Paleontology of the Medora Public Fossil Dig Site (Paleocene: Sentinel Butte Formation), Billings County, North Dakota

John W. Hoganson, Jeff J. Person, and Becky Gould

Background Photo. Bullion Creek and Sentinel Butte Formations exposed along the Little Missouri River in the South Unit of Theodore Roosevelt National Park.

Introduction

While inspecting an abandoned oil well site in 2004 Darrell Nodland, at that time a field inspector with the Oil and Gas Division of the North Dakota Industrial Commission, discovered fossil bones weathering out of a butte slope, east of Medora. The bones were from a champsosaur, a crocodile-like animal that was a common inhabitant of ponds and swamps in North Dakota about 60 to 55 million years ago. More champsosaur bones were found when Darrell, Brett Woodward (formerly with the NDGS), and I (JWH) visited the site later that year. Fossil bones from several kinds of animals other than champsosaurs, including crocodiles and turtles, were also found slowly emerging from a thin but extensive bone bed at the site. We were developing our public fossil dig program at that time, and I (JWH) felt that this would be a good site for one of those digs due to the abundance of fossils found there and the relatively easy access to the site.

The site, now referred to as the Medora site, is located on Theodore Roosevelt Medora Foundation property. I (JWH) approached the Foundation to explore the idea of partnering with them to administer public digs there. They were enthusiastic about providing another activity for visitors to the Medora area, and we began excavating the site in 2005. We have conducted public fossil digs, each lasting at least a week, every year since. Over the past 6 years, more than 300 volunteers from 15 states have worked with us at this site, although excessive June rainfall prevented us from doing much there during the summer of 2010. The primary objective of all of our public fossil dig projects is to discover more about the animals and plants that lived in North Dakota at different times in the geologic past, and to decipher what these fossil remains can reveal about the climate and environment in which the animals and plants lived.

Geology, Stratigraphy, and Depositional Setting of the Medora Site

The Medora site is located in highly dissected badland terrain on an isolated knoll about 2 miles (3 km) east of Medora (fig. 1). The fossils are entombed in a thin, < 2 inches (< 5 cm) black to rust colored carbonaceous (lignitic) mudstone within the Paleocene Sentinel Butte Formation. The base of the fossil-bearing carbonaceous zone contains yellow to orange oxidized plant debris. This fossiliferous carbonaceous mudstone is overlain by a thinly bedded, gray with rust-colored banding, variegated muddy siltstone that is about 3 feet (1 m) thick. These lithologies indicate initial deposition in a paludal (swampy) environment that later became a ponded water habitat. Above the variegated strata is a 10-foot- (3-m-) thick gray, popcorn weathered claystone. This is the top of the section beneath prairie grasses.

The carbonaceous mudstone is underlain by an indurated, gray mudstone that contains plant fossil debris. The origin of these sediments was primarily from rivers and streams flowing from the west. The thin organic, lignitic layer, where most of the fossils are entombed, is derived from aquatic plants in the swampy environment and leaves, branches, etc. from trees and shrubs growing in and adjacent to the swamp. The bone bed is about 20 feet (6.5 m) above the top of a reddish clinker (HT Butte Bed) that marks the contact between the Bullion Creek and Sentinel Butte Formations (Fort Union Group) (fig. 1). Remains of the bear-like

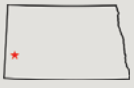

Figure 1. HT Butte clinker (red) overlain by the Sentinel Butte Formation (gray) at the Medora site. Map of North Dakota showing location of the Medora site (red star).

animal *Titanoides* along with those of *Neoplagiaulax* (squirrel-like animal), and *Palaeoryctes* (shrew-like animal) suggest a Tiffanian mammal age (60-56 million years ago) for this fossil site (Lofgren et al., 2004).

Field and Laboratory Procedures

Excavation at the site began with removal of overburden from the thin, fossil-bearing carbonaceous mudstone with picks and shovels. Because the fossils entombed in the mudstone are fragile and mostly small, delicate tools such as biological probes and small brushes are used to free them from the matrix. The fossils are

Figure 2. Cluster of freshwater bivalves exposed at the Medora site. Inset: The original shell material is preserved on these 60 million year old clams.

then padded with tissue, stored in vials, and placed in study cabinets in the State Fossil Collection. Larger and semi-articulated specimens are removed using standard plaster casting techniques. As the excavation has proceeded, the increased thickness of overburden has required removal by heavy equipment, and a front end loader was commissioned. Matrix was bulk sampled, disaggregated, and washed/processed through < $^{1}/_{16}$ inch (1 mm) mesh screen (smaller than most window screens) to extract microfossils. Fossils are being prepared in the North Dakota Geological Survey, Johnsrud Paleontology Laboratory at the North Dakota Heritage Center in Bismarck and are being cataloged into the North Dakota State Fossil Collection at the Heritage Center.

Paleontology

The fossil assemblage recovered so far from the Medora dig site consists of disarticulated remains of a diverse vertebrate fauna, freshwater mollusks, and trace fossils.

Fossils of freshwater mussels are abundant at this site and often occur in clusters (fig. 2). The original shell material is preserved, and they are difficult to collect because they are so fragile. At least two species of freshwater snails, including *Campeloma*, and a much smaller species are also found at the site. Minute snail opercula (the plate that covers the opening of the shell) have also been collected.

The only semi-articulated specimens found up to now are two partial skeletons of the champsosaur, *Champsosaurus gigas* (fig. 3). Several isolated vertebrae, teeth, ribs, limb bones, and gastralia of this species have also been recovered. *Champsosaurus gigas* was a crocodile-like reptile that lived in lakes, ponds, and swamps during the Paleocene (fig. 4). As suggested by its name, *Champsosaurus gigas* was the largest of the species of champsosaurs attaining lengths of up to about 12 feet (3.5 m). Although they were not crocodiles, they in some ways resemble the living long-snouted gavial crocodylians that inhabit parts of India today. Because of its hydrodynamic body, powerful back legs, and long snout studded with small, sharp, needle-like teeth, it is believed that *Champsosaurus gigas* was an aggressive underwater predator that fed on fish. It is likely that this animal would spend much of its time underwater, lying on the bottom waiting for prey. When a fish swam by, the champsosaur would quickly lunge off the bottom after it, propelled by its large, powerful back legs. Although common members of freshwater communities during the Paleocene, champsosaurs are now extinct.

The largest animals we have found fossils of at the Medora site are crocodiles. Hundreds of crocodile teeth have been recovered as well as vertebrae, limb bones, and scutes (bony dermal armor). This Medora wetland existed about 5 million years or so after the extinction

Figure 3. Partial, disarticulated skeleton of *Champsosaurus gigas* being excavated at the Medora site. Inset: Arrows point to skeletal parts in place within the mudstone.

of the dinosaurs, and crocodiles were the main predators in North Dakota after that extinction. It is likely that the crocodile remains recovered from the Medora site are from *Borealosuchus*, the large, common, crocodile that lived here at that time. Several skeletons of *Borealosuchus* have been excavated from the Wannagan Creek site (a similar-aged site) a few miles west of Medora (Erickson, 1999).

The largest crocodile teeth we have recovered from the Medora site are 1.5 inches (35 mm) in length, suggesting that they were massive animals. These teeth and the scutes found with them are as large as those of the largest *Borealosuchus* specimens collected at the Wannagan Creek site, indicating that the crocodiles at the Medora site probably measured as much as 15 feet (4.5 m) in length (fig. 5). These crocodiles probably fed on turtles, champsosaurs, fish, birds, mammals, and other crocodiles. The crocodiles also deposited feces (coprolites) in the pond. Some of these coprolites, as big as Red River Valley potatoes, are another indication that the crocodiles were huge. Fossils, including gar scales and fish bones, are embedded in some of the coprolites.

Several thousand fossilized bones, including parts of skulls, teeth, spines, vertebrae, and scales, of several species of fish have been collected at the Medora site. The fish that lived in the Medora swamp included *Amia* (bowfin, Amiidae), *Lepisosteus* (gar, Lepisosteidae), and *Esox* (pike, Esocidae) (fig. 6). Species of these families of fish still exist in North American freshwater environments today. Like their modern relatives, the Paleocene fish were voracious, indiscriminate predators that ate smaller fish (of which we have bones, but have not yet identified), invertebrates, lizards, and perhaps even small mammals.

Turtle fossils, including carapace pieces (upper shell), plastron pieces (lower shell), limb bones and toe bones, representing at least two species, including "*Plastomenus*," a soft-shelled turtle; have also been recovered from the site. "*Plastomenus*" was similar to the soft-shelled turtles that live today in swamps and ponds. They had a low, rounded shell, a long mobile neck and grew to lengths of about 18 inches (46 cm). Unlike most turtles, soft-shelled turtles do not have a true horny covering; instead, the underlying bony plates are covered with a layer of leathery skin. "*Plastomenus*" was probably omnivorous and would have eaten plants, insects, mollusks, and small fish.

The remains of mammals, birds, lizards, and the giant, "Hellbender"-sized 3-foot- (1-m-) long salamander, *Piceoerpeton*, indicate that these animals were also members of the interesting aquatic community at the Medora site.

The remains of at least two different species of birds have also been excavated. A humerus (upper arm bone) from a duck-sized bird and fragments of coracoids (shoulder bones) from an American Robin- to Blue Jay-sized bird have been found. Since bird bones are hollow and exceedingly fragile, they are rarely found in fossil faunas so it was very exciting to find these fossils.

Recent screen-washing of sediment from the bone bed has yielded numerous small mammal teeth and jaws. Most of the teeth are the size of the head of a pin (or smaller!), but three jaws have been recovered so far, two of them less than half-an-inch (< 1 cm) in length. Small teeth from an extinct group of mammals referred to as multituberculates (which filled the rodent niche) and insectivorous mammal teeth have been identified from the screen-washed matrix. Remains of much larger mammals have also been recovered from the site including toe bones from a black bear-sized animal (*Titanoides*?) and limb bones from a smaller (porcupine- to beaver-sized) mammal. These mammal fossils will help us determine, we hope with very

Figure 4. Painting of *Champsosaurus gigas* by Jerome Connolly, Science Museum of Minnesota, St. Paul.

Figure 5. Painting of the crocodile *Borealosuchus* in a North Dakota Paleocene swamp. Portion of mural at the North Dakota Heritage Center.

Figure 6. Fish (*Esox*) jaw being excavated at the Medora site.

Figure 7. Habitat reconstruction painting of a North Dakota Paleocene swamp. Mural at the North Dakota Heritage Center.

fine resolution (probably within a few hundred thousand years), the age of the site.

Paleoecology

Even though we have collected thousands of fossils from a diverse group of animals at the Medora site we must keep in mind that this fossil assemblage represents only a fraction of the animals that would have inhabited the Medora swamp and areas adjacent to it. For example, very few soft-bodied animals, such as most insects and worms, would have survived decay to become part of the fossil record. Keeping that in mind, we can speculate what the Medora swamp would have been like about 60 million years ago.

The Medora swamp was a quiet, shallow water ecosystem that was teeming with life (fig. 7). Paleobotanical evidence from other sites of similar age in western North Dakota indicates that the setting was subtropical, hot and humid (Hoganson, 2006). This swamp was probably a temporary backwater of a larger lake, as suggested by the numerous, large predaceous fish *Esox*, *Amia*, and *Lepisosteus*, some of which grew to at least 2 ft. (67 cm) in length. These fish, and the soft-shelled turtles, preyed on smaller fish, mollusks, and other small animals inhabiting the swamp. The forest canopy and underbrush around the swamp provided habitats for multituberculates, insectivores, and other mammals. Birds also frequented the swampy area. Other studies have revealed that trees and shrubs growing in western North Dakota at this time included exotic subtropical trees such as *Taxodium* (Bald Cypress), *Magnolia*, *Platanus* (Sycamore), *Cercidiphyllum* (Katsura), *Ginkgo*, *Metasequoia* (Dawn Redwood), and palm (Erickson, 1999; Hoganson, 2006).

The Medora swamp was a feeding ground for crocodiles and champsosaurs. This is indicated by the disarticulated skeletons, crushed bone, and abundant crocodile coprolites in the site. The champsosaurs were primarily feeding on fish and the crocodiles were feeding on everything they could catch, probably including mammals that wandered too close to the water. Numerous depressions in the bone bed are interpreted to be crocodile footprints, and broken bones found at the site suggest that these large animals trampled and bioturbated the swampy area while scavenging for food. The Medora swamp would have been a putrid, smelly, disgusting place because of the decaying carcasses, rotting flesh, and abundant feces of the animals that fed on them.

Figure 8. Fossil diggers on family day at the Medora site.

Future Studies at the Medora Site

We plan on continuing public fossil digs at the Medora site, and one will be conducted there next summer (fig. 8). The fossils that have already been collected are at our Heritage Center paleontology laboratory in Bismarck, where they are being prepared (cleaned) and studied. The extraction of additional microscopic fossils from bulk sediment samples by screen-washing will also be part of our continuing study of this site.

References

Erickson, B.R., 1999, Fossil Lake Wannagan (Paleocene: Tiffanian), Billings County, North Dakota: North Dakota Geological Survey Miscellaneous Series 87, 9 p.

Hoganson, J.W., 2006, Dinosaurs, sharks, and woolly mammoths -- Glimpses of life in North Dakota's prehistoric past: North Dakota Geological Survey Educational Series 31, 60 p.

Loftgren, D.L., Lillegraven, J.A., Clemens, W.A., Gingerich, P.D., and Williamson, T.E., 2004, Paleocene biochronology: The Puercan through Clarkforkian Land Mammal Ages, *in*, Woodburne, M.O., (ed.), Late Cretaceous and Cenozoic mammals of North America, Biostratigraphy and Geochronology, New York, Columbia University Press, p. 43-105.