Dinosaurs, Sharks, and Woolly Mammoths: Glimpses of Life in North Dakota's Prehistoric Past

By John W. Hoganson

Introduction

The history of life in North Dakota from the time that monstrous sea creatures inhabited the primordial oceans millions of years ago to the appearance of humans only a few thousand years ago is a fascinating saga. That history is being deciphered by **paleontologists** through the study of fossils, our primary means of documenting the evolutionary history of past life. **Fossils** define the kinds of plants and animals that inhabited North Dakota at various times in the geologic past. They also are important indicators of how the region's climates and environments have changed through time. Fossils studied by paleontologists can be actual remains of animals or plants, such as shell, bone, and seeds, or can be traces, such as tracks or burrows. Objects constructed by humans (pottery, projectile points, buildings, etc.)

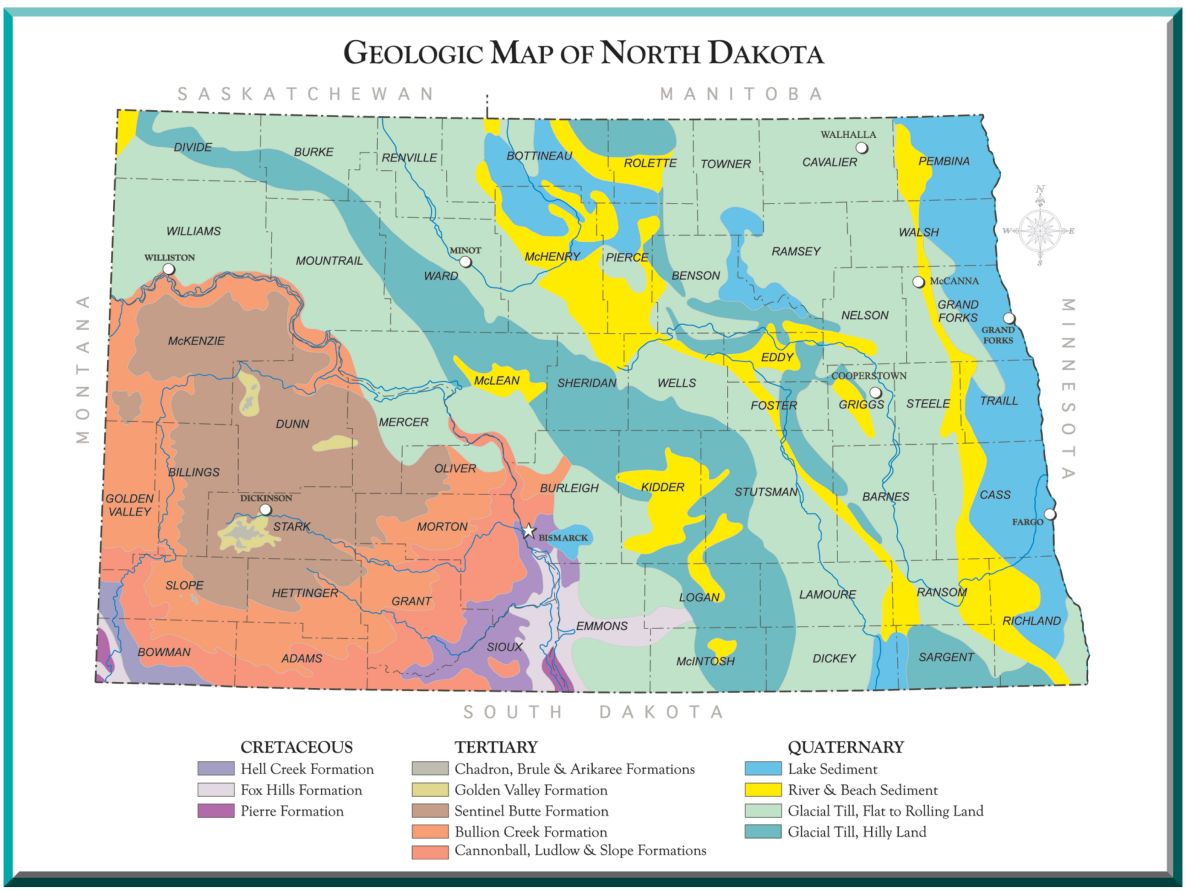


Figure 1. Geological map of North Dakota. *(Graphic by Brian R. Austin)*

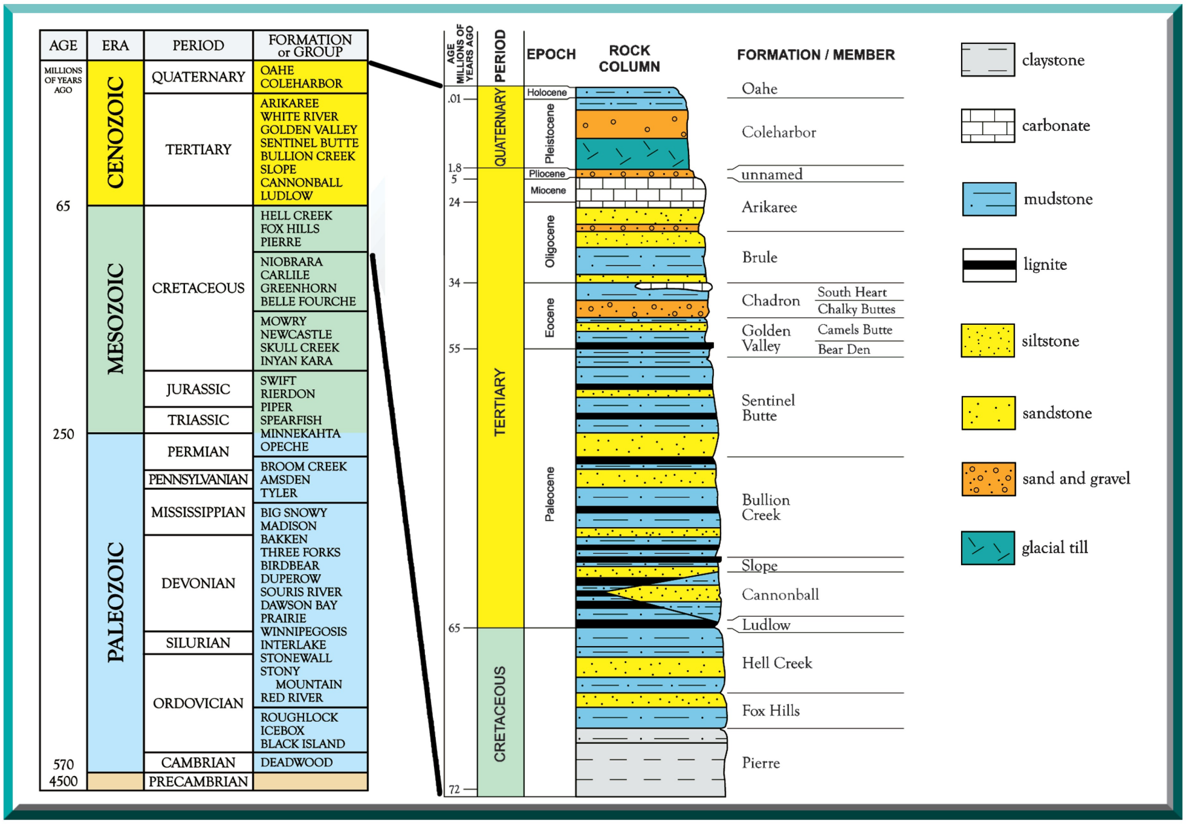


Figure 2. The North Dakota stratigraphic column lists the names of the rock formations that occur in North Dakota and the types of rocks of which they are composed. This list of formations is arranged on the Geologic Time Scale from oldest to youngest in "stratigraphic" order. *(Graphic by Brian R. Austin)*

are termed **artifacts**, not fossils, and are studied by archaeologists, not paleontologists. Fossils are an important part of our natural heritage and should be preserved whenever possible.

Like historical events, paleontological events have little meaning unless they are put into a time perspective. Beginning about 1820, a calendar called the **Geologic Time Scale** was developed—and is still being refined—that divides the Earth's history into segments of time (eras, periods, epochs) which are most often based on changes in life forms. So, for example, the major time divisions—the **Paleozoic**, **Mesozoic**, and **Cenozoic Eras**—literally mean "ancient life" (Paleozoic), "middle life" (Mesozoic), and "recent life" (Cenozoic). The numerical dates of these time divisions, usually expressed in millions of years, are based on measurements of the radioactive decay of minerals found in rock formations. This is called **radiometric dating**. The geologic calendar is frequently expressed through the use of a stratigraphic column.

Geologists also name the rock formations that were deposited during each geologic time period. The names are based on the location where the best example of the rocks can be seen. Formations are defined by the characteristics of the rocks, such as composition (sandstone, siltstone, mudstone, for example), color, thickness, the kinds of fossils they contain, and many other attributes. The areas where a particular formation appears on the surface can be mapped and plotted on a geologic map. Paleontologists can use these geologic maps to guide them to places where rocks containing particular kinds of fossils may be found. For example, the North Dakota geologic map shows areas where the rocks known as the **Hell Creek Formation** surface. (The name of this formation comes from Hell Creek in northeastern Montana, where extensive exposures

Figure 3. **Plaster-casting a mosasaur fossil** at the Cooperstown site, Griggs County. Plaster casts are placed on fossils to protect them during transport. *(Courtesy of John Hoganson)*

of the rocks are found.) The stratigraphic column of North Dakota identifies the Hell Creek Formation as having been deposited between about sixty-seven and sixty-five million years ago—at the very end of the age of dinosaurs. Paleontologists would therefore expect those areas to have the potential for yielding dinosaur fossils. Knowledge of the location, lithology (rock type), age, and kinds of fossils found in the formations presented on the Geologic Map and Stratigraphic Column of North Dakota has been accumulating since the 1800s, based on research conducted by geologists and paleontologists from North Dakota and many other places. The following glimpses of life in North Dakota's prehistoric past provide a summary of this knowledge accumulated over many decades. The reader should be advised that this knowledge is continually being refined through frequent discovery of fossils of plants and animals that were previously not known to exist in North Dakota.

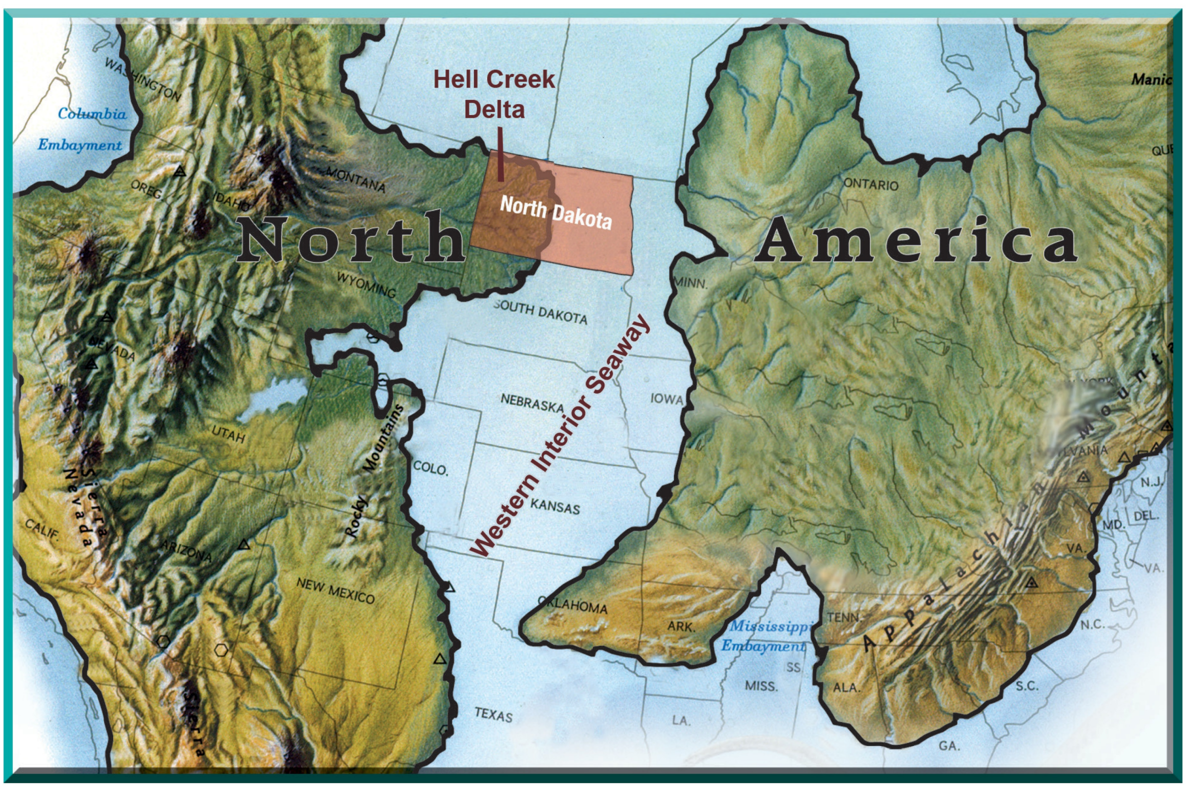
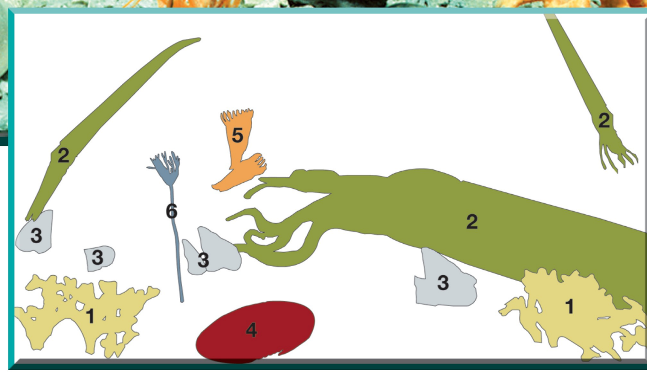


Figure 4. **During most of the past 570 million years, North Dakota was covered by warm, shallow oceans** that filled what is called the Western Interior Seaway. By about sixty-eight million years ago, the ocean waters had begun to recede, and the Hell Creek Delta began to form in what is now western North Dakota. This is the formation on which dinosaur fossils have been found in North Dakota. *(Graphic by Robin Pursley)*



Figures 5 & 6. North Dakota as it may have looked about 450 million years ago. *(Courtesy of Smithsonian Institution)* **RIGHT Key.** Fossils mentioned in text are indicated in bold. 1. Bryozoans. 2. Cephalopods. 3. **Brachiopods.** 4. **Trilobite.** 5. **Corals.** 6. Echinoderm (sea lily). *(Graphic by Robin Pursley)*

North Dakota's Primordial Seas

The oldest exposed rocks containing fossils in North Dakota that paleontologists can explore are only about eighty-five million years old, and yet the fossil record of life in the state extends back to the **Cambrian Period**, over five hundred million years ago. This early record of life is revealed by fossils found in oil well cores (cylinders of rock) and cuttings (rock fragments) brought to the Earth's surface, often from thousands of feet below, during exploration for petroleum. The oldest fossils found in North Dakota are from the late Cambrian and early Ordovician (approximately five hundred million years old), recovered from depths of about fourteen thousand feet (4,200 meters) in the **Deadwood Formation** in Williams County. They are the microscopic tooth-like remains of the enigmatic, wormlike marine animals called conodonts, believed by many to be early vertebrates.[1] Brachiopods (clam-like animals), trilobites, echino-

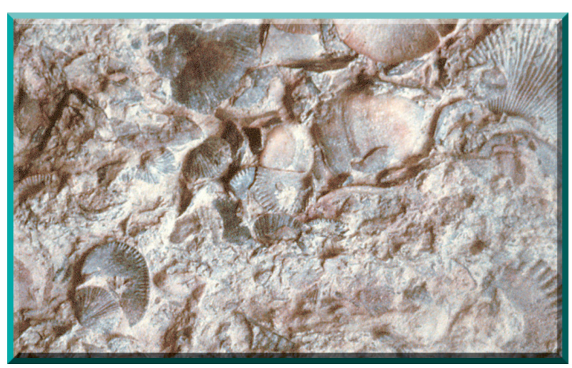


Figure 7. Brachiopods, Ordovician, Stony Mountain Formation, 2,456 feet, Ramsey County, width 10 cm. *(UND A2602.241)*

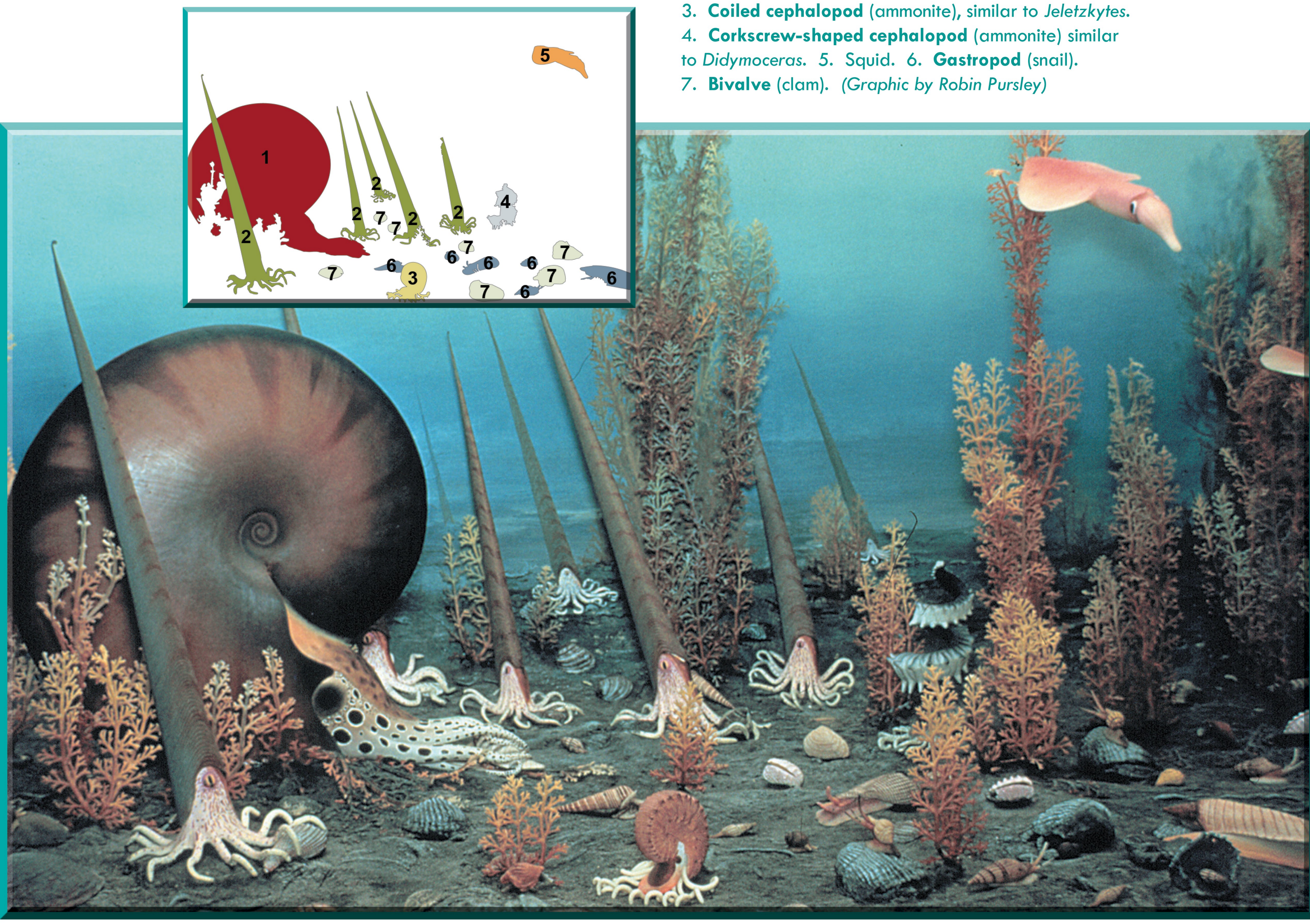
derms (sea lilies), gastropods (snails), and trace fossils (burrows created by unknown organisms) have also been found in Deadwood Formation cores.[2]

During most of the Paleozoic and Mesozoic Eras, from about 570 million to about sixty-five million years ago, North Dakota was covered by warm, shallow seas bordered by marine lagoon and estuary habitats, in some cases similar to areas in the Caribbean near the Bahamas today.[3] During this time there were also periods when North Dakota was dry land. We know that seas covered the state during the Paleozoic because the types of rocks—mostly limestone, dolomite, shale, siltstone and evaporates—and fossils indicate marine environments. Most of the fossils are remains of invertebrate animals such as gastropods, bivalves (clams), brachiopods, corals, stromatoporoids (sponge-like animals), trilobites, and echinoderms. Rarely, remains of vertebrates other than conodonts, particularly fish, are found.[4] In some cases fossils are abundant enough to allow us to reconstruct what the animal communities were like in these primordial seas.

North Dakota's Cretaceous Underwater World

During the **Cretaceous Period**, from about eighty-five million to sixty-five million years ago, North Dakota was either completely or partially covered by shallow, subtropical to warm-temperate oceans similar to those that had covered the state during Paleozoic times. These oceans occupied what is called the **Western Interior**

Figures 8 & 9. This diorama illustrates a Cretaceous seafloor community. *(Courtesy of Smithsonian Institution)* **TOP Key.** Fossils mentioned in text are indicated in bold. 1. **Coiled cephalopod** (ammonite) similar to *Sphenodiscus*. 2. **Straight-shelled cephalopod** (ammonite) similar to *Baculites*. 3. **Coiled cephalopod** (ammonite), similar to *Jeletzkytes*. 4. **Corkscrew-shaped cephalopod** (ammonite) similar to *Didymoceras*. 5. Squid. 6. **Gastropod** (snail). 7. **Bivalve** (clam). *(Graphic by Robin Pursley)*



Seaway, so called because at times the oceans were extensive enough to connect the Arctic Ocean with the Gulf of Mexico, splitting the North American continent in two. In North Dakota these Cretaceous seas were probably never more than about five hundred feet (150 m) deep. Fine-grained sediments, mostly silt and clay, deposited on the floor of those oceans have become rock and now make up the Carlile, Niobrara, and Pierre Formations. Near the end of the Cretaceous, shallow marine and shoreline habitats existed in central North Dakota, as indicated by sandstones and siltstones of the **Fox Hills Formation**. These Cretaceous marine rocks are the oldest rocks exposed in the state and contain fossils of the animals and plants that inhabited these ancient oceans.

Figure 10. Photograph of Niobrara and Pierre Formation outcrops near Walhalla in Cavalier County. *(Courtesy John Hoganson)*

We know these oceans were shallow and warm primarily because of the fossilized remains of the animals that lived in them. One fossil site that illustrates what a Cretaceous underwater animal community was like is the seventy-five-million-year-old Pierre Formation site in Griggs County near Cooperstown. Fossils of corals, gastropods (*Trachytriton*), bivalves (*Nemodon*, *Inoceramus*), cephalopods (*Didymoceras*, *Solenoceras*, and *Baculites*), shrimp (*Callianassa*), crabs, echinoderms (starfish and sea urchins), coral-like bryozoans, and clam-like brachiopods (*Lingula*) are found weathering out of the rocks there. The most spectacular fossils discovered at the Cooperstown site, however, are those of the large vertebrate animals: mosasaurs, sea turtles, sharks, and seabirds.[5]

Figure 11. Fossils from the Pierre Formation found near Cooperstown, Griggs County (unless otherwise noted). 1. Cephalopod (*Baculites gregoryensis*), length 56 mm. *(ND 00-11.5)* 2. Cephalopod (*Didymoceras*), height 27 mm. *(ND 00-11)* 3. Gastropod (*Trachytriton*), height 20 mm. *(ND 00-11.9)* 4. Bivalve (*Inoceramus*), Bowman County, width 68 mm. *(UND 132A)* 5. Coral, height 9 mm. *(ND 00-11.10)*

A nearly complete twenty-three-foot-long (7 m) skeleton of the mosasaur *Plioplatecarpus* was collected from this site by the North Dakota Geological Survey and is now on display at the North Dakota Heritage Center. **Mosasaurs** were huge marine lizards, some forty feet (12 m) or more in length, that inhabited the world's oceans during the Cretaceous. Unlike their terrestrial lizard relatives, mosasaurs' limbs were modified to form paddles or flippers. Mosasaurs were active predators and among the main carnivores in the Cretaceous oceans. They had a good sense of sight and a poor sense of smell. They probably preyed on other

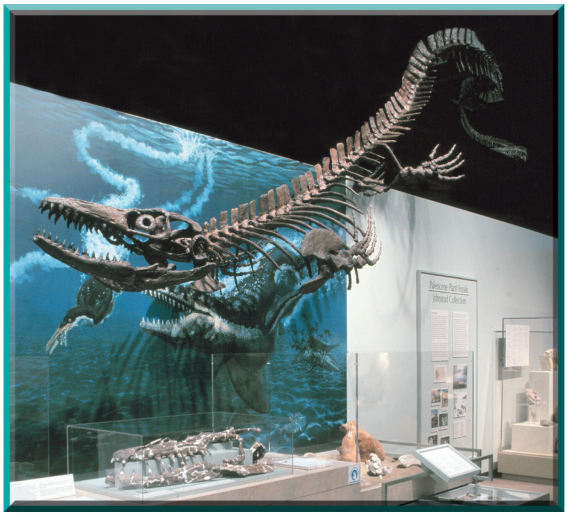
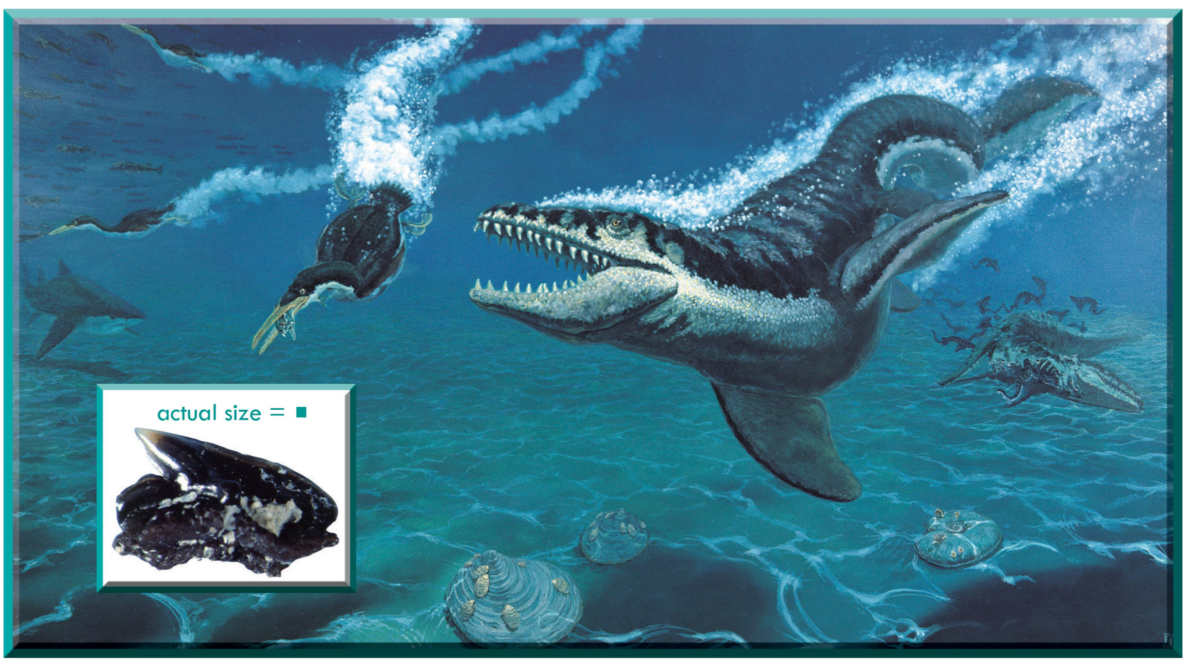


Figure 12. This *Plioplatecarpus* fossil skeleton was discovered in 1995 in the Sheyenne River valley near Cooperstown, Griggs County, North Dakota. A study of the nearly complete skull and other parts of the skeleton indicate that it is a new species of *Plioplatecarpus* not found elsewhere. Length 7 m. *(ND 97-115.1)*

mosasaurs, fish, turtles, and invertebrates such as cephalopods. Although mosasaurs were not dinosaurs, they lived at the same time as dinosaurs and also became extinct when they did—about sixty-five million years ago.

Teeth of several species of sharks, including the "tiger shark" *Squalicorax* and the "dogfish shark" *Squalus*, have also been found in the **Pierre Formation** at the Cooperstown site. We generally only find teeth of these fish because their cartilaginous skeletons seldom fossilize before decomposing. These ancient tiger sharks were predators high on the food chain that probably competed with mosasaurs for prey. Dogfish sharks, which still exist, are small sharks that grow to lengths of about three feet (1 m). They usually live in schools and eat bony fish, other sharks, various invertebrate animals, and even marine mammals. We know that *Squalus* was also a scavenger of mosasaur carcasses during the Cretaceous because we have

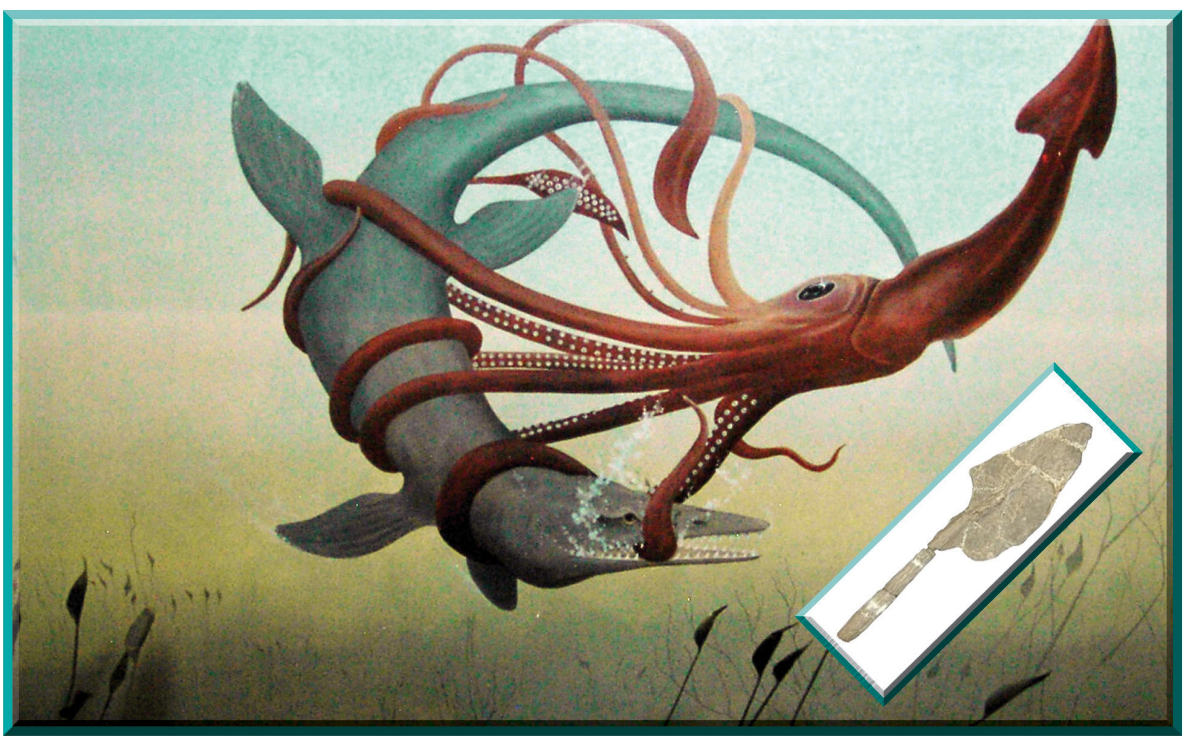


Figures 13 & 14. This painting of the Pierre Sea is based on fossils found near Cooperstown, Griggs County. The mosasaur *Plioplatecarpus* is attacking the diving seabird *Hesperornis*. In the background the carcass of a decaying *Plioplatecarpus* is being scavenged by dogfish sharks, *Squalus*. The mosasaur on exhibit at the Heritage Center was found in this position, with gnaw marks on some of its bones from feeding dogfish sharks. In the left side of the painting, the sand-tiger shark *Carcharias* cruises near the sea floor, which is littered with shells of an ammonite, *Sphenodiscus* and the large clam *Inoceramus*. *(Painting by David Miller, North Dakota Heritage Center)* **INSET *Squalus* tooth,** Pierre Formation, Griggs County, length 3 mm. *(ND 97-115)* found gnaw marks on bones of our *Plioplatecarpus* and other mosasaur skeletons that are identifiable as having been produced by *Squalus* teeth.

Prey of both sharks and mosasaurs was *Hesperornis*, a large diving seabird that grew to about five feet (1.5 m) tall. Although incapable of flight, it was a swift swimmer that could propel itself through the water with its powerful hind legs and grebe-like webbed feet. Its jaws had sharp, pointed teeth adapted for preying on fish and squids.

Other sites in North Dakota have also yielded fossils of Pierre Sea animals. The remains of another species of mosasaur, at least twice as big as our *Plioplatecarpus* skeleton, were recently found near McCanna. The remains of another huge animal, a giant squid called *Tusoteuthis longa*, have also been found at **Pembina Gorge**. Squids, although they are invertebrates, have a rigid support structure in their bodies called a *gladius* or *pen*. The pen is in many ways similar to a backbone but is made

Figures 15 &16. Drawing of a *Hesperornis regalis* skeleton. *(O.C. Marsh,* Odontornithes: A Monograph on the Extinct Toothed Birds of North America*, 1880)* **INSET Pelvis, femur, and tibia,** *Hesperornis regalis*, Pierre Formation, Cavalier County, length 280 mm. *(ND 06-12.2)*



Figures 17 &18. A *Tusoteuthis longa* squid locked in battle with a mosasaur. *(Courtesy of Canadian Fossil Discovery Centre)* **INSET Pen of a *Tusoteuthis*,** found near Walhalla at the Pembina Gorge site, length 1.8 m. *(ND00-60.1)* of shell-like material, not bone. These pens are rarely found as fossils. One was discovered at the Pembina Gorge site, however, and it is six feet (1.8 m) long—indicating that the squid from which it came was a giant, perhaps fifteen feet (4.5 m) long!

By about sixty-eight million years ago the Pierre Sea had receded from western North Dakota, and the huge Hell Creek Delta—similar to the Mississippi Delta today—had begun to form. The eastern edge of this delta was near Bismarck, and the shoreline of the Fox Hill Sea (the name geologists give to the less-extensive ocean that replaced the Pierre Sea) was located in south-central North Dakota. Associated with this shoreline were estuary and lagoon habitats that formed adjacent to the delta. The sands, silts, and muds deposited in these shallow marine areas are called the Fox Hills Formation. We know a great deal about invertebrate life in the shallow marine Fox Hills waters because of the abundant and beautifully preserved fossils found in this formation.[6] Among them are bivalves (*Corbicula*, *Tancredia*, *Crassatellina*, *Panopea*), gastropods (*Euspira*), cephalopods (the ammonites *Sphenodiscus lenticularis* and *Jeletzkytes nebrascensis*), sea urchins, lobsters, horseshoe crabs (*Casterolimulus kletti*), shrimp (*Callianassa*) and their burrows (*Ophiomorpha*), and many others.

Remains of vertebrate animals that inhabited the Fox Hills Sea are less abundant but include sharks (*Carcharias* and *Squalicorax*), ratfish (*Ischyodus rayhassi*), rays (*Myledaphus bipartitus*), and several species of bony fish (e.g., *Vorhisia vulpes*).[7] Sea turtles and mosasaurs also resided in the shallow marine and estuarine habitats.[8] Mosasaurs and sharks were the main predators in these waters, with ratfish and rays feeding primarily on the invertebrates. As would be expected, remains of animals that lived on the delta—salamanders (*Opisthotriton kayi*, *Lisserpeton bairdi*), turtles, crocodiles (*Borealosuchus*), crocodile-like champsosaurs, birds, and dinosaurs (*Tyrannosaurus*)—would occasionally be washed into the marine waters and are now part of the Fox Hills Formation fossil record.[9]

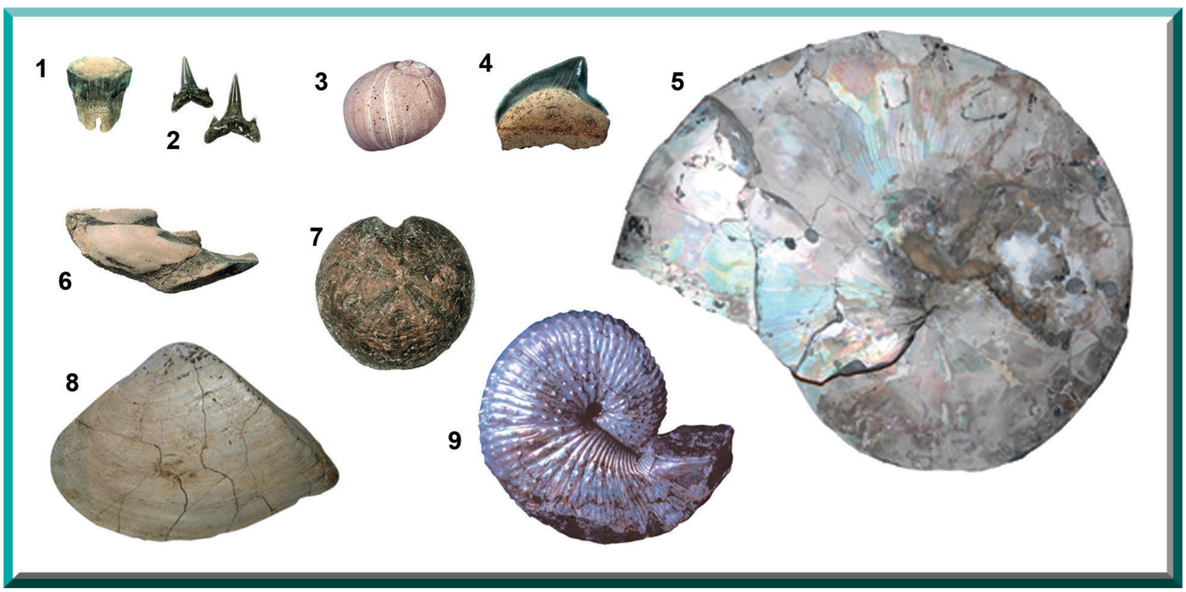
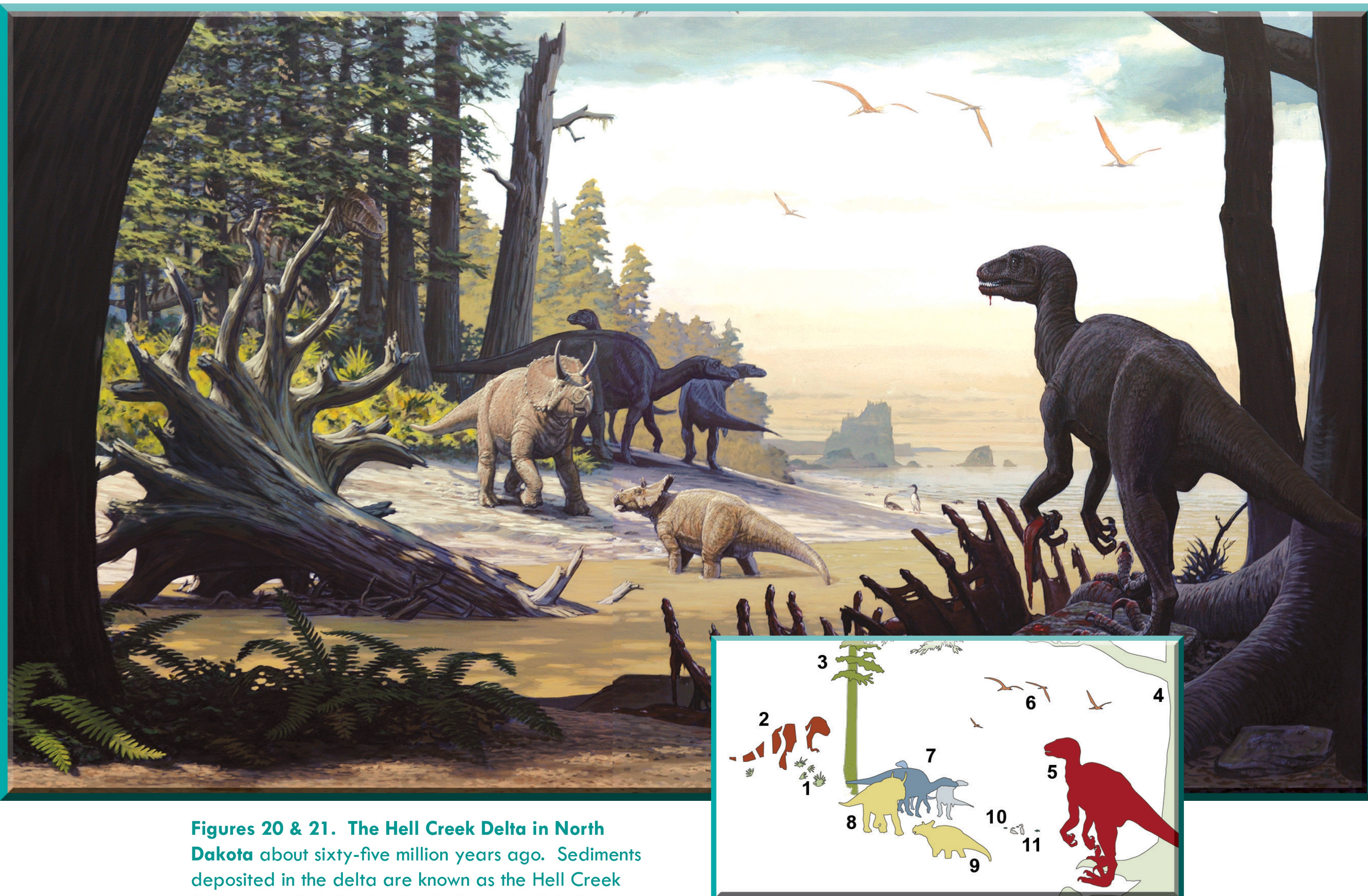


Figure 19. Fossils found in the Fox Hills Formation. 1. Ray tooth (*Myledaphus bipartitus*), Morton County, height 7 mm *(UND RMF134-80-3)* 2. Shark teeth (*Carcharias*), Griggs County, height 7 mm, *(ND 95-40)* 3. Gastropod (*Euspira*), Logan County, length 23 mm *(ND 99-6)* 4. Shark tooth (*Squalicorax pristodontis*), Bowman County, width 22 mm *(SLU 1832)* 5. Cephalopod (*Sphenodiscus lenticularis*), Emmons County, width 365 mm *(ND 99-118.1)* 6. Ratfish dental plate (*Ischyodus rayhaasi*), Logan County, width 65 mm *(ND 99-6.1)* 7. Sea urchin, Emmons County, width 42 mm *(ND 21.3)* 8. Bivalve (*Crassatellina hollandi*), Logan County, width 159 mm *(ND 95-13.1)* 9. Cephalopod (*Jeletzkytes nebrascensis*), Emmons County, width 118 mm *(ND 7.2)*



Figures 20 & 21. The Hell Creek Delta in North Dakota about sixty-five million years ago. Sediments deposited in the delta are known as the Hell Creek Formation. *(Painting by Geoff Elsen, North Dakota Heritage Center)* **RIGHT Key.** Fossils mentioned in text are indicated in bold. 1. *Sabalites*. 2. ***Tyrannosaurus rex***. 3. ***Metasequoia***. 4. *Liriodendrites*. 5. **Dromaeosaur**. 6. ***Pteranodon***. 7. ***Edmontosaurus***. 8. ***Triceratops*—adult**. 9. ***Triceratops*—juvenile**. 10. Sea turtles. 11. ***Hesperornis***. *(Graphic by Brian R. Austin)*

When Dinosaurs Ruled the Hell Creek Delta

The **Hell Creek Delta** was the eastern edge of a well-drained lowland corridor that existed between the rising Rocky Mountains to the west and the Western Interior Seaway (Fox Hills Sea) to the east during the Late Cretaceous. As the Rocky Mountains rose through tectonic pressures generated deep within the Earth, sediments eroded from them were carried eastward by rivers and streams and formed a fan-shaped delta, much like today's Mississippi River delta in Louisiana, once they reached the Fox Hills Sea. These sediments, now turned into sandstone, siltstone, and mudstone, are called the Hell Creek Formation.

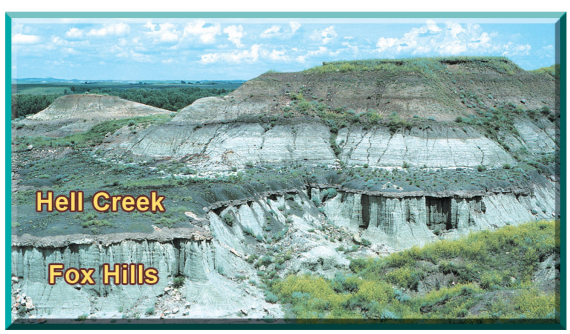


Figure 22. Outcrop in Sioux County showing the Fox Hills Formation overlain by the Hell Creek Formation. See Figure 1 for outcrop locations. *(Courtesy John Hoganson)*

Many areas of this delta plain were forested and contained hundreds of species of plants dominated by angiosperms, which were mostly small- to medium-sized flowering trees.[10] A coastal marsh forest containing cycads, palms, ferns, conifers, and many other plants existed along the Fox Hills Sea shoreline in central North Dakota.[11]

North Dakota's climate during the Late Cretaceous was warm-temperate to subtropical, probably similar to that of south Florida today. The woodlands, ponds, and swamps provided abundant habitats for many types of animals, including dinosaurs. The Hell Creek Formation is the only rock formation in North Dakota that contains abundant dinosaur remains—fossils of fourteen species have been discovered here.[12]

The Hell Creek dinosaur community was dominated by large herbivores. One of the most common herbivores was ***Triceratops***, among the largest and heaviest of the plant-eating, horned (ceratopsid) dinosaurs. This creature grew to lengths of about twenty-five feet (8 m) and could weigh as much as eight tons. It was at least three times the size of the largest living rhinoceros.[13] Even though its front legs were short, they were powerfully built to support the weight of its extremely heavy head. *Triceratops* skulls, often at least six feet (1.8 m) long in adult specimens, are distinctively equipped with two long brow horns, one short nose horn (hence its name), and a large, solid bone frill that covered its neck. The function of the frill and horns has been debated for many years. Damage to many *Triceratops* skulls suggests that these animals probably sparred with one another by locking horns and shoving and twisting, possibly to win mates or establish territory.[14] It is easy to imagine that *Triceratops* may have charged predators such as ***Tyrannosaurus rex***, much as an enraged rhinoceros does today. The horns and frills may also have been used to help regulate body temperature. Its powerful jaws ended in a parrot-like beak and contained batteries of small teeth adapted for shearing fibrous plants. *Triceratops* was one of the last dinosaur species to ever live on Earth.

Figure 23. *Triceratops horridus* skull on display in the North Dakota Industrial Commission office building in Bismarck. The skull was collected by the North Dakota Geological Survey in Slope County from USDA Forest Service-Dakota Prairie Grasslands-administered land. It is 1.5 m long. *(ND 92-19.1)*

Figure 24. Plant fossils of the Hell Creek coastal forest. 1. Magnolia leaf (*Liriodendrites*), Fox Hill Formation, Emmons County, length 120 mm. *(ND 03-1.75)* 2. Conifer cone (*Metasequoia*), Hell Creek Formation, Morton County, height 52 mm. *(ND 93-6.3)*

The **duck-billed** (hadrosaurid) **dinosaur** *Edmontosaurus* was another of the common herbivores that resided in North Dakota at the end of the Cretaceous. A hadrosaur face was elongated into a broad, flattened snout with a toothless beak, which resembles the bill of a modern duck, hence the popular name "duck-billed dinosaur." *Edmontosaurus* used its beak for foraging, possibly to strip bark and leaves from trees.[15] It was one of the largest hadrosaurids, growing to forty feet (12 m) long and weighing about four tons. It is also one of the best-known dinosaurs because many *Edmontosaurus* skeletons have been found and studied. It had large pillar-like legs, powerful ankles, and bony tendons along its backbone that helped support the animal as it walked. Each foot possessed three broad, widely spaced toes ending in hoof-like nails. It had strong lower jaws that contained batteries of hundreds of small teeth, which formed grinding surfaces for tough plant food like conifer needles, twigs, and cones. There were no teeth in the front of the mouth. Worn teeth were continually replaced by new ones throughout the life of the animal. Rare mummified *Edmontosaurus* skeletons preserve skin impressions, which indicate that it had a thin, leathery hide studded with horny bumps, or tubercles. Bite marks on *Edmontosaurus* bones indicate that *Tyrannosaurus rex* preyed on, or at least scavenged, this dinosaur.[16] Its only real defense against predators would have been to run away from danger. Many hadrosaurs lived in large herds, and some may have cared for their young at nesting sites.[17]

Fossils of the two-legged, herbivorous "thick-headed" dinosaurs *Pachycephalosaurus* and *Stygimoloch* are uncommon in the Hell Creek Formation, and only a few specimens have been found in North Dakota.[18] Both of these dinosaurs are called pachycephalosaurs because of their thickened skull roofs. In fact, the skull cap is often the only part of the animal that is preserved. The function of the thick dome skulls of pachycephalosaurs has been a matter of debate. Some paleontologists believe they were for sexual display; others think they were used for combat with rivals, as in head-to-head butting or flank butting.[19] The skull of *Pachycephalosaurus* was studded with bony knobs, while the skull of *Stygimoloch* was decorated with long spikes. These bipedal dinosaurs were not large—*Pachycephalosaurus* was about fifteen feet (4.5 m) long, and *Stygimoloch* about seven (2 m). They were browsers and ate leaves, stems, fruits, and possibly insects.[20]

As in ecosystems today, herbivores far outnumbered carnivores in the Hell Creek dinosaur community. Nevertheless, several species of carnivorous dinosaurs, or theropods, did inhabit North Dakota during the Late Cretaceous, including *Tyrannosaurus rex*, one of the largest terrestrial carnivores of all time. Adults grew to lengths of forty feet (12 m), measured from the tip of the nose to the end of the tail, and weighed about six to eight tons. They stood up to twenty feet (6 m) tall on their hind legs. Heads of the adults were huge, about five feet (1.5 m) long, and possessed approximately fifty large, dagger-like teeth, some as large as bananas.[21] These blade-like serrated teeth could puncture bone and carve through flesh. The long, heavy tails of *T. rex* were held off the ground to counterbalance their heads. Bipedal, their legs were long and powerfully built, with three forward-pointing toes on each broad foot. Each toe ended in a sharply curved talon. Their arms were very short, with two clawed fingers on each hand. A *T. rex* could tear off as much as five hundred pounds (225 kg) of flesh at one time with its powerful jaws.[22] It had a keen sense of smell and could travel at high speeds for short distances.

In recent years a debate has developed over whether *T. rex* was an active hunter or a mere scavenger.[23] The

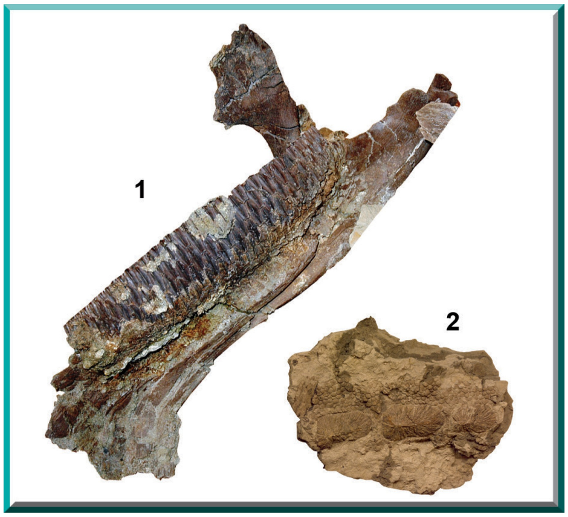


Figure 25. *Edmontosaurus* fossils found by Tyler Lyson, Marmarth, in the Hell Creek Formation in Slope County. 1. Back of the lower jaw of *Edmontosaurus*, a duck-billed dinosaur. Note the dense batteries of small teeth, width 487 mm. *(ND 06-6.1)* 2. *Edmontosaurus* skin impression, width 180 mm.

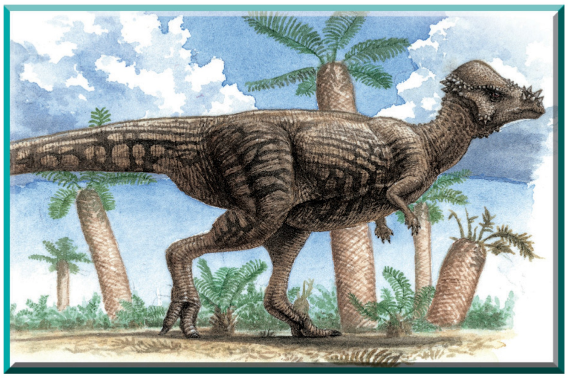


Figure 26. Artist's rendering of a *Pachycephalosaurus*. The trees in the background are cycads. *(Courtesy of Natural History Museum, London)*

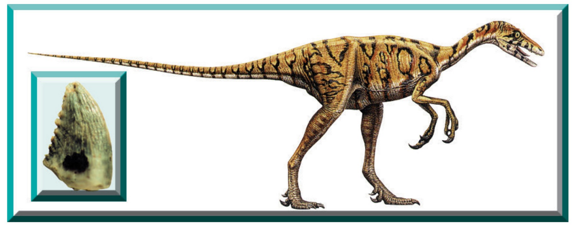
active-hunter argument is based on its long and massive teeth, long and strong legs for running down prey, and stereoscopic vision (indicated by the placement of the eye sockets). The assertion that *T. rex* was a scavenger is based on its relatively small eyes and small arms—too small, some believe, to have easily held onto prey. It is likely that *T. rex* was an opportunistic predator, possibly hunting in family groups, and would scavenge carcasses when they were encountered.[24] In either case, *Edmontosaurus* and *Triceratops* were among the prey of *T. rex*.[25] No complete skeletons of this dinosaur have been found in North Dakota, but *T. rex* teeth and bones have been recovered from several fossil sites in the state.[26]

Figures 27 & 28. *Tyrannosaurus rex* in a Late Cretaceous habitat. *(Painting by and courtesy of John Sibbick)* **INSET *Tyrannosaurus rex* tooth,** Morton County. *T. rex* lost teeth throughout its life, growing replacement teeth much like a shark does. Length of the tooth is 64 mm. *(ND 93-11.1)*

Figures 29 & 30. Cast of a dromaeosaur skeleton. INSET Dromaeosaur tooth, Hell Creek Formation, Morton County. It is 7 mm long. *(ND 93-1.6)*

Teeth of smaller theropod dinosaurs, including dromaeosaurids, are more common in the Hell Creek Formation in North Dakota.[27] Dromaeosaurids ("swift-running lizards") were small, meat-eating dinosaurs often called "raptors"; they were among the most ferocious predators during the Cretaceous. Most were less than six feet (2 m) tall, with lightly built, speedy bipedal bodies. They had large heads with sharp, serrated, meat-shearing teeth and long arms with clawed, three-fingered hands.[28] The second toe of each hind foot was modified into a sickle-shaped, recurved raptorial claw or talon; in this sense it resembled its close relatives *Deinonychus* ("terrible claw"), found in Montana, and *Velociraptor*, the Asian dinosaur of Jurassic Park fame. These claws were offensive weapons probably used like daggers for slashing through flesh and disemboweling prey. Dromaeosaurid tails were long, flexible, and reinforced with delicate rods. Their brains were large, and some scientists believe these dinosaurs hunted in packs.[29] Fast, agile, and intelligent, they were predators built for the chase and kill. Because of their aggressive lifestyles, some paleontologists believe that dromaeosaurs were endothermic (warm-blooded), like modern birds and mammals. Many skeletal features of dromaeosaurs are birdlike, and some fossilized dromaeosaur skeletons even show the presence of feathers.[30] Indeed, most scientists believe that birds evolved from small, feathered theropod dinosaurs related to ancestors of dromaeosaurids or troodontids.[31]

Fossils of ***Troodon***, another small meat-eating dinosaur related to the dromaeosaurs, have also been found in the Hell Creek Formation in North Dakota. *Troodon* was a man-sized predator. It grew to lengths of about six feet (2 m) but weighed only around fifty pounds.[32] It had a narrow head, long snout, large eyes, serrated teeth, long, slender hind limbs, and raptorial hands. Like dromaeosaurs, *Troodon* also possessed an enlarged sickle-shaped claw on each foot that likely was used for bringing down prey.[33] Its lightly built body and long, slender legs suggest that it was very agile. It may have had excellent sight and hearing because of its large eye sockets and well-developed middle ears. The size of the brain cavity of *Troodon* compared to its body suggests it was one of the more intelligent dinosaurs. It is thought to have preyed on other dinosaurs, hatchlings, and mammals, and possibly also ate dinosaur eggs and insects.



Figures 31 & 32. *Troodon* was a mansized, meat-eating dinosaur. *(Courtesy of John Sibbick)* **INSET *Troodon* tooth,** Hell Creek Formation, Morton County, length 4 mm. *(ND 93-1)*

Figure 33. Cast of a skeleton of the Late Cretaceous flying reptile *Pteranodon*. *(ND 06-5.1, Courtesy of Brian R. Austin)*

Because of the dominance of dinosaurs, it is easy to overlook the other animals that were part of the Hell Creek Delta community. Freshwater fishes, salamanders, lizards, turtles, crocodiles, **champsosaurs** (crocodile-like animals), birds, gastropods, bivalves, and other creatures coexisted with the dinosaurs, and fossils of these animals are also found in the Hell Creek Formation. Rodent-sized mammals lived here, too. One final spectacular animal, however, should be mentioned: the huge flying reptile called *Pteranodon*.

Pteranodon ("toothless flier") was one of the flying reptiles called pterosaurs that lived during the Mesozoic Era.[34] Pterosaurs were not dinosaurs but were their contemporaries and dominated the air as dinosaurs did the land. More than two hundred million years ago during the Triassic Period, pterosaurs were the first vertebrate animals to develop the capability of sustained flight with control over steering and direction. The wing membrane in pterosaurs was stretched over a single long finger termed the "wing finger." The other three fingers terminated in powerful, sharp, curved claws used for climbing rock ledges or trees. Pterosaur bodies were lightly built, and their wing bones, like those of birds, were hollow with extremely thin walls. They probably were fairly helpless on land, but they had webbed feet and likely could swim. At least some pterosaurs had hair and fur and were probably warm-blooded. They ranged worldwide and, like dinosaurs and mosasaurs, became extinct at the end of the Cretaceous.

Pteranodon was gigantic. Though its body was quite small, weighing only about thirty-five pounds (15 kg), its wingspan was more than twenty feet (6 m). *Pteranodon* was a powerful flier who also could glide and soar effortlessly on rising air thermals over great distances and for long periods of time. It had a long, thin bone crest at the back of its head that was possibly used for sexual display or functioned as a stabilizer for its long head during flight. The crest could also have served as a counterweight to the animal's long beak. Unlike many pterosaurs, *Pteranodon* did not have teeth. A fish eater, it lived along the coast of the ocean that covered parts of North Dakota at the end of the Cretaceous. Although not closely related to birds, it led a life similar to that of the modern-day albatross, which has a ten-foot (3 m) wingspan and spends most of its life soaring over marine waters. *Pteranodon* lived in North Dakota at the same time as the flightless seabird *Hesperornis*.

The K-T Boundary Extinction

A mass extinction that was one of the greatest biological catastrophes of all time occurred about sixty-five million years ago, marking the end of the Cretaceous Period. This is commonly called the **K-T boundary extinction** because it occurred at the boundary between the Cretaceous and Tertiary Periods. It was global in extent. The last of the dinosaurs and about three-quarters of all plant and animal species worldwide died out at that time.[35] This event marks the end of the **Age of Reptiles**, the Mesozoic Era, and the beginning of the **Age of Mammals**, the Cenozoic Era. The cause of the catastrophe is aggressively debated among scientists, but the most intriguing explanation is called the **"asteroid impact theory."**

According to this explanation, Earth was struck by a huge asteroid or comet about sixty-five million years ago. It has been estimated that the asteroid would have been more than six miles (10 km) in diameter and was traveling at about fifty thousand miles (90,000 km) per hour at impact. The energy released by the impact is calculated to have been equivalent to one hundred million megatons of high explosives, a billion times as much as that released by the atomic bomb dropped on Hiroshima.[36]

A crater one hundred miles (160 km) wide and more than ten miles (16 km) deep has been identified beneath Mexico's Yucatan Peninsula and is believed to be the impact site. The explosion would have vaporized plants and animals within a few hundred miles of the impact site, and the intense heat would have been devastating to life worldwide.[37]

Following the collision, the climate of Earth would have been drastically altered because of dust, other particles, and smoke from wildfires blown into the atmosphere. The resulting "nuclear winter" would have caused global temperatures to drop to near the freezing point, photosynthesis to cease, and land and sea plants to die, including those that lived in North Dakota.[38] Most of the animals and plants that survived the initial explosion and intense heat would have died because of this climate change. Only the most adaptable species would have survived. The last of the non-avian dinosaurs disappeared during this event (almost all paleontologists now believe that birds are descendents of dinosaurs and therefore dinosaurs are still with us).

One line of evidence suggesting that Earth was impacted by a huge asteroid sixty-five million years ago is the occurrence of a very thin layer of clay at the Cretaceous-Tertiary (K-T) geological boundary. This clay layer, which can be seen in certain places in North Dakota, is rich in iridium, a platinum-group element rare in Earth's crust but found in high concentrations in celestial bodies such as asteroids or meteors. Many scientists believe that the iridium is left over from the asteroid responsible for the extinction event. There appears to be no doubt that a huge meteor struck Earth at this time.

The "asteroid impact theory" for the K-T boundary extinction is intriguing. Many scientists, however, question whether the impact was the cause of this mass extinction.[39] This is primarily because dinosaurs were already on the decline and many groups of animals survived the event, including crocodiles, champsosaurs, turtles, birds, mammals, and many others.[40] There were volcanic eruptions in India sixty-five million years ago that would have blown massive amounts of volcanic ash and other particulates into the atmosphere. This would have disrupted climate and could have caused the extinction of many organisms. Also at the time, there was a significant drop in worldwide sea levels that would have altered habitats, changed climate, and had a major impact on life. It should be noted that four other major extinctions, and several "minor" ones, had occurred on Earth before the K-T boundary extinction. One of these, at the Permian-Triassic boundary about 250 million years ago, was even more devastating, wiping out about 95 percent of all species on Earth.

The K-T boundary extinction paved the way for development of new life on Earth, particularly the evolution of mammals. The Paleocene (first epoch of the Tertiary Period) was a period of recovery and renewal, when the world began rebounding from this biological catastrophe.

Figures 34 & 35. Swampland habitat during the Paleocene sixty million years ago in western North Dakota. Farther east in North Dakota was the Cannonball Sea. *(Painting by Geoff Elsen, North Dakota Heritage Center)* **INSET Key.** Fossils mentioned in text are indicated in bold. 1. ***Plesiadapis.*** 2. ***Metasequoia.*** 3. **Bald Cypress.** 4. Shore bird. 5. ***Borealosuchus.*** *(Graphic by Brian R. Austin)*

North Dakota Everglades

At the beginning of the **Paleocene**, about sixty-five million years ago, warm, shallow oceans covered much of central and eastern North Dakota, and huge forested swamplands similar in many ways to today's Florida Everglades existed in the western part of the state. During the early Paleocene in North Dakota temperatures were mild, averaging about 50°F; by the late Paleocene mean annual temperature has been estimated to be 65°F, with winter temperatures no colder than 55°F.[41]

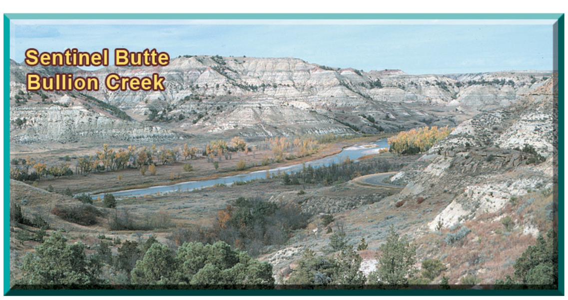


Figure 36. Outcrops of the Paleocene Bullion Creek and Sentinel Butte Formations, Theodore Roosevelt National Park, South Unit, Billings County. *(Courtesy John Hoganson)*

Figure 37. Sandstone and mudstone outcrops of the Paleocene Cannonball Formation along the Heart River near Mandan, Morton County. *(Courtesy Ed Murphy)*

Figure 38. Paleocene Fossils. 1. *Gingko* leaf, Morton County, width 81 mm. *(ND 447.3)* 2. Sycamore leaf (*Platanus*), Williams County, width 150 mm. *(ND 92-59.1)* 3. Winged seed similar to modern maple, Morton County, width 41 mm. *(ND 03-38.84)* 4. Walnut seed cluster (*Platycarya americana*), Golden Valley Formation, Stark County, length 56 mm *(ND 92-91.11)* 5. Fern, McLean County, length 107 mm. *(ND 183.1)* 6. Land snail (*Planorbis planoconvexus*), Mercer County, width 34 mm. *(ND 92-15.40)* 7. Gar fish jaw (*Lepisosteus*), Billings County, length 46 mm. *(ND 94-225)* 8. Bivalve (mussels) and *Campeloma* (snail), Billings County, width 63 mm. *(ND 95-124.1, Theodore Roosevelt National Park exhibit)*

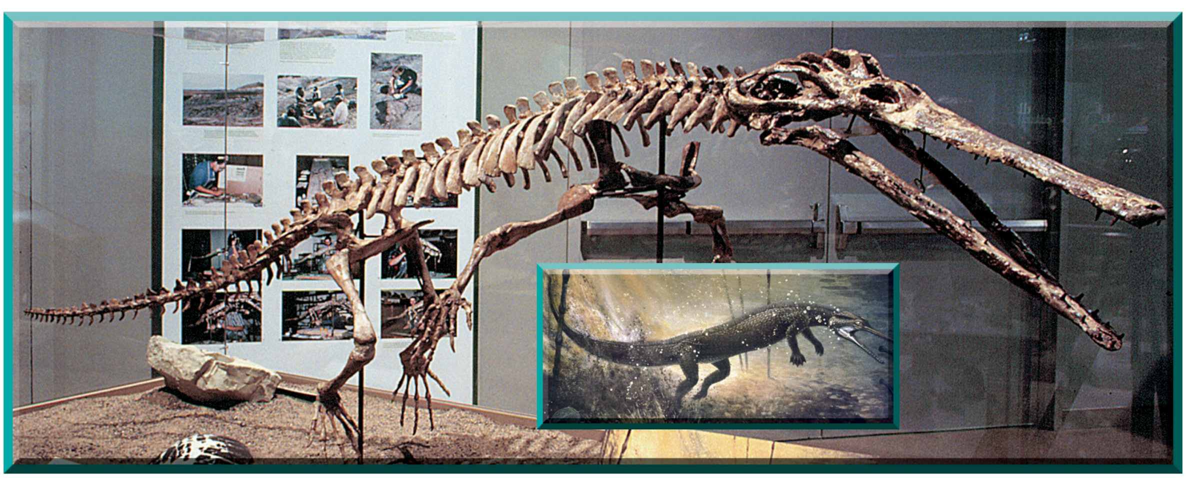
During this time, sediments eroded from the rising Rocky Mountains were carried by rivers to western North Dakota and deposited in river channels and floodplains. Volcanic ash, generated by volcanoes in the western part of the country, was occasionally blown as far east as North Dakota and deposited on the landscape and in the lakes and swamps. The sediments turned into sandstone, siltstone, mudstone, claystone, and lignite, and are referred to as the Ludlow, Slope, Bullion Creek, Sentinel Butte, and Golden Valley Formations, now seen most dramatically in Theodore Roosevelt National Park. In central and eastern North Dakota, sediments deposited in the Cannonball Sea—as the waters occupying the Western Interior Seaway at this time have been designated—formed sandstones and mudstones called the **Cannonball Formation**.

The hot, humid, swampy lowlands of western North Dakota provided habitat for many exotic plants and animals. Lush forests filled with ferns, cycads, figs, bald cypresses, magnolias, ginkgos, sycamores, dawn redwoods, palms, and other subtropical plants flourished. Water lilies and *Equisetum* (horsetail) grew in the ponds and swamps. Mats of vegetation dozens of feet thick built up in the swamps; after millions of years of pressure and heat, the plant material transformed into layers—some as thick as thirty feet (10 m)—of lignite coal.[42]

Many kinds of vertebrates lived in and around the aquatic habitats of western North Dakota. The last dinosaurs had become extinct by the Paleocene Epoch, but the primary predators were still reptiles: crocodiles, alligators, champsosaurs, and turtles. The largest of these animals was the crocodile *Borealosuchus*, which grew to lengths of fifteen feet (4.5 m) and was similar in appearance to the living crocodile. The main predator at the time, it fed on turtles, champsosaurs, fish, birds, and mammals. Fossils of *Borealosuchus* have been recovered from many sites in North Dakota. At one remarkable site in Billings County called Wannagan Creek, the remains of about eighty *Borealosuchus* skeletons have been found in an area roughly the size of an ice hockey rink.[43]

Champsosaurus gigas was one of the now-extinct species of crocodile-like reptiles that inhabited North Dakota's ponds and swamps during the Paleocene. It was the largest species of *Champ-*

Figure 39. *Borealosuchus* skeleton, 1.5 m. *(ND 408.1, Photo by Brian R. Austin)*



Figures 40 & 41. *Champsosaurus gigas* skeleton. *(ND 94-225.1)* **INSET *Champsosaurus gigas*.** *(Courtesy of the Science Museum of Minnesota, St. Paul)* *sosaurus*, up to twelve feet (3.5 m) in length. Although not a crocodile, it resembled the living long-snouted gavial crocodilians that are found in India today. Because of its hydrodynamic body, powerful back legs, and long snout lined with sharp, pointed teeth, it is believed that *Champsosaurus gigas* was an aggressive underwater predator that fed on fish. These animals likely spent much of their time submerged in water, 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.

Soft-shelled (*Plastomenus*) and snapping (*Protochelydra*) turtles also inhabited the Paleocene swamps and ponds. *Plastomenus* was similar to soft-shelled turtles that live today. It grew to lengths of about eighteen inches (46 cm) and had a low, rounded shell. Unlike most other turtles, soft-shelled turtles do not have a true horny covering; instead, the underlying bony plates are covered with a layer of soft, leathery skin. *Plastomenus* had a long, mobile neck. It was probably omnivorous and would have eaten plants, insects, mollusks, and even small fish. *Protochelydra* was similar to the living snapping turtle. Its shells, about twenty-four inches (60 cm) long, look much like those of its modern relatives. Like today's snapping turtle, it was carnivorous, with fish probably being the main part of its diet. Bite marks on some *Protochelydra* shells indicate that it was a prey of crocodiles.

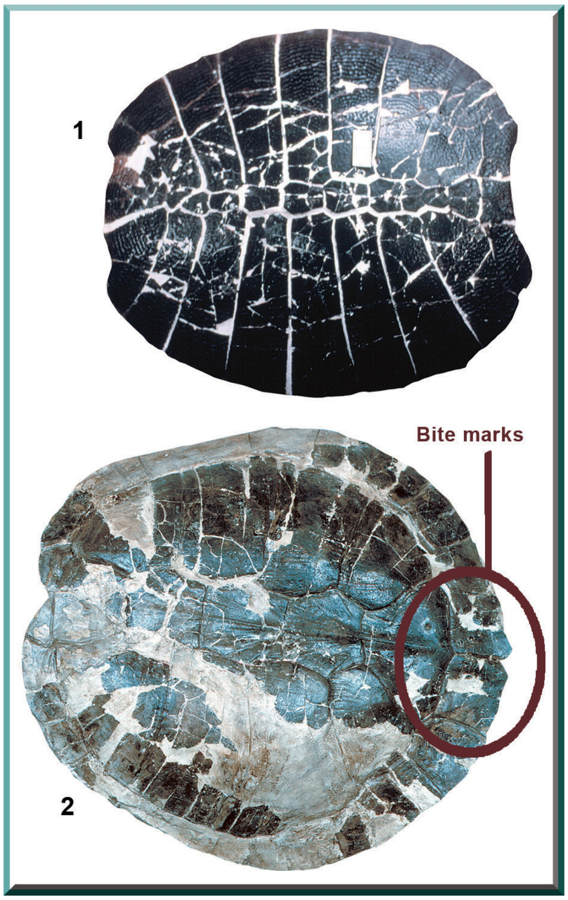


Figure 42. Turtle shells. 1. *Plastomenus* shell, USDA Forest Service-Dakota Prairie Grasslands-administered land, Sentinel Butte Formation, Billings County, length 320 mm. *(ND 213.1)* 2. *Protochelydra* shell, Sentinel Butte Formation, Billings County, length 370 mm. *(ND 94-186.1, Theodore Roosevelt National Park exhibit)*

Several kinds of fish lived in North Dakota's Paleocene aquatic environments, including dogfish (*Amia*), gars (*Lepisosteus*), and freshwater rays (*Myledaphus*). Remains of snakes, frogs, varanid (monitor) lizards, and giant salamanders (*Piceoerpeton*) indicate that these animals were also part of this interesting swampland community. Bird fossils are extremely rare because bird bones are hollow and are not often preserved. However, bones of plover-like shorebirds (and their tracks), as well as owls, have been found.[44] Insect fossils are equally scarce. Nevertheless, the remains of mayflies, dragonflies, and beetles indicate that they thrived in the swampy habitat. Plant fossils showing damage from insect feeding have also been found.

Prior to the Paleocene, when dinosaurs dominated life on land, mammals were small (mouse- or rat-sized) and few in number. Some paleontologists believe this was because dinosaurs simply out-competed mammals during the Cretaceous.[45] But mammals quickly diversified after the final demise of the dinosaurs, occupying many of the niches vacated by their reptilian competitors. Very quickly, many new mammalian groups evolved in the warm, forested swamplands. This evolutionary radiation of mammals was unprecedented and spectacular in biological terms. There were eighty-four genera (major groups) of mammals in North America by the middle of the Paleocene, and one hundred by the late Paleocene, compared to just eighteen in the Late Cretaceous.[46] In fact, by the early Eocene, just ten to twelve million years after the Cretaceous-Tertiary boundary extinction, all orders of living mammals had evolved.[47]

Paleocene rocks in western North Dakota contain fossils of some of these mammals, including *Plesiadapis*, a lemur-like mammal about two feet (60 cm) long, somewhat larger than a modern squirrel. It had a long tail, agile limbs with claws rather than nails, and eyes situated on the sides of its head. Structures of the skull indicate that it probably had a good sense of smell. *Plesiadapis* had long, clawed fingers and toes and was well-adapted for climbing trees in the swampy wood-lands of Paleocene western North Dakota. It probably occupied an ecological niche similar to that of squirrels today.[48]

Figure 43. Skeleton (cast) of the lemur-like mammal *Plesiadapis* on a petrified log, length 60 cm. *(ND 06-03.1, Photo by Brian R. Austin)*

Figure 44. Modern Sand-tiger Shark. Its teeth are identical to the Paleocene shark *Carcharias*. *(Painting by and Courtesy of Richard Ellis)*

The beginning of the Paleocene marked dramatic changes in the Cannonball Sea occupying much of central and eastern North Dakota, as well as in the swampy lowlands to the west. The fossils found in the Cannonball Formation, the name given to the lithified sediments deposited in that sea, do not include mosasaurs and plesiosaurs, the large marine reptiles that lived in the Cretaceous seas, because they had become extinct at the end of the Creta-ceous along with the dinosaurs. Instead, the main predators in the Cannonball Sea were new species of sharks. The most common shark found in the Cannonball Formation was *Carcharias*.[49] One of the main predators in the Cannonball Sea, it was well adapted for ripping into the flesh of prey with its long, slender, sharp teeth. This ten-foot-long (3 m) shark undoubtedly patrolled the sea's shorelines, competing with other sharks for prey. *Carcharias* still lives today in temperate to tropical oceans, generally inhabiting shallow coastal waters.

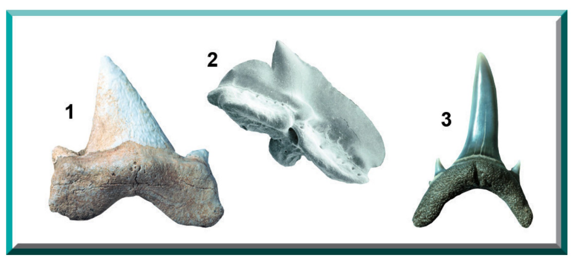


Figure 45. Shark teeth. 1. *Otodus obliquus*, Burleigh County, height 31 mm. *(UND 15807)* 2. *Megasqualus orpiensis*, Bowman County, width 2.9 mm. *(UND 15817)* 3. *Carcharias taurus*, Burleigh County, height 27.4 mm. *(UND 967)*

Rays and ratfish were also common in the Can-nonball Sea.[50] *Myliobatis* resembled the modern eagle ray, while *Dasyatis* looked like today's sting-rays. Both had numerous small, flat teeth that were tightly arranged in the mouth to produce a crushing surface for breaking open the shells of clams, snails, crabs, and other animals. Some rays, including *Myledaphus bipartitus*, also lived in fresh- and brackish-water environments. Ratfish such as *Ischyodus* were likewise shallow marine dwellers that could crush shells with their powerful jaws. These were strange-looking fish with faces resem-bling a rat's. *Ischyodus* was small, up to about three feet (1 m) long, with large eyes, pursed lips, a tall dorsal fin, fanlike pectorals, and a whiplash tail. It crushed shells not with teeth but with hard dental plates. As in today's warm, shallow oceans, fish with skeletons made of bone were also abundant in the Cannonball Sea; many fossils from these animals have been found in North Dakota.

The shallow-water and shoreline areas of the Cannonball Sea were also havens for diverse communities of warm-water invertebrate animals. Fossils of hundreds of species have been recovered from the Cannonball Formation, including corals, cephalopods, bivalves, gastropods, crabs, lobsters, bryozoans (small animals that form colonies similar to corals), echinoids (sea urchins), and starfishes.[51]

Figures 46 & 47. Modern ratfish, painted by B. Deane (1906), are about three feet long. Mouths of ratfish contain bony dental plates used to crush shellfish. **INSET Ratfish upper dental plates** (*Ischyodus dolloi*), Morton County, length 30.5 mm. *(UND 15801)*

***Teredo*-bored petrified wood**, North Dakota's state fossil, likewise occurs in the Cannonball Formation. This is driftwood that had been bored into by shipworms (clams) before becoming petrified. The borings in the petrified wood resemble sinuous tubes. Collectively, the fossils found in the Cannonball Formation indicate that the Cannonball Sea was shallow and its water warm.

About sixty million years ago, the Cannonball Sea receded from all of North Dakota, marking the end of the Western Interior Seaway's presence in the state, a presence that had lasted about one hundred million years. As the forests and swamps that covered western North Dakota spread over the remainder of the state, the animals also spread east, including the new mammalian groups that were rapidly filling the niches formerly occupied

Figure 48. Fossils. 1. Stingray tooth (*Dasyatis concavifoveus*), Bowman County, width 1.8 mm. *(USNM 456243)* 2. *Teredo*-bored petrified wood, North Dakota State Fossil, Morton County, width 166 mm. *(SHSND 12151)* 3. Crab (*Camarocarcinus arnesoni*), Burleigh County, width 56 mm. *(ND 376.1)* 4. Bivalve (*Glycymeris*), Morton County, width 29 mm. *(UND 9527)* 5. Gastropod (*Semitriton*), Burleigh County, height 33 mm. *(ND 385)*. 6. Cephalopod (*Hercoglossa ulrichi*), Morton County, width 174 mm. *(UND A2132)*

by dinosaurs. Some of the first large mammals to leave a fossil record in North Dakota lived in these dense forests of the Paleocene Epoch.

The largest mammal that inhabited North Dakota sixty million years ago was ***Titanoides***, one of the early Cenozoic browsing mammals called pantodonts. Bearlike in size and appearance, *Titanoides* had short, stout limbs and feet with five clawed digits. Even though it had huge canine tusks, its limbs—adapted for digging roots—and the shape of its cheek teeth indicate that it was a herbivore. It is likely that *Titanoides* at times fell prey to crocodiles, the main predators at the time. The largest mammalian predators during the Paleocene were only the size of small dogs.

Figures 49 & 50. *Titanoides*. *(Courtesy of National History Museum, London)* **INSET Crushed skull and lower jaws** of *Titanoides*, Sentinel Butte Formation. Recovered from USDA Forest Service-Dakota Prairie Grasslands-administered land in Billings County. Length 300 mm. *(ND 98-38, Photo by Brian R. Austin)*

The global warming during the Paleocene continued into the early Eocene, fifty-five million years ago. Plant fossils from the Golden Valley Formation in North Dakota and elsewhere in the upper Midwest indicate mean annual temperatures as high as 65°F, compared to the present mean annual temperature in western North Dakota of 41°F.[52] In contrast to today's grasslands, dense tropical forests—similar to those now found in Central American areas like Panama—grew in North Dakota during the early Eocene.[53] North Dakota was a hot, humid, densely forested, swampy lowland transected by sluggish streams. The state was likely frost free. Several species of aquatic plants, ferns, herbs, shrubs, vines, and trees (including palms) grew in this forested swampland.[54] The diverse animal community that inhabited the area consisted of fish, amphibians, reptiles (e.g., turtles, lizards, crocodiles, and alligators), birds, and mammals including insectivores, rodents, the early horse "*Hyracotherium*," the large tapir-like pantodont *Coryphodon*, and carnivores.[55]

During the early Eocene there was a major migration of mammals into North America from Asia. One such immigrant was *Coryphodon*, the largest mammal—up to about eight feet (2.5 m) long—that lived in North Dakota at this time. Bulky and slow-moving, it was similar in some ways to the hippopotamus. ***Coryphodon*** was probably semi-aquatic; it dug up swamp plants with its canine tusks, although it also browsed on forest vegetation. For its size, *Coryphodon* had an extremely small brain, the smallest ratio of brain to body weight in any mammal.

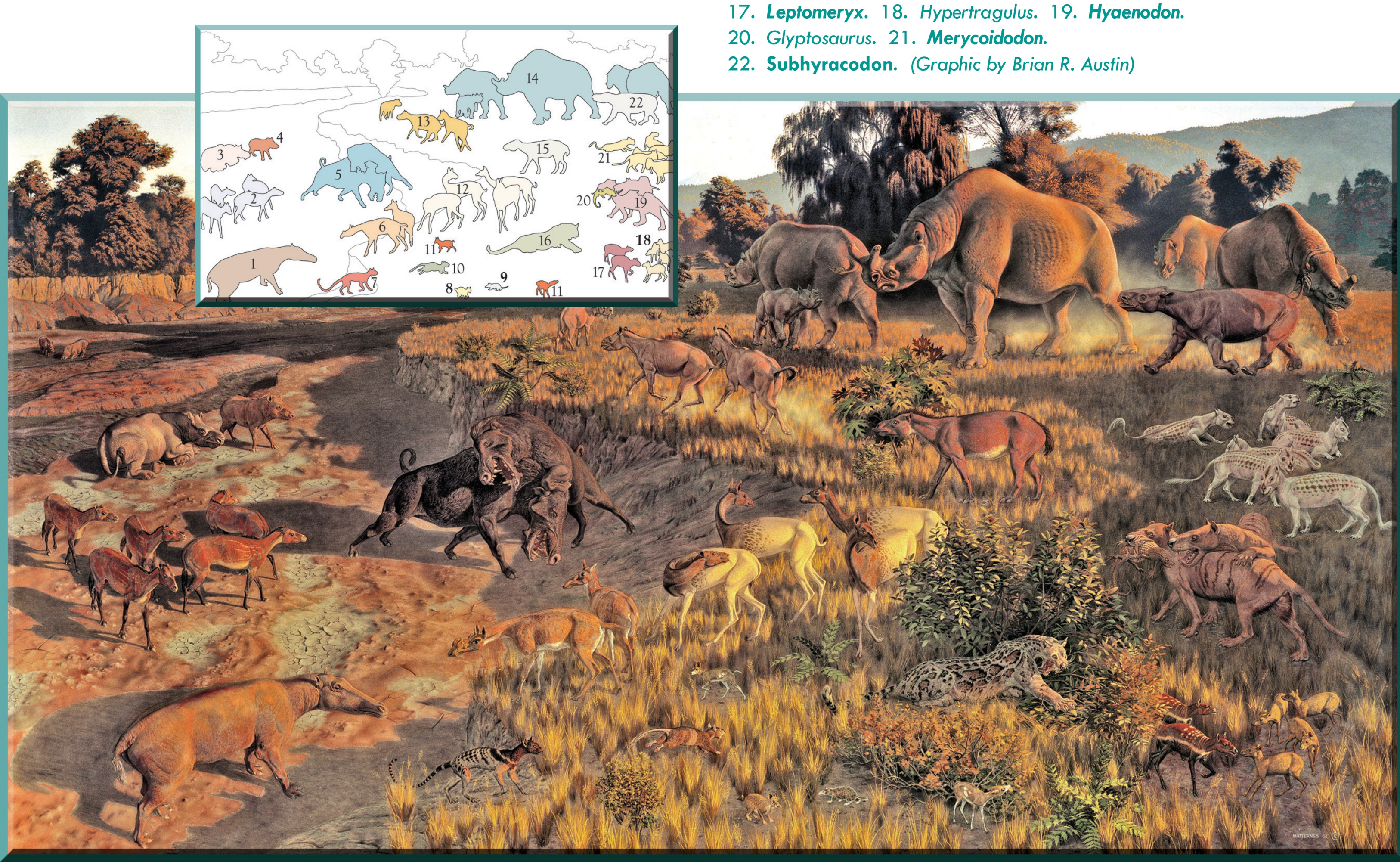
The early Eocene greenhouse conditions gradually came to an end by the early **Oligocene**, about thirty-five million years ago. During this time there was a worldwide climate cooling that resulted in the formation of ice sheets on Antarctica.[56] It has been estimated that global temperatures dropped by almost 22°F.[57] In North Dakota the equable, humid, warm-temperate to subtropical climate that had prevailed during the Paleocene and early Eocene became cooler and drier. The swampy environments of the Paleocene and early Eocene began to disappear, along with the plants and animals that had inhabited them. Alligator fossils are found in the **Eocene Chadron Formation** in North Dakota, indicating that the climate was still warm and wet enough to support them even though conditions were changing.[58] After that time these reptiles essentially disappeared from North Dakota, never to return. By the Miocene Epoch, about twenty-four million years ago, the climate here was cool-temperate and semiarid to arid, with pronounced dry seasons.

North Dakota Savanna

By the Oligocene, about thirty million years ago, the subtropical, swampy forests had given way to a mostly treeless plain, similar to a savanna, in North Dakota. This open plain was a scrubland consisting of shrubs, herbaceous plants, and possibly some grasses. True savanna habitats, dominated by grasslands similar to parts of Africa today, did not become established in the state until the Miocene. The Oligocene climate was seasonal and temperate, with an annual rainfall similar to that in the state today. Ponds and lakes punctuated the open plain, and gallery woodlands grew along the margins of streams and rivers. Rivers flowed across the plain, depositing sand and gravel in their channels. There were seasonal droughts and floods, with the latter spreading silt and mud over vast floodplain areas. Layers of volcanic ash in the rocks indicate that volcanoes were active in the western part of the continent. Sediments deposited in these ways, now lithified, are the Chadron (Eocene), Brule (Oligocene), and Arikaree (Miocene) Formations.[59] These rocks have mostly eroded away in North Dakota, but remnants of them cap many buttes in the western part of the state; one place where they are exposed is the Little Badlands of Stark County.

Figure 51. Outcrops of the Oligocene Brule Formation, Little Badlands, Stark County. *(Courtesy John Hoganson)*

Figures 52 & 53. Habitat reconstruction of a late Eocene/Oligocene mammal community. *(Mural by J.H. Matternes)*
INSET Key. Fossils mentioned in text are indicated in bold. 1. *Aepinacodon*. 2. ***Mesohippus***. 3. *Trigonias*. 4. *Perchoerus*. 5. ***Archeaotherium***. 6. *Protoceras*. 7. ***Hesperocyon***. 8. ***Palaeolagus***. 9. ***Leptictis***. 10. ***Ischyromys***. 11. *Hypisodus*. 12. ***Poebrotherium***. 13. *Hyracodon*. 14. ***Brontotherium***. 15. *Protapirus*. 16. *Hoplophoneus*. 17. ***Leptomeryx***. 18. *Hypertragulus*. 19. ***Hyaenodon***. 20. *Glyptosaurus*. 21. ***Merycoidodon***. 22. ***Subhyracodon***. *(Graphic by Brian R. Austin)*



The most spectacular mammals that lived during the late Eocene in North Dakota were the brontotheres. The size of elephants, about eight feet (2.5 m) tall at the shoulder, they were some of the largest mammals ever to live in North Dakota. They are also call titanotheres, or **"thunder beasts,"** because of their immense size. Brontotheres resembled rhinoceroses and browsed on the soft forest vegetation in the dry woodlands of that period.[60] The large, bony knobs on their snouts, which were probably covered with skin as in modern-day giraffes, were used for display or as weapons during fights among males to establish dominance. Fossils of these animals are found in the Chadron Formation.[61] Brontotheres lived during the transition from warm swampland to cooler open-plain conditions, and apparently they did not survive this change because their fossils are not found in the younger Oligocene Brule Formation. Other plants and animals also became extinct at this time.

Fossils recovered from the **Brule Formation** show that the number of mammal species, mostly adapted for grazing, and the abundance of mammals dramatically increased in the warm-temperate, dry, open-plain Oligocene habitats in North Dakota following the Eocene extinctions. Most of these mammals migrated to North America from Asia as a result of a drop in sea level caused by climate cooling and glacier development.[62] These immigrants were ancestral members of families that still exist today, including dogs, cats, camels, deer, squirrels, beavers, horses, rabbits, rhinoceroses, and mice.[63] Fish, turtles, lizards, amphibians, birds, insects, gastropods, and bivalves also lived in North Dakota.

Although there were no dense forests (and thus few tree-dwelling mammals like primates), sparse gallery woodlands grew along the waterways and other water bodies. We know little about the flora of these riparian forests because few plant fossils have been found. Calcified seeds of hackberry trees (*Celtis*) are present, indicating that this tree grew here during the Oligocene. The sparse forests appear to have been the favored habitat of several mammals, although surely these creatures would

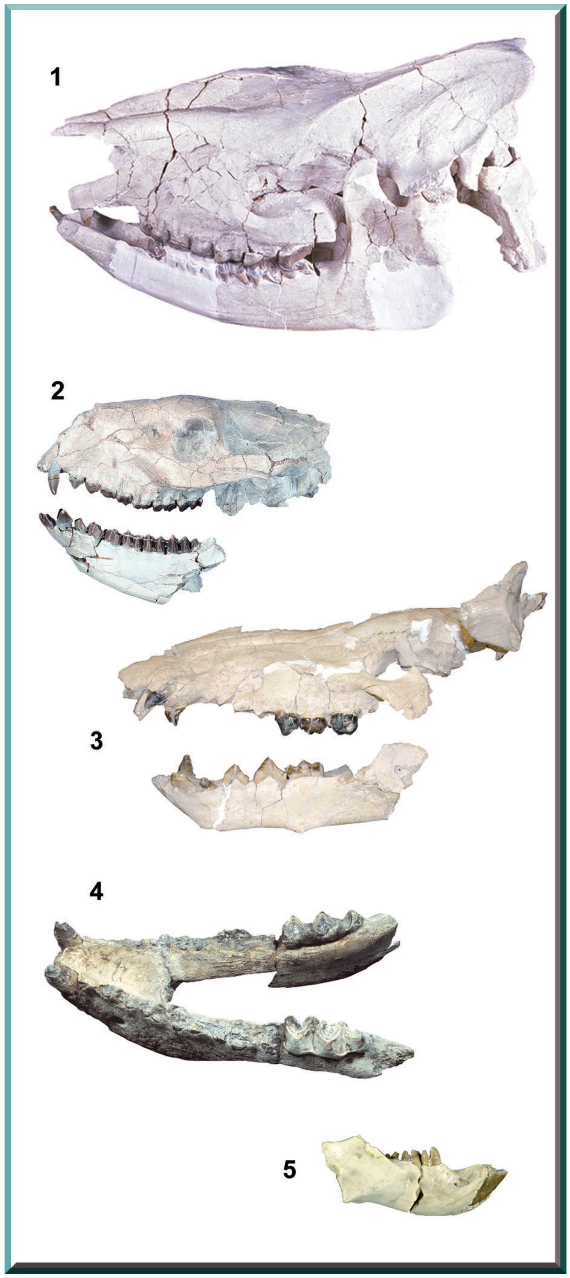


Figure 54. Mammal Fossils. 1. Rhinoceros skull (*Subhyracodon occidentalis*), Brule Formation, Oligocene, Stark County, length 520 cm. *(Courtesy The Manitoba Museum)* 2. Skull and Lower jaws of *Merycoidodon culbertsoni*, Brule Formation, Oligocene, Stark County, length 198 mm. *(ND 303.1)* 3. Skull and lower jaws of *Archaeotherium*, Brule Formation, Stark County, length 435 mm. *(MM V-1766)* 4. *Brontops* lower jaws, Chadron Formation, Eocene, Bowman County, length 410 mm. *(UND D-232)* 5. Lower jaw of *Ischyromys*, Brule Formation, Stark County, length 20 mm. *(ND 248)*

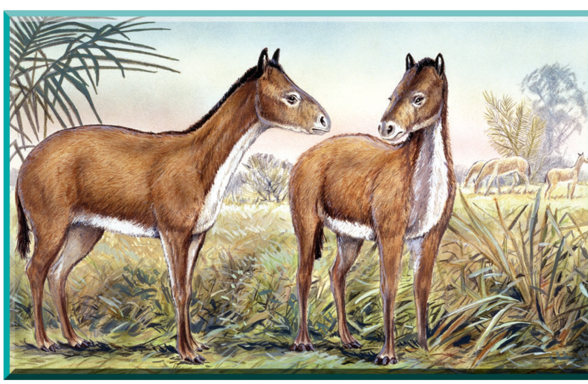
have roamed the open plains, too. The largest of these were the giant pig-like *Archaeotherium*, the hippo-like *Metamynodon*, and *Subhyracodon*, one of the early rhinoceroses. Tapir-like in appearance, *Subhyracodon* had short, stout limbs, four-toed front feet, and three-toed hind feet. It had a large, hornless head and grew to lengths of about eight feet (2.5 m). *Subhyracodon* was a plant-eater that lived in herds.

Archaeotherium belonged to the group of pig-like mammals called entelodonts. It was similar in appearance to the living warthog and grew to about four feet (1.2 m) long. It had an elongated skull, with unusual protrusions of bone beneath the eyes. These bony knobs probably provided attachment points for the powerful jaw muscles. *Archaeotherium* mostly ate roots and tubers, but with its powerful jaws and teeth it could have eaten most anything, even carrion; in this sense it was like modern-day pigs. These animals had strong shoulder and neck muscles, as indicated by their bone structure. They may have spent much of their time rooting and grubbing in the ground. Large olfactory lobes suggest that they had a keen sense of smell.

Another pig-like mammal, *Merycoidodon*, and the diminutive horse *Mesohippus* were among the most common animals that lived in North Dakota during the Oligocene. *Merycoidodon* was a member of the now-extinct family Merycoidodontidae, and are also sometimes referred to as oreodonts. They possessed advanced teeth, with long-lasting grinding surfaces adapted for effective side-to-side chewing of vegetation. *Merycoidodon* was sheep-sized, about four feet (1.2 m) long, but probably looked more like a pig or peccary. It was heavily built, with short legs and four-toed feet, and was not an efficient runner. Fossils of *Merycoidodon* are common, indicating that these browsing animals lived in large herds.

Mesohippus was one of the early species of horses. It superficially resembled the modern horse, except that it was much smaller—only around two feet (60 cm) tall at the shoulder, and up to four feet (1.2 m) long. It was about the size of a greyhound dog. *Mesohippus* had slender limbs adapted for trotting and running. It had three toes on each foot, in contrast to the modern horse, which has one. Another difference between *Mesohippus* and today's horse is that *Mesohippus* teeth were low-crowned and therefore suited for browsing leaves from bushes and trees, whereas teeth of a modern horse are high-crowned and suited for grazing primarily on grasses.

Other mammals that inhabited the wooded areas during the Oligocene were the squirrel-like rodent *Ischyromys*, the rabbit *Palaeolagus*, and the beaver *Agnotocastor*. *Ischyromys* is one of the earliest of the true rodents. Similar in appearance to today's rodents, it had a characteristic pair of upper



Figures 55 & 56. *Mesohippus*. LEFT Painting of *Mesohippus*. *(Painting by Michael R. Long, courtesy of the Natural History Museum, London)* **RIGHT Skeleton (cast) of *Mesohippus bairdi*** on exhibit at the North Dakota Cowboy Hall of Fame Museum in Medora, Brule Formation, height 465 mm. *(Photo by Brian R. Austin)*

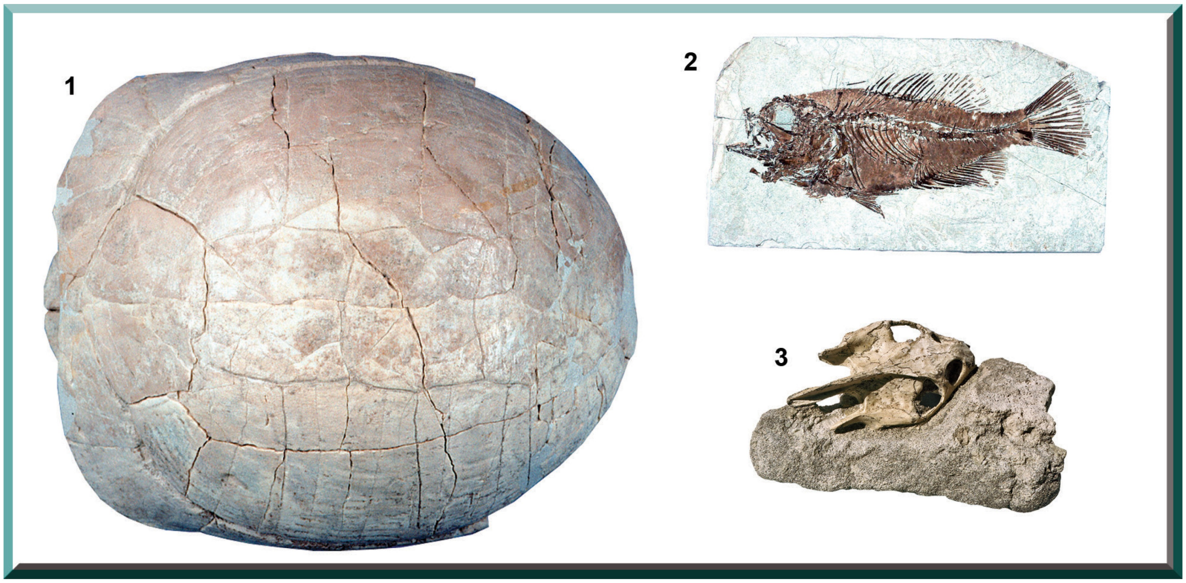
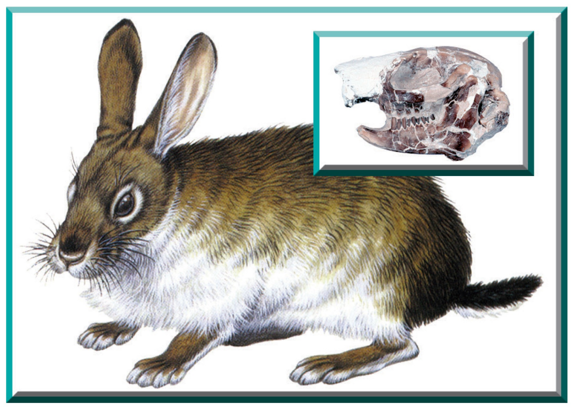


Figure 57. Eocene and Oligocene Fossils. 1. Tortoise shell, *Stylemys nebrascensis*, Brule Formation, Stark County, length 226 mm. *(MM V-1931)* 2. *Plioplarcus* fish skeleton, Eocene, Chadron Formation, Golden Valley County, length 80 mm. *(ND 421.1)* 3. *Trionyx* turtle skull, Brule Formation, Stark County, length 65 mm. *(ND 97-116.2)*

incisors, as well as other rodent head features. Its strong hind limbs, with five clawed toes on each of its hind feet, were also like those of modern rodents. *Ischyromys* grew to lengths of two feet (60 cm). It is believed to have been an efficient tree climber, like today's squirrels.



Figures 58 & 59. *Palaeolagus*. *(Courtesy of Marshall Editions Ltd.)* **INSET Skull and lower jaws of *Palaeolagus*,** Brule Formation, Stark County, length 51 mm. *(ND 146.1)*

Palaeolagus is in the Lagomorpha family, which includes pikas, rabbits, and hares. Because of their small size and continually growing incisors (gnawing teeth), lagomorphs are much like rodents, except that they have two pairs of incisors—one immediately behind the other—in the upper jaws, compared to a single pair in rodents. The chewing action is also different in the two groups. In lagomorphs the jaws work sideways, in rodents backwards and forwards. *Palaeolagus* was similar in appearance to the modern rabbit except that its hind legs were proportionally shorter, which suggests that it was better adapted for scampering than for hopping. *Palaeolagus* grew to lengths of about ten inches (25 cm).

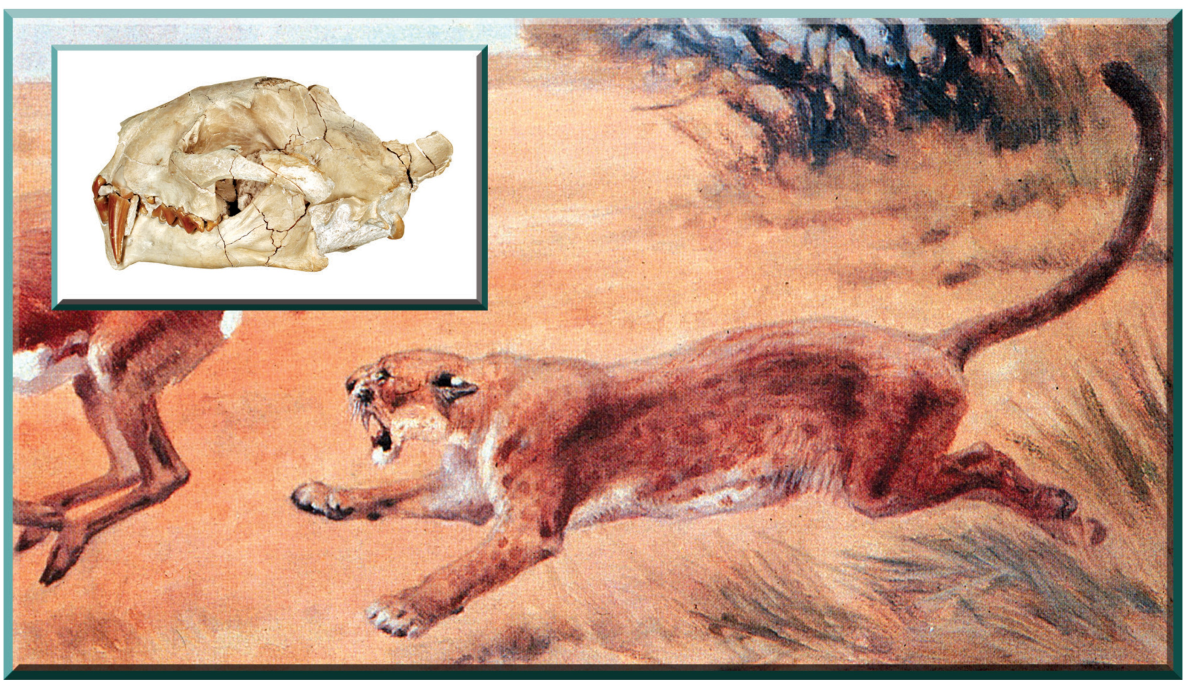
Large tortoises (*Stylemys*) and other turtles such as *Trionyx* and *Testudo* lived in and around streams, ponds, and lakes during this time. *Stylemys* is in the family of dryland tortoises. It was similar to the modern Galapagos turtle. *Stylemys* grew to lengths of four feet (1.2 m) and had a high, domed shell and large legs. It was a herbivore. Its frequent presence in the Brule Formation indicates dry conditions were prevalent during the Oligocene. *Trionyx*, which inhabited ponds and quiet stream-marginal areas, was similar to the soft-shelled turtles that live today. It probably fed on plants, insects, mollusks, and even small fish.

Fish were common in the aquatic habitats, too. Spectacular fossil skeletons of the perch *Plioplarcus* have been found in the Chadron Formation. Remains of land snails, including pupillids and the large-shelled *Skinnerelix*, pupal cells of burrowing beetles (*Pallichus*), and larval cells of sweat bees (*Celliforma*) have been discovered, indicating that they also lived in the streamside woodlands.

While herds of larger mammals like *Merycoidodon* and *Mesohippus* also frequented the open plain, smaller mammals seem to have been more abundant in that habitat. Fossils of several species of rodents have been found. *Eumys* was an early representative of the highly successful rat and mouse group of rodents, which today includes hamsters and voles. In recent times this has become the most widespread and abundant group of rodents, indeed of all mammals.

The small, gazelle-like camel *Poebrotherium* and tiny deer *Leptomeryx* were also common dwellers of the plains. *Leptomeryx* was a small, antler-less, cloven-hoofed deer about two feet (60 cm) long. Graceful and dainty, with long, slender limbs, it was no larger than a jackrabbit. *Leptomeryx* resembled the chevrotain or "mouse-deer" living in Asia today.

Herbivores greatly outnumbered carnivores on the North Dakota Oligocene plain, as is the case today on the African savannas. Nevertheless, fossils of several groups of carnivores and insectivores have been found in the Brule Formation. *Dinictis* was one of the early saber-toothed cats. Technically these were not true cats, belonging instead to a group of catlike carnivores known as mimravids. Their sleek, three- to four-foot long (1.2 m) bodies resembled that of the present-day lynx. They were much smaller than the huge saber-toothed cat *Smilodon* that lived during the Ice Age, only a few thousand years ago. *Dinictis* was an extremely efficient predator. Its upper canine teeth, like those of saber-toothed cats, were elongate, serrated, and curved. These were used to stab into the throat and lower neck of prey, as well as to slice into the muscle after a kill had been made. The modified lower jaws of *Dinictis* could open to a wide gape. The animal also possessed very strong neck muscles.



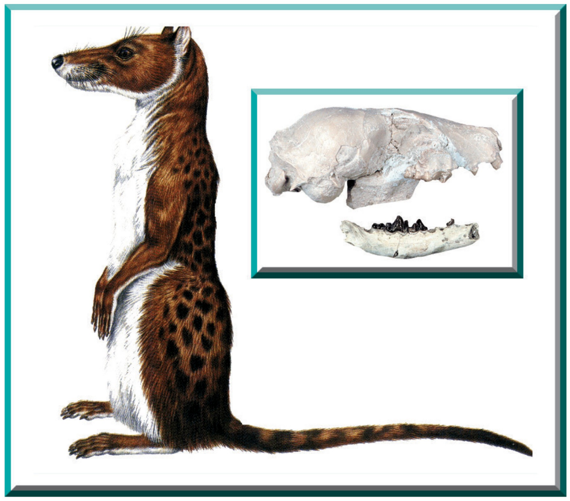
Figures 60 & 61. ***Dinictis*** was one of the early saber-toothed cats. *(Painting by Charles R. Knight, courtesy of the American Museum of Natural History)* **INSET *Dinictis* skull,** Brule Formation, Stark County. Length 180 mm. *(ND 05-67.1)*

Hesperocyon was one of the earliest members of the Canidae, or dog, family. Its appearance, however, was more like that of a meerkat, a living mongoose. Small, active, and weasel-like, it had a slender body about two feet (60 cm) in length, short, weak legs, five-toed feet, and a long tail. It was a carnivore, with meat-cutting teeth similar to a modern dog's.

Daphoenus was another predator and a member of the primitive carnivorous group called bear-dogs. It was a lightly built animal about three feet (90 cm) long—similar to a greyhound dog. It had a long tail, long limbs, and a badger-like skull with crushing molar teeth and well-developed carnassial (cheek) teeth. *Daphoenus* was one of the main hunters of the abundant game present in North Dakota during the Oligocene. It has been suggested that *Daphoenus* may be an ancestor of the present-day wolf.

Hyaenodon was a member of the primitive and extinct group of flesh-eating mammals called creodonts. Creodonts had huge heads compared to the size of their bodies. Their posterior carnassial teeth were modified to form specialized shearing surfaces for eating flesh. The four-foot (1.2 m) long *Hyaenodon* had long legs, suggesting that it could run, but probably not fast because of its spreading toes. Its strong canines, large premolars, and shearing carnassial teeth indicate that the animal was probably an active hunter and also a scavenger, like the living hyena.

Insectivores were common on the North Dakota Oligocene plain. Well-preserved skulls of *Leptictis*, an insect-eating mammal distantly related to modern shrews, have also been found in the Brule Formation. Its cheek teeth had high, pointed cusps ideally suited for eating insects and other small animals. Like most insectivores, *Leptictis* was a small creature, about a foot (30 cm) in length. It had a long snout similar to that of the hairy hedgehog which lives in Southeast Asia today.



Figures 62 & 63. *Hesperocyon*. *(Courtesy of Marshall Editions Ltd.)* **INSET Skull and lower jaw of *Hesperocyon*,** Brule Formation, Oligocene, Stark County, length 85 mm. *(MM V-1770, V1771)*

Figure 64. Skull of the doglike mammal *Daphoenus*, Brule Formation, Oligocene, Stark County, length, 120 mm. *(ND 282.7)*

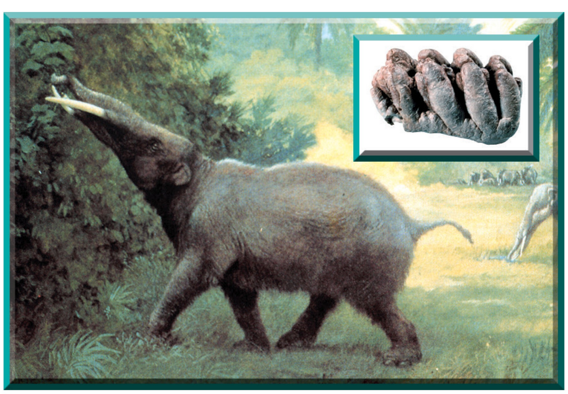
Figure 65. *Leptictis* skull, Brule Formation, Stark County, length 60 mm. *(North Dakota State University)*

By the late Oligocene and early Miocene (about twenty-five million years ago) the climate had cooled still further, and North Dakota and other areas of the High Plains had become more arid.

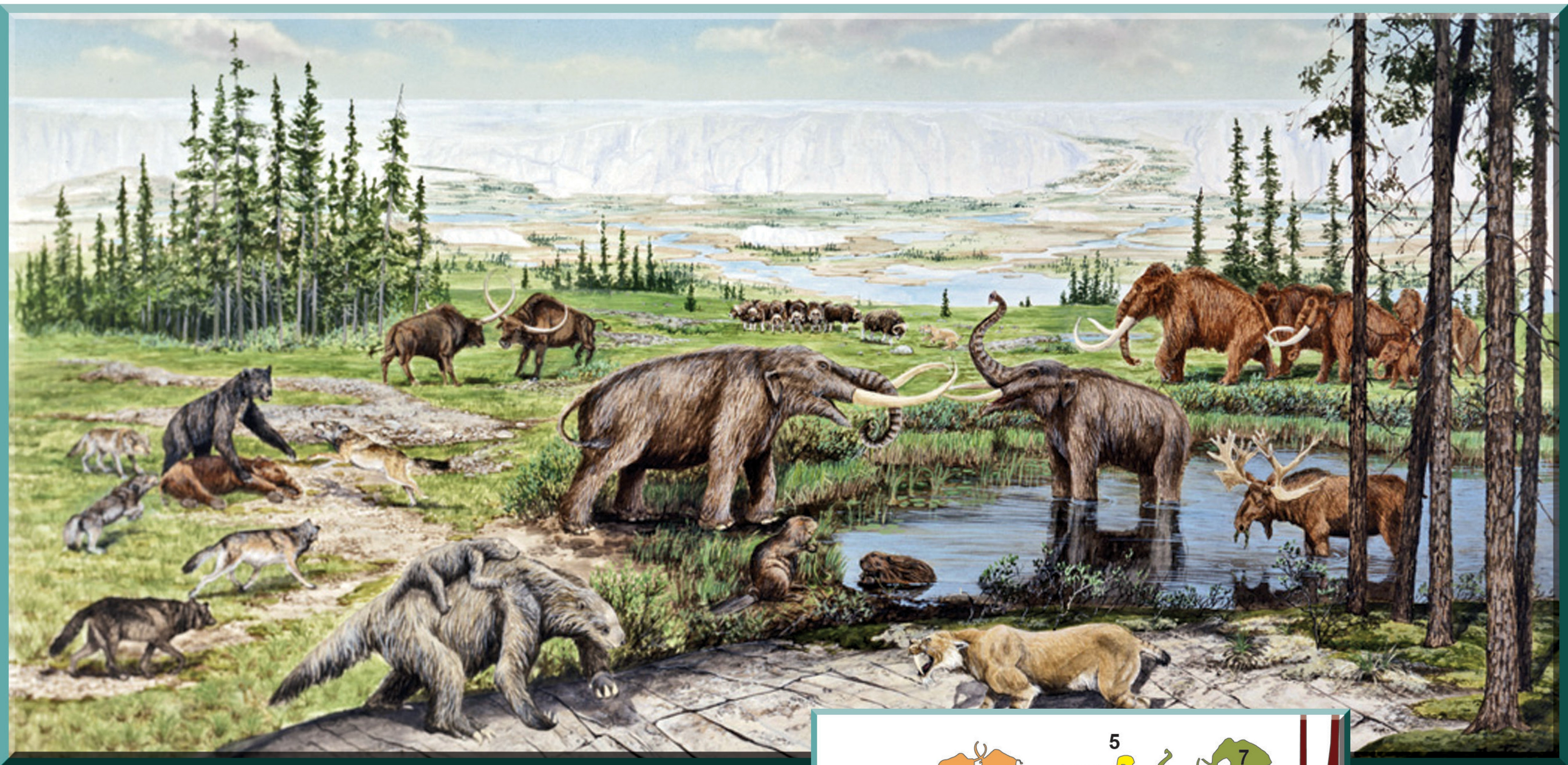
Open grasslands with riparian forests, similar to African savannas today, were established in the state by the Miocene. Average annual rainfall was only around fourteen to eighteen inches (35-45 cm), about what it is in western North Dakota today.[64] Little is known about life in North Dakota during this cool, dry period because most of the rocks that would have been deposited then, along with the fossils entombed therein, have been removed by erosion. Also, land mammal diversity in the mid-continent was then at an all-time low.[65] Remains of a few grassland mammals, including the oreodont *Merychyus*, the horse *Miohippus*, and the unusual burrowing beaver *Palaeocastor*, have been found in the remnant Miocene-age rocks.[66] *Palaeocastor* is one of the earliest known beavers. Unlike today's aquatic beaver, *Palaeocastor* was terrestrial. It was about a foot (30 cm) long—the size of a muskrat. It excavated and lived in two-foot-long (60 cm) corkscrew-shaped burrows. Scratch marks on the walls of these burrows indicate that the beavers dug them by scraping with their teeth. The helical-shaped burrows are preserved as trace fossils and are called 'Devil's corkscrews'; their scientific name is *Daemonelix*.

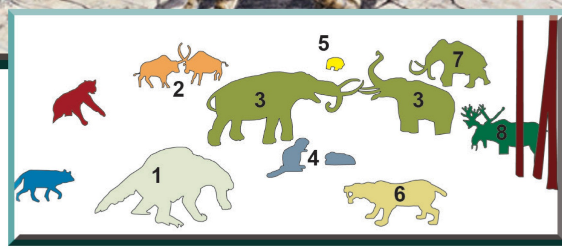
Figure 66. Cross-section of *Daemonelix*, burrow made by *Palaeocastor*, after L.D. Martin and D.K. Bennett, "The Burrows of the Miocene Beaver *Palaeocastor*, Western Nebraska, USA," *Palaeogeography, Palaeoclimatology, Palaeoecology* (1977)

There is almost no record of prehistoric life in North Dakota from about twenty million years ago (most of the Miocene and all of the Pliocene) until about fifty thousand years ago, during the Pleistocene. Rocks deposited during that time, and the fossils that would have been found inside them, have also been removed by millennia of erosion. This was a time of global climatic flux, from warm conditions in the early Miocene to cooling in the middle part of that epoch. Isolated fossils which are occasionally found in North Dakota provide tantalizing hints of what life was like during this mysterious time. One of these finds is the tooth of the "shovel-tusked" gomphothere *Amebelodon*. Gomphotheres were elephant-like animals that migrated to North America from Eurasia across the Bering land bridge during the Miocene, about 16.5 million years ago. *Amebelodon* was about ten feet (3 m) tall at the shoulder and resembled a modern elephant. The skull and tusks of *Amebelodon*, however, were quite different from those of the living elephant. Three-foot-long (90 cm) flattened, spade-like tusks projected from its lower jaws. These flattened tusks would have been used like shovels to dig up rooted water plants in rivers and ponds. *Amebelodon* was the largest herbivore that roamed the North Dakota plains during the Late Miocene.



Figures 67 & 68. *Amebelodon* was the largest herbivore that roamed the North Dakota plains during the Late Miocene. **INSET Tooth, *Amebelodon*,** Miocene, Emmons County, width 112 mm. *(SHSND 15032)*





Figures 69 & 70. North Dakota's Ice Age landscape resembled the one depicted in this painting. *(Painting by Betsy Thorsteinson, courtesy of the Manitoba Museum)* **INSET Ice Age Landscape Mural Key.** Animals in text are identified in bold. 1. **Jefferson's Ground Sloth** *Megalonyx jeffersonii*. 2. **Giant Bison** *Bison latifrons*. 3. **American Mastodon** (*Mammut americanum*). 4. Giant Beaver (*Castorioides ohioensis*). 5. Woodland Musk Ox (*Symbos cavifrons*). 6. Saber-toothed Cat (*Smilodon*). 7. **Woolly Mammoth** (*Mammuthus primigenius*). 8. Stag Moose (*Cervalces scotti*). *(Graphic by Robin Pursley)*

The Great Ice Age

The last **Great Ice Age**, during the **Pleistocene Epoch**, began about 1.8 million years ago, although climate cooling and the development of ice caps at both poles had commenced at the end of the Pliocene, about 3.5 million years ago.[67] It was a harsh time in North Dakota, as the geology and life of the state were dramatically affected by the climate and events associated with glaciation. **Glaciers**, some several hundred feet thick, advanced into North Dakota from Canada on numerous occasions during the colder times. (Worldwide temperatures were about 8–10°F cooler during times of glacial advance than in the interglacial periods.) Ice sheets extended as far south as the present Missouri River Valley during the last of the major glacial incursions, called the **Wisconsinan glaciation**, about twenty thousand years ago. During earlier times glaciers had moved even farther south. At glacial maximum the center of the North American ice sheet in Canada was about two miles (over 3 km) thick, and global sea levels were about four hundred feet (120 m) lower than today because of the huge amount of water frozen as glacial ice. These glaciers altered river courses and molded the landscape, creating the gently rolling, hilly topography seen in most areas of the state today. Tundra and northern spruce forest habitats, like those in northern Canada today, developed in front of the glaciers. When the glaciers melted, the sediment incorporated in the ice, called **"glacial till,"** was deposited on the land surface; flowing water from the glaciers also deposited outwash sands and gravels. The northeastern three-fourths of North Dakota is veneered with glacial deposits, in some areas more than four hundred feet (120 m) thick. Fossils of the cold-adapted animals and plants that lived in the state during the Pleistocene are found in these glacial deposits. The most impressive of them were the large mammals, including mammoths, mastodons, giant bison, ground sloths, and horses.[68] Most of these large mammals became extinct at the end of the Pleistocene, about eleven to ten thousand years ago.

Fossils of **woolly mammoths** (*Mammuthus primigenius*, a migrant from Eurasia across the Bering land bridge), particularly teeth, are fairly common in North Dakota, and fossils of the larger Columbian mammoth (*Mammuthus columbi*) have also been found here.[69] Complete skeletons of either animal have so far eluded discovery in the state. Woolly mammoths are in the same family as modern elephants. They were relatively small for a mammoth, growing to heights of about nine feet (almost 3 m). As with today's elephants, their upper incisors were greatly elongated to form tusks. These recurved tusks were used for brushing away snow, digging up roots, debarking trees, and fighting. Finger-like projections on the end of their trunks were used for grasping. Woolly mammoths were grass eaters, and their huge, flattened teeth were adapted for grinding vegetation. They had a thick coat of shaggy, black-to-brown hair for insulation against the severe Ice Age climate, as well as an undercoat of fine hair and a layer of fat to help stay warm. Much is known about the anatomy of woolly mammoths because frozen carcasses of these animals have been found in Siberia. Early people hunted them for food and clothing; in Siberia dwellings were constructed from their bones, and painted and etched images of them are found on cave walls in France and Spain. They became extinct about ten thousand years ago, at the end of the Pleistocene Epoch, except for a small group of dwarf mammoths that survived on an Arctic island until about six thousand years ago.

Figure 71. This woolly mammoth tooth is about eleven thousand years old. The root of the tooth is at the bottom. Oliver County, width 332 mm. *(SHSND 1991.1258)*

Figure 72. Skeleton of the Highgate Mastodon on display at the North Dakota Heritage Center, Bismarck; the skeleton is 3 m tall at the shoulder. *(SHSND 1988.240)*

The **American mastodon**, *Mammut americanum*, was one of the most common proboscideans that lived in North America at the end of the Pleistocene, but few fossils of these animals have been found in North Dakota.[70] Unlike the woolly mammoth, a recent migrant from Eurasia, the mastodon had been a resident of North America for millions of years. Mastodons were elephant-like and elephant-sized—about as large as the Indian elephant that lives today—but they were neither true elephants nor very closely related to mammoths. Adults were about ten feet (3 m) tall at the shoulder. The heads of these animals were long and held low, with long, curved tusks. They probably used their tusks to break branches and bark from trees. Like the woolly mammoth that lived in North Dakota at the same time, mastodons were covered with long, shaggy hair for insulation against the Ice Age cold. Mummified specimens indicate that they had coarse, brownish outer hair, with a fine woolly undercoat similar to that of semi-aquatic animals such as moose. They were browsers and lived in boggy spruce woodlands. Stomach contents found with mummified mastodon skeletons indicate that they ate a variety of plants, including parts of conifer trees, leaves of various kinds, grasses, bog plants, and mosses. As

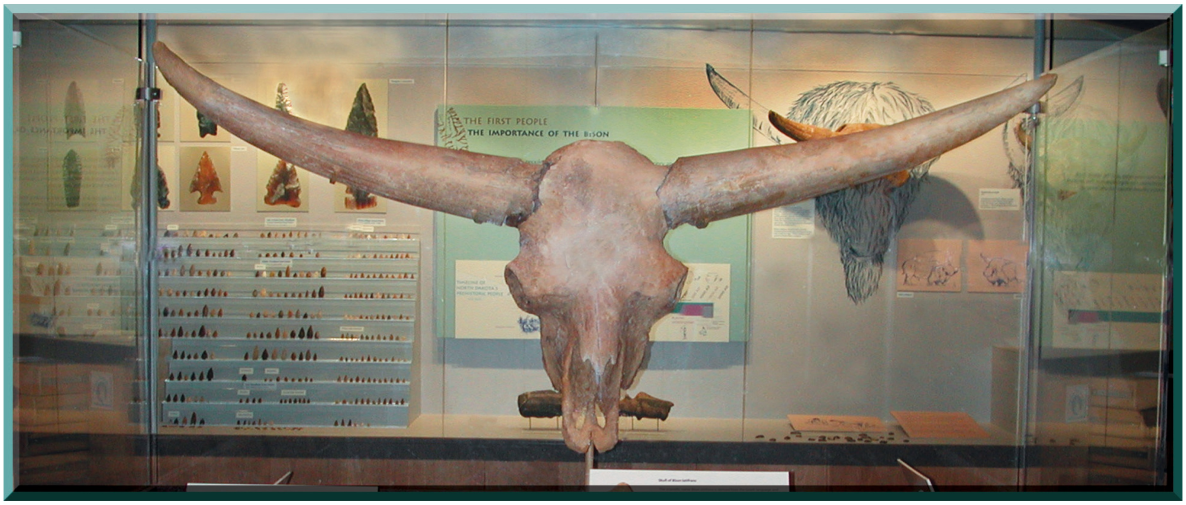


Figure 73. This specimen, the only *Bison latifrons* skull ever found in North Dakota, was discovered by Kent Pelton on U.S. Army Corps of Engineers-administered land within the Fort Berthold Reservation near New Town. Width 2.2 m. *(ND 98-44.1)*

with the mammoths, Paleo-Indians hunted these animals. Mastodons became extinct at about the same time as woolly mammoths, about ten thousand years ago.

Bison migrated to North America from Eurasia about three hundred thousand years ago, during the Pleistocene.[71] The scientific name of the giant Ice Age bison, *Bison latifrons*, is derived from Greek and refers to this animal's broad cranium and large horns. They were massive animals, the largest of all North American bison, with horns that spanned over seven feet (2 m)—more than twice as wide as those of the living North American bison. *Bison latifrons* bodies were about 25 percent larger than those of their living relatives. Unlike the grassland-dwelling modern bison, ***Bison latifrons*** lived in small groups and inhabited wooded areas.[72] They became extinct several thousand years ago. Only one fossil skull of *Bison latrifrons* has ever been found in North Dakota—a fifty-thousand-year-old specimen discovered in a glacial outwash channel.[73]

Ground sloths, emigrants from South America, were also members of the North Dakota Pleistocene mammal community, as indicated by a fossil of the giant sloth *Megalonyx jeffersonii*. The name *Megalonyx jeffersonii*, or Jefferson's ground sloth, is also derived from Greek and refers to the large claw on the third digit of each of the animal's hind feet. Thomas Jefferson, a paleontologist amongst other things, gave the name *Megalonyx* to these giant ground sloths in a 1797 presentation to the American Philosophical Society.[74] It was later given the name *Megalonyx jeffersonii* in his honor. *Megalonyx jeffersonii* was a bear-sized ground sloth that sometimes grew more than six feet (2 m) long. It lived in North Dakota about twelve thousand years ago and was widespread in North America during that time.[75] It became extinct with many of the other large Ice Age mammals at the end of the Pleistocene.

The Ice Age horse was very similar to today's horse and, like its modern counterpart, is also called *Equus*. Fossils of "*Hyracotherium*" recovered from the Golden Valley Formation indicate that horses have lived in North Dakota since the Eocene, about fifty million years ago.[76] Remains of *Equus*, meanwhile, have also been found here in Pleistocene deposits that are about fifty thousand years old.[77] Like today's horse, the Ice Age horse had one toe on each foot and high-crowned teeth adapted for eating grasses. Horses were wide-ranging during the Pleistocene in North America, but became extinct on this continent at about the same time as many of the other large Ice Age mammals. Why they became extinct in North America and not in the Old World is a matter of debate.

After about twenty thousand years ago—the last glacial maximum in North Dakota—the climate began to warm and glaciers began to melt; spruce-aspen forests became established south of the glacial ice.[78] The climate was still cool and moist, however. Ponds and bogs existed in these forests. Fossils found in pond and bog sediments dating to about eleven thousand years ago indicate that cold-adapted frogs, fish, insects, crustaceans, mollusks, plants, and small mammals, including beavers and muskrats, inhabited North Dakota.[79] Great volumes of meltwater entered the drainage systems, creating large channels across North Dakota, and glacial Lake Agassiz formed in what is now the Red River Valley as the ice margin retreated into Canada. At its maximum, this lake was about three hundred feet (90 m) deep near present-day Fargo, and more than one hundred (30 m) feet of lake sediment was deposited in most areas of the valley. These nutrient-rich sediments now constitute some of the flattest and richest farmland in the world. Lake Agassiz occupied portions of eastern North Dakota until about eight thousand years ago.[80]

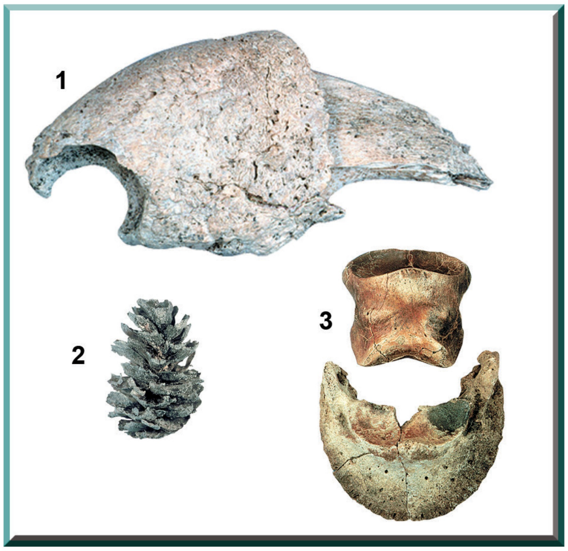


Figure 74. Ice Age Fossils. 1. This claw is the first fossil of *Megalonyx Jeffersonii* found in North Dakota. It was discovered south of Bismarck in 2000 by Linda and Doug Vannurden on what is now U.S. Army Corps of Engineers-administered land. Width 165 mm. *(ND 00-10.1)* 2. Spruce Cone (*Picea glauca*), about 11,000 years old, Sheridan County, Height 33 mm. *(UND 14256)* 3. These *Equus* foot bones are about fifty thousand years old and were found in McKenzie County in an Ice Age river channel on land administered by the U.S. Army Corps of Engineers within the Fort Berthold Reservation. Length 109 mm. *(ND 63-2)*

Artifacts in glacial sediments indicate that the first people to reside in North Dakota were here by twelve thousand years ago. They were big-game hunters, preying on mammoths and other large mammals, as well as gatherers of wild edible plants. Nearly all of the large Pleistocene mammals—thirty-two species, including mammoths, mastodons, horses, and camels—became extinct in North America between about eleven thousand and nine thousand years ago.[81] Only the medium-sized (bison, deer, pronghorns) and smaller mammals survived.

Figure 75. Paleo-Indians butchering a *bison antiquus* at the end of the Ice Age. *(SHSND, Pembina State Museum, 1996.25.1)*

The possible cause or causes of the extinction of the large mammal populations has been debated for decades. One of the most controversial theories, termed the "overkill hypothesis," suggests that they were hunted to extinction by humans.[82] Others argue that the large mammals became extinct because they could not adapt to the rapid climate warming and resulting habitat changes that occurred at the end of the Pleistocene.[83] It is likely that hunting by humans, drastic climate change, and perhaps other factors all played roles in driving the large Pleistocene mammals to extinction.[84] Whatever the reasons for this extinction, most of the large mammals of the Pleistocene world were gone by the beginning of the Holocene, ten thousand years ago.

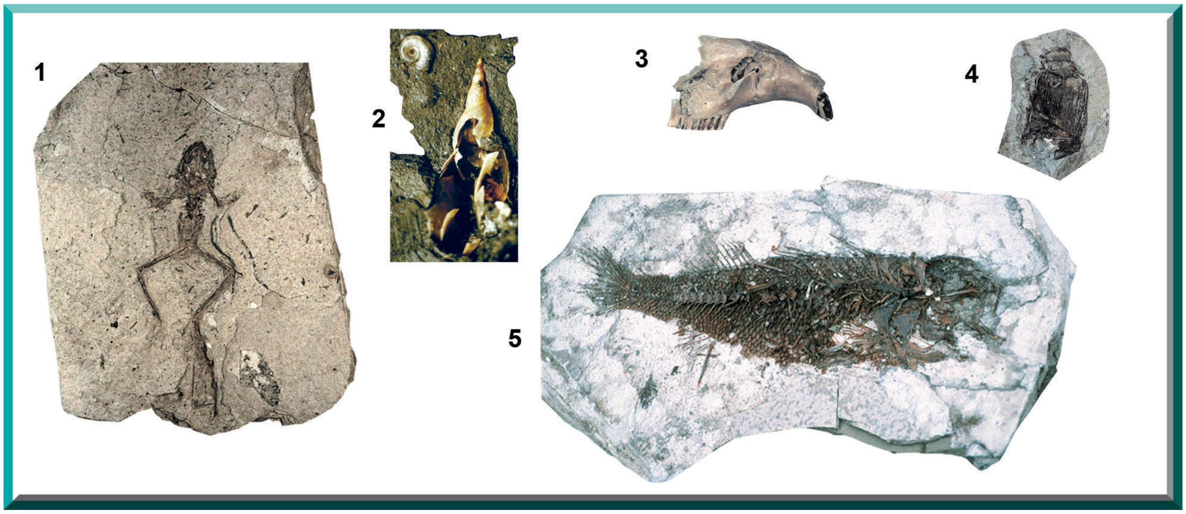


Figure 76. Glacial meltwater created many ponds and bogs that were inhabited by cold-adapted species, including frogs, fish, insects, mollusks, and small mammals. All fossils illustrated above are about eleven thousand years old. 1. Leopard frog (*Rana pipiens*) Stutsman County, Length 78 mm. *(UND 13015)* 2. Gastropods *Lymnaea* (high spired) *Helisoma* (coiled), Stutsman County, Height 32 mm (*Lymnaea*). *(NDSU)* 3. Muskrat skull (*Ondatra zibethicus*), Stutsman County, Width 24 mm. *(UND 13901)* 4. Ground beetle, Sheridan County, Length 26 mm. *(UND 14280)* 5. Yellow Perch (*Perca flavescens*), Sheridan County, Length 175 mm. *(UND)*

Between about nine thousand and seven thousand years ago, as the climate warmed and became drier, prairie habitats became established in North Dakota.[85] It was during this time that plants and animals that live in the state today began colonizing the area. But climate was still in a state of flux. Pollen fossils from lake sediments indicate that prairie ecosystems were drastically affected by intense drought conditions between about eight thousand and four thousand years ago.[86] Fluctuations in climate influence life on the North Dakota prairie even today.

Study of the history of life in North Dakota based on the fossil record mostly ends at the point when prairie ecosystems became established, although "recent" fossils are occasionally unearthed, providing insights about life here during historic times. The remains of bison and elk, which lived here in vast herds when Native Peoples were the only human residents and when Lewis and Clark passed through here two hundred years ago, are an example. These recent fossils corroborate knowledge of life in the state based on oral and written accounts. Perturbations in climate during historic times can also be detected from fossils, particularly those found in lake, pond, or bog sediments.

Figure 77. This flower, found in the Sentinel Butte Formation, Morton County, is sixty million years old, and shows how life has changed over time. It thrived in a lush, humid, swampy landscape, much like that of today's Florida Everglades. Width 6 mm. *(ND 388.18)*

The ever-changing story of life in North Dakota continues today with the introduction of new plant and animal species, the loss of old ones, and adjustments to the ranges of those that have lived here for hundreds or thousands of years. This story is now being deciphered by botanists, zoologists, and ecologists.

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