended they follow the steps outlined below to ensure proper paleontological resource management.

- Photo-document the specimen without moving it from its location if it is loose. Include a common item, such as a coin, pen, or pencil, for scale if a ruler or scale bar is not available.
- If a GPS unit is available, record the location of the specimen. If GPS is not available, record the general location within THRO and height within the outcrop, if applicable. If possible, revisit the site when a GPS unit is available. Most smartphones can also record coordinates; if no GPS unit is available, attempt to record the coordinates with a phone.
- Write down associated data, such as rock type, general description of the fossil, type of fossil if identifiable, general location in THRO, sketch of the fossil, position within the outcrop or if it is loose on the ground, any associated fossils, and any other additional information.
- Do not remove the fossil unless it is loose in an area of heavy traffic, such as a public trail, and is at risk of being taken or destroyed. If the fossil is removed, be sure to wrap in soft material, such as tissue paper, and place in a labeled plastic bag with associated notes. Because THRO has many culturally important sites, simply documenting the fossil and leaving it in place is the best course of action until natural resource staff is contacted.

Literature Cited

Allen, J. A. 1876. The Little Missouri "Bad Lands". American Naturalist 10:207–216. Available at: https://www.biodiversitylibrary.org/page/40811117 (accessed November 23, 2021).

Amberg, S., K. Kilkus, M. Komp, A. Nadeau, K. Stark, L. Danielson, S. Gardner, E. Iverson, E. Norton, and B. Drazkowski. 2014. Theodore Roosevelt National Park: natural resource condition assessment. Natural Resource Report NPS/THRO/NRR—2014/776. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2207875 (accessed November 23, 2021).

Baker, C. H., Jr. 1967. Geology and groundwater resources of Richland County. Part 1. Geology. North Dakota Geological Survey, Bismarck, North Dakota. Bulletin 46.

Belt, E. S., N. E. Tibert, H. A. Curran, J. A. Diemer, J. H. Hartman, T. J. Kroeger, and D. M. Harwood. 2005. Evidence for marine influence on a low-gradient coastal plain: ichnology and invertebrate paleontology of the lower Tongue River Member (Fort Union Formation, middle Paleocene), western Williston Basin, U.S.A. Rocky Mountain Geology 40(1):1–24.

Benson, R. D. 1999. *Presbyornis isoni* and other late Paleocene birds from North Dakota. Smithsonian Contributions to Paleobiology 89:253–259.

Berg, D. J., and J. A. Brophy. 1963. An investigation of fossil wood from the South Unit, Theodore Roosevelt National Memorial Park. Unpublished. Department of Geology, North Dakota State University, Fargo, North Dakota. Available at THRO.

Bickel, D. 1976. Two new species of non-marine Mollusca from the Fort Union Group (Paleocene) of North Dakota and Montana. Nautilus 90:94–98. Available at: https://www.biodiversitylibrary.org/page/8276464 (accessed November 23, 2021).

Bickel, D. 1977. A new genus and species of freshwater gastropod from the Paleocene Tongue River Formation of North Dakota. Journal of Paleontology 51(1):123–130.

Bickley, W. B., Jr. 1972. Stratigraphy and history of the Sakakawea Sequence, south-central North Dakota. Dissertation. University of North Dakota, Grand Forks, North Dakota. Available at: https://commons.und.edu/theses/22/ (accessed November 23, 2021).

Biek, R. F. 1995. An unusual example of the Taylor Bed silcrete. DMR Newsletter 22(2):4–5.

Biek, R. F., and M. A. Gonzalez. 2001. The geology of Theodore Roosevelt National Park: Billings and McKenzie Counties, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. Miscellaneous Series 86.

Biek, R. F., and E. C. Murphy. 1997. Dickinson geology: a guide to the geology, mineral resources, and geologic hazards of the Dickinson area. North Dakota Geological Survey, Bismarck, North Dakota. Geologic Investigation 1.

Bown, T. M., and K. D. Rose. 1987. Patterns of dental evolution in early Eocene anaptomorphine primates (Omomyidae) from the Bighorn Basin, Wyoming. Paleontological Society Memoir 23.

Brown, R. W. 1948. Correlation of Sentinel Butte shale in western North Dakota. Bulletin of the American Association of Petroleum Geologists 32(7):1265–1274.

Brown, R. W. 1962. Paleocene flora of the Rocky Mountains and Great Plains. U.S. Geological Survey, Washington, D.C. Professional Paper 375. Available at: https://pubs.er.usgs.gov/publication/pp375 (accessed November 23, 2021).

Brownstein, C. D. 2022. High morphological disparity in a bizarre Paleocene fauna of predatory freshwater reptiles. BMC Ecology and Evolution 22: article number 34.

Call, V. B., and D. L. Dilcher. 1994. *Parvileguminophyllum coloradensis*, a new combination for *Mimosites coloradensis* Knowlton, Green River Formation of Utah and Colorado. Review of Palaeobotany and Palynology 80(3–4):305–310.

Campbell, M. R., and others. 1915. Guidebook of the western United States. Part A. The Northern Pacific route, with a side trip to Yellowstone Park. U.S. Geological Survey, Washington, D.C. Bulletin 611. Available at: https://pubs.er.usgs.gov/publication/b611 (accessed November 23, 2021).

Cherven B. 1973. High-and low-sinuosity stream deposits of the Sentinel Butte Formation (Paleocene) McKenzie County, North Dakota. Thesis. University of North Dakota, Grand Forks, North Dakota. Available at: https://commons.und.edu/theses/54/ (accessed November 23, 2021).

Cherven, V. B. 1978. Fluvial and deltaic facies in the Sentinel Butte Formation, central Williston Basin. Journal of Sedimentary Petrology 48(1):159–170.

Clayton, L., W. B. Bickley, Jr., and S. R. Moran. 1976. Stratigraphy, origin, and climatic implications of late Quaternary upland silt in North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. Miscellaneous Series 54.

Clayton, L., C. G. Carlson, W. L. Moore, G. Groenewold, F. D. Holland, Jr., and S. R. Moran. 1977. The Slope (Paleocene) and Bullion Creek (Paleocene) Formations of North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. Report of Investigation 59.

Clayton, L., S. R. Moran, J. P. Bluemle, and C. G. Carlson. 1980. Geologic map of North Dakota. U.S. Geological Survey, Washington, D.C. Scale 1:500,000. Available at: https://ngmdb.usgs.gov/Prodesc/proddesc_16520.htm (accessed November 23, 2021).

Clechenko, E. R., D. C. Kelly, G. J. Harrington, and C. A. Stiles. 2007. Terrestrial records of a regional weathering profile at the Paleocene-Eocene boundary in the Williston Basin of North Dakota. Geological Society of America Bulletin 119(3):428–442.

Clites, E. C., and V. L. Santucci. 2012. Protocols for paleontological resource site monitoring at Zion National Park. Natural Resource Report NPS/ZION/NRR—2012/595. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2191254 (accessed November 23, 2021).

Coffin, H. G. 1984. Preliminary report—identification of petrified wood from Theodore Roosevelt National Park. Unpublished. Loma Linda University, Loma Linda, California.

Crane, P. R., S. R. Manchester, and D. L. Dilcher. 1990. A preliminary survey of fossil leaves and well-preserved reproductive structures from the Sentinel Butte Formation (Paleocene) near Almont, North Dakota. Fieldiana: Geology (New Series) 20. Available at: https://www.biodiversitylibrary.org/page/47002431 (accessed November 23, 2021).

Cvancara, A. M., I. Clayton, W. B. Bickley, Jr., A. F. Jacob, A. C. Ashworth, J. A. Brophy, C. T. Shay, L. D. Delorme, and G. E. Lammers. 1971. Paleolimnology of late Quaternary deposits: Seibold site, North Dakota. Science 171(3967):172–174.

Delimata, J. J. 1969. Fort Union (Paleocene) mollusks from southern Golden Valley and southeastern Billings Counties, North Dakota. Thesis. University of North Dakota, Grand Forks, North Dakota. Available at: https://commons.und.edu/theses/72/ (accessed November 23, 2021).

Douglass, E. 1909. A geological reconnaissance in North Dakota, Montana, and Idaho; with notes on Mesozoic and Cenozoic geology. Annals of the Carnegie Museum 5:211–288. Available at: https://www.biodiversitylibrary.org/page/9966920 (accessed November 23, 2021).

Erickson, B. R. 1972. The lepidosaurian reptile *Champsosaurus* in North America. Science Museum of Minnesota, St. Paul, Minnesota. Monograph 1.

Erickson, B. R. 1973. A new chelydrid turtle *Protochelydra zangerli* from the late Paleocene of North Dakota. Scientific Publications of the Science Museum of Minnesota 2(2).

Erickson, B. R. 1981. *Champsosaurus tenuis* (Reptilia, Eosuchia): a new species from the late Paleocene of North America. Scientific Publications of the Science Museum of Minnesota 5(1).

Erickson, B. R. 1982. The Wannagan Creek quarry and its reptilian fauna (Bullion Creek Formation, Paleocene) in Billings County, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. Report of Investigation 72.

Erickson, B. R. 1987. *Simoedosaurus dakotensis*, new species, a diapsid reptile (Archosauromorpha; Choristodera) from the Paleocene of North America. Journal of Vertebrate Paleontology 7(3):237–251.

Erickson, B. R. 1991. Flora and fauna of the Wannagan Creek Quarry: late Paleocene of North America. Scientific Publications of the Science Museum of Minnesota 7(3).

Erickson, B. R. 1999. Fossil Lake Wannagan (Paleocene: Tiffanian): Billings County, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. Miscellaneous Series 87.

Erickson, B. R. 2005. Crocodile and arthropod tracks from the late Paleocene Wannagan Creek fauna of North Dakota, USA. Ichnos 12(4):303–308.

Erickson, B. R. 2012. History of the Wannagan Creek expeditions 1970–1996. Science Museum of Minnesota, St. Paul, Minnesota. Monograph 6.

Erickson, J. M. 1983. *Trichopterodomus leonardi*, a new genus and species of psychomyiid caddisfly (Insecta: Trichoptera) represented by retreats from the Paleocene of North Dakota. Journal of Paleontology 57(3):560–567.

Estes, R. 1969. A new fossil discoglossid frog from Montana and Wyoming. Breviora 328. Available at: https://www.biodiversitylibrary.org/page/4293454 (accessed November 23, 2021).

Estes, R. 1981. Handbuch der Paläoherpetologie/Encyclopedia of Paleoherpetology. Part 2. Gymnophiona, Caudata. Gustav Fischer Verlag, Stuttgart, Germany.

Estes, R. 1988. Lower vertebrates from the Golden Valley Formation, early Eocene of North Dakota (U.S.A.). Acta Zoologica Cracoviensia 31(11–27):541–562.

Evans, T. J. 2016. General standards for geologic maps. Section 3.1 *in* M. B. Carpenter and C. M. Keane, compilers. The geoscience handbook 2016. AGI Data Sheets, 5th Edition. American Geosciences Institute, Alexandria, Virginia.

Fastovsky, D. E., and K. McSweeney. 1991. Paleocene paleosols of the petrified forests of Theodore Roosevelt National Park, North Dakota: a natural experiment in compound pedogenesis. Palaios 6(1):67–80.

Federal Writers of the Works Progress Administration. 1938. North Dakota: a guide to the northern prairie state. American Guide Series. Knight Printing Company, Fargo, North Dakota. Available at: https://www.gutenberg.org/ebooks/46661 (accessed November 23, 2021).

Fennah, R. G. 1968. A new genus and species of Ricaniidae from Palaeocene deposits in North Dakota. Journal of Natural History 2(1):143–146.

Fullerton, D. S., R. B. Colton, and C. A. Bush. 2004. Limits of mountain and continental glaciations east of the Continental Divide in northern Montana and north-western North Dakota, USA. Developments in Quaternary Sciences 2(part B):131–150.

Gingerich, P. D. 1991. Systematics and evolution of early Eocene Perissodactyla (Mammalia) in the Clarks Fork Basin, Wyoming. Contributions from the Museum of Paleontology, the University of Michigan 28(8):181–213. Available at: https://hdl.handle.net/2027.42/48544 (accessed November 23, 2021).

Gingerich, P. D., and E. L. Simons. 1977. Systematics, phylogeny, and evolution of early Eocene Adapidae (Mammalia, Primates) in North America. Contributions from the Museum of Paleontology, the University of Michigan 24(22):245–279. Available at: https://hdl.handle.net/2027.42/48489 (accessed November 23, 2021).

Gomez, K., L. Myczek, M. Salgado, N. Stenberg, J. J. Person, C. A. Boyd, and M. F. Guenther. 2018. Reconstruction of the Paleocene ecosystem of the Medora site, Billings County, North Dakota, using microfossils. Geological Society of America – Abstracts with Programs 50(6):paper 32-42.

Gonzalez, M. A. 2004a. Surface geology—Eagle Draw Quadrangle, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. 24K Series, EglD-sg. Scale 1:24,000.

Gonzalez, M. A. 2004b. Surface geology —Hanks Gully Quadrangle, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. 24K Series, HnkG-sg. Scale 1:24,000.

Gonzalez, M. A. 2004c. Surface geology—Roosevelt Creek East Quadrangle, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. 24K Series, RsvC E-sg. Scale 1:24,000.

Gonzalez, M. A. 2004d. Surface geology—Roosevelt Creek West Quadrangle, North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. 24K Series, RsvC W-sg. Scale 1:24,000.

Gradstein, F. M., J. G. Ogg, M. D. Schmitz, and G. M. Ogg, editors. 2020. Geologic time scale 2020. Elsevier, Amsterdam, Netherlands.

Gruber, D. L., and D. Bickel. 1973. Ostracoda from the Tongue River Formation (Paleocene), Ward County, North Dakota. Proceedings of the North Dakota Academy of Science 26(2, Part 2):21–27.

Haire, S. A., H. D. Hanks, and B. R. Erickson. 2018. Insect fossils from the late Paleocene (Bullion Creek Formation) of Wannagan Creek, North Dakota. Geological Society of America – Abstracts with Programs 50(4):paper 30-5.

Harington, C. R., and A. C. Ashworth. 1986. A mammoth (*Mammuthus primigenius*) tooth from late Wisconsin deposits near Embden, North Dakota, and comments on the distribution of woolly mammoths south of the Wisconsin ice sheets. Canadian Journal of Earth Sciences 23(7):909–918.

Harmon, D. 1986. At the open margin: the NPS's administration of Theodore Roosevelt National Park. Theodore Roosevelt Nature and History Association, Medora, North Dakota. Available at: http://npshistory.com/publications/thro/adhi/index.htm (accessed November 23, 2021).

Harr, J. L., and F. T. C. Ting. 1977. Modern and Paleocene *Metasequoias*: a comparison of foliage morphology. Pages 109–131 *in* R. C. Romans, editor. Geobotany. Plenum Press, New York, New York.

Hartman, J. H., and A. J. Kihm. 1991. Stratigraphic distribution of *Titanoides* (Mammalia: Pantodonta) in the Fort Union Group (Paleocene) of North Dakota. Pages 207–215 *in* J. E. Christopher and F. M. Haidl, editors. Sixth International Williston Basin Symposium. Saskatchewan Geological Society, Regina, Canada. Special Publication 11.

Hartman, J. H., and A. J. Kihm. 1992. Chronostratigraphy of Paleocene strata in the Williston Basin. Pages 52–75 *in* R. B. Finkelman, S. J. Tewalt, and D. J. Daly, editors. Geology and utilization of Fort Union lignites. Environmental and Coal Associates, Reston, Virginia.

Hauge, L. J. 1884. A missionary's notes on a silicified wood from Pyramid Park. Bulletin of the Minnesota Academy of Natural Sciences 3:75–76. Available at: https://digitalcommons.morris.umn.edu/jmas/vol3/iss1/10/ (accessed November 23, 2021).

Hay, O. P. 1924. The Pleistocene of the middle region of North America and its vertebrated animals. Carnegie Institute of Washington Publication 322A. Available at: https://www.biodiversitylibrary.org/item/156452 (accessed November 23, 2021).

Henkel, C. J., W. P. Elder, V. L. Santucci, and E. C. Clites. 2015. Golden Gate National Recreation Area: Paleontological Resource Inventory. Natural Resource Report NPS/GOGA/NRR—2015/915. National Park Service, Fort Collins, Colorado.

Hibbard, H. V. 1906. A description of the plateau region of North Dakota. North Dakota Agricultural College Survey 3rd Biennial Report:133–142. Available at: https://books.google.com/books?id=GQFFAQAAMAAJ (accessed November 23, 2021).

Hickey, L. J. 1977. Stratigraphy and paleobotany of the Golden Valley Formation (early Tertiary) of western North Dakota. Geological Society of America, Boulder, Colorado. Memoir 150.

Hoffman, G. L., and R. A. Stockey. 1994. Sporophytes, megaspores, and massulae of *Azolla stanleyi* from the Paleocene Joffre Bridge locality, Alberta. Canadian Journal of Botany 72(3):301–308.

Hoganson, J. 1994. Survey receives grant to study fossils of Theodore Roosevelt National Park. DMR Newsletter 21(3):2.

Hoganson, J. W. 1997. Paleontological fieldwork on the Little Missouri Grassland with the United States Forest Service. DMR Newsletter 24(4):12–13.

Hoganson, J. W. 2010. Ice Age mammals of North Dakota: where have all the large mammals gone? North Dakota Geological Survey, Bismarck, North Dakota. Geo News 37(2):3–7.

Hoganson, J. W., and J. Campbell. 1997. Paleontology of Theodore Roosevelt National Park. NDGS Newsletter 24(1):12–23.

Hoganson, J. W., and J. M. Campbell. 1998. Paleontological appraisal of the Paleocene Bullion Creek and Sentinel Butte Formations, Theodore Roosevelt National Park, North Dakota. Conference on Fossil Resources—Abstracts with Programs 5:unpaginated.

Hoganson, J. W., and J. Campbell. 2002. Paleontology of Theodore Roosevelt National Park. North Dakota Notes 9.

Hoganson, J. W., and H. G. McDonald. 2007. First report of Jefferson's Ground Sloth (*Megalonyx jeffersonii*) in North Dakota: its paleobiogeographical and paleoecological significance. Journal of Mammalogy 88:73–80.

Hoganson, J. W., and E. C. Murphy. 2003. Geology of the Lewis & Clark Trail in North Dakota. Mountain Press Publishing Company, Missoula, Montana.

Hoganson, J., J. Person, and B. Gould. 2011. Paleontology of the Medora public fossil dig site (Paleocene: Sentinel Butte Formation), Billings County, North Dakota. Geo News 38(1):17–20.

Holtzman, R. C. 1978. Late Paleocene mammals of the Tongue River Formation, western North Dakota. North Dakota Geological Survey, Bismarck, North Dakota. Report of Investigation 65.

Huber, J. K., and C. L. Hill. 2003. Paleoecological inferences based on pollen and stable isotopes for mammoth-bearing deposits of the Oahe Formation (Aggie Brown Member), eastern Montana. Current Research in the Pleistocene 20:95–97.

Jacob, A. F. 1973. Depositional environments of Paleocene Tongue River Formation, western North Dakota. The American Association of Petroleum Geologists Bulletin 57(6):1038–1052.

Jain, R. K., and J. W. Hall. 1969. A contribution to the early Tertiary fossil record of the Salviniaceae. American Journal of Botany 56(5):527–539.

Jenkins, F. A., Jr. 1961. Studies of the Golden Valley Formation (Eocene) of North Dakota, lithology, coprolites, paleoecology. Senior thesis. Princeton University, Princeton, New Jersey.

Jepsen, G. L. 1963. Eocene vertebrates, coprolites, and plants in the Golden Valley Formation of western North Dakota. Geological Society of America Bulletin 74(6):673–684.

Kays, G. B. 1999. Description and taphonomy of a turtle assemblage (Chelonia: Trionychidae) in the Sentinel Butte Formation (Paleocene), Billings County, North Dakota. Thesis. University of North Dakota, Grand Forks, North Dakota. Available at: https://commons.und.edu/theses/156/ (accessed November 23, 2021).

KellerLynn, K. 2007. Theodore Roosevelt National Park Geologic Resource Evaluation Report. Natural Resource Report NPS/NRPC/GRD/NRR—2007/006. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/652350 (accessed November 23, 2021).

Kenworthy, J. P., and V. L. Santucci. 2006. A preliminary investigation of National Park Service paleontological resources in cultural context: Part 1, general overview. New Mexico Museum of Natural History and Science Bulletin 34:70–76. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2195223 (accessed November 23, 2021).

Kihm, A. J., and J. H. Hartman. 1991. Age of the Sentinel Butte Formation, North Dakota. Journal of Vertebrate Paleontology 11(supplement to 3):40A.

Kihm, A. J., and J. H. Hartman. 2004. A reevaluation of the biochronology of the Brisbane and Judson local faunas (late Paleocene) of North Dakota. Bulletin of Carnegie Museum of Natural History 2004(36):97–107.

Kihm, A. J., J. H. Hartman, and D. W. Krause. 1993. A new late Paleocene mammal local fauna from the Sentinel Butte Formation of North Dakota. Journal of Vertebrate Paleontology 13(supplement to 3):44A.

Kottkamp, S., V. L. Santucci, J. S. Tweet, J. De Smet, and E. Starck. 2020. Agate Fossil Beds National Monument: paleontological resources management plan (public version). Natural Resource Report NPS/AGFO/NRR—2020/2172. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2278685 (accessed November 23, 2021).

Kuehn, D. D. 1993. Landforms and archaeological site location in the Little Missouri Badlands: a new look at some well-established patterns. Geoarchaeology 8(4):313–332.

Laird, W. M. 1950. The geology of the South Unit, Theodore Roosevelt National Memorial Park. North Dakota History 17(4):225–240.

Laird, W. M. 1956. Geology of the North Unit Theodore Roosevelt National Memorial Park. North Dakota History 23(2):53–77.

Lewis, S. E. 1988. A dragon-fly (Odonata: Aeschnidae) from the Paleocene of North Dakota. Occasional Papers in Paleobiology (St. Cloud State University) 2(2).

Lofgren, D. L., J. A. Lillegraven, W. A. Clemens, P. D. Gingerich, and T. E. Williamson. 2004. Paleocene biochronology: the Puercan through Clarkforkian Land Mammal Ages. Pages 43–105 *in* M. O. Woodburne, editor. Late Cretaceous and Cenozoic mammals of North America. Columbia University Press, New York, New York.

Lucas, S. G. 1998. Fossil mammals and the Paleocene/Eocene series boundary in Europe, North America, and Asia. Pages 451–500 *in* M.-P. Aubry, S. G. Lucas, and W. A. Berggren, editors. Late Paleocene–early Eocene climatic and biotic events in the marine and terrestrial records. Columbia University Press, New York, New York.

Manchester, S. R. 2014. Revisions to Roland Brown’s North American Paleocene flora. Acta Musei Nationalis Pragae 70(3–4):153–210.

Manum, S. B., M. N. Bose, and R. T. Sawyer. 1991. Clitellate cocoons in freshwater deposits since the Triassic. Zoologica Scripta 20:347–366.

McInerney, F. A., and S. Wing. 2011. A perturbation of carbon cycle, climate, and biosphere with implications for the future. Annual Review of Earth and Planetary Sciences 39:489–516.

Melchior, R. C. 1977. On the occurrence of *Minerisporites mirabilis* in situ. Scientific Publications of the Science Museum of Minnesota 3(4).

Melchior, R. C., and B. R. Erickson. 1979. Paleontological notes on the Wannagan Creek quarry site (Paleocene, North Dakota): ichnofossils I. Scientific Publications of the Science Museum of Minnesota 4(4).

Melchior, R. C., and J. W. Hall. 1983. Some megaspores and other small fossils from the Wannagan Creek site (Paleocene), North Dakota. Palynology 7:133–145.

National Park Service, Geologic Resources Division. 2004. Summary of Theodore Roosevelt NP GRI meeting, June 10, 2002. National Park Service, Geologic Resources Division, Denver, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2251449 (accessed November 23, 2021).

National Park Service. 2006. National Park Service management policies. National Park Service, U.S. Department of the Interior, Washington, D.C. Available at: https://www.nps.gov/orgs/1548/upload/ManagementPolicies2006.pdf (accessed November 23, 2021).

National Park Service. 2014. Foundation Document: Theodore Roosevelt National Park, North Dakota. National Park Service, Denver, Colorado. THRO 387/124075. Available at: https://www.nps.gov/thro/learn/management/upload/Theodore-Roosevelt-National-Park-Foundation-Document-2014.pdf (accessed November 23, 2021).

Newbrey, M., and M. Bozek. 2000. A new species of *Joffrichthys* (Teleostei: Osteoglossidae) from the Sentinel Butte Formation, (Paleocene) of North Dakota, USA. Journal of Vertebrate Paleontology 20(1):12–20.

Nichols, D. J., and F. T. C. Ting. 1975. Palynology of Paleocene petrified peat. Geoscience and Man 11:158.

Peppe, D. J., and L. J. Hickey. 2014. Fort Union Formation fossil leaves (Paleocene, Williston Basin, North Dakota, USA) indicate evolutionary relationships between Paleocene and Eocene plant species. Bulletin of the Peabody Museum of Natural History 55(2):171–189.

Pitman, J. K., L. C. Price, and J. A. LeFever. 2001. Diagenesis and fracture development in the Bakken Formation, Williston Basin; implications for reservoir quality in the middle member. U.S. Geological Survey, Reston, Virginia. Professional Paper 1653. Available at: https://pubs.usgs.gov/pp/p1653/ (accessed November 23, 2021).

Public Lands History Center. 2017. Theodore Roosevelt National Park, North Dakota: historic resource study. Colorado State University, Fort Collins, Colorado. Available at: http://www.npshistory.com/publications/thro/hrs.pdf (accessed November 23, 2021).

Radinsky, L. B. 1963. Origin and early evolution of the North American Tapiroidea. Peabody Museum of Natural History Bulletin 17.

Roosevelt, T. 1885. Hunting trips of a ranchman: sketches of sport on the northern cattle plains. G. P. Putnam's Sons, New York and London. Available at: https://www.google.com/books/edition/Hunting_Trips_of_a_Ranchman/6FdDAAAAIAAJ (accessed November 23, 2021).

Royse, C. F., Jr. 1967. A stratigraphic and sedimentologic analysis of the Tongue River and Sentinel Butte Formations (Paleocene), western North Dakota. Dissertation. University of North Dakota, Grand Forks, North Dakota. Available at: https://commons.und.edu/theses/250/ (accessed November 23, 2021).

Royse, C. F. Jr., 1970. A sedimentological analysis of the Tongue River–Sentinel Butte interval (Paleocene) of the Williston Basin, western North Dakota. Sedimentary Geology 4:19–80.

Sampson, S. D., M. A. Loewen, A. A. Farke, E. M. Roberts, C. A. Forster, J. A. Smith, and A. L. Titus. 2010. New horned dinosaurs from Utah provide evidence for intracontinental dinosaur endemism. PLoS ONE 5(9):e12292. doi:10.1371/journal.pone.0012292. Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0012292 (accessed November 23, 2021).

Santucci, V. L., and A. L. Koch. 2003. Paleontological resource monitoring strategies for the National Park Service. Park Science 22(1):22–25. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2201293 (accessed November 23, 2021).

Santucci, V. L., J. Kenworthy, and R. Kerbo. 2001. An inventory of paleontological resources associated with National Park Service caves. NPS Geological Resources Division, Denver, Colorado. Technical Report NPS/NRGRD/GRDTR-01/02. Available at: https://irma.nps.gov/DataStore/Reference/Profile/573879 (accessed November 23, 2021).

Santucci, V. L., J. P. Kenworthy, and A. L. Mims. 2009. Monitoring in situ paleontological resources. Pages 189–204 *in* R. Young and L. Norby, editors. Geological monitoring. Geological Society of America, Boulder, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2203105 (accessed November 23, 2021).

Santucci, V. L., J. M. Ghist, and R. B. Blodgett. 2014. Inventory of U.S. Geological Survey paleontology collections to identify fossil localities in National Park Service areas. Proceedings of the 10th Conference on Fossil Resources. Dakoterra 6:215–218. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2256493 (accessed November 23, 2021).

Santucci, V. L., J. S. Tweet, and T. B. Connors. 2018. The Paleontology Synthesis Project and establishing a framework for managing National Park Service paleontological resource archives and data. New Mexico Museum of Natural History and Science Bulletin 79:589–601. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2257152 (accessed November 23, 2021).

Szalay, F. S. 1976. Systematics of the Omomyidae (Tarsiiformes, Primates): taxonomy, phylogeny, and adaptations. Bulletin of the American Museum of Natural History 156(3). Available at: http://hdl.handle.net/2246/617 (accessed November 23, 2021).

Tarr, R. S. 1898. The bad lands of North Dakota. The Independent 50(2599):837–840. Available at: https://books.google.com/books?id=gJoeAQAAMAAJ&pg=PA837 (accessed November 23, 2021).

Tarr, R. S. 1900. The Bad Lands of North Dakota. Scientific American. Supplement 49(1254):20101–20102. Available at: https://books.google.com/books?id=YgE_AQAAMAAJ&pg=PA20101 (accessed November 23, 2021).

Trimble, D. E. 1990. The geologic story of the Great Plains. Theodore Roosevelt Nature and History Association, Medora, North Dakota.

Tweet, J. S., V. L. Santucci, and J. P. Kenworthy. 2011. Paleontological resource inventory and monitoring: Northern Great Plains Network. Natural Resource Technical Report NPS/NRPC/NRTR—2011/437. National Park Service, Fort Collins, Colorado.

Various. 1928. Boundaries of certain National Parks: hearings before the Committee on Public Lands and Surveys, United States Senate, Seventieth Congress, Second Session pursuant to S. Res. 237. A resolution to investigate the advisability of establishing certain additional National Parks and the proposed changes in, and boundary revisions of, certain other National Parks. Proposed Roosevelt and Kildeer National Parks, North Dakota, Part 1. July 14, 1928. United States Government Printing Office, Washington, D.C. Available at: https://books.google.com/books?id=grdFAQAAMAAJ (accessed November 23, 2021).

Wallick, B. P. 1984. Sedimentology of the Bullion Creek and Sentinel Butte Formations (Paleocene) in a part of southern McKenzie County, North Dakota. Thesis. University of North Dakota, Grand Forks, North Dakota. Available at: https://commons.und.edu/theses/311/ (accessed November 23, 2021).

West, R. M. 1973. New records of fossil mammals from the early Eocene Golden Valley Formation, North Dakota. Journal of Mammalogy 54(3):749–750.

Wheeler, O. D. 1895. Sketches of Wonderland. Chas. S. Fee, Northern Pacific Railroad, St. Paul, Minnesota. Available at: https://books.google.com/books?id=7xkVAAAAYAAJ (accessed November 23, 2021).

Whiting, E., and A. Hastings. 2020. Systematics and paleoecology of fossil lizards from the middle–late Paleocene Wannagan Creek fossil site in western North Dakota. Geological Society of America – Abstracts with Programs 52(5):paper 30-8.

Wilf, P., C. C. Labandeira, W. J. Kress, C. L. Staines, D. M. Windsor, A. L. Allen, and K. R. Johnson. 2000. Timing the radiations of leaf beetles: hispines on gingers from latest Cretaceous to recent. Science 289:291–294.

Winser, H. J. 1883. The great northwest: a guide-book and itinerary for the use of tourists and travelers over the lines of the Northern Pacific Railroad, the Oregon Railway and Navigation Company, and the Oregon and California Railroad. G. P. Putnam's Sons, New York, New York. Available at: https://books.google.com/books?id=cOk6AQAAIAAJ (accessed November 23, 2021).

Zhou, X., Z. Zeng, M. Belobraydic, and Y. Han. 2008. Geomechanical stability assessment of Williston Basin Formations for petroleum production and CO_2 sequestration. American Rock Mechanics Association, Alexandria, Virginia. AMRA 08-211.

Appendix A: Paleontological Species

The following table (Appendix Table A-1) documents the fossil species found at THRO in stratigraphic context, as reported in the literature, in museum collections, and through personal observations. The rows are organized systematically, placing taxa of the same broad groups together, with leading bold rows providing summaries of each group. The columns are organized by formation, which are presented in ascending order (oldest to youngest) left to right. The columns also include the group (first column), taxon (second column), and references (last column; included in "Literature Cited" above). If a taxon is present in a given formation at a locality that can be placed within THRO, that cell is marked "Y"; if there is some question about the formation or whether the locality is within THRO, the cell is marked "?". A null record is marked "–". Appendix Table A-2 lists fossil species found in equivalent strata outside of THRO boundaries, to document taxa that may be found in THRO with further investigation. This table is organized identically to Appendix Table A-1.

It is likely that some of the genera and species cited here are actually cases in which different authors identifying the same forms using different names. In addition, genera and species are frequently synonymized or transferred to other taxa. This publication is not intended to settle such questions; the rule of thumb is that the usage in the most recent publication is preferred, and any older usages are listed in the notes section following the tables. Exceptions to this "hands-off" policy include corrections of typographical errors. In some cases an author included a non-standard, obsolete, or otherwise unconventional usage that cannot be evaluated without further information; therefore, these records have been reproduced as originally presented.

Unit acronyms (after Biek and Gonzalez 2001; units not given acronyms in that work have been given acronyms following the same style):

Tbc = Bullion Creek Formation

Tsb = Sentinel Butte Formation

Tgv = Golden Valley Formation

Qco = Coleharbor Group

Qoa = Oahe Formation

Appendix Table A-1. Fossil taxa reported from THRO in stratigraphic context. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Plants	**Plants overall**	**Y**	**Y**	**Y**	**–**	**–**	**–**
	Azolla stanleyi	–	Y	–	–	–	Jain and Hall 1969; Hoffman and Stockey 1994
	Cercidiphyllum genetrix	–	Y	–	–	–	Fastovsky and McSweeney 1991
	Cercidiphyllum sp.	Y	Y	–	–	–	Fastovsky and McSweeney 1991; Hoganson and Campbell 1997; KellerLynn 2007
	Dacrydium sp.	–	Y	–	–	–	Coffin 1984
	Equisetum sp.	–	Y	–	–	–	Fastovsky and McSweeney 1991
	Metasequoia sp.	–	Y	–	–	–	Hoganson field notes
	Nyssidium arcticum	–	Y	–	–	–	South Unit Loop Road survey
	Platanus nobilis	–	Y	–	–	–	Fastovsky and McSweeney 1991
	Podocarpaceae undetermined	–	Y	–	–	–	THRO Paleo Catalog
	Podocarpaceae undetermined, second type	–	Y	–	–	–	Arct in Fastovsky and McSweeney 1991
	Porosia verrucosa	–	Y	–	–	–	South Unit Loop Road survey
	Reed impressions	–	Y	–	–	–	Hoganson field notes
	Sciadopitys sp.	–	Y	–	–	–	Berg and Brophy 1963
	Taxodiaceae undetermined	–	Y	–	–	–	Fastovsky and McSweeney 1991
	Fossil amber	–	Y	–	–	–	Hoganson field notes
	Undetermined fern fossils	–	Y	–	–	–	Hoganson field notes
	Undetermined petrified wood	Y	Y	–	Y	–	KellerLynn 2007; THRO Paleo Catalog
	Undetermined plant fossils (charcoal, debris, foliage, silicified peat, seeds, etc.)	Y	Y	Y	–	Y	Kuehn 1993; Hoganson field notes; Hoganson and Campbell 1997; Biek and Gonzalez 2001; South Unit Loop Road survey; THRO Paleo Catalog
Invertebrates	**Invertebrates overall**	**Y**	**Y**	**–**	**–**	**–**	**–**

Appendix Table A-1 (continued). Fossil taxa reported from THRO in stratigraphic context. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mollusca	Mollusca undetermined	Y	–	–	–	–	Hoganson field notes
Mollusca: Class Bivalvia (clams, oysters, etc.)	*Eupera missouriensis*	–	Y	–	–	–	Bickel 1976
	Plesielliptio sp.	–	Y	–	–	–	Fastovsky and McSweeney 1991; Hoganson and Campbell 1997
	Sphaerium sp.	–	Y	–	–	–	Hoganson and Campbell 1997
	"Mytilidae" undetermined[1]	–	Y	–	–	–	THRO Paleo Catalog
	Undetermined pill clams (potentially *Pisidium* or *Sphaerium*)	Y	Y	–	–	–	Hoganson field notes
	Unionidae or Unionacea undetermined	Y	Y	–	–	–	Fastovsky and McSweeney 1991; Hoganson field notes
	Veneridae undetermined[1]	–	Y	–	–	–	THRO Paleo Catalog
	Undetermined freshwater clams	Y	Y	–	–	–	Hoganson field notes
	Bivalvia undetermined	Y	Y	–	–	–	TRS20-019; include "brachiopods" of THRO 3079
Mollusca: Class Gastropoda (snails)	*Campeloma* sp.	Y	Y	–	–	–	Hoganson field notes; Hoganson and Campbell 1997
	Lioplacodes sp.	–	Y	–	–	–	Hoganson and Campbell 1997
	Lioplacodes?	–	Y	–	–	–	Hoganson field notes
	Viviparus sp.	–	Y	–	–	–	Hoganson and Campbell 1997
	Physidae undetermined	Y	–	–	–	–	Hoganson field notes
	Viviparidae undetermined	Y	Y	–	–	–	Hoganson field notes

[1] Mytilidae and Veneridae are primarily marine groups, so mistaken identity based on general similarity is possible. Hoganson (1994 field notes) noted that the THRO specimens identified as Mytilidae are freshwater clams. Unionids, freshwater mussels, can resemble saltwater mussels (including mytilids), and sphaeriids (small freshwater clams) can resemble tiny venerids (marine clams). In addition, under some classifications, sphaeriids are within a group Veneroidea.

Appendix Table A-1 (continued). Fossil taxa reported from THRO in stratigraphic context. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mollusca: Class Gastropoda (snails) (continued)	Gastropoda undetermined	Y	Y	–	–	–	Fastovsky and McSweeney 1991; THRO Paleo Catalog
Arthropoda: Class Insecta	Coleoptera undetermined	–	Y	–	–	–	Hoganson and Campbell 1997
Arthropoda: Class Ostracoda (seed shrimp)	Ostracoda undetermined	Y	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Ostracoda undetermined?	–	Y	–	–	–	Hoganson field notes
Vertebrates	**Vertebrates overall**	**Y**	**Y**	**–**	**Y**	**Y**	**–**
Osteichthyes (bony fish)	*Amia* sp.	Y	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Esox sp.	–	Y	–	–	–	TRS20-028
	Lepisosteus sp.	Y	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Osteichthyes undetermined	–	Y	–	–	–	Hoganson field notes
Amphibia: Order Urodela (salamanders)	*Piceoerpeton* sp.	–	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
Reptilia: Order Testudines (turtles)	*Plastomenus* sp	–	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Protochelydra sp.	Y	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Baenidae undetermined	–	Y	–	–	–	Hoganson field notes
	cf. Trionychoidea	–	Y	–	–	–	South Unit Loop Road survey
	Testudines undetermined	–	Y	–	–	–	Hoganson field notes; South Unit Loop Road survey
Reptilia: Order Choristodera (champsosaurs)	*Champsosaurus* sp.	Y	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	"*Simoedosaurus*" sp.	–	Y	–	–	–	Hoganson and Campbell 1997

Appendix Table A-1 (continued). Fossil taxa reported from THRO in stratigraphic context. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Reptilia: Order Crocodilia (crocodiles and alligators)	*Borealosuchus* sp.?	Y	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	"*Leidyosuchus gigas*"[2]	–	Y	–	–	–	THRO Paleo Catalog
	Alligatoroidea undetermined	–	Y	–	–	–	TRS20-011
	"Alligator"	–	Y	–	–	–	Hoganson and Campbell 1997
Aves	cf. Aves	–	Y	–	–	–	South Unit Loop Road survey
Mammalia	*Bison* sp.	–	–	–	Y	Y	THRO Paleo Catalog; Hoganson and Campbell 1997
	Phenacodus grangeri or *magnus*	–	Y	–	–	–	TRN21-048
	Plesiadapis sp.	–	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Titanoides sp.	–	Y	–	–	–	Hoganson and Campbell 1997; KellerLynn 2007
	Cimolesta undetermined	–	Y	–	–	–	TRN21-005
	Mammalia undetermined	–	Y	–	–	–	Hoganson and Campbell 1997
Ichnofossils (footprints, burrows, coprolites, etc.)	**Ichnofossils overall**	**Y**	**Y**	**–**	**–**	**–**	**–**
	Bird footprint	–	Y	–	–	–	TRN21-033
	Bird and/or insect damage to wood	–	Y	–	–	–	Hoganson and Campbell 1997
	Bite damage to turtle carapace	–	Y	–	–	–	Hoganson and Campbell 1997
	Coprolites	Y	Y	–	–	–	Hoganson field notes
	Worm burrows	Y	Y	–	–	–	TRN21-033, TRS21-037

[2] There is no such species; the specimen is identified as a crocodilian, so "*gigas*" is most likely an accidental introduction of the champsosaur species name.

Appendix Table A-2. Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Plants	**Plants overall**	**Y**	**Y**	**Y**	**–**	**–**	**–**
Lycopodiophyta: Isoetales (quillworts)	*Isoetites horridus*	Y	–	–	–	–	Erickson 1991
	Minerisporites mirabilis	Y	–	–	–	–	Melchior 1977; Melchior and Hall 1983
	Minerisporites sp. A	Y	–	–	–	–	Melchior and Hall 1983
	Minerisporites sp. B	Y	–	–	–	–	Melchior and Hall 1983
Polypodiophyta: Equisetales (horsetails)	*Equisetum magnum*	–	–	Y	–	–	Hickey 1977
	Equisetum sp	Y	–	–	–	–	Erickson 1991
Polypodiophyta: ferns	*Azolla stanleyi*	Y	–	–	–	–	Erickson 1991
	Dennstaedtia americana	–	Y	–	–	–	Brown 1962
	Dryopteris meeteetseana	–	Y	–	–	–	NDGS Paleo Catalog
	Onoclea hesperia	–	Y	Y	–	–	Hickey 1977; NDGS Paleo Catalog
	Osmunda macrophylla	–	–	Y	–	–	Hickey 1977
	Osmunda sp.	–	–	Y	–	–	Hickey 1977
	Woodwardia arctica	–	Y	–	–	–	Brown 1962
	Woodwardia gravida	–	–	Y	–	–	Hickey 1977
Cycadophyta (cycads)	*Zamia coloradensis*	Y	–	–	–	–	Erickson 1991
Ginkgophyta (ginkgoes)	*Ginkgo adiantoides*	Y	Y	–	–	–	Crane et al. 1990; Erickson 1991
	Ginkgo sp.	–	Y	–	–	–	NDGS Paleo Catalog
Pinophyta (conifers)	*Amentotaxus campbelli*	Y	–	–	–	–	Erickson 1991
	Glyptostrobus europaeus	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Glyptostrobus nordenskioldi	Y	–	–	–	–	Erickson 1991
	Metasequoia occidentalis	Y	Y	Y	–	–	Brown 1962; Hickey 1977; Erickson 1991
	Metasequoia sp.	–	Y	Y	–	–	Fennah 1968; NDGS Paleo Catalog
	cf. *Parataxodium* sp.	–	Y	–	–	–	Crane et al. 1990

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Pinophyta (conifers) (continued)	*Pinus peregrinus*	–	–	Y	–	–	Hickey 1977
	Taxodium olriki	Y	–	–	–	–	Erickson 1991
	Taxodium? sp.	–	Y	–	–	–	NDGS Paleo Catalog
	Thuites interruptus	–	–	Y	–	–	Hickey 1977
Magnoliophyta (flowering plants)	*Acer* sp.	–	–	Y	–	–	Fennah 1968; Hickey 1977
	Aesculus hickeyi	–	Y	–	–	–	NDGS Paleo Catalog
	Alismaphyllites grandifolius	Y	–	–	–	–	Erickson 1991
	Ampelopsis acerifolia	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Averrhoites affinis	–	Y	Y	–	–	Hickey 1977; Crane et al. 1990
	Beringiaphyllum cupanioides	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Cabomba inermis	Y	–	–	–	–	Erickson 1991
	Canariophyllum ampla	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Canticocculus sp.	–	Y	–	–	–	Crane et al. 1990
	Carpolithes arcticus	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Carpolithes lunatus	–	–	Y	–	–	Hickey 1977
	Carpolithes sp.	Y	–	–	–	–	Erickson 1991
	Carya antiquorum	Y	–	Y	–	–	Hickey 1977
	Castanea intermedia	Y	–	–	–	–	Erickson 1991
	Celtis newberryi	Y	–	–	–	–	Erickson 1991
	Celtis peracuminata	Y	–	–	–	–	Erickson 1991
	Cercidiphyllum arcticum	–	Y	–	–	–	Brown 1962
	Cercidiphyllum genetrix	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Cercidiphyllum sp.	–	–	Y	–	–	Fennah 1968
	Chaetoptelea microphylla	–	–	Y	–	–	Hickey 1977

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Magnoliophyta (flowering plants) (continued)	*Cissus marginata*	Y	–	–	–	–	Erickson 1991
	Cocculus flabella	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Cornus hyperborea	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Cornus sp.	–	Y	–	–	–	Crane et al. 1990
	Corylus acutertiaria	–	–	Y	–	–	Hickey 1977
	Corylus insignis cf. *acutertiaria*	Y	–	–	–	–	Erickson 1991
	Cyclocarya brownii	–	Y	–	–	–	Crane et al. 1990
	Cyclocarya sp.	–	Y	–	–	–	NDGS Paleo Catalog
	Cyperacites sp.	Y	–	–	–	–	Erickson 1991
	Davida antiqua	Y	–	–	–	–	NDGS Paleo Catalog
	Dicotylophyllum anomalum	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Dicotylophyllum hansonium	Y	–	–	–	–	Peppe and Hickey 2014
	Dicotylophyllum hebronensis	Y	–	–	–	–	Erickson 1991
	Dicotylophyllum mercerensis	–	–	Y	–	–	Hickey 1977
	Dicotylophyllum oblongatum	–	–	Y	–	–	Hickey 1977
	"*Ficus artocarpoides* cf. *Dictyophyllum*"	Y	–	–	–	–	Erickson 1991
	"*Ficus minutidens* cf. *Dictyophyllum*"	Y	–	–	–	–	Erickson 1991
	"*Ficus planicostata* cf. *Dictyophyllum*"	Y	–	–	–	–	Erickson 1991
	"*Ficus subtruncata* cf. *Dictyophyllum*"	Y	–	–	–	–	Erickson 1991
	Hamamelites inaequalis	Y	–	–	–	–	Erickson 1991
	Hydrangea antica	Y	–	–	–	–	Erickson 1991

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Magnoliophyta (flowering plants) (continued)	*Juglans taurina*	Y	–	–	–	–	Erickson 1991
	"Kalmia" *elliptica*	–	–	Y	–	–	Hickey 1977
	Laurophyllum perseanum	Y	–	–	–	–	Erickson 1991
	Magnolia berryi	Y	–	–	–	–	Erickson 1991
	Magnolia magnifolia	Y	–	–	–	–	Erickson 1991
	Magnolia regalis	Y	–	–	–	–	Erickson 1991
	Melastomites montanensis	Y	–	–	–	–	Erickson 1991
	Meliosma longifolia	–	–	Y	–	–	Hickey 1977
	Meliosma rostellata	–	Y	–	–	–	Crane et al. 1990
	Meliosma thriviensis	Y	–	–	–	–	Peppe and Hickey 2014
	Meliosma vandaelium	Y	–	–	–	–	Peppe and Hickey 2014
	Menispermites parvareolatus	–	–	Y	–	–	Hickey 1977
	Morus montanensis	Y	–	–	–	–	Erickson 1991
	Musophyllum complicatum	–	–	Y	–	–	Hickey 1977
	Nelumbium tenuifolium	Y	–	–	–	–	Erickson 1991
	Nordenskioldia borealis	–	Y	–	–	–	Brown 1962; Crane et al. 1990
	Nyssidium arcticum	–	Y	–	–	–	Crane et al. 1990
	Oreopanax dakotensis	Y	–	–	–	–	Erickson 2012
	Palaeocarpinus sp.	–	Y	–	–	–	Crane et al. 1990; NDGS Paleo Catalog
	Palaeophytocrene sp.	–	Y	–	–	–	Crane et al. 1990
	Paloreodoxites plicatus	Y	–	–	–	–	Erickson 1991
	Paranymphaea crassifolia	–	–	Y	–	–	Hickey 1977
	Parvileguminophyllum coloradensis	Y	–	–	–	–	Erickson 1991

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Magnoliophyta (flowering plants) (continued)	*Penosphyllum cordatum*	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Persea brossiana	Y	–	–	–	–	Erickson 1991
	Persites argutus	–	–	Y	–	–	Hickey 1977
	Planera microphylla	Y	–	–	–	–	Erickson 1991
	Platanus nobilis	Y	–	Y	–	–	Erickson 2012
	Platanus raynoldsii	Y	Y	–	–	–	Brown 1962
	Platanus sp.	–	–	Y	–	–	Fennah 1968
	Porosia verrucosa	Y	Y	Y	–	–	Hickey 1977; Crane et al. 1990; Erickson 1991
	Protophyllum semotum	–	–	Y	–	–	Hickey 1977
	Prunus perita	Y	–	–	–	–	Erickson 1991
	Psidium? sp.	–	Y	–	–	–	Crane et al. 1990
	Pterocarya hispida	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Quercus sullyi	Y	Y	–	–	–	Brown 1962; Erickson 1991
	Quercus sp.	–	–	Y	–	–	Fennah 1968
	Rhamnus cleburni	Y	–	–	–	–	Erickson 1991
	Sagittaria megasperma	–	Y	–	–	–	Brown 1962
	Salix aquilina	Y	–	–	–	–	Erickson 1991
	Sassafras thermale	Y	–	–	–	–	Erickson 1991
	Sparganium parvum	–	–	Y	–	–	Hickey 1977
	Sparganium stygium	Y	–	–	–	–	Erickson 2012
	Ternstromites paucimissouriensis	Y	–	–	–	–	Peppe and Hickey 2014
	“Trapa” *angulata*	–	–	Y	–	–	Hickey 1977
	Trochodendroides serrulata	–	–	Y	–	–	Hickey 1977

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Magnoliophyta (flowering plants) (continued)	*Trochodendron* sp.	Y	–	–	–	–	Erickson 2012
	Ulmus rhamnifolia	Y	–	–	–	–	Erickson 1991
	Viburnum antiquum	Y	–	Y	–	–	Hickey 1977; Erickson 1991
	Viburnum asperum	Y	Y	–	–	–	NDGS Paleo Catalog; Erickson 1991
	cf. *Viburnum antiquum*	–	Y	–	–	–	Crane et al. 1990
	Vitis olriki	Y	–	–	–	–	Erickson 1991
	Wardiaphyllum daturaefolium	–	–	Y	–	–	Hickey 1977
	Zelkova planeroides	Y	–	–	–	–	Erickson 1991
	Zingiberopsis isonervosa	–	–	Y	–	–	Wilf et al. 2000
	Ziziphus fibrillosus	Y	–	–	–	–	Erickson 1991
	Reproductive structures of undetermined angiosperm taxa (fruits, seeds, etc.)	–	Y	–	–	–	Crane et al. 1990
	Undetermined angiosperms	–	–	Y	–	–	Hickey 1977
Invertebrates	**Invertebrates overall**	**Y**	**Y**	**Y**	**–**	**–**	**–**
Mollusca: Class Bivalvia (clams, oysters, etc.)	*Bicorbula mactriformis*	Y	–	–	–	–	Delimata 1969
	Protelliptio (Plesielliptio) priscus	–	Y	–	–	–	Delimata 1969; Erickson 1983
	Rhabdotophorus senectus	Y	–	–	–	–	Delimata 1969
	Sphaerium sp.	–	Y	–	–	–	NDGS Paleo Catalog
	Sphaeriidae undetermined	–	Y	–	–	–	Kays 1999
	Unionidae undetermined	Y	Y	–	–	–	NDGS Paleo Catalog; Erickson 1991
Mollusca: Class Gastropoda (snails)	*Bellamya campaniformis*	Y	–	–	–	–	Bickel 1976
	Campeloma nebrascensis	Y	Y	–	–	–	Delimata 1969
	Campeloma sp.	–	Y	–	–	–	Delimata 1969
	Hydrobia sp.	Y	–	–	–	–	Erickson 2012

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mollusca: Class Gastropoda (snails) (continued)	*Lioplacodes limnaeformis*	Y	Y	–	–	–	Delimata 1969
Mollusca: Class Gastropoda (snails) (continued)	*Lioplacodes nebrascensis*	Y	–	–	–	–	Delimata 1969
Mollusca: Class Gastropoda (snails) (continued)	*Lioplacodes* sp.	Y	Y	–	–	–	Erickson 2012; NDGS Paleo Catalog
Mollusca: Class Gastropoda (snails) (continued)	*Lioplacodes tenuicarinata*	Y	Y	–	–	–	Delimata 1969
Mollusca: Class Gastropoda (snails) (continued)	*Viviparus retusus*	Y	–	–	–	–	Delimata 1969
Mollusca: Class Gastropoda (snails) (continued)	*Viviparus trochiformis*	Y	–	–	–	–	Delimata 1969
Mollusca: Class Gastropoda (snails) (continued)	*Viviparus* sp.	Y	Y	–	–	–	Delimata 1969; Erickson 2012
Arthropoda: Class Insecta	Caddisfly?	Y	–	–	–	–	Haire et al. 2018
Arthropoda: Class Insecta	Coleoptera undetermined	Y	Y	–	–	–	Kays 1999; Erickson 2012
Arthropoda: Class Insecta	*Cotradechites lithinus*	–	–	Y	–	–	Fennah 1968
Arthropoda: Class Insecta	Cyclorrhaphan fly puparium	Y	–	–	–	–	Haire et al. 2018
Arthropoda: Class Insecta	*Gomphaeschna schrankii*	Y	–	–	–	–	Lewis 1988
Arthropoda: Class Insecta	Lepidoptera undetermined	Y	–	–	–	–	Erickson 2012
Arthropoda: Class Insecta	Odonata undetermined	Y	–	–	–	–	Haire et al. 2018
Arthropoda: Class Insecta	*Trichopterodomus leonardi*	–	Y	–	–	–	Erickson 1983
Arthropoda: Class Ostracoda (seed shrimp)	*Candona* sp.	Y	Y	–	–	–	Gruber and Bickel 1973
Arthropoda: Class Ostracoda (seed shrimp)	*Cypridea* (*Bisulcocypridea*) *bisulcata*	Y	Y	–	–	–	Gruber and Bickel 1973
Arthropoda: Class Ostracoda (seed shrimp)	*Darwinula* cf. *D. stevensoni*	Y	Y	–	–	–	Gruber and Bickel 1973
Vertebrates	**Vertebrates overall**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
Chondrichthyes	*Myliobatis* sp.	Y	–	–	–	–	Erickson 2012
Osteichthyes	*Amia uintaensis*	–	–	Y	–	–	Estes 1988
Osteichthyes	*Atractosteus occidentalis*	–	–	Y	–	–	Estes 1988
Osteichthyes	*Cyclurus fragosus*	Y	–	Y	–	–	Estes 1988; Erickson 2012

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Osteichthyes (continued)	cf. *Eohiodon* sp.	Y	–	–	–	–	Erickson 2012
Osteichthyes (continued)	*Esox* cf. *E. tiemani*	Y	–	–	–	–	Erickson 2012
Osteichthyes (continued)	*Esox* sp.	–	Y	Y	–	–	Hoganson et al. 2011
Osteichthyes (continued)	*Joffrichthys symmetropterus*	Y	–	–	–	–	Erickson 2012
Osteichthyes (continued)	*Joffrichthys triangulpterus*	–	Y	–	–	–	Crane et al. 1990; Newbrey and Bozek 2000
Osteichthyes (continued)	*Kindleia* [*Stylomyleodon*] sp.	–	–	Y	–	–	Jenkins 1961; Jepsen 1963
Osteichthyes (continued)	*Lepisosteus* sp.	Y	Y	Y	–	–	Jepsen 1963; Hoganson and Campbell 1997; Erickson 2012
Osteichthyes (continued)	*Protamia* [*Pappichthys*] sp.	–	–	Y	–	–	Jenkins 1961; Jepsen 1963
Osteichthyes (continued)	Lepisosteidae undetermined	–	Y	–	–	–	NDGS Paleo Catalog
Osteichthyes (continued)	Teleostei undetermined	–	Y	Y	–	–	Estes 1988; Gomez et al. 2018
Amphibia: Order Urodela (salamanders)	*Batrachosauroides gotoi*	–	–	Y	–	–	Estes 1969, 1981, 1988
Amphibia: Order Urodela (salamanders)	*Batrachosauroides* sp.	–	–	Y	–	–	Jepsen 1963
Amphibia: Order Urodela (salamanders)	*Chrysotriton tiheni*	–	–	Y	–	–	Estes 1981, 1988
Amphibia: Order Urodela (salamanders)	*Piceoerpeton willwoodense*	Y	–	–	–	–	Erickson 2012
Amphibia: Order Urodela (salamanders)	*Scapherpeton* sp.	Y	–	–	–	–	Erickson 2012
Amphibia: Order Urodela (salamanders)	Ambystomatidae undetermined	–	–	Y	–	–	Jepsen 1963
Amphibia: Order Urodela (salamanders)	Salamandridae undetermined	Y	–	–	–	–	Erickson 2012
Amphibia: Order Urodela (salamanders)	Urodela undetermined	–	Y	–	–	–	Crane et al. 1990
Amphibia: Order Anura (frogs)	Anura undetermined	Y	–	Y	–	–	Jepsen 1963; Estes 1988; Erickson 2012
Reptilia	**Reptilia overall**	**Y**	**Y**	**Y**	**–**	**–**	**–**
Reptilia: Order Choristodera	*Champsosaurus gigas*	Y	Y	–	–	–	Erickson 1972, 2012
Reptilia: Order Choristodera	*Champsosaurus tenuis*	Y	–	–	–	–	Erickson 1981

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Reptilia: Order Choristodera (continued)	*Kosmodraco dakotensis*	Y	–	–	–	–	Erickson 1987, 2012
Reptilia: Order Testudines (turtles)	*Baptemys tricarinata*	–	–	Y	–	–	Estes 1988
	Echmatemys megaulax	–	–	Y	–	–	Jenkins 1961
	Echmatemys testudinea	–	–	Y	–	–	Estes 1988
	cf. *Echmatemys* sp.	–	–	Y	–	–	Jepsen 1963
	Hoplochelys sp.	–	–	Y	–	–	Jenkins 1961; Jepsen 1963
	Plastomenus sp.	Y	–	Y	–	–	Erickson 2012
	Protochelydra zangerli	Y	–	–	–	–	Erickson 1973, 2012
	Trionyx [*Plastomenus*] sp.	–	–	Y	–	–	Jenkins 1961; Jepsen 1963; Estes 1969
	Trionyx sp.	–	Y	–	–	–	Wallick 1984
	Trionyx/*Aspideretes*	Y	–	–	–	–	Erickson 2012
	Emydidae undetermined	Y	–	–	–	–	Erickson 2012
	Polycryptodira indet.	Y	–	–	–	–	Erickson 2012
	Trionychidae undetermined	–	Y	–	–	–	Kays 1999
Reptilia: Order Squamata (lizards, snakes, etc.)	*Coniophis precedens*	–	Y	–	–	–	Gomez et al. 2018
	Exostinus sp.	Y	–	–	–	–	Whiting and Hastings 2019
	“Gerrhonotus” sp.	Y	–	–	–	–	Whiting and Hastings 2019
	Peltosaurus sp.	–	–	Y	–	–	Jepsen 1963
	Provaranosaurus sp.	Y	–	–	–	–	Whiting and Hastings 2019
	Restes sp.	Y	–	–	–	–	Whiting and Hastings 2019
	Saniwa cf. S. ensidens	–	–	Y	–	–	Jepsen 1963
	cf. *Xestops* sp.	–	–	Y	–	–	Estes 1988
	Anguidae undetermined	–	–	Y	–	–	Jepsen 1963

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Reptilia: Order Squamata (lizards, snakes, etc.) (continued)	Glyptosaurinae undetermined	–	–	Y	–	–	Estes 1988
	Ophidia undetermined	Y	–	–	–	–	Erickson 2012
	Teiidae undetermined	–	Y	–	–	–	Gomez et al. 2018
	Varanidae undetermined	Y	–	–	–	–	Erickson 2012
Reptilia: Order Crocodilia (crocodiles, alligators, etc.)	cf. *Alligator* sp.	–	–	Y	–	–	Jepsen 1963
	Allognathosuchus sp.	–	–	Y	–	–	Jepsen 1963; Estes 1988
	Borealosuchus formidabilis	Y	–	–	–	–	Erickson 2012
	Borealosuchus sp.	Y	–	–	–	–	THRO Paleo Catalog
	Chrysochampsa mlynarskii	–	–	Y	–	–	Estes 1988
	Crocodylus sp.	–	–	Y	–	–	Jepsen 1963
	cf. *Procaimanoidea* sp.	–	–	Y	–	–	Jepsen 1963
	Wannaganosuchus brachymanus	Y	–	–	–	–	Erickson 2012
	Crocodylidae undetermined	–	–	Y	–	–	Estes 1988
Aves	*Dakotornis cooperi*	Y	–	–	–	–	Erickson 2012
	Presbyornis isoni	Y	–	–	–	–	Benson 1999; Erickson 2012
	Undetermined plover-like shorebird	Y	–	–	–	–	Erickson 2012
	Aves undetermined	–	–	Y	–	–	Jepsen 1963
Mammalia	**Mammalia overall**	**Y**	**Y**	**Y**	**Y**	**Y**	**–**
Mammalia: Order Metatheria	*Peradectes* sp.	Y	–	–	–	–	Erickson 2012
	Metatheria indet.	–	Y	–	–	–	Kihm and Hartman 1991
Mammalia: Order Multituberculata	*Catopsalis* sp.	Y	–	–	–	–	Erickson 2012
	Mimetodon silberlingi	–	Y	–	–	–	Kihm et al. 1993
	Neoplagiaulax hazeni	Y	–	–	–	–	Erickson 2012

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mammalia: Order Multituberculata (continued)	*Neoplagiaulax mckennai*	Y	–	–	–	–	Erickson 2012
	Neoplagiaulax cf. *N. hazeni*	–	Y	–	–	–	Kihm et al. 1993
	Neoplagiaulax cf. *N. hunteri*	Y	–	–	–	–	Erickson 2012
	Neoplagiaulax sp.	–	Y	–	–	–	Hoganson et al. 2011
	cf. *Parectypodus* sp.	–	–	Y	–	–	West 1973
	Prochetodon sp.	–	Y	–	–	–	Kihm et al. 1993
	Ptilodus kummae	–	Y	–	–	–	Holtzman 1978; Kihm et al. 1993
	Ptilodus wyomingensis	Y	–	–	–	–	Erickson 2012
	Ptilodus sp.	Y	–	–	–	–	Erickson 2012
	Multituberculata indet.	–	Y	–	–	–	Kihm and Hartman 1991
Mammalia: Order Cimolesta	cf. *Bisonalveus* sp.	–	Y	–	–	–	Kihm et al. 1993
	Coryphodon molestus	–	–	Y	–	–	West 1973
	Coryphodon cf. *C. molestus*	–	–	Y	–	–	Jepsen 1963; Lucas 1998
	Coryphodon sp.	–	–	Y	–	–	Jenkins 1961
	Labidolemur soricoides	Y	–	–	–	–	Erickson 2012
	Palaeoryctes sp.	–	Y	–	–	–	Hoganson et al. 2011
	cf. *Palaeoryctes* sp.	Y	–	–	–	–	Erickson 2012
	Palaeosinopa sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	Propalaeosinopa sp.	Y	Y	–	–	–	Holtzman 1978; Erickson 2012
	Titanoides primaevus	–	Y	–	–	–	Holtzman 1978; Hartman and Kihm 1991
	Titanoides sp.	Y	Y	–	–	–	Hartman and Kihm 1991; Erickson 2012; NDGS Paleo Catalog

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mammalia: Order "Condylarthra"	*Ectocion* sp.	Y	Y	–	–	–	Kihm et al. 1993; Erickson 2012
	Hyopsodus cf. *H. miticulus*	–	–	Y	–	–	Jepsen 1963; West 1973
	Hyopsodus loomisi	–	–	Y	–	–	Jepsen 1963; West 1973
	Hyopsodus sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	Phenacodus magnus	–	Y	–	–	–	Holtzman 1978
	Phenacodus sp.	Y	–	–	–	–	Erickson 2012
	Thryptacodon cf. *T. australis*	Y	–	–	–	–	Erickson 2012
	Thryptacodon sp.	Y	–	–	–	–	Erickson 2012
	Arctocyonidae indet.	–	Y	–	–	–	Holtzman 1978
Mammalia: Order Leptictida	*Adunator collinus*	–	Y	–	–	–	Holtzman 1978
	Adunator magnus	–	Y	–	–	–	Holtzman 1978
	Adunator minutus	–	Y	–	–	–	Kihm et al. 1993
	Leptictis sp.	Y	–	–	–	–	Erickson 2012
	Prodiacodon sp.	–	Y	–	–	–	Kihm et al. 1993
	Prodiacodon cf. *P. tauricinerei*	–	–	Y	–	–	Jepsen 1963; West 1973
Mammalia: Order Primates	*Anemorhysis tenuiculus*	–	–	Y	–	–	Szalay 1976
	Cantius sp.	–	–	Y	–	–	Lucas 1998
	Ignacius sp.	Y	–	–	–	–	Erickson 2012
	Microsyops angustidens	–	–	Y	–	–	West 1973
	Microsyops cf. *M. angustidens*	–	–	Y	–	–	Jepsen 1963
	Pelycodus cf. *P. ralstoni*	–	–	Y	–	–	Jepsen 1963; West 1973
	Pelycodus trigonodus	–	–	Y	–	–	Gingerich and Simons 1977
	Phenacolemur praecox	–	–	Y	–	–	West 1973
	cf. *Phenacolemur* sp.	Y	–	–	–	–	Erickson 2012

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mammalia: Order Primates (continued)	*Plesiadapis churchilli*	Y	–	–	–	–	Erickson 2012
	Plesiadapis sp.	Y	–	–	–	–	Hoganson and Campbell 1997; Erickson 2012
	Teilhardina crassidens	–	–	Y	–	–	Bown and Rose 1987
	Tetonoides cf. *T. pearcei*	–	–	Y	–	–	Jepsen 1963; West 1973
Mammalia: Order Artiodactyla	*Bison* sp.	–	–	–	–	Y	Clayton et al. 1976
	Camelus sp.[3]	–	–	–	–	Y	Hoganson 2010
	Cervus canadensis	–	–	–	–	Y	THRO Paleo Catalog
	Diacodexis? sp.	–	–	Y	–	–	Jepsen 1963; West 1973; Lucas 1998
Mammalia: Order Perissodactyla	*Equus* sp.	–	–	–	–	Y	Hoganson 2010
	Hyracotherium sp.	–	–	Y	–	–	Jepsen 1963; West 1973; Lucas 1998
	Homogalax aureus	–	–	Y	–	–	Gingerich 1991
	Homogalax cf. *H. protapirinus*	–	–	Y	–	–	Jepsen 1963; Radinsky 1963; West 1973
	Homogalax sp.	–	–	Y	–	–	Jenkins 1961
Mammalia: Order "Creodonta"	cf. *Didelphodus* sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	Sinopa sp	–	–	Y	–	–	Jepsen 1963; West 1973
Mammalia: Carnivoramorpha	*Didymictis* sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	Miacis sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	Protictis cf. *P. microlestes*	Y	–	–	–	–	Erickson 2012
	Viverravidae undetermined	–	–	Y	–	–	Jepsen 1963; West 1973
Mammalia: Order Carnivora	*Taxidea taxus*	–	–	–	–	Y	Baker 1967; Hoganson 2010

[3] Western Hemisphere camel genus *Camelops* instead?

Appendix Table A-2 (continued). Fossil taxa found in the same formations as THRO outside of the park. References are provided where appropriate.

Group	Taxon	Tbc	Tsb	Tgv	Qco	Qoa	References
Mammalia: Order Eulipotyphla	*Entomolestes* sp.	Y	–	–	–	–	Erickson 2012
	cf. *Entomolestes* sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	Leptacodon? sp.	–	–	Y	–	–	Jepsen 1963; West 1973
	cf. *Leptacodon* sp.	Y	–	–	–	–	Erickson 2012
Mammalia: Order Pilosa	*Megalonyx jeffersoni*	–	–	–	–	Y	Hoganson and McDonald 2007
Mammalia: Order Rodentia	*Lophiparamys* cf. *L. murinus*	–	–	Y	–	–	Jepsen 1963; West 1973
	Ondatra zibethicus	–	–	–	–	Y	Cvancara et al. 1971; Hoganson 2010
	Paramys cf. *P. excavatus*	–	–	Y	–	–	Jepsen 1963; West 1973
	Reithroparamys sp.	–	–	Y	–	–	West 1973
Mammalia: Order Proboscidea	*Mammut americanum*	–	–	–	–	Y	Hoganson 2010
	Mammuthus columbi	–	–	–	Y	–	Harington and Ashworth 1986
	Mammuthus primigenius	–	–	–	Y	–	Harington and Ashworth 1986
	Mammuthus sp.	–	–	–	–	Y	Hoganson 2010
	Elephantidae indet.	–	–	–	–	Y	Hay 1924
Mammalia: Order Palaeonodonta	*Palaeanodon*? sp.	–	–	Y	–	–	Jepsen 1963; West 1973
Ichnofossils (footprints, burrows, coprolites, etc.)	**Ichnofossils overall**	**Y**	**–**	**Y**	**–**	**–**	**–**
	Borealosuchipus hanksi	Y	–	–	–	–	Erickson 2005, 2012
	Cephaloleichnites strongi	–	–	Y	–	–	Wilf et al. 2000
	Dictyothylakos sp.	Y	–	–	–	–	Melchior and Hall 1983
	Kouphichnium pentapodus	Y	–	–	–	–	Erickson 2012
	Liticuniculatus erectus	Y	–	–	–	–	Melchior and Erickson 1979
	Oligichnos limnos	Y	–	–	–	–	Melchior and Erickson 1979

Taxonomic Notes

- Except for typographical errors, the floral lists in Erickson (1991), (1999), and (2012) are the same, and the 1991 list is used here. A more recent taxonomy of Paleocene High Plains plants can be found in Manchester (2014), but it is not employed here because it is not certain how the Wannagan Creek identifications would correlate in the absence of published descriptions. For vertebrates, the 2012 list is preferred.
- To conserve space in the tables, references in Appendix Table A-2 are limited to selected recent reports.
- For simplicity, the use of Salienta in Jepsen (1963) is treated as the same as Anura in other references.
- Golden Valley Formation taxa from Hickey (1977) included here are limited to those from the Bear Den Member.
- It is likely that there are redundancies in the identification of wood types from the park, i.e., some of the identifications refer to the same thing. However, it is not possible to be sure which examples are redundant.
- Different authors may employ question marks before or after a questionable genus.
- *Amia fragosa* = *Kindleia fragosa* = *Cyclurus fragosus*
- *Ampelopsia* = typo for *Ampelopsis*
- *Carpites verrucosus* = *Porosia verrucosa*
- *Credneria daturaefolia* (or *daturifolia*) = *Wardiaphyllum daturaefolia*
- *Cynodontomys angustidens* = *Microsyops angustidens*
- *Cypericites* = typo for *Cyperacites*
- *Dictyothylakos* of Wannagan Creek was interpreted by Melchior and Hall (1983) as possibly nets produced by spongilla fly larvae or trichopteran larvae; this taxon is now interpreted as annelid cocoon fossils (Manum et al. 1991).
- *Dictyophyllum* = typo for *Dicotylophyllum*, not the fern genus; it is unclear what is intended by the various "*Ficus* [species] cf. *Dictyophyllum* [sic]" taxa in Erickson (1991, 1999, 2012), so they have been left as originally written.
- *Dypoterus meeteeeana* = typo for *Dryopteris meeteetseana*
- *Leidyosuchus formidabilis* = *Borealosuchus formidabilis*
- *Minerisporites mirabilis* at Wannagan Creek represents spores of *Isoetites horridus* (Melchior 1977; Melchior and Hall 1983).
- *Minostites coloradensis* (Erickson 1991, 1999, 2012) appears in no other document; it seems most likely to be a typo for *Mimosites coloradensis* (now *Parvileguminophyllum coloradensis* Call and Dilcher 1994), otherwise known from the younger Eocene Green River Formation of Colorado and Utah.

- *Palaeictops tauricinerei* = *Prodiacodon tauricinerei*
- *Pensophyllum cordatum* = typo for *Penosphyllum cordatum*
- *Persia brossiana* = typo for *Persea brossiana* (may also be seen as *brosseana*)
- *Plesielliptio priscus* = *Protelliptio* (*Plesielliptio*) *priscus*
- *Polareodoxites plicatus* = typo for *Paloreodoxites plicatus*
- *Simoedosaurus dakotensis* = *Kosmodraco dakotensis*; instances of *Simoedosaurus* sp. are here referred to using quotation marks (e.g., "*Simoedosaurus*" sp.)
- Taxodiaceae is no longer considered a true family; most but not all members (e.g., *Sciadopitys*) are now assigned to Cupressaceae, the cypress family.
- *Viburnum cupanioides* = *Beringiaphyllum cupanioides*
- *Zizyphus* = deprecated alternate spelling of *Ziziphus*

Appendix B: Museum Collections Data

Appendix Table B-1 lists the specimens catalogued in THRO paleontological collections predating the present inventory. For clarity, the seemingly irrelevant attachment of "cubichnia" to a number of body fossils has been omitted. Identifications have been left as provided, which does result in some anachronisms (*Leidyosuchus*) and probable inaccuracies derived from comparisons to modern forms (a western box turtle in the White River Formation). Some specimens may not be fossils.

Appendix Table B-1. THRO paleontological collections predating 2020–2021 inventory.

Catalog #	Higher taxon	Taxon	Park unit	Geologic unit	Description
THRO 117	Mammalia	*Bison bison*	North	Alluvial fill	Bison molar
THRO 149	Plantae	Indeterminate	South	Sentinel Butte	Petrified wood (cypress?) Stump, recovered in thro before established
THRO 865	Plantae	Indeterminate	North	Sentinel Butte	Petrified wood chunk
THRO 1061	Plantae	Indeterminate	South	Sentinel Butte	Unidentified plant
THRO 1063	Plantae	*Equisetum*	Not stated	Bullion Creek	*Equisetum*
THRO 1064	Plantae	Indeterminate	Not stated	Bullion Creek	Unidentified
THRO 1185	Reptilia	*Leidyosuchus* sp.	Near South	Bullion Creek	Osteoderms, metatarsals, teeth, bone fragments, and snail shells, collected by Science Museum of Minnesota
THRO 1670	Reptilia	*Terrapene ornata*	Near South	White River	Fragmentary western box turtle
THRO 2145	Plantae	Indeterminate	Not THRO	Sentinel Butte	Four cut slabs of petrified wood
THRO 2190	Mammalia	*Cervus canadensis*	Not THRO	Not stated	Elk; given to the Rocky Mountain Elk Foundation
THRO 2428 (at MWAC)	Unknown	Unknown	Elkhorn Ranch	Unknown	Fossil or concretion that resembles a tobacco pipe bowl; appears to be a three-dimensional stem piece
THRO 2435 (at MWAC)	Plantae	Indeterminate	Elkhorn Ranch	Unknown	Sandstone piece with fossil leaf impression
THRO 3041	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plants

Appendix Table B-1 (continued). THRO paleontological collections predating 2020–2021 inventory.

Catalog #	Higher taxon	Taxon	Park unit	Geologic unit	Description
THRO 3059	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3060	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plants
THRO 3061	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3062	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plants
THRO 3063	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3064	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3065	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3066	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plants
THRO 3067	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3068	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3069	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3070	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3071	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plant
THRO 3072	Bivalvia	Mytiloida	Not stated	Sentinel Butte	Unidentified oysters
THRO 3073	Bivalvia	Veneroidea	Not stated	Sentinel Butte	Unidentified clam
THRO 3074	Bivalvia	Veneroidea	Not stated	Sentinel Butte	Unidentified clam
THRO 3076	Fish	Indeterminate	Not stated	Sentinel Butte	Unidentified fish
THRO 3077	Fish	Indeterminate	Not stated	Sentinel Butte	Unidentified fish
THRO 3078	Reptilia	Indeterminate	Not THRO	Sentinel Butte	Unidentified reptile
THRO 3079	“Brachiopoda”	Indeterminate	Not stated	Sentinel Butte	Unidentified bivalves
THRO 3190	Bivalvia	Veneroidea	Not stated	Sentinel Butte	Unidentified clam
THRO 3191	Bivalvia	Veneroidea	Not stated	Sentinel Butte	Unidentified clam
THRO 3192	Plantae	Indeterminate	Not stated	Sentinel Butte	Unidentified plants
THRO 3194	Mammalia	Indeterminate	Not stated	Sentinel Butte	Unidentified mammal
THRO 3195	Mammalia	Merycoidodontidae	Not THRO	White River	Unidentified oreodont

Appendix Table B-1 (continued). THRO paleontological collections predating 2020–2021 inventory.

Catalog #	Higher taxon	Taxon	Park unit	Geologic unit	Description
THRO 3196	Mammalia	Merycoidodontidae	Not THRO	White River	Unidentified oreodont
THRO 6290	Vertebrata	Indeterminate	South	Unknown	Petrified bone
THRO 6291	Vertebrata	Indeterminate	South	Unknown	Petrified tooth
THRO 6296	Reptilia	*Leidyosuchus gigas* [sic]	North	Sentinel Butte (by location)	108 fragments and teeth
THRO 6300	Animalia	Indeterminate	Not stated	Sentinel Butte	Unidentified bone or shell fragment
THRO 6301	Vertebrata	Indeterminate	South	Unknown	Possible petrified bone
THRO 6302	Plantae	Indeterminate	South	Sentinel Butte	Three pieces of clinker with fern-like fossils
THRO 6303	Vertebrata	Indeterminate	South	Unknown	Possible petrified bone
THRO 6304	Unknown	Indeterminate	South	Unknown	Rock with lines and spots on it [is this even a fossil?]
THRO 6305	Plantae	Indeterminate	South	Sentinel Butte	Two pieces of sandstone with a leaf part/counterpart
THRO 6306	Vertebrata	Indeterminate	South	Sentinel Butte	18 possible bone fragments
THRO 6307	Gastropoda	Indeterminate	South	Sentinel Butte	17 gastropod shells
THRO 6308	Bivalvia	Indeterminate	South	Sentinel Butte	Bivalve shell
THRO 6309	Bivalvia	Indeterminate	South	Sentinel Butte	Bivalve shell
THRO 6310	Bivalvia	Indeterminate	South	Sentinel Butte	Bivalve shell
THRO 7422	Plantae	Indeterminate	South	Unknown [listed as "Bullion Butte???"]	Petrified wood, unauthorized collection by visitor
THRO 7428	Plantae	Angiosperm	South	Unknown	Mudstone or claystone with broadleaf fossils and mold
THRO 7829	Reptilia	*Champsosaurus* sp.	South	Sentinel Butte	Partial skeleton
THRO 7830	Mammalia	*Titanoides* sp.	South	Sentinel Butte	Partial skeleton
THRO 7831	Reptilia	*Champsosaurus* sp.	South	Sentinel Butte	Partial skeleton

Appendix Tables B-2 and B-3 document the specimens collected during the 2020–2021 inventory. These specimens will be held at the North Dakota Heritage Center under THRO numbers. Taxonomic identifications are incomplete at this time, particularly for the 2021 material.

Appendix Table B-2. Material collected during 2020 inventory.

Locality	Higher taxon	Taxon	Park unit	Formation	Description
TRS20-006	Plantae	indet. fern	South	Sentinel Butte	Impression of fern leaf
TRS20-009	Reptilia	*Borealosuchus* sp.	South	Sentinel Butte	Osteoderm
TRS20-011	Vertebrata	indet. vertebrate	South	Sentinel Butte	Identifiable bone fragments
TRS20-011	Osteichthyes	indet. teleost	South	Sentinel Butte	Two pieces of a vertebrae that go together
TRS20-011	Reptilia	indet. turtle	South	Sentinel Butte	Fragments of shell
TRS20-011	Reptilia	Alligatoroid?	South	Sentinel Butte	Osteoderm
TRS20-012	Reptilia	indet. turtle	South	Sentinel Butte	Shell fragments, heavily weathered
TRS20-013	Osteichthyes	indet. teleost	South	Sentinel Butte	Vertebrae
TRS20-017	Reptilia	indet. turtle	South	Sentinel Butte	Shell fragments, partial limbs, partial vertebra
TRS20-018	Reptilia	indet. turtle	South	Sentinel Butte	Shell fragments
TRS20-020	Reptilia	indet. turtle?	South	Sentinel Butte	Shell fragments, bone fragments
TRS20-024	Osteichthyes	indet. teleost	South	Sentinel Butte	Tooth fragment
TRS20-025	Reptilia	indet. crocodilian	South	Sentinel Butte	Shed tooth
TRS20-026	Osteichthyes	indet. teleost	South	Sentinel Butte	Two different tooth types
TRS20-027	Reptilia	*Plastomenus* sp.	South	Sentinel Butte	Weathered parts of shell
TRS20-029	Reptilia	indet. crocodilian	South	Sentinel Butte	Fragments of crocodilian osteoderms
TRS20-030	Reptilia	*Plastomenus* sp.	South	Sentinel Butte	Carapace fragments
TRS20-032	Reptilia	indet. alligatoroid	South	Sentinel Butte	Osteoderm, float
TRS20-033	Vertebrata	indet. vertebrate	South	Sentinel Butte	Tooth fragment, float
TRS20-034	Reptilia	*Plastomenus* sp.	South	Sentinel Butte	Carapace fragments, float

Appendix Table B-2 (continued). Material collected during 2020 inventory.

Locality	Higher taxon	Taxon	Park unit	Formation	Description
TRS20-038	Osteichthyes	indet. teleost	South	Sentinel Butte	Vertebrae
TRS20-038	Mammalia	Indet. mammal	South	Sentinel Butte	Teeth, needs prep
TRS20-038	Vertebrata	indet. vertebrate	South	Sentinel Butte	Osteoderm (not croc or turtle)
TRS20-039	Osteichthyes	indet. teleost	South	Sentinel Butte	Vertebrae
TRS20-040	Osteichthyes	indet. teleost	South	Sentinel Butte	Vertebrae
TRS20-041	Reptilia	indet. reptile	South	Sentinel Butte	Bone fragments, possibly limb?
TRS20-042	Osteichthyes	indet. teleost	South	Sentinel Butte	Vertebra
TRN20-002	Reptilia	indet. crocodilian	South	Sentinel Butte	Osteoderms, bone fragments, digits, limb; friable
TRN20-002	Osteichthyes	indet. teleost	South	Sentinel Butte	Vertebrae

Appendix Table B-3. Material collected during 2021 inventory.

Locality	Formation	Park Unit	Collected	Quantity
TRS21-004	Sentinel Butte	South	Fish vertebrae and bone fragments	2
TRS21-005	Bullion Creek	South	Sample of microsite include vertebrae and a possible osteoderm/scale	1
TRS21-010	Sentinel Butte	South	Turtle shell, limb, and bone fragments	63
TRS21-011	Sentinel Butte	South	Turtle shell fragments	13
TRS21-012	Sentinel Butte	South	Turtle shell and bone fragments	10
TRS21-018	Bullion Creek	South	Choristodere centrum, limb fragments, rib fragments, and bone fragments	38
TRS21-024	Bullion Creek	South	Choristodere vertebral elements, pelvic fragments, limb fragments, and bone fragments	220
TRS21-025	Bullion Creek	South	Crocodilian osteoderms	2
TRS21-028	Bullion Creek	South	Indeterminate vertebrate bone fragments	43

Appendix Table B-3 (continued). Material collected during 2021 inventory.

Locality	Formation	Park Unit	Collected	Quantity
TRS21-029	Bullion Creek	South	Turtle shell fragments	3
TRS21-044	Bullion Creek	South	Choristodere vertebral, rib, limb, and bone fragments	322
TRS21-045	Bullion Creek	South	Crocodilian osteoderm, centrum, phalanges, and bone fragments	43
TRS21-046	Sentinel Butte	South	*Borealosuchus* osteoderm, limb fragment, and bone fragments	5
TRS21-052	Sentinel Butte	South	Fish bone fragments	5
TRS21-053	Sentinel Butte	South	Turtle shell, croc teeth, choristodere? tooth, limb elements, miscellaneous bone fragments	99
TRS21-055	Sentinel Butte	South	Fish (*Amia*) bones and scales	16
TRN21-005	Sentinel Butte	North	Turtle shell material and a cimolestid jaw fragment with premolar	989
TRN21-006	Sentinel Butte	North	Croc bones, osteoderms, teeth, vertebral elements, limb elements, rib fragments, skull bones; choristodere vertebra, *Piceoerpeton* centrum, turtle shell fragments	747
TRN21-006 area	Sentinel Butte	North	Croc osteoderms, teeth, phalanges, vertebral elements, ribs, and small bone fragments; choristodere vertebral elements	1008
TRN21-009	Sentinel Butte	North	Vertebra centrum	1
TRN21-010	Sentinel Butte	North	Bone fragments; possibly turtle shell among them	70
TRN21-012	Sentinel Butte	North	Bone fragments, turtle shell fragments, an ungual?, vertebral elements (choristodere, turtle?)	202
TRN21-013	Sentinel Butte	North	Croc bone elements, possibly skull elements, and 1 osteoderm	22
TRN21-015	Sentinel Butte	North	Turtle shell elements, choristodere centrum, a limb fragment, and some bone fragments	21

Appendix Table B-3 (continued). Material collected during 2021 inventory.

Locality	Formation	Park Unit	Collected	Quantity
TRN21-019	Sentinel Butte	North	Choristodere? centrum, croc tooth, turtle shell, phalanges, bone elements, and an osteoderm/scale	24
TRN21-022	Sentinel Butte	North	Osteoderm, fish scales, limb elements, soft-shelled turtle	36
TRN21-030	Sentinel Butte	North	Leaf impression	1
TRN21-033	Sentinel Butte	North	Trace fossils and a shell fragment	2
TRN21-035	Sentinel Butte	North	Choristodere vertebra, limb elements, skull, and bone fragments	526
TRN21-040	Sentinel Butte	North	Soft-shelled turtle shell fragments	6
TRN21-045	Sentinel Butte	North	Leaf impressions	2
TRN21-048	Sentinel Butte	North	Condylarth teeth	3
TRN21-053	Sentinel Butte	North	Crocodilian osteoderms, vertebra, and bone fragments, turtle shells, mammal dentary fragment	3 1-gallon bags

Finally, Paleo Solutions staff collected a small number of specimens during the survey of the South Unit Loop Road in September 2021, listed below (J. Munson and P. Murphey, pers. comm., November 2021) (Appendix Table B-4).

Appendix Table B-4. Specimens collected during the South Unit Loop Road survey, Paleo Solutions, September 2021 (all specimens from the Sentinel Butte Formation of the South Unit).

Catalog #	Locality	Higher taxon	Taxon	Description
THRO 7904	F210923-72-03	Reptilia	cf. Trionychoidea	Claw (ungual)
THRO 7905	F210923-72-03	Aves	cf. Aves	Proximal ulna
THRO 7906	F210923-72-03	Reptilia	cf. Reptilia	Proximal phalanx
THRO 7907	F210923-72-03	Reptilia	cf. Reptilia	Phalanx fragment
THRO 7908	F210923-72-03	Reptilia	Testudines (mixed)	Approximately 98 shell fragments
THRO 7909	F210923-72-03	Reptilia	cf. Trionychoidea	Distal lateral hypoplastral processes (3)
THRO 7911	F210923-80-01	Plantae	*Porosia verrucosa*	Seed or leaf of an aquatic angiosperm

Appendix Table B-4 (continued). Specimens collected during the South Unit Loop Road survey, Paleo Solutions, September 2021 (all specimens from the Sentinel Butte Formation of the South Unit).

Catalog #	Locality	Higher taxon	Taxon	Description
THRO 7912	F210923-80-01	Plantae	*Nyssidium arcticum*	Fruit (contains small winged seeds)
THRO 7913	F210923-80-01	Plantae	*Nyssidium arcticum*	Fruit (contains small winged seeds)
THRO 7914	F210923-80-01	Plantae	*Porosia verrucosa*	Seed or leaf of an aquatic angiosperm
THRO 7915	F210923-80-01	Plantae	*Porosia verrucosa*	Seed or leaf of an aquatic angiosperm
THRO 7916	F210923-80-01	Plantae	*Porosia verrucosa*	Seed or leaf of an aquatic angiosperm
THRO 7917	F210923-80-01	Plantae	*Porosia verrucosa*	Seed or leaf of an aquatic angiosperm
No number assigned at this time	F210923-80-01	Plantae	Angiospermopsida	Poorly preserved leaves and plant fragments (4)

Appendix C: Repository Contact Information

Contact information for institutions known to have collections from THRO are included below. Addresses, links, and email addresses to departments are included as available. This information is subject to change, particularly hyperlinks.

Bays Mountain Park & Planetarium
853 Bays Mountain Park Rd
Kingsport, TN 37660
(423) 229-9447
https://www.baysmountain.com/

Florida Museum of Natural History (FLMNH)
3215 Hull Rd
Gainesville, FL 32611
https://www.floridamuseum.ufl.edu/

Midwest Archeological Center (MWAC)
100 Centennial Mall North, Room 474
Lincoln, NE 68508
(402) 437-5392
https://www.nps.gov/orgs/1740/index.htm

North Dakota Geological Survey (NDGS)
(701) 328-8000
https://www.dmr.nd.gov/ndgs/

> Street address:
> 1016 E Calgary Ave
> Bismarck, ND 58503
>
> Mailing address:
> 600 E Boulevard Ave
> Bismarck, ND 58505
>
> Paleontology program and fossil collection:
> Clarence Johnsrud Paleontology Laboratory (North Dakota Heritage Center & State Museum)
> 612 E Boulevard Ave
> Bismarck, ND 58505
> (701) 328-2666
> https://www.dmr.nd.gov/dmr/paleontology

Peabody Museum of Natural History at Yale University (YPM)
P.O. Box 208118
170 Whitney Ave
New Haven, CT 06520
https://peabody.yale.edu/
peabody.collections@yale.edu

Smithsonian Institution, National Museum of Natural History (USNM)
Department of Paleobiology
P.O. Box 37012
NHB MRC 121
Washington, DC 20013
https://naturalhistory.si.edu/research/paleobiology
paleodept@si.edu

University of Kansas (KU)
KU Biodiversity Institute & Natural History Museum
1345 Jayhawk Blvd.
Lawrence, KS 66045
https://biodiversity.ku.edu/home
biodiversity@ku.edu

Appendix D: Paleontological Resource Law and Policy

The following material is reproduced in large part from Henkel et al. (2015); see also Kottkamp et al. (2020):

In March 2009, the Paleontological Resources Preservation Act (PRPA) (16 USC 460aaa) was signed into law (Public Law 111–11). This act defines paleontological resources as

> *…any fossilized remains, traces, or imprints of organisms, preserved in or on the [E]arth's crust, that are of paleontological interest and that provide information about the history of life on [E]arth.*

The law stipulates that the Secretary of the Interior should manage and protect paleontological resources using scientific principles. The Secretary should also develop plans for

> *…inventory, monitoring, and the scientific and educational use of paleontological resources.*

Paleontological resources are considered park resources and values that are subject to the "no impairment" standard in the National Park Service Organic Act (1916). In addition to the Organic Act, PRPA will serve as a primary authority for the management, protection and interpretation of paleontological resources. The proper management and preservation of these non-renewable resources should be considered by park resource managers whether or not fossil resources are specifically identified in the park's enabling legislation.

The Paleontological Resources Management section of NPS Reference Manual 77 provides guidance on the implementation and continuation of paleontological resource management programs. Administrative options include those listed below and a park management program will probably incorporate multiple options depending on specific circumstances:

- **No action**—no action would be taken to collect the fossils as they erode from the strata. The fossils would be left to erode naturally and over time crumble away, or possibly be vandalized by visitors, either intentionally or unintentionally. This is the least preferable plan of action of those listed here.
- **Surveys—**will be set up to document potential fossil localities. All sites will be documented with the use of GPS and will be entered into the park GIS database. Associated stratigraphic and depositional environment information will be collected for each locality. A preliminary faunal list will be developed. Any evidence of poaching activity will be recorded. Rates of erosion will be estimated for the site and a monitoring schedule will be developed based upon this information. A NPS Paleontological Locality Database Form will also be completed for each locality. A standard version of this form will be provided by the Paleontology Program of the Geologic Resources Division upon request and can be modified to account for local conditions and needs.
- **Monitoring**—fossil-rich areas would be examined periodically to determine if conditions have changed to such an extent that additional management actions are warranted. Photographic records should be kept so that changes can be more easily ascertained.

- **Cyclic prospecting**—areas of high erosion which also have a high potential for producing significant specimens would be examined periodically for new sites. The periodicity of such cyclic prospecting will depend on locality-specific characteristics such as rates of sediment erosion, abundance or rarity of fossils, and proximity to visitor use areas.
- **Stabilization and reburial**—significant specimens which cannot be immediately collected may be stabilized using appropriate consolidants and reburied. Reburial slows down but does not stop the destruction of a fossil by erosion. Therefore, this method would be used only as an interim and temporary stop-gap measure. In some situations, stabilization of a locality may require the consideration of vegetation. For example, roots can destroy in situ fossils, but can also protect against slope erosion, while plant growth can effectively obscure localities, which can be positive or negative depending on how park staff want to manage a locality.
- **Shelter construction**—it may be appropriate to exhibit certain fossil sites or specimens in situ, which would require the construction of protective shelters to protect them from the natural forces of weathering and erosion. The use of shelters draws attention to the fossils and increases the risk of vandalism or theft, but also provides opportunities for interpretation and education.
- **Excavation**—partial or complete removal of any or all fossils present on the surface and potentially the removal of specimens still beneath the surface which have not been exposed by erosion.
- **Closure**—the area containing fossils may be temporarily or permanently closed to the public to protect the fossil resources. Fossil-rich areas may be closed to the public unless accompanied by an interpretive ranger on a guided hike.
- **Patrols**—may be increased in areas of known fossil resources. Patrols can prevent and/or reduce theft and vandalism. The scientific community and the public expect the NPS to protect its paleontological resources from vandalism and theft. In some situations a volunteer site stewardship program may be appropriate (for example the “Paleo Protectors” at Chesapeake & Ohio Canal National Historical Park).
- **Alarm systems/electronic surveillance**—seismic monitoring systems can be installed to alert rangers of disturbances to sensitive paleontological sites. Once the alarm is engaged, a ranger can be dispatched to investigate. Motion-activated cameras may also be mounted to visually document human activity in areas of vulnerable paleontological sites.

National Park Service Management Policies (2006; Section 4.8.2.1) also require that paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. In 2010, the National Park Service established National Fossil Day as a celebration and partnership organized to promote public awareness and stewardship of fossils, as well as to foster a greater appreciation of their scientific and educational value (https://www.nps.gov/subjects/fossilday/index.htm). National Fossil Day occurs annually on Wednesday of the second full week in each October in conjunction with Earth Science Week.

Related Laws, Legislation, and Management Guidelines

National Park Service Organic Act

The NPS Organic Act directs the NPS to manage units

> *…to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner as will leave them unimpaired for the enjoyment of future generations.* (16 U.S.C. § 1).

Congress reiterated this mandate in the Redwood National Park Expansion Act of 1978 by stating that the NPS must conduct its actions in a manner that will ensure no

> *…derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress.* (16 U.S.C. § 1 a-1).

The Organic Act prohibits actions that permanently impair park resources unless a law directly and specifically allows for the acts. An action constitutes an impairment when its impacts

> *…harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources and values.* (Management Policies 2006 1.4.3).

Paleontological Resources Protection Act (P.L. 111-011, Omnibus Public Land Management Act of 2009, Subtitle D)

Section 6302 states

> *The Secretary (of the Interior) shall manage and protect paleontological resources on Federal land using scientific principles and expertise. The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources, in accordance with applicable agency laws, regulations, and policies. These plans shall emphasize interagency coordination and collaborative efforts where possible with non-Federal partners, the scientific community, and the general public.*

Federal Cave Resources Protection Act of 1988 (16 USC 4301)

This law provides a legal authority for the protection of all cave resources on NPS and other federal lands. The definition for "Cave Resource" in Section 4302 states

> *Cave resources include any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems.*

NPS Management Policies 2006

NPS Management Policies 2006 include direction for preserving and protecting cultural resources, natural resources, processes, systems, and values (National Park Service 2006). It is the goal of the NPS to avoid or minimize potential impacts to resources to the greatest extent practicable consistent with the management policies. The following is taken from section 4.8.2.1 of the NPS Management Policies 2006, "Paleontological Resources and their contexts":

> *Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.*
>
> *The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.*
>
> *Parks will exchange fossil specimens only with other museums and public institutions that are dedicated to the preservation and interpretation of natural heritage and qualified to manage museum collections. Fossils to be deaccessioned in an exchange must fall outside the park's scope of collection statement. Systematically collected fossils in an NPS museum collection in compliance with 36 CFR 2.5 cannot be outside the scope of collection statement. Exchanges must follow deaccession procedures in the Museum Handbook, Part II, chapter 6.*
>
> *The sale of original paleontological specimens is prohibited in parks.*
>
> *The Service generally will avoid purchasing fossil specimens. Casts or replicas should be acquired instead. A park may purchase fossil specimens for the park museum collection only after making a written determination that*
>
> - *The specimens are scientifically significant and accompanied by detailed locality data and pertinent contextual data;*
> - *The specimens were legally removed from their site of origin, and all transfers of ownership have been legal;*

- *The preparation of the specimens meets professional standards;*
- *The alternatives for making these specimens available to science and the public are unlikely;*
- *Acquisition is consistent with the park's enabling legislation and scope of collection statement, and acquisition will ensure the specimens' availability in perpetuity for public education and scientific research.*

All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

(See Natural Resource Information 4.1.2; Studies and Collections 4.2; Independent Research 5.1.2; Artifacts and Specimens 10.2.4.6. Also see 36 CFR 2.5.)

NPS Director's Order-77, Paleontological Resources Management

DO-77 describes fossils as non-renewable resources and identifies the two major types: body fossils and trace fossils. It describes the need for managers to identify potential paleontological resources using literature and collection surveys, identify areas with potential for significant paleontological resources, and conduct paleontological surveys (inventory). It also describes appropriate actions for managing paleontological resources including: no action, monitoring, cyclic prospecting, stabilization and reburial, construction of protective structures, excavation, area closures, patrols, and the need to maintain confidentiality of sensitive location information.

Excerpt from Clites and Santucci (2012):

Monitoring

An important aspect of paleontological resource management is establishing a long-term paleontological resource monitoring program. National Park Service paleontological resource monitoring strategies were developed by Santucci et al. (2009). The park's monitoring program should incorporate the measurement and evaluation of the factors stated below.

Climatological Data Assessments

These assessments include measurements of factors such as annual and storm precipitation, freeze/thaw index (number of 24-hour periods per year where temperature fluctuates above and below 32 degrees Fahrenheit), relative humidity, and peak hourly wind speeds.

Rates of Erosion Studies

These studies require evaluation of lithology, slope degree, percent vegetation cover, and rates of denudation around established benchmarks. If a park does not have this information, there may be opportunities to set up joint projects, because erosion affects more than just paleontological resources.

Assessment of Human Activities, Behaviors, and Other Variables

These assessments involve determining access/proximity of paleontological resources to visitor use areas, annual visitor use, documented cases of theft/vandalism, commercial market value of the fossils, and amount of published material on the fossils.

Condition Assessment and Cyclic Prospecting

These monitoring methods entail visits to the locality to observe physical changes in the rocks and fossils, including the number of specimens lost and gained at the surface exposure. Paleontological prospecting would be especially beneficial during construction projects or road repair.

Periodic Photographic Monitoring

Maintaining photographic archives and continuing to photo-document fossil localities from established photo-points enables visual comparison of long-term changes in site variables.

Appendix E: Paleontological Locality Data

Appendix Tables E-1 and E-2 provide details on the localities documented during the 1994–1996 survey. Appendix Table E-3 provides details on the localities documented during the 2020–2021 inventory.

Appendix Table E-1. South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS1	Sentinel Butte	Freshwater snails, fish, turtle, croc	–
TRS2	Sentinel Butte	Freshwater clams/snails	–
TRS3	Sentinel Butte	None	In situ petrified stumps
TRS4	Sentinel Butte	Freshwater clams/snails	–
TRS5	Sentinel Butte	Freshwater clams	–
TRS6	Sentinel Butte	Freshwater clams	–
TRS7	Sentinel Butte	Freshwater clams/snails	–
TRS8	Sentinel Butte	Freshwater clams/snails	–
TRS9	Sentinel Butte	Freshwater clams/snails	–
TRS10	Sentinel Butte	Freshwater clams/snails, gator osteoderms	–
TRS11	Sentinel Butte	Freshwater clams	–
TRS12	Sentinel Butte	Freshwater clams, turtle fragments	–
TRS13	Sentinel Butte	Freshwater clams/snails, part turtle carapace, croc caudal	–
TRS14	Sentinel Butte	Freshwater clams/snails, croc tooth	–
TRS15	Sentinel Butte	Freshwater clams/snails	–
TRS16	Sentinel Butte	Freshwater clams/snails	–
TRS17	Sentinel Butte	Freshwater clams/snails	–
TRS18	Sentinel Butte	Freshwater clams	–
TRS19	Sentinel Butte	Freshwater clams/snails	–
TRS20	Sentinel Butte	Leaf impressions (*Metasequoia*?)	–
TRS21	Sentinel Butte	Freshwater clams/snails	–
TRS22	Sentinel Butte	Freshwater clams/snails	–
TRS23	Sentinel Butte	Freshwater clams/snails, turtle/gator fragments	–
TRS24	Sentinel Butte	Freshwater clams/snails	–
TRS25	Sentinel Butte	Freshwater clams	–
TRS26	Sentinel Butte	Freshwater clams/snails	–
TRS27	Sentinel Butte	Freshwater clams	–
TRS28	Sentinel Butte	None	Freshwater clams

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS29	Sentinel Butte	Freshwater snails	–
TRS30	Sentinel Butte	None	Freshwater clams
TRS31	Sentinel Butte	None	In situ petrified stumps
TRS32	Sentinel Butte	Seeds	Leaves, katsura seeds
TRS33	Sentinel Butte	None	Freshwater clams
TRS34	Sentinel Butte	Freshwater clams/snails	–
TRS35	Sentinel Butte	None	Freshwater clams
TRS36	Sentinel Butte	Freshwater snail/ostracode	–
TRS37	Sentinel Butte	Freshwater clams	–
TRS38	Sentinel Butte	Freshwater clams/snails	–
TRS39	Sentinel Butte	None	In situ petrified stumps
TRS40	Sentinel Butte	Freshwater clams/snails/ostracodes	–
TRS41	Sentinel Butte	Leaf fossils	–
TRS42	Sentinel Butte	None	Freshwater clams
TRS43	Sentinel Butte	None	Freshwater clams
TRS44	Sentinel Butte	Silicified peat	–
TRS45	Sentinel Butte	None	Freshwater clams
TRS46	Sentinel Butte	None	In situ petrified stumps
TRS47	Sentinel Butte	None	Freshwater clams
TRS48	Sentinel Butte	Freshwater clams/snails	–
TRS49	Sentinel Butte	None	In situ petrified stumps
TRS50	Sentinel Butte	Freshwater clams	–
TRS51	Sentinel Butte	None	Silicified peat bed
TRS52	Sentinel Butte	None	In situ petrified stumps
TRS53	Sentinel Butte	None	Silicified peat bed
TRS54	Sentinel Butte	None	Petrified log
TRS55	Sentinel Butte	None	Freshwater clams
TRS56	Sentinel Butte	None	In situ petrified stumps
TRS57	Sentinel Butte	None	Silicified peat bed
TRS58	Sentinel Butte	None	In situ petrified stumps
TRS59	Sentinel Butte	Leaf fossils	–
TRS60	Sentinel Butte	Plant/leaf fossils	–
TRS61	Sentinel Butte	None	In situ petrified stumps
TRS62	Sentinel Butte	Freshwater clams/snails	–
TRS63	Sentinel Butte	None	Freshwater clams

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS64	Sentinel Butte	Freshwater clam and turtle shell fragments	–
TRS65	Sentinel Butte	Freshwater clams/snails, large fish bone	–
TRS66	Sentinel Butte	None	Freshwater clams
TRS67	Sentinel Butte	Freshwater clams/snails, turtle shell fragments, choristodere rib fragments	–
TRS67	Sentinel Butte	Trionychid fragments	–
TRS68	Sentinel Butte	None	Freshwater clams
TRS69	Sentinel Butte	None	In situ petrified stumps
TRS70	Sentinel Butte	Fish vertebra	–
TRS71	Sentinel Butte	None	Petrified stumps
TRS72	Sentinel Butte	None	Freshwater clams
TRS73	Sentinel Butte	None	Freshwater clams
TRS74	Sentinel Butte	None	In situ petrified stumps
TRS75	Sentinel Butte	None	In situ petrified stumps
TRS76	Bullion Creek	None	Freshwater snails
TRS77	Bullion Creek	None	Freshwater snails
TRS78	Bullion Creek	None	Freshwater snails
TRS79	Bullion Creek	Freshwater clams/snails	–
TRS80	Bullion Creek	Freshwater clams/snails	–
TRS81	Bullion Creek	Freshwater clams/snails	–
TRS82	Bullion Creek	Freshwater snails	–
TRS83	Bullion Creek	None	Freshwater snails
TRS84	Bullion Creek	None	Freshwater snails
TRS85	Bullion Creek	None	Freshwater snails
TRS86	Bullion Creek	None	Freshwater snails
TRS87	Bullion Creek	Freshwater snails	–
TRS88	Bullion Creek	None	Freshwater snails
TRS89	Bullion Creek	None	Freshwater clams/snails
TRS90	Bullion Creek	Freshwater snails/clams, ostracodes, turtles, choristoderes, crocs	Leaves also observed just above
TRS91	Bullion Creek	None	Freshwater clams/snails
TRS92	Bullion Creek	None	Freshwater snails
TRS93	Bullion Creek	Freshwater snails	–
TRS94	Bullion Creek	Leaf fossils	–
TRS95	Bullion Creek	None	Freshwater snails
TRS96	Bullion Creek	Freshwater clams/snails	–

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS97	Bullion Creek	None	Shell hash, freshwater clams/snails
TRS98	Bullion Creek	None	Freshwater clams/snails
TRS99	Bullion Creek	Freshwater clams/snails	–
TRS100	Bullion Creek	None	Freshwater snails
TRS101	Bullion Creek	Freshwater clams/snails	–
TRS102	Bullion Creek	Choristodere	–
TRS102	Bullion Creek	Choristodere	Some still in rock, plant debris also at this loc
TRS103	Bullion Creek	None	Freshwater snails
TRS104	Bullion Creek	None	Freshwater clams/snails
TRS105	Sentinel Butte	Turtle shell fragment, choristodere rib fragment	Also freshwater clams
TRS106	Sentinel Butte	Freshwater clams	–
TRS107	Sentinel Butte	None	Freshwater clams
TRS108	Sentinel Butte	None	Freshwater clams
TRS109	Sentinel Butte	Freshwater clams/snails	–
TRS110	Sentinel Butte	None	Freshwater clams
TRS111	Sentinel Butte	None	Freshwater clams
TRS112	Sentinel Butte	Freshwater snails	–
TRS113	Sentinel Butte	Freshwater clams/snails	–
TRS114	Sentinel Butte	Freshwater clams/snails	–
TRS115	Sentinel Butte	None	In situ petrified stumps
TRS116	Sentinel Butte	None	Freshwater clams
TRS117	Sentinel Butte	Silicified peat w/seeds	–
TRS118	Sentinel Butte	Leaf fossils	–
TRS119	Sentinel Butte	Freshwater clams/snails	–
TRS120	Sentinel Butte	Freshwater snails	Freshwater clams
TRS121	Sentinel Butte	None	Freshwater clams/snails
TRS122	Sentinel Butte	Freshwater clams/snails	–
TRS123	Sentinel Butte	None	Freshwater clams
TRS124	Sentinel Butte	None	Freshwater clams/snails
TRS125	Sentinel Butte	Freshwater clams/snails	–
TRS126	Sentinel Butte	None	Freshwater clams/snails
TRS127	Sentinel Butte	Freshwater clams/snails/ostracodes, leaf fossils	–
TRS128	Sentinel Butte	None	Freshwater clams/snails

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS129	Sentinel Butte	None	Petrified logs
TRS130	Sentinel Butte	Freshwater clams/snails, croc bones	–
TRS131	Sentinel Butte	Freshwater clams/snails	–
TRS132	Sentinel Butte	Freshwater clams/snails	–
TRS133	Quaternary	None	Bison skull, Holocene alluvium
TRS134	Sentinel Butte	None	Freshwater clams/snails
TRS135	Sentinel Butte	None	Freshwater clams/snails
TRS136	Sentinel Butte	None	Freshwater clams/snails
TRS137	Sentinel Butte	Freshwater clams/snails	–
TRS138	Sentinel Butte	Freshwater clams/snails	–
TRS139	Sentinel Butte	Freshwater clams/snails	–
TRS140	Sentinel Butte	None	In situ petrified stump
TRS141	Sentinel Butte	Freshwater snails, fish bone	Freshwater clams
TRS142	Sentinel Butte	Freshwater clams/snails	–
TRS143	Sentinel Butte	None	Freshwater clams/snails
TRS144	Sentinel Butte	Coprolite	–
TRS145	Sentinel Butte	None	Freshwater clams/snails
TRS146	Sentinel Butte	Salamander vertebrae	Coprolite; freshwater clams/snails below
TRS147	Sentinel Butte	None	Freshwater clams
TRS148	Sentinel Butte	None	Freshwater clams
TRS149	Sentinel Butte	None	Freshwater clams/snails
TRS150	Sentinel Butte	None	Freshwater clams
TRS151	Sentinel Butte	None	Freshwater clams
TRS152	Sentinel Butte	Freshwater clams, fern fossils	–
TRS153	Sentinel Butte	Trionychid fragments	Also float w/freshwater clams/snails
TRS154	Sentinel Butte	None	Freshwater clams
TRS155	Sentinel Butte	Freshwater clams/snails, leaf fossils	–
TRS156	Sentinel Butte	None	Freshwater clams/snails
TRS157	Sentinel Butte	None	Freshwater clams
TRS158	Sentinel Butte	Freshwater clams/snails	–
TRS159	Sentinel Butte	Freshwater clams/snails	–
TRS160	Sentinel Butte	None	Freshwater clams
TRS161	Sentinel Butte	None	Plant fossils, mostly twigs and roots
TRS162	Sentinel Butte	None	Freshwater clams/snails

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS163	Bullion Creek	None	Freshwater clams/snails
TRS164	Bullion Creek	None	Freshwater snails
TRS165	Bullion Creek	None	Freshwater clams/snails
TRS166	Bullion Creek	None	Freshwater clams/snails
TRS167	Bullion Creek	None	Freshwater snails
TRS168	Bullion Creek	Freshwater snails	Also freshwater clams
TRS169	Bullion Creek	None	Freshwater clams/snails
TRS170	Bullion Creek	None	Freshwater clams/snails
TRS171	Bullion Creek	Freshwater clams/snails	–
TRS172	Bullion Creek	Freshwater snails	–
TRS173	Bullion Creek	Freshwater clams/snails/ostracodes	–
TRS174	Bullion Creek	None	Freshwater clams
TRS175	Bullion Creek	Freshwater snails	–
TRS176	Bullion Creek	Freshwater clams	–
TRS177	Bullion Creek	None	Freshwater snails
TRS178	Bullion Creek	None	Freshwater snails
TRS179	Bullion Creek	None	Freshwater clams/snails
TRS180	Bullion Creek	Freshwater clams	–
TRS181	Bullion Creek	Snails, plant debris	–
TRS182	Bullion Creek	None	Freshwater snails
TRS183	Bullion Creek	None	Freshwater snails
TRS184	Bullion Creek	None	Freshwater snails
TRS185	Bullion Creek	None	Freshwater clams
TRS186	Bullion Creek	None	Freshwater clams
TRS187	Bullion Creek	Freshwater snails	–
TRS188	Bullion Creek	None	Mollusk shell frags
TRS189	Bullion Creek	None	Mollusk shell frags
TRS190	Bullion Creek	None	Freshwater clams/snails
TRS191	Sentinel Butte	None	Freshwater clams/snails
TRS192	Bullion Creek	None	Freshwater snails
TRS193	Bullion Creek	None	Freshwater clams/snails
TRS194	Bullion Creek	None	Freshwater clams/snails
TRS195	Bullion Creek	None	Freshwater clams/snails
TRS196	Bullion Creek	None	Freshwater clams/snails
TRS197	Bullion Creek	None	Freshwater clams
TRS198	Bullion Creek	None	Freshwater clams

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS199	Bullion Creek	Freshwater snails	–
TRS200	Bullion Creek	None	Freshwater clams/snails
TRS201	Bullion Creek	Freshwater clams/snails, ostracodes, coprolites	–
TRS202	Bullion Creek	None	Freshwater snails
TRS203	Bullion Creek	None	Freshwater clams
TRS204	Bullion Creek	None	Freshwater clams
TRS205	Bullion Creek	None	Freshwater clams/snails
TRS206	Bullion Creek	None	Leaf fossils
TRS207	Bullion Creek	Freshwater clams/snails	–
TRS208	Bullion Creek	Freshwater clams/snails/ostracodes	–
TRS209	Bullion Creek	None	Freshwater clams/snails
TRS210	Bullion Creek	Freshwater snails	–
TRS211	Bullion Creek	None	In situ petrified stumps
TRS212	Sentinel Butte	None	In situ petrified tree w/evidence of bird pecking
TRS213	Sentinel Butte	None	Freshwater clams
TRS214	Sentinel Butte	None	Freshwater clams/snails
TRS215	Sentinel Butte	None	Freshwater clams
TRS216	Sentinel Butte	None	Freshwater clams
TRS217	Sentinel Butte	None	Freshwater clams
TRS218	Sentinel Butte	None	Freshwater clams
TRS219	Sentinel Butte	None	Petrified log
TRS220	Sentinel Butte	None	Freshwater clams
TRS221	Sentinel Butte	Freshwater clams/snails	–
TRS222	Sentinel Butte	Freshwater clams/snails	–
TRS223	Sentinel Butte	None	Freshwater clams
TRS224	Sentinel Butte	Freshwater clams/snails, *Amia*, *Lepisosteus*, salamanders?, turtles, choristoderes, crocs, gators	Plant debris and coprolites
TRS225	Sentinel Butte	*Amia*, *Lepisosteus*, turtles, croc	–
TRS226	Sentinel Butte	None	In situ petrified tree
TRS227	Sentinel Butte	None	In situ petrified tree
TRS228	Sentinel Butte	None	Freshwater clams
TRS229	Sentinel Butte	None	Freshwater clams
TRS230	Sentinel Butte	Turtle/croc fragments	–
TRS231	Sentinel Butte	Freshwater clams/snails	–

Appendix Table E-1 (continued). South Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRS232	Sentinel Butte	None	Freshwater clams/snails
TRS233	Sentinel Butte	Two partial choristoderes	–

Appendix Table E-2. North Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRN1	Sentinel Butte	None	Freshwater clams/snails
TRN2	Sentinel Butte	Freshwater clams/snails, plant debris, seeds	–
TRN3	Sentinel Butte	Freshwater clams/snails	–
TRN4	Sentinel Butte	Freshwater clams/snails, plant debris	–
TRN5	Sentinel Butte	Freshwater clams/snails	–
TRN6	Sentinel Butte	Freshwater clams/snails	–
TRN7	Sentinel Butte	Freshwater clams/snails	–
TRN8	Sentinel Butte	Freshwater clams/snails	–
TRN9	Sentinel Butte	None	Fossil logs
TRN10	Sentinel Butte	Amber	In lignite
TRN11	Sentinel Butte	Ostracodes, turtle carapace, plant debris	–
TRN12	Sentinel Butte	Freshwater clams/snails	–
TRN13	Sentinel Butte	Freshwater snails	–
TRN14	Sentinel Butte	Freshwater snails	–
TRN15	Sentinel Butte	Freshwater clams/snails	–
TRN16	Sentinel Butte	Freshwater clams/snails	–
TRN17	Sentinel Butte	Freshwater clams/snails	–
TRN18	Sentinel Butte	Freshwater clams/snails	–
TRN19	Sentinel Butte	Freshwater clams/snails	–
TRN20	Sentinel Butte	Freshwater snails	–
TRN21	Sentinel Butte	Freshwater clams/snails	–
TRN22	Sentinel Butte	Freshwater clams/snails	–
TRN23	Sentinel Butte	Freshwater clams/snails	–
TRN24	Sentinel Butte	Choristodere/croc bones	–
TRN25	Sentinel Butte	Freshwater clams/snails	–
TRN26	Sentinel Butte	Freshwater clams/snails	–
TRN27	Sentinel Butte	Freshwater clams/snails, fish bone?	–
TRN28	Sentinel Butte	Freshwater clams/snails	–
TRN29	Sentinel Butte	None	Fossil logs
TRN30	Sentinel Butte	Freshwater clams/snails	–

Appendix Table E-2 (continued). North Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRN31	Sentinel Butte	Freshwater clams/snails	–
TRN32	Sentinel Butte	Freshwater clams/snails	–
TRN33	Sentinel Butte	Freshwater clams/snails	–
TRN34	Sentinel Butte	Freshwater clams/snails	–
TRN35	Sentinel Butte	Turtle/choristodere bones	–
TRN36	Sentinel Butte	None	Freshwater clams/snails
TRN37	Sentinel Butte	Freshwater clams/snails	–
TRN38	Sentinel Butte	Freshwater snails	–
TRN39	Sentinel Butte	Turtle/choristodere bones, leaves, other plant fossils	–
TRN40	Sentinel Butte	Freshwater clams/snails	–
TRN41	Sentinel Butte	Freshwater clams/snails	–
TRN42	Sentinel Butte	Freshwater clams/snails, insect fossils, leaves, seeds	–
TRN43	Sentinel Butte	Choristodere gastralia	–
TRN44	Sentinel Butte	Freshwater clams/snails	–
TRN45	Sentinel Butte	Freshwater snails	–
TRN46	Sentinel Butte	Freshwater clams/snails	–
TRN47	Sentinel Butte	Freshwater snails	–
TRN48	Sentinel Butte	Freshwater snail	Freshwater clams/snails
TRN49	Sentinel Butte	None	Freshwater clams
TRN50	Sentinel Butte	None	Freshwater snails
TRN51	Sentinel Butte	None	Freshwater clams/snails
TRN52	Sentinel Butte	None	Freshwater clams
TRN53	Sentinel Butte	Two trionychid plastrons	Freshwater clams/snails
TRN54	Sentinel Butte	Turtle/choristodere bones	Freshwater clams/snails
TRN55	Sentinel Butte	Freshwater snails	Choristodere bones
TRN56	Sentinel Butte	Freshwater snails	Freshwater clams
TRN57	Sentinel Butte	Unspecified	Croc tooth, fish vertebra, turtle remains, freshwater clams/snails
TRN58	Sentinel Butte	None	Freshwater clams
TRN59	Sentinel Butte	None	Freshwater clams/snails
TRN60	Sentinel Butte	Freshwater clams/snails	–
TRN61	Sentinel Butte	Unspecified	Croc tooth, fish vertebra, turtle remains, freshwater clams/snails

Appendix Table E-2 (continued). North Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRN62	Sentinel Butte	Unspecified	Croc bones, turtle shell, *Protochelydra*, choristodere, fish, salamander, freshwater clams/snails
TRN63	Sentinel Butte	None	Freshwater snails
TRN64	Sentinel Butte	None	Freshwater snails
TRN65	Sentinel Butte	Unspecified	Choristodere bones, freshwater snails
TRN66	Sentinel Butte	None	Freshwater clams/snails
TRN67	Sentinel Butte	None	Freshwater clams/snails
TRN68	Sentinel Butte	None	Freshwater clams/snails
TRN69	Sentinel Butte	Choristodere bones	–
TRN70	Sentinel Butte	None	Freshwater clams/snails
TRN71	Sentinel Butte	Unspecified	Fish scale, freshwater clams/snails, plant debris
TRN72	Sentinel Butte	Choristodere bones	–
TRN73	Sentinel Butte	Freshwater snails	–
TRN74	Sentinel Butte	None	Freshwater snails
TRN75	Sentinel Butte	None	Freshwater clams/snails
TRN76	Sentinel Butte	None	Freshwater clams/snails
TRN77	Sentinel Butte	Unspecified	Freshwater clams/snails
TRN78	Sentinel Butte	None	Petrified stumps in situ
TRN79	Sentinel Butte	None	Leaf impressions, petrified wood, in situ stumps, freshwater clams/snails
TRN80	Sentinel Butte	None	Freshwater clams
TRN81	Sentinel Butte	Unspecified	Freshwater clams/snails
TRN82	Sentinel Butte	None	Freshwater clams
TRN83	Sentinel Butte	Freshwater clams/snails	Petrified stumps
TRN84	Sentinel Butte	Freshwater snails	–
TRN85	Sentinel Butte	None	Freshwater clams/snails
TRN86	Sentinel Butte	Trionychid turtle shell fragments, mammal tooth	Freshwater clams
TRN87	Sentinel Butte	None	Freshwater clams/snails
TRN88	Sentinel Butte	None	Freshwater snails
TRN89	Sentinel Butte	None	Freshwater snails
TRN90	Sentinel Butte	None	Freshwater snails
TRN91	Sentinel Butte	Freshwater snails	–

Appendix Table E-2 (continued). North Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRN92	Sentinel Butte	Unspecified	Freshwater clams/snails
TRN93	Sentinel Butte	None	Freshwater clams
TRN94	Sentinel Butte	None	Freshwater clams
TRN95	Sentinel Butte	None	Freshwater snails
TRN96	Sentinel Butte	None	Freshwater snails
TRN97	Sentinel Butte	None	Freshwater snails
TRN98	Sentinel Butte	None	Freshwater clams/snails
TRN99	Sentinel Butte	Unspecified	Leaves, seeds, fish scales, coprolites, freshwater snails/clams
TRN100	Sentinel Butte	Freshwater clams/snails	–
TRN101	Sentinel Butte	None	Petrified stump in situ, freshwater snails
TRN102	Sentinel Butte	None	Freshwater clams
TRN103	Sentinel Butte	Freshwater snail	Freshwater clams
TRN104	Sentinel Butte	None	Freshwater snails
TRN105	Sentinel Butte	None	Freshwater clams/snails
TRN106	Sentinel Butte	Partial choristodere skull	–
TRN107	Sentinel Butte	None	Freshwater snails
TRN108	Sentinel Butte	None	Freshwater snails
TRN109	Sentinel Butte	Unspecified	Freshwater clams/snails
TRN110	Sentinel Butte	None	Freshwater snails
TRN111	Sentinel Butte	Partial skeleton (identified as choristodere elsewhere)	Petrified wood
TRN112	Sentinel Butte	Leaves, freshwater snails	–
TRN113	Sentinel Butte	Croc osteoderm	–
TRN114	Sentinel Butte, Quaternary	*Plastomenus* carapace	Freshwater clams, bison skull
TRN115	Sentinel Butte	Fish bones	–
TRN116	Sentinel Butte	None	Freshwater snails
TRN117	Sentinel Butte	None	Freshwater snails
TRN118	Sentinel Butte	None	Freshwater snails
TRN119	Sentinel Butte	Freshwater clams/snails	–
TRN120	Sentinel Butte	Freshwater clams/snails	–
TRN121	Sentinel Butte	Unspecified	Choristodere rib, leaf impressions, seeds (*Cercidiphyllum*), freshwater clams/snails
TRN122	Sentinel Butte	None	Freshwater snails

Appendix Table E-2 (continued). North Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRN123	Sentinel Butte	None	Freshwater clams/snails
TRN124	Sentinel Butte	None	Freshwater snails
TRN125	Sentinel Butte	Freshwater clams/snails	–
TRN126	Sentinel Butte	Freshwater snail	Freshwater clams
TRN127	Sentinel Butte	None	Freshwater clams
TRN128	Sentinel Butte	Freshwater clams	–
TRN129	Sentinel Butte	Freshwater clams/snails	–
TRN130	Sentinel Butte	Freshwater clams/snails	–
TRN131	Sentinel Butte	None	Freshwater clams/snails
TRN132	Sentinel Butte	Freshwater clams	Possible root traces, freshwater snails
TRN133	Sentinel Butte	None	Leaf impressions, freshwater clams/snails
TRN134	Sentinel Butte	Freshwater snail	–
TRN135	Sentinel Butte	None	Freshwater clams/snails
TRN136	Sentinel Butte	None	Freshwater snails
TRN137	Sentinel Butte	None	Freshwater snails
TRN138	Sentinel Butte	Petrified wood and other unspecified material	Fish bones?, katsura seed?, freshwater clams/snails
TRN139	Sentinel Butte	Freshwater clam	–
TRN140	Sentinel Butte	None	Petrified wood, freshwater clams/snails
TRN141	Sentinel Butte	Disarticulated turtle shell	Freshwater snails
TRN142	Sentinel Butte	None	Freshwater clams/snails
TRN143	Sentinel Butte	None	Freshwater clams/snails
TRN144	Sentinel Butte	Unspecified	Gar scales, fish vertebrae, croc and alligator teeth, *Plastomenus* and perhaps another trionychid, choristodere ribs and gastralia, multituberculate tooth, two mammal jaws, snail operculum
TRN145	Sentinel Butte	Freshwater snail	–
TRN146	Sentinel Butte	Unspecified	Baenid and trionychid turtles, croc osteoderm, freshwater clams/snails
TRN147	Sentinel Butte	Unspecified	*Plastomenus*, choristodere rib, freshwater snails, coprolites
TRN148	Sentinel Butte	None	Freshwater clams/snails
TRN149	Sentinel Butte	Freshwater snails	–

Appendix Table E-2 (continued). North Unit localities documented during the 1994–1996 survey.

Site	Formation	Collected	Other Observed
TRN150	Sentinel Butte	Unspecified	Leaves, freshwater clams/snails
TRN151	Sentinel Butte	None	Freshwater snails
TRN152	Sentinel Butte	None	Leaves
TRN153	Sentinel Butte	None	Freshwater snails
TRN154	Sentinel Butte	None	Freshwater snails
TRN155	Sentinel Butte	None	Freshwater clams
TRN156	Sentinel Butte	None	Freshwater clams
TRN157	Sentinel Butte	None	Freshwater snails
TRN158	Sentinel Butte	None	Freshwater clams/snails
TRN159	Sentinel Butte	None	Bone fragment, freshwater clams/snails
TRN160	Sentinel Butte	None	Freshwater clams
TRN161	Sentinel Butte	None	Freshwater clams/snails
TRN162	Sentinel Butte	None	Freshwater clams/snails
TRN163	Sentinel Butte	None	Plant debris
TRN164	Sentinel Butte	None	Freshwater clams
TRN165	Sentinel Butte	Freshwater snails	Freshwater clams
TRN166	Sentinel Butte	Croc skull bone piece	Petrified wood, freshwater clams
TRN167	Sentinel Butte	Unspecified	Plant debris, freshwater clams/snails

Appendix Table E-3. Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRS20-001	South	Sentinel Butte	None	–
TRS20-002	South	Sentinel Butte	None	Petrified wood
TRS20-003	South	Sentinel Butte	None	Petrified wood
TRS20-004	South	Sentinel Butte	None	Fossil leaf impressions
TRS20-005	South	Sentinel Butte	None	*Bison bison* rib head
TRS20-006	South	Sentinel Butte	Impression of fern leaf	–
TRS20-007	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS20-008	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS20-009	South	Sentinel Butte	Croc osteoderm	–
TRS20-010	South	Sentinel Butte	None	Freshwater bivalves
TRS20-011	South	Sentinel Butte	Vertebrate bone fragments, two pieces of teleost vertebra, turtle shell fragment, alligatoroid? osteoderm	–
TRS20-012	South	Sentinel Butte	Turtle shell fragment	Freshwater bivalves
TRS20-013	South	Sentinel Butte	Teleost vertebrae	Freshwater bivalve fragments
TRS20-014	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS20-015	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS20-016	South	Sentinel Butte	None	Petrified wood stump
TRS20-017	South	Sentinel Butte	Turtle shell fragments, partial limbs, partial vertebra	–
TRS20-018	South	Sentinel Butte	Turtle shell fragments	–
TRS20-019	South	Bullion Creek	None	Freshwater bivalves and gastropods

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRS20-020	South	Sentinel Butte	Turtle? shell and bone fragments	–
TRS20-021	South	Sentinel Butte	None	Petrified wood and stumps
TRS20-022	South	Sentinel Butte	None	Petrified wood and stumps
TRS20-023	South	Sentinel Butte	None	Freshwater bivalves
TRS20-024	South	Sentinel Butte	Fish tooth	Freshwater bivalves
TRS20-025	South	Sentinel Butte	Croc tooth	Freshwater bivalves
TRS20-026	South	Sentinel Butte	Two different fish teeth	Freshwater bivalves
TRS20-027	South	Sentinel Butte	*Plastomenus* shell fragments	–
TRS20-028	South	Sentinel Butte	Fish vertebrae (*Esox*), bone fragment	Articulated
TRS20-029	South	Sentinel Butte	Croc osteoderm fragments	–
TRS20-030	South	Sentinel Butte	*Plastomenus* carapace fragments	–
TRS20-031	South	Sentinel Butte	None	Petrified wood stump
TRS20-032	South	Sentinel Butte	Alligatoroid osteoderm fragment	–
TRS20-033	South	Sentinel Butte	Vertebrate tooth fragment	–
TRS20-034	South	Sentinel Butte	*Plastomenus* carapace fragments	–
TRS20-035	South	Sentinel Butte	None	Petrified wood; freshwater bivalves
TRS20-036	South	Sentinel Butte	None	Petrified wood stumps
TRS20-037	South	Sentinel Butte	None	Fossil leaf impressions
TRS20-038	South	Sentinel Butte	Teleost vertebrae, vertebrate osteoderm	Freshwater bivalves
TRS20-039	South	Sentinel Butte	Teleost vertebrae	Freshwater bivalves
TRS20-040	South	Sentinel Butte	Teleost vertebrae	Freshwater bivalves
TRS20-041	South	Sentinel Butte	Reptile bone fragments	Freshwater bivalves
TRS20-042	South	Sentinel Butte	Teleost vertebrae	Freshwater bivalves
TRS20-043	South	Sentinel Butte	Teleost vertebrae and bone fragments	Freshwater bivalves

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRS20-044	South	Sentinel Butte	Teleost vertebrae	Freshwater bivalves
TRS21-001	South	Sentinel Butte	None	Freshwater gastropods?
TRS21-002	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS21-003	South	Sentinel Butte	None	Well preserved freshwater mollusks
TRS21-004	South	Sentinel Butte	Fish vertebrae and bone fragments	Indet. freshwater mollusk; fish vertebra was not found in the bag
TRS21-005	South	Bullion Creek	Sample of microsite include vertebrae and a possible osteoderm/scale	Freshwater bivalve
TRS21-006	South	Sentinel Butte	None	Fossil leaf impressions
TRS21-007	South	Sentinel Butte	None	Freshwater bivalves
TRS21-008	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS21-009	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS21-010	South	Sentinel Butte	Turtle shell, limb, and bone fragments	Bivalves; 39 fossils from north side; 23 fossils from west side; 1 fossil from east side
TRS21-011	South	Sentinel Butte	Turtle shell fragments	Freshwater bivalves
TRS21-012	South	Sentinel Butte	Turtle shell and bone fragments	Likely forms a layer with TRS21-010 and TRS21-011
TRS21-013	South	Sentinel Butte	None	Freshwater bivalves
TRS21-014	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS21-015	South	Sentinel Butte	None	Freshwater bivalves and gastropods

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRS21-016	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRS21-017	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-018	South	Bullion Creek	Choristodere centrum, limb fragments, rib fragments, and bone fragments	Freshwater bivalves and gastropods?
TRS21-019	South	Bullion Creek	None	Freshwater bivalves
TRS21-020	South	Bullion Creek	None	Freshwater bivalves
TRS21-021	South	Bullion Creek	None	Freshwater bivalves
TRS21-022	South	Bullion Creek	None	Fossil leaf impressions
TRS21-023	South	Bullion Creek	None	Freshwater gastropods
TRS21-024	South	Bullion Creek	Choristodere vertebral elements (14), pelvic fragments (6), limb fragments (8), and bone fragments (192)	Freshwater gastropods?
TRS21-025	South	Bullion Creek	Crocodilian osteoderms	Freshwater bivalves; close to HT clinker
TRS21-026	South	Sentinel Butte	None	Freshwater bivalves
TRS21-027	South	Bullion Creek	None	Freshwater gastropods
TRS21-028	South	Bullion Creek	Indeterminate vertebrate bone fragments	In a game trail; freshwater bivalves just above it
TRS21-029	South	Bullion Creek	Turtle shell fragments	All float
TRS21-030	South	Sentinel Butte	None	Freshwater bivalves
TRS21-031	South	Bullion Creek	None	Freshwater bivalves
TRS21-032	South	Bullion Creek	None	Petrified wood
TRS21-033	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-034	South	Bullion Creek	None	Freshwater bivalves

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRS21-035	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-036	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-037	South	Bullion Creek	None	Freshwater bivalves and gastropods; worm burrow trace
TRS21-038	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-039	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-040	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-041	South	Bullion Creek	None	Fossil leaf impressions
TRS21-042	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-043	South	Sentinel Butte	None	Freshwater bivalves
TRS21-044	South	Bullion Creek	Choristodere vertebral elements (23), rib fragments (8), limb fragments (8), and bone fragments (283, more going into hillside)	Lignite, freshwater bivalves
TRS21-045	South	Bullion Creek	Crocodilian osteoderms (8), centra (3), phalanges (2), and bone fragments (26)	–
TRS21-046	South	Sentinel Butte	*Borealosuchus* osteoderm, limb fragment, and bone fragments	Plant impressions, petrified wood chips, bivalves
TRS21-047	South	Bullion Creek	None	Freshwater bivalves
TRS21-048	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-049	South	Bullion Creek	None	Freshwater gastropods

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRS21-050	South	Bullion Creek	None	Freshwater bivalves and gastropods
TRS21-051	South	Sentinel Butte	None	Freshwater bivalves
TRS21-052	South	Sentinel Butte	Fish bone fragments	Was found in a layer with bivalves and gastropods
TRS21-053	South	Sentinel Butte	Turtle shell fragments (6), limb fragments (2), rib fragments (2), and vertebral element; choristodere tooth; croc teeth (2); miscellaneous bone fragments (85)	Bivalve and gastropod layer below vertebrate material; 2 bones were still going into the hill; 1 fish scale was found but lost during collection
TRS21-054	South	Sentinel Butte	None	Petrified wood stump
TRS21-055	South	Sentinel Butte	Fish bones and scales (1 long bone, 7 miscellaneous bone fragments, 5 fish scales, 3 operculum/skull bone fragments)	Found above a mollusk layer with primarily bivalves
TRS21-056	South	Sentinel Butte	None	Freshwater bivalves
TRS21-057	South	Sentinel Butte	None	Freshwater bivalves; petrified wood
TRS21-058	South	Sentinel Butte	None	Freshwater bivalves and gastropods; petrified wood
TRS21-059	South	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN20-001	North	Sentinel Butte	None	Petrified wood stumps
TRN20-002	North	Sentinel Butte	Croc osteoderms, bone fragments, digits, teleost vertebrae	Lignite
TRN21-001	North	Sentinel Butte	None	Petrified wood trunk
TRN21-002	North	Sentinel Butte	None	Freshwater gastropods
TRN21-003	North	Sentinel Butte	None	Freshwater gastropods
TRN21-004	North	Sentinel Butte	None	Petrified wood stump

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRN21-005	North	Sentinel Butte	Turtle shell material (one plastron nearly intact) and a cimolestid jaw fragment with premolar; 4 bags collected (1: 291 shell fragments, 15 bone fragments; 2: 345 shell fragments, 40 bone fragments; 3: 191 shell fragments, 31 bone fragments; 4: 76 shell fragments from the articulated plastron)	Vertebrate fossils above the large dark bentonite layer; petrified wood float
TRN21-006	North	Sentinel Butte	*Piceoerpeton* centrum, turtle shell fragments (6); choristodere vertebra; croc osteoderms (137), teeth (13), vertebral elements (11), limb elements/rib fragments (66), limb elements (16), skull fragments (83); ungual; misc. bone fragments (414)	Large area; total with long float field would include at least 3 different crocodilians
TRN21-006 area	North	Sentinel Butte	Choristodere vertebral elements (2); croc osteoderms (213), teeth (23), phalanges (6), vertebral elements (4), ribs (8), and small bone fragments (958); other vertebral elements (7)	This is one long float field in the large area of bones
TRN21-007	North	Sentinel Butte	None	Petrified wood stump
TRN21-008	North	Sentinel Butte	None	Freshwater gastropods
TRN21-009	North	Sentinel Butte	Vertebral centrum found as float	Best used for interpretation
TRN21-010	North	Sentinel Butte	Bone fragments; possibly turtle shell among them	Freshwater bivalves
TRN21-011	North	Sentinel Butte	None	Petrified wood stump
TRN21-012	North	Sentinel Butte	Turtle shell fragments (38) and possible vertebral element; choristodere vertebrae (3); an ungual?; bone fragments (159)	Turtle shell and other bone still in wall; choristodere material from 0.5 m above the turtle shell

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRN21-013	North	Sentinel Butte	Croc bone elements (18), possible skull elements (3), and osteoderm	2 spots (1 against the wall, the other south of it in front of a hill); possibly same layer as trn21-012
TRN21-014	North	Sentinel Butte	None	Freshwater bivalves
TRN21-015	North	Sentinel Butte	Turtle shell elements (26); choristodere centra (2); limb fragment; and bone fragments (2)	–
TRN21-016	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-017	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-018	North	Sentinel Butte	None	Freshwater bivalves
TRN21-019	North	Sentinel Butte	Turtle shell fragments (3); choristodere? centrum; croc tooth; a phalanx; bone fragments (17); and an osteoderm/scale	Long gastropod layer with material
TRN21-020	North	Sentinel Butte	None	Freshwater gastropods
TRN21-021	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-022	North	Sentinel Butte	None	Freshwater bivalves
TRN21-023	North	Sentinel Butte	None	Freshwater bivalves
TRN21-024	North	Sentinel Butte	None	Freshwater bivalves
TRN21-025	North	Sentinel Butte	None	Freshwater bivalves
TRN21-026	North	Sentinel Butte	None	Freshwater bivalves and gastropods; petrified wood
TRN21-027	North	Sentinel Butte	None	Petrified wood; freshwater bivalves
TRN21-028	North	Sentinel Butte	None	Freshwater bivalves and gastropods

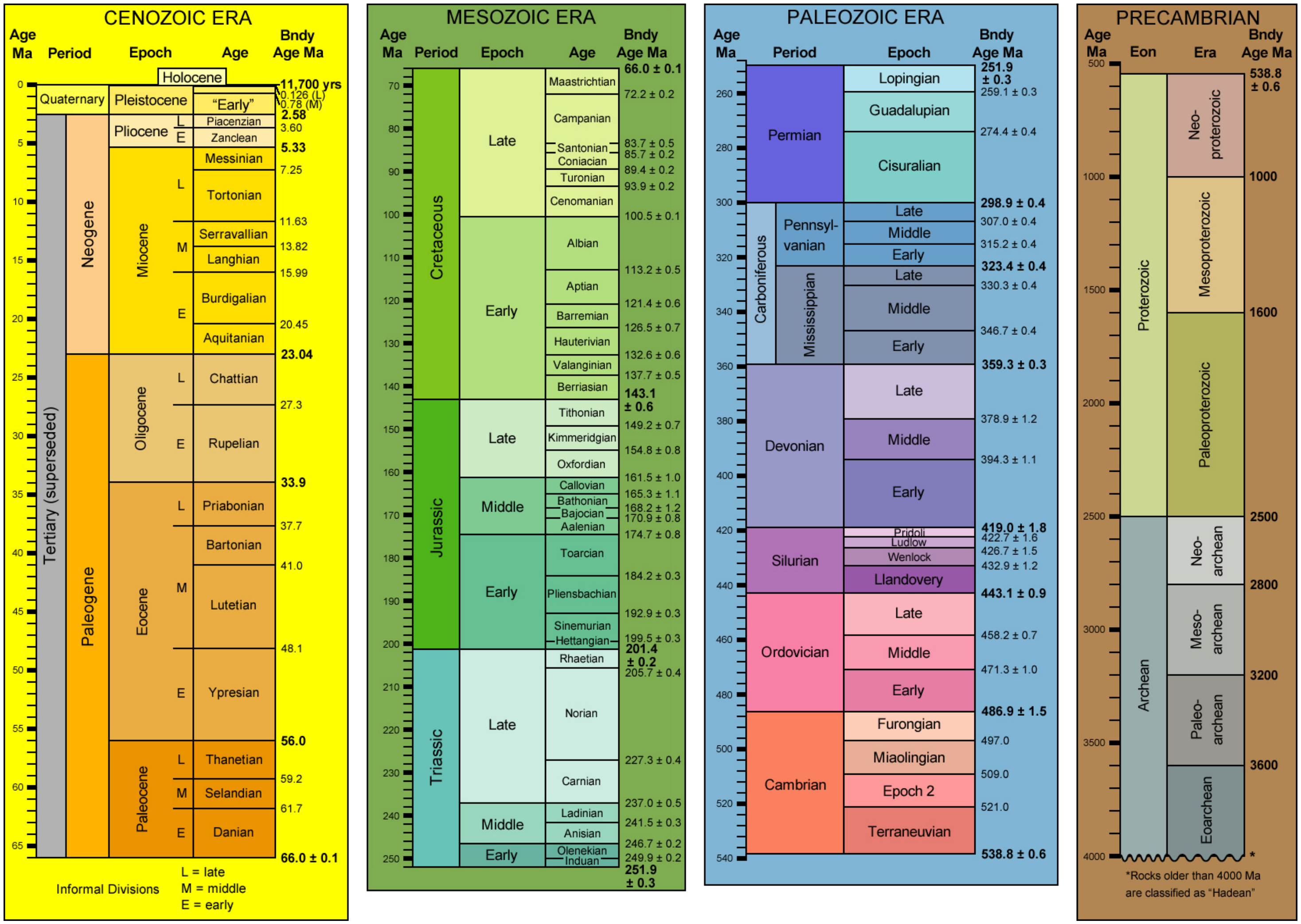
Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRN21-029	North	Sentinel Butte	None	Petrified wood; freshwater bivalves and gastropods
TRN21-030	North	Sentinel Butte	Leaf impression	Various mudstone occurrences that are fossiliferous; above the Eastern Buckhorn Trail
TRN21-031	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-032	North	Sentinel Butte	Osteoderm (unknown affinity); fish scales (6, gar?); bone fragments (24); soft-shelled turtle carapace piece; turtle shell piece	–
TRN21-033	North	Sentinel Butte	A shell fragment and trace fossils including a bird track	Petrified wood and turtle shell fragment (not collected)
TRN21-034	North	Sentinel Butte	None	Freshwater bivalves and gastropods; fossil leaf impressions
TRN21-035	North	Sentinel Butte	Choristodere vertebral elements (72), limb elements (63), skull elements (3), and bone fragments (63 bones from in situ and 325 misc. fragments)	More bones are still left in situ
TRN21-036	North	Sentinel Butte	None	Petrified wood stump
TRN21-037	North	Sentinel Butte	None	Petrified wood stump
TRN21-038	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-039	North	Sentinel Butte	None	Freshwater bivalves; petrified wood
TRN21-040	North	Sentinel Butte	Soft-shelled turtle shell fragments	Not far from locality with petrified wood and another with bivalve fossils
TRN21-041	North	Sentinel Butte	None	Petrified wood stump

Appendix Table E-3 (continued). Localities documented during the 2020–2021 inventory.

Locality	Park unit	Formation	Collected	Other Observed
TRN21-042	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-043	North	Sentinel Butte	None	Petrified wood stumps; freshwater bivalves
TRN21-044	North	Sentinel Butte	None	Freshwater gastropods and bivalves?
TRN21-045	North	Sentinel Butte	Leaf impressions	Petrified wood and logs nearby
TRN21-046	North	Sentinel Butte	None	Fossil leaf impressions; petrified wood and logs
TRN21-047	North	Sentinel Butte	None	Petrified wood stumps; freshwater bivalves
TRN21-048	North	Sentinel Butte	*Phenacodus* teeth (1 premolar, 2 fragments of 1 molar), found on the Western Buckhorn Trail	–
TRN21-049	North	Sentinel Butte	None	Petrified wood log
TRN21-050	North	Sentinel Butte	None	Freshwater bivalves and gastropods
TRN21-051	North	Sentinel Butte	None	Freshwater bivalves
TRN21-052	North	Sentinel Butte	None	Petrified wood stumps
TRN21-053	North	Sentinel Butte	Croc osteoderms, vertebrae, bone fragments; mammal dentary fragment; turtle shell fragment	Mollusk shell fragments

Appendix F: Geologic Time Scale



Ma=Millions of years old. **Bndy Age**=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf). Dates after Gradstein et al. (2020).

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