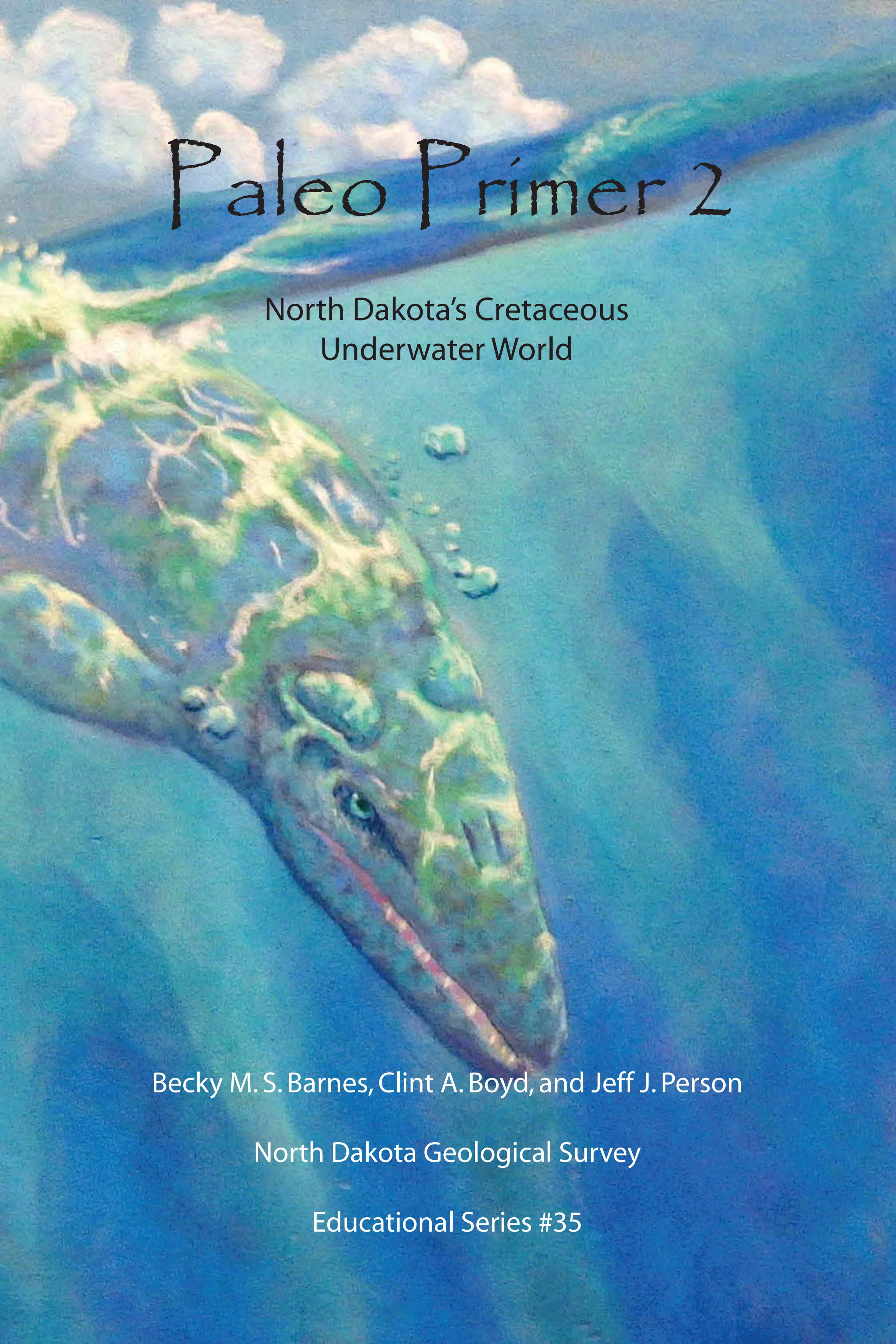


Paleo Primer 2

North Dakota's Cretaceous Underwater World

Becky M. S. Barnes, Clint A. Boyd, and Jeff J. Person

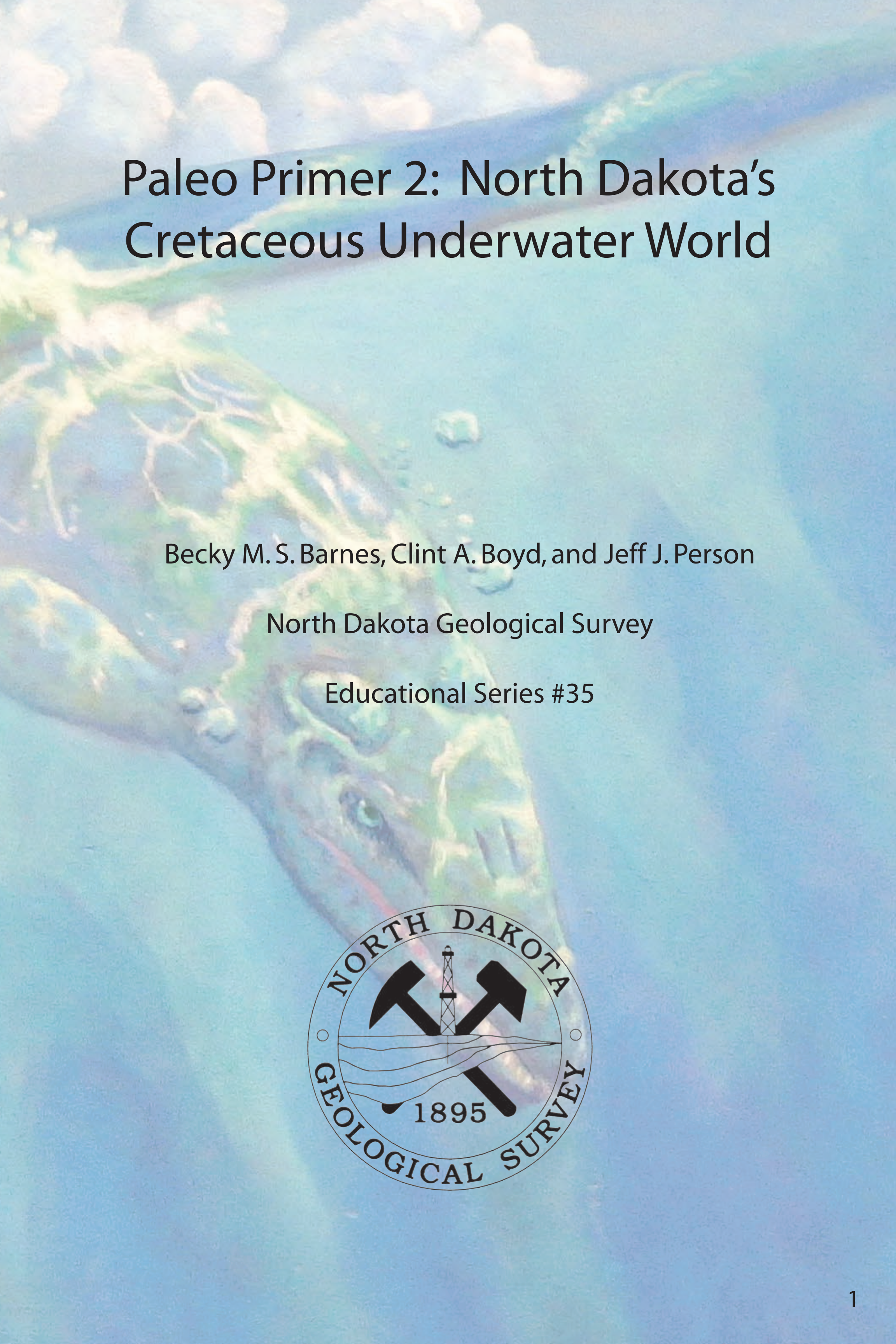
North Dakota Geological Survey

Educational Series #35

All fossils within this publication that reside in the North Dakota State Fossil Collection are listed with their catalog numbers.

North Dakota Geological Survey
600 East Boulevard
Bismarck, ND 58505
https://www.dmr.nd.gov/ndfossil/

Cover: *Mosasaur*, 2017, by Becky Barnes



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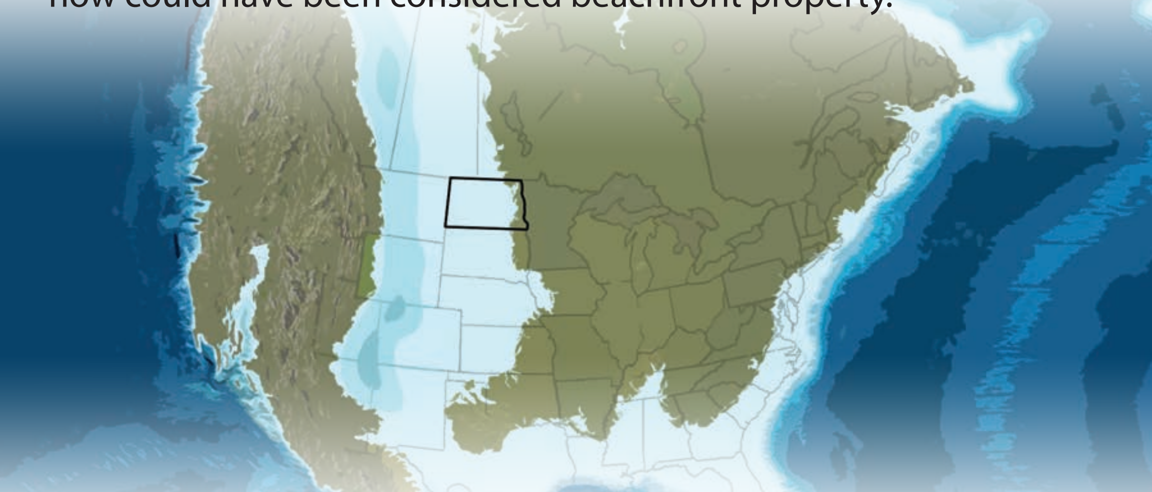
NORTH DAKOTA GEOLOGICAL SURVEY 1895

Water water everywhere...

North Dakota is a landlocked state – dry land on all sides. In prehistoric times, that wasn't always the case. The amount of ice locked in polar glaciers determines how much water is available in the world's oceans. We live in a time when there is quite a lot of ice locked away, which means more land is available to live on. The amount of ice at the poles has changed many times; during warm periods when the polar ice caps were absent, our oceans expanded to fill areas that today are above sea-level.

One such expansion was called the Western Interior Seaway. This seaway was so large it split North America in two, connecting the Arctic Ocean with the Gulf of Mexico. The shores shifted east and west over time, but vast areas of North Dakota were underwater for millions of years.

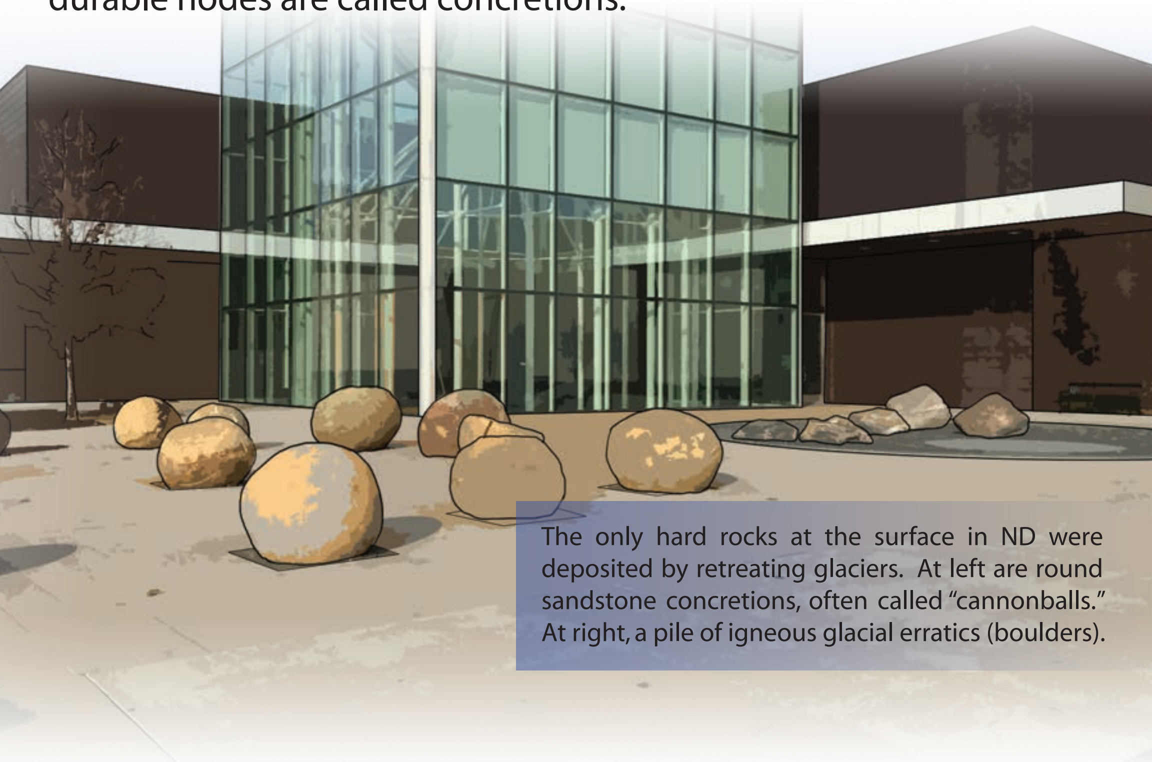
There were times when the area that Bismarck-Mandan occupies now could have been considered beachfront property.



The Western Interior Seaway was not a very deep body of water – perhaps only a couple hundred feet at most. It was inhabited by numerous plants and animals that are found today in the form of fossils. Even though the seaway stretched across much of central and eastern North Dakota, we don't find marine (sea or ocean) fossils everywhere – only where marine rocks are exposed at the surface.

Not all rock is the same

You may think of rocks as hard objects, such as granite or fieldstone. These **igneous** rocks (from molten origins) are not the type of rocks that paleontologists are generally interested in. Instead, they concentrate on soft rocks such as sandstone, mudstone, or shale. An aggregate (concentration) of minerals or sediment formed through the natural processes of water or air creates **sedimentary** rock. Not all sedimentary rock is soft however – as water seeps through spaces between those particles, they can deposit tough minerals that act like glue, forming resistant nodules within the rock. Some of these durable nodes are called concretions.



The only hard rocks at the surface in ND were deposited by retreating glaciers. At left are round sandstone concretions, often called "cannonballs." At right, a pile of igneous glacial erratics (boulders).

What a paleontologist can study is restricted by what rocks are available at the surface. It's not practical to blindly dig holes in search for fossils. Instead they spend a lot of time walking the surface (called prospecting), looking for fragments of a bone or tooth that has weathered out of the surrounding rock. Once a part of a fossil has been located, the digger has to find where that bone came from. Is it in situ (in place)? Has it rolled down a hill? Is there more in the ground?

Survival of the fossil...

While paleontology is the study of prehistoric life, it could also be called the study of prehistoric roadkill. A paleontologist studies things left over after Mother Nature is done with them. This branch of study is called **Taphonomy**, which follows how things decay and become a fossil.

After a plant or animal dies, there are many natural and environmental factors that influence the remains. Predators and scavengers (nature's cleanup crew) scatter and reduce animal carcasses. Herbivores, fungi, and bacteria make short work of plants. Whatever is buried afterwards has a chance at becoming a fossil. That may mean bits of bone, a few scattered leaves, or a beautiful skeleton.

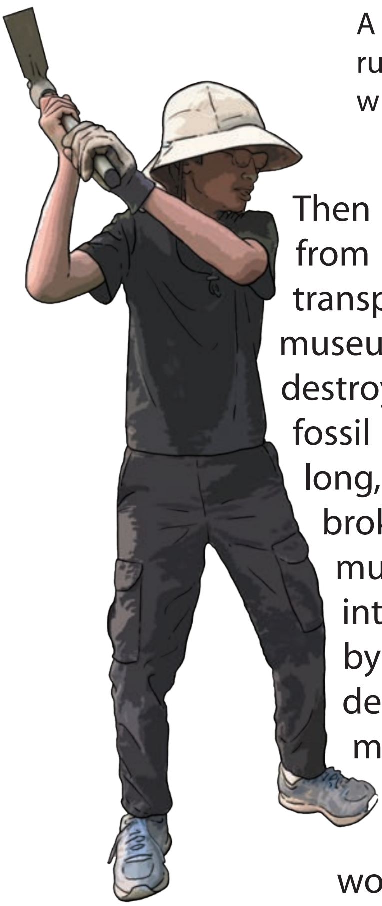
After a fossil-to-be is buried, it still must endure the ravages of time. Geologic processes such as a landslides or earthquakes can do a lot of damage. Similarly, a river meandering across the plains, carves up whatever is in its path. Living things also leave an impact by digging through or ingesting soils and sediment, a process called "bioturbation." A badger decides that the perfect place to dig a burrow is right through a specimen, and kicks the bits out of its way. Clams, worms, and plants weave their way through a lake bottom, shifting things out of their way.

After all this chance, a human still has to stumble across the fossil once it erodes out of the surface and needs to recognize it for what it is: a fossil.

A rancher walking her land may come across petrified trees weathering out of a hillside.

An adventurous hiker may stumble across bones washing into a river.

A bulldozer operator may run into a mammoth tusk while doing road repairs.



Then it needs to be removed from the ground and transported back to a museum without being destroyed in the process. If the fossil stays on the surface too long, it will eventually be broken down. Finally, it must survive the processes of human interaction. Curious visitors destroying fossils by grabbing them, fires, and war have all destroyed priceless fossils as they have sat motionless in exhibits for us to learn from and admire. After this seemingly endless gauntlet of potential destruction, it is a wonder that we have any fossils at all.

Digging etiquette

North Dakota legislators instituted the Paleontological Resource Protection Act in 1989 to protect fossils within our borders. To simplify, if fossils are found on North Dakota state managed land they belong to the public. Lands managed by the US government, such as the Forest Service, Bureau of Land Management, etc. have their own rules and guidelines regarding fossils. Any fossils found on public lands (US or state) should be excavated by people who have obtained proper permits, and then stored in a safe space for future exhibits, research, and conservation.

However, if a fossil is found on private land, that fossil belongs to the landowner, and they may do with it what they wish. Make sure you always obtain permission from a landowner before prospecting on their property.

What should you do if you find a fossil on public land? Leave it alone, photograph it, take a GPS reading if you can, and contact the North Dakota Geological Survey or other land agency. Let them know that you found something, and a specialist will check it out.

It may be nothing – but it may be the next great discovery. The fossil is only part of the science; finding out where it came from and what rocks are around can help unravel its past.

Make sure you photograph it with something for scale. Use anything of standard size such as a pen or a coin – anything to let a specialist know how big or small it is. Even a camera lense cover, like in the case above with a partial *Mesohippus* skeleton.

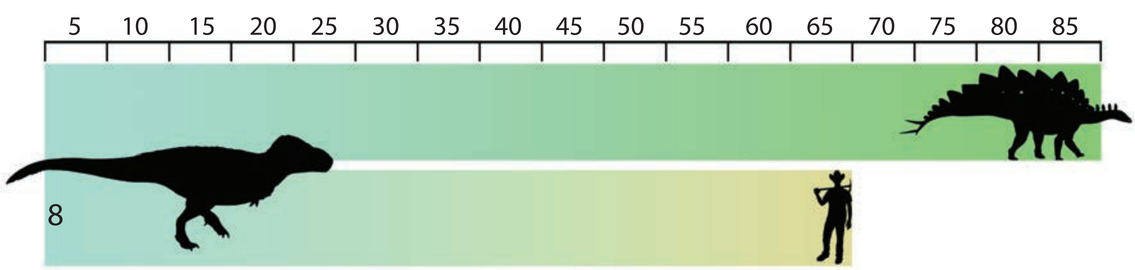
Take a few photos too - you can always delete the blurry ones, but sending an out-of-focus photo for identification is not helpful.

It's all a matter of time

Fossils have been weathering out of the ground for millions of years. When *Tyrannosaurus* was alive, the fossils of its predecessors would have been present. Trilobites, corals, ferns, cycads, early amphibians, and mammal-like reptiles – all of these and more could have been exposed, only to turn back to dust. How much has been lost? How much is still under our feet today?

The asian tyrannosaurid *Tarbosaurus* (~70 mya) walking past a gorgonopsid skull (~270mya).

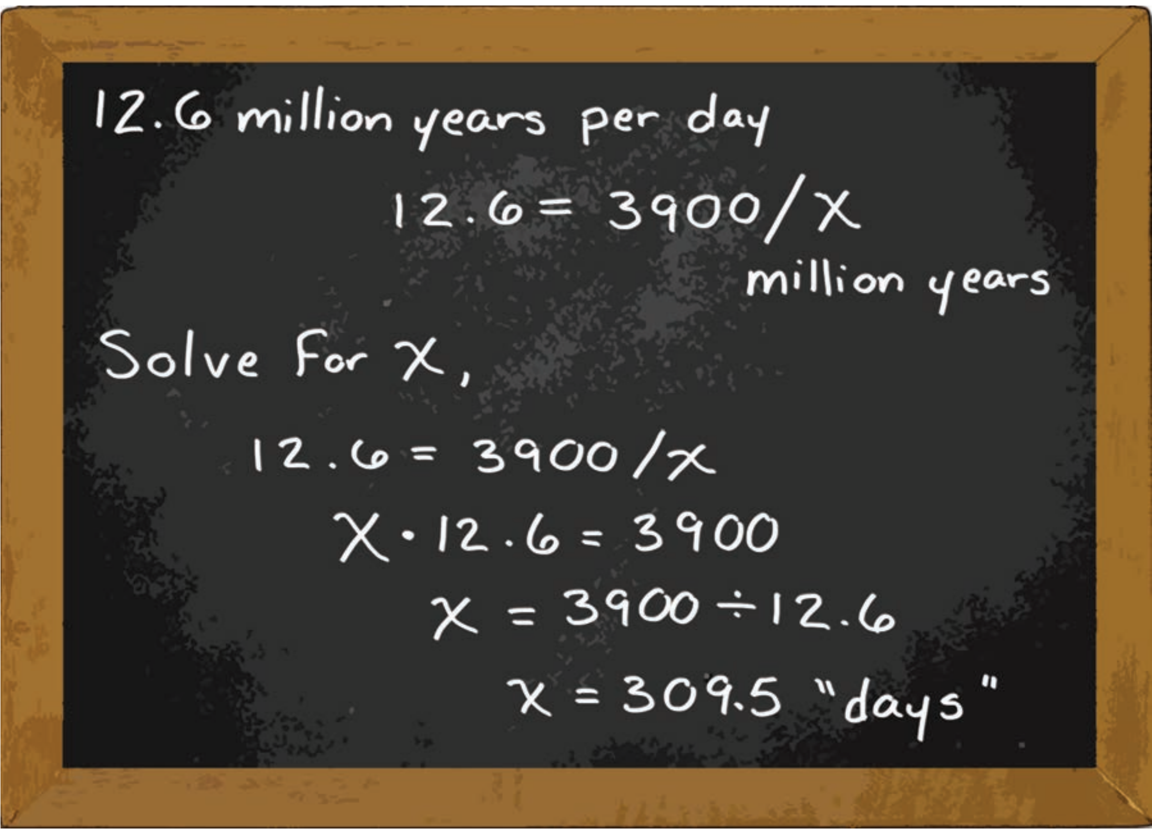
People like to group similar things together, such as dinosaurs. However, not all dinosaurs were alive at the same time. Dinosaurs first evolved about 230 million years ago during the Triassic. They went extinct about 66 million years ago at the end of the Cretaceous. That leaves us with a block of time spanning over 160 million years! During that time, many lineages of dinosaur rose and fell. *Tyrannosaurus rex* lived at the end of the Cretaceous, 68-66 mya, whereas *Stegosaurus* lived during the Jurassic, 155-150 mya. This puts a difference in time of ~85 million years between the two animals. They never met! There is more time between *T. rex* and *Stegosaurus*, than *T. rex* and humans.



Experiment Time!

Time can often be a difficult concept, and with Earth being 4.6 billion years old, it's hard to get such a large number into an easy-to-understand context. A single year, however, is much easier to visualize. Let's squish 4.6 billion years into 1 year to make this easier. First let's switch our units from billion to million , making 4.6 billion = 4,600 million. Now…

Dividing 4,600 million years of Earth's history by 365 calendar days gives us ~12.6 million years per calendar day. If we take the date below, where the first cell life formed ~3,900 million years ago, then:



Now, this is 309.5 days *prior* to our December 31, end of the calendar year. So counting backwards this gives us a date of about February 25th. Try using the equation to figure out the remaining events listed below, or come up with some of your own historical events!

Event	Millions of Years Ago	Calendar Days Ago	Calendar Date
Earth formed	4,600	365	January 1st
First cell life	3,900	309.5	February 25, 12:00pm
First fish	505		
First land plants	470		
First dinosaurs	230	18.25	December 15, 6:00am
Dinosaur extinction	66		
First *Homo sapiens*	0.2-0.3		
Last Ice Age	0.012		
Great Pyramid of Giza built	0.004578 (2560 BC)	0.00036	December 31, 12:59:31pm

**Hint: depending on how many zeroes your caculator goes out to, you can really pinpoint yours times in history. For instance...

1 day = 24 hours

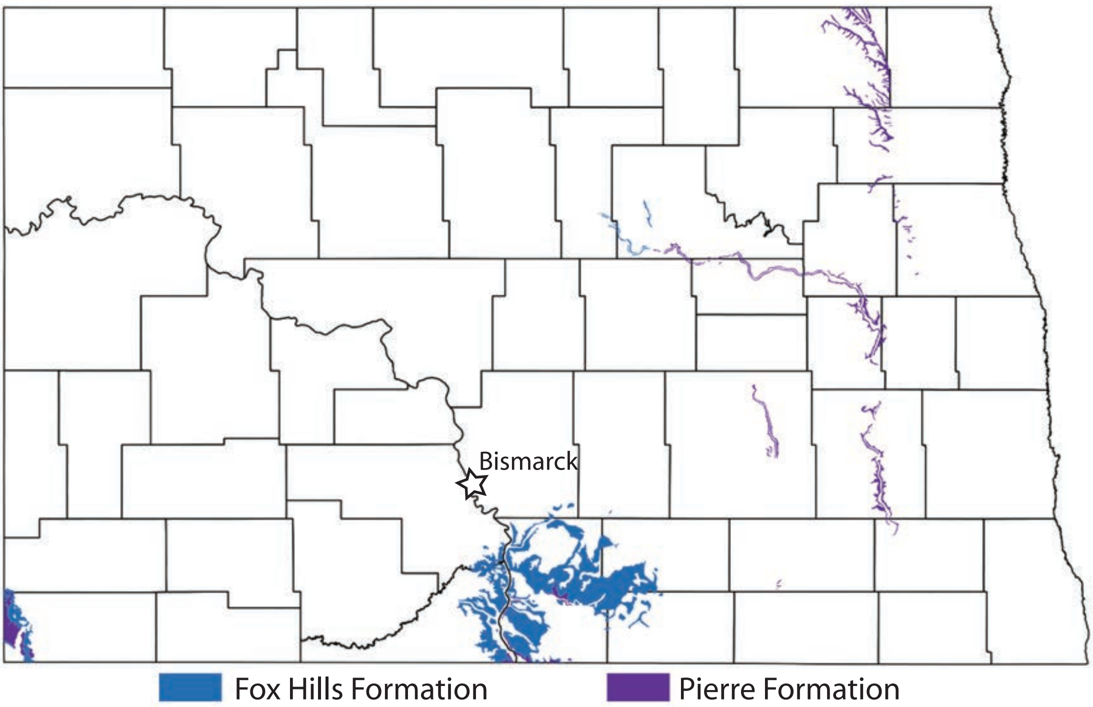
1 hour = .04167 "days" = 60 minutes

1 minute = .000694 "days" = 60 seconds

1 second = .000011567 "days"

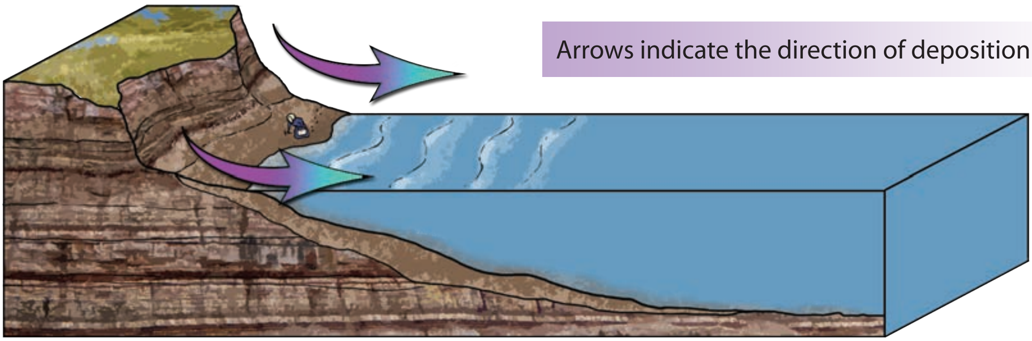
Back to water...

Part of being a paleontologist is investigation and problem solving. Putting clues together (the fossils and surrounding rock) to tell a story from the past that no human was around to see. Part of that story for North Dakota includes the Western Interior Seaway and all its inhabitants. Rock that can tell this story is generally found in the northeastern corner (Cavalier and Pembina Counties), south-central region (Burleigh, Emmons, Sioux, Morton, and Grant Counties), and the southwestern corner (Slope and Bowman Counties).



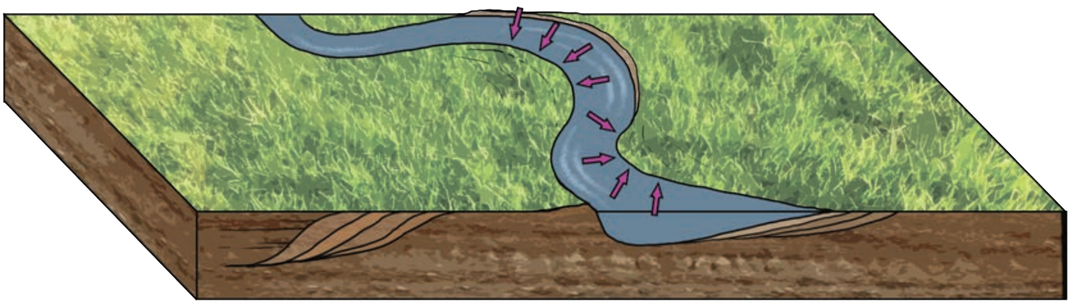
Most of eastern ND was bulldozed by a glacier during the last ice age, and portions were under glacial Lake Agassiz. Both of these recent events (a very young 10 thousand years ago) left the surface rocks covered with lake sediment and glacial till. Certain areas experienced a lot of glacial meltwater runoff and river cuts, which sliced through the top layers of rock and soil to expose older rock formations. The Niobrara and Pierre Formations are visible in portions of Cavalier and Pembina Counties. The southern counties contain the Pierre Shale and Fox Hills Formations at the surface, but not the older Niobrara Formation.

Rock formations are exposed in some spots, but not others. With the Principle of Original Horizontality, where each rock layer is deposited in a horizontal fashion, rock and dirt can only spread so far as there is material to use (via erosion), and a place to put it (via deposition). This means as sediment is raining down on our seaway floor; it will collect in the lower portions first, filling up any gaps. Thanks to gravity, it won't spread up and out over the beaches and shore or nearby hills. The sediment is restricted as it is deposited.



Arrows indicate the direction of deposition.

When the seaway dried up, a stretch of marine rocks were left behind. As new rivers flowed, and glaciers ponderously made their way down from Canada, some rock layers were added to, while others washed away.



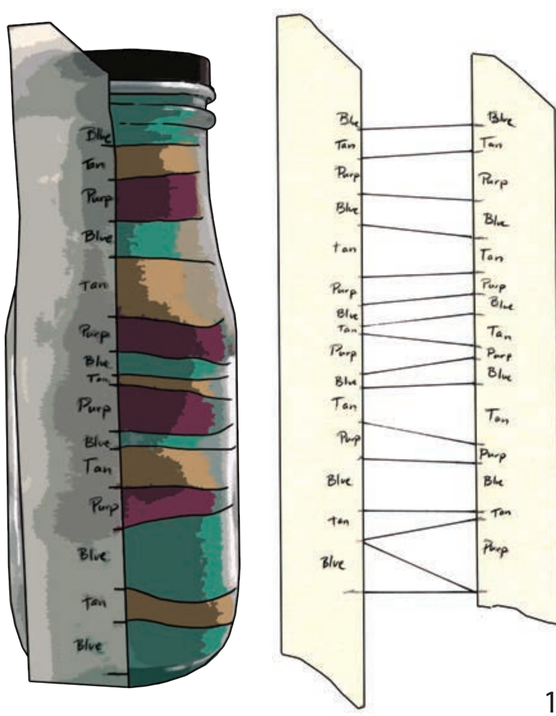
The end results are numerous layers of rock sandwiched over one another. Some places the rock layers stretch far and wide – other areas they pinch out into thin bands.

Experiment Time!

Sand in a bottle: You will need to obtain or recycle a clear glass or plastic container (jar, soda bottle, etc.). You will also need at least two colors of craft sand.

Have your containers of sand ready, and alternate pouring in a little at a time to make layers. If you have a funnel, you will notice the sand forms a hill in the middle, but then due to gravity spills down the side, slowly filling in the available space.

After the container is filled, add two pieces of paper or tape to the outside of the bottle in a vertical strip, on opposite sides. Draw the contact lines between your colors for both sides, remove, then compare. Do they line up exactly? Are some thicker, while others are thinner? Did some pinch out entirely? Depending on how much sand you added for each line, only a certain amount was available to spread out. This is why geologists and paleontologists make stratigraphic trenches and take core samples – to compare where all the similar layers are, and find out where others begin, thin, or end.

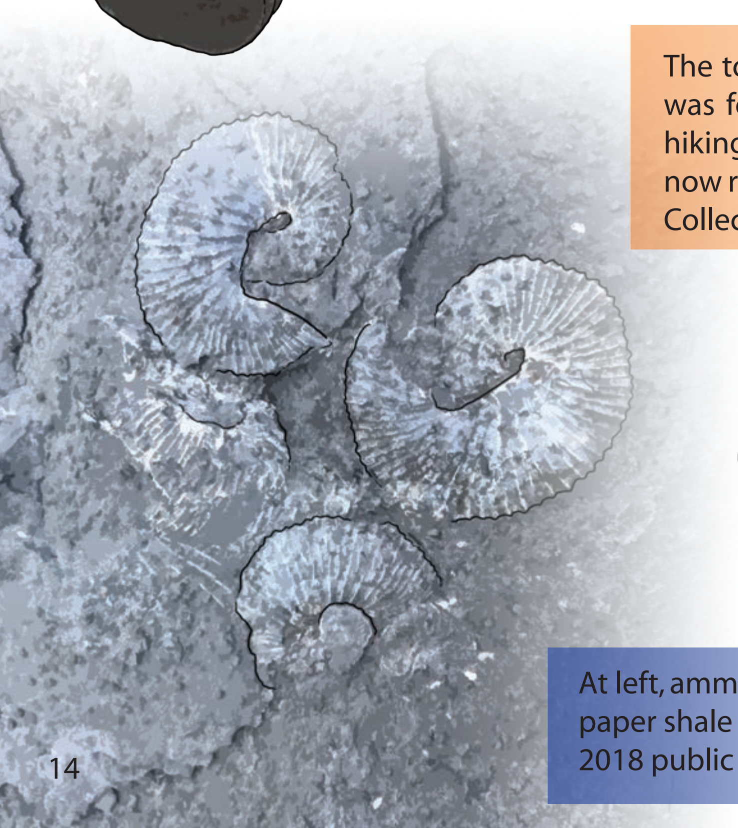


Niobrara Formation

Fine-grained silts and clays are all that is left of the Western Interior Sea floor. These soft rocks contain fossils from extinct creatures that once cruised the warm waters. The Niobrara Formation holds some of the oldest surface rocks that fossils have been collected from North Dakota. Bivalves (animals with two shells) such as pectin and oysters are common. Bones from fish and marine reptiles called mosasaurs have also been found.


Mosasaur vertebrae

The top-right mosasaur vertebra was found by a young man out hiking in 2016. The specimen now resides in the ND State Fossil Collection.



Mosasaur tail vertebra

At left, ammonites found within the paper shale of the Niobrara, during the 2018 public fossil digs.

Bivalves

The word bivalve literally means "two doors," referring to the two halves of the shell that makes up a protective coating around the animal. They are part of the phylum Mollusca, which is made up of other soft-bodied animals, many of which also have a secreted shell of some sort. Most bivalves are filter feeders and can be found buried in the bottom of lakes or oceans, but of course there are occasional exceptions.

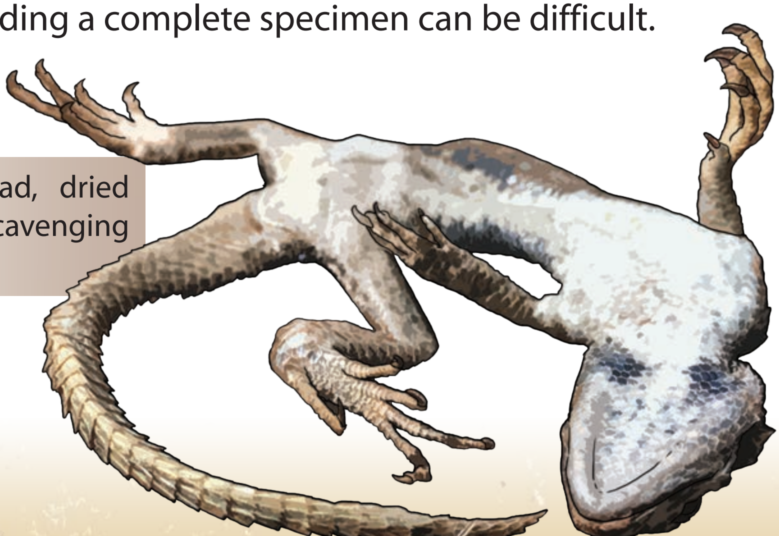
Pecten is a type of bivalve related to modern day scallops; Cavalier County.

These tiny encrusting oysters, *Pseudoperna congesta*, are often found in tight groups, attached to other, larger shells such as *Inoceramus*.

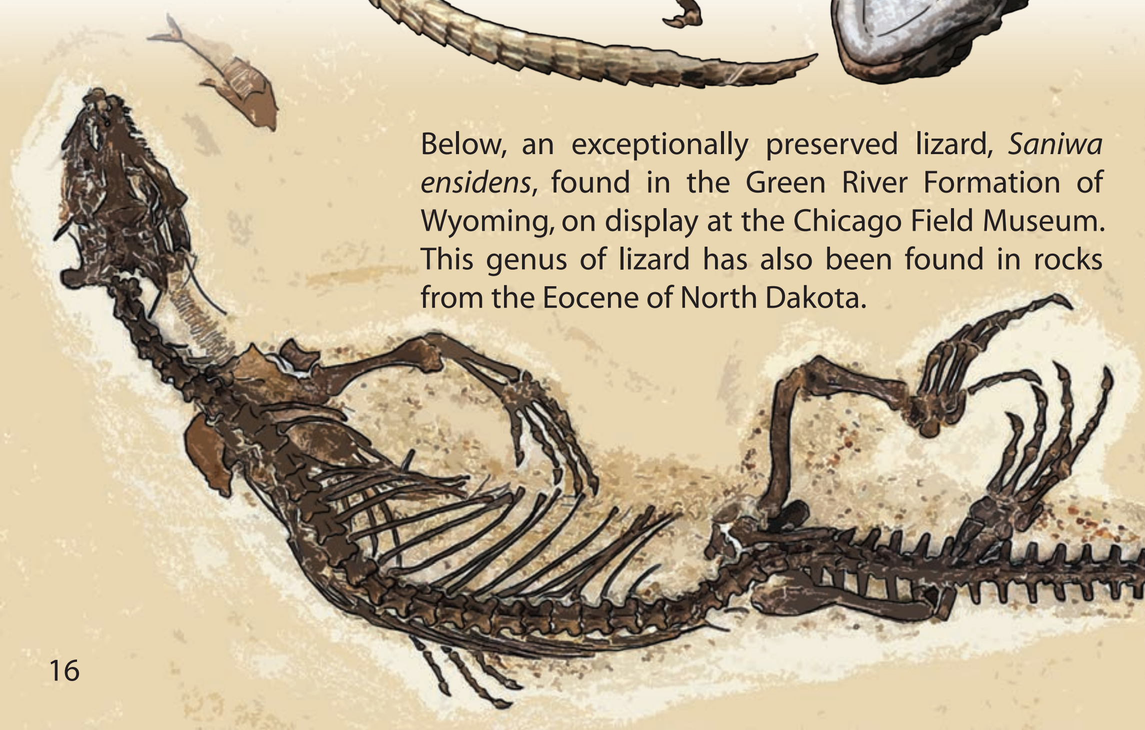
NDGS 4057

Pierre Formation

Most of the "sea monsters" that come from North Dakota are excavated from the shales in the Pierre Formation, often just called "Pierre shale." So why does the Pierre shale hold so many fossils in North Dakota, while other formations hold less? This goes back to our erosion and deposition topic. Organisms tend to fossilize easier in a water (depositional) environment than a land (erosional) one. A plant or animal that dies in the water has a better chance of getting covered with sediment than something that dies on land. The caveat to this is that organisms also have an easy time rotting and decaying in water, so finding a complete specimen can be difficult.



At right, a dead, dried lizard, prior to scavenging or burial.



Below, an exceptionally preserved lizard, *Saniwa ensidens*, found in the Green River Formation of Wyoming, on display at the Chicago Field Museum. This genus of lizard has also been found in rocks from the Eocene of North Dakota.

What is a mosasaur?

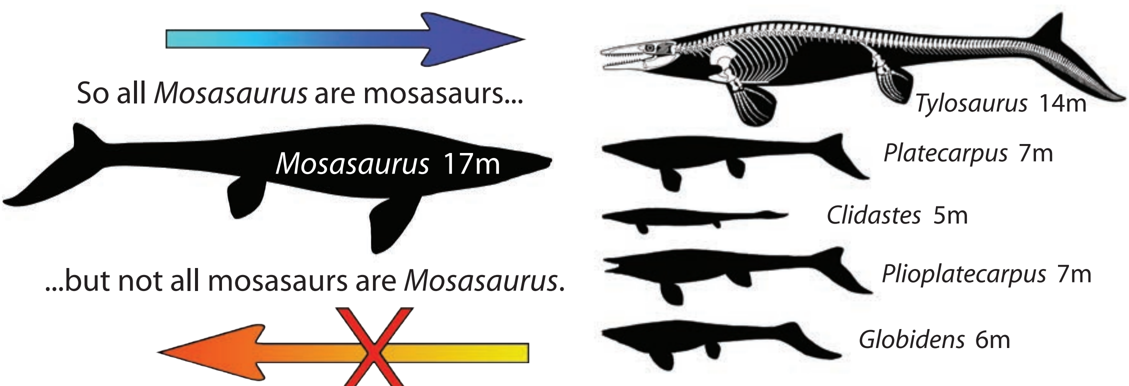
Mosasaurs are very impressive creatures, yet they have a little identity crisis. Many people refer to them as "water dinosaurs" or just plain "dinosaur." This is not true – they are marine reptiles! Much the same problem happens when pterosaurs are called "flying dinosaurs," when they should be called flying reptiles. This can be clarified by using another group of animals people are more comfortable with: mammals.

Take a cat (land), a bat (flying), and a whale (swimming). All three are mammals, all three can live during the same time period, yet they are not closely related. You wouldn't call a whale a water-cat, would you? The same goes with marine reptiles, dinosaurs, and flying reptiles. They can all live during the same time, they are all reptiles, yet they are only distantly related to each other.

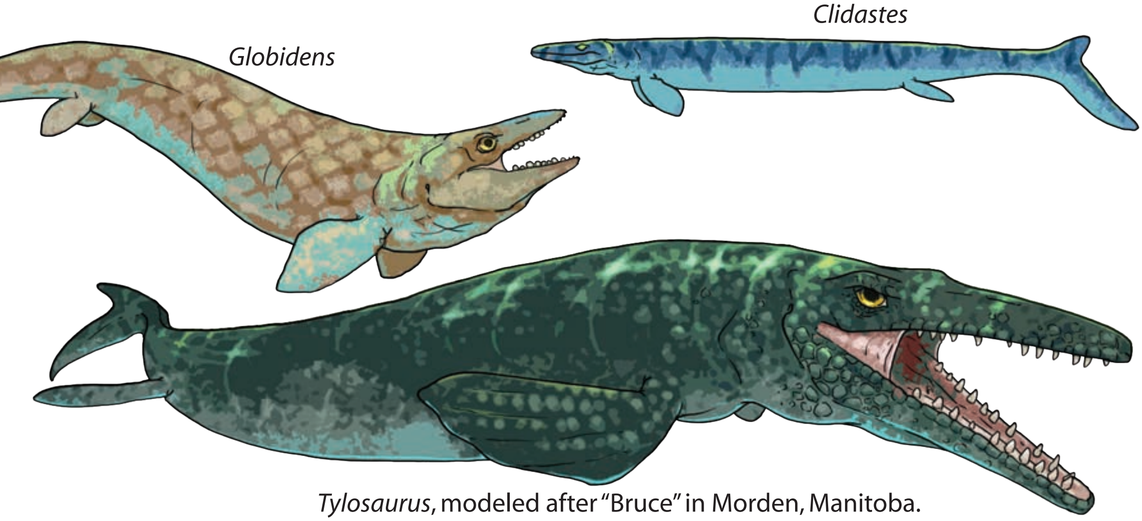
One of the closest living relatives to a mosasaur is the Komodo dragon – a large varanid lizard that lives in Indonesia. While dinosaurs were first named in 1842, mosasaurs had been studied since the 1770s. The first animals were discovered near the Meuse River in the Netherlands, and their name, mosasaur, actually means "Meuse reptile."


Komodo dragon

Sometimes a genus name gets a little too close to a common name, making things confusing. The word "mosasaur" is a common name – much like saying "dog." The name "*Mosasaurus*" when capitalized and italicized, is a genus name identifying a single subgroup of animals – much like saying "German shepherd." Other mosasaurs from North Dakota include *Plioplatecarpus*.



Many mosasaurs have been found in the Pierre Formation from Kansas to North Dakota. They had a global presence, and have been found on many continents including North and South America, Europe, Africa, Australia, and recently even Antarctica! They were a diverse group of animals which ranged in size and diet. From the 2m long fish-eating *Clidastes*, and the 6m long shell-crushing *Globidens*, to the nightmare-inducing 14m long *Tylosaurus* which undoubtably ate whatever it wanted. Mosasaurs filled many niches in the Cretaceous seas.



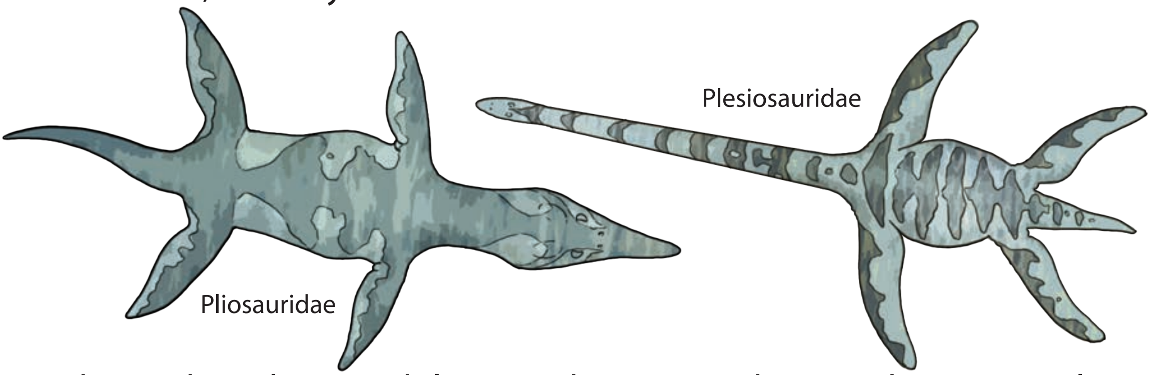
Tylosaurus, modeled after "Bruce" in Morden, Manitoba.

Mosasaurs were not the first reptile to return to the ocean. During the Triassic, successful dolphin-like ichthyosaurs and large-flippered plesiosaurs made the waters their home. As time went on, these groups began to decline, opening up niches for the globally dominating mosasaurs.

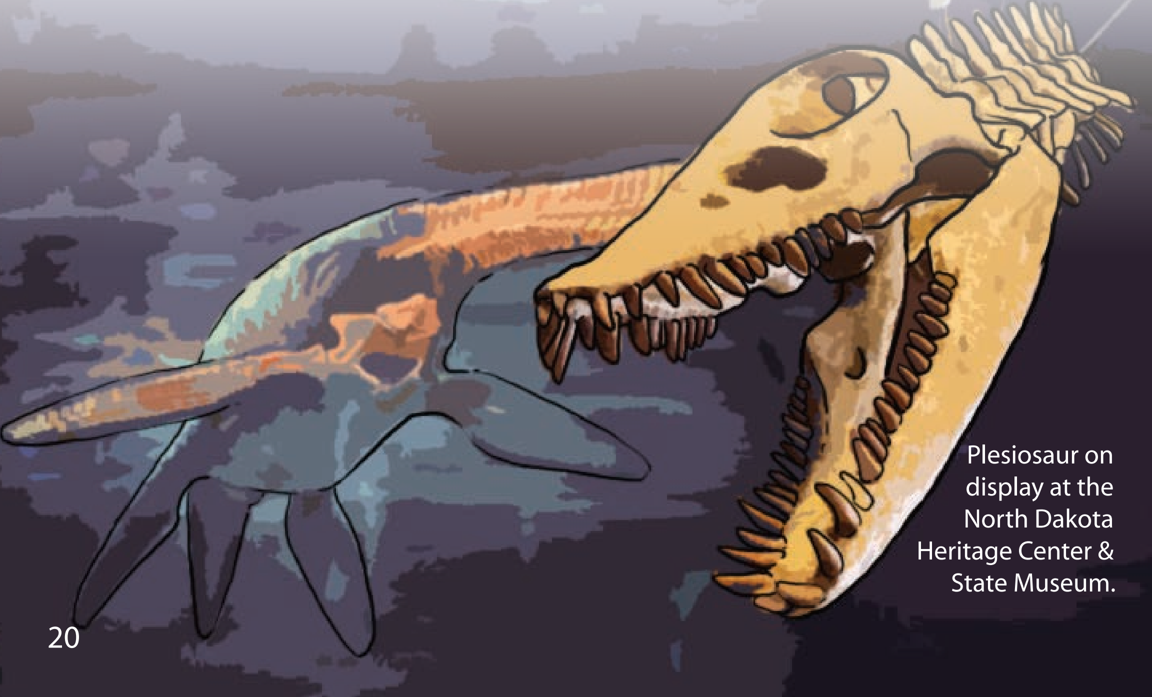
Ichthyosaur discovered by paleontologist Mary Anning ~1836 on display at Oxford.

Plesiosaurs

Another group of marine reptiles that made the seas of North Dakota their home are the plesiosaurs, which include the long-necked *Cimoliasaurus*, *Elasmosaurus*, and *Styxosaurus*. Plesiosaurs branch into two divisions: the Pliosauridae had large heads and short necks, while the Plesiosauridae had small heads and long necks. The fossils found in ND are from the Plesiosauridae branch. We don't have a Loch Ness, but maybe we could have a Lake Sakakawea Monster?



What makes a long neck, long? In humans and most other mammals, we have seven cervical (neck) vertebrae. A long-necked mammal like a giraffe simply has seven really long cervical vertebrae. For a long-necked reptile, they may have long bones, or simply more bones. *Elasmosaurus* had a whopping 70 vertebrae in its neck alone!

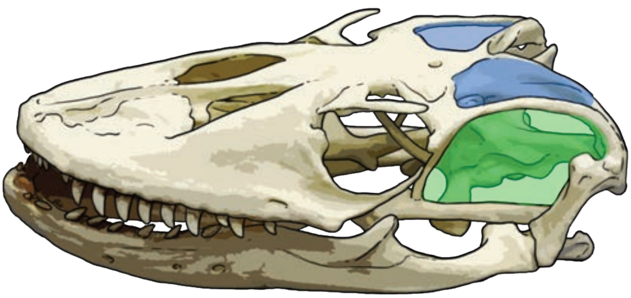


Plesiosaur on display at the North Dakota Heritage Center & State Museum.

Plesiosaurs, like ichthyosaurs, have a "euryapsid" skull. This is a descriptive condition that relates to how many temporal fenestrae (openings behind the eye) are in the skull, and where they are located.

Turtles are considered **anapsid**, because their skulls do not have temporal openings.

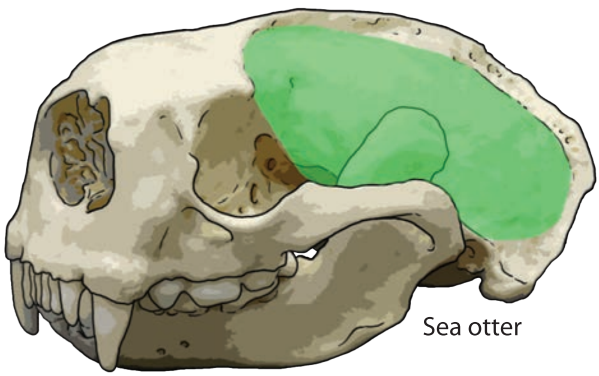
Loggerhead sea turtle



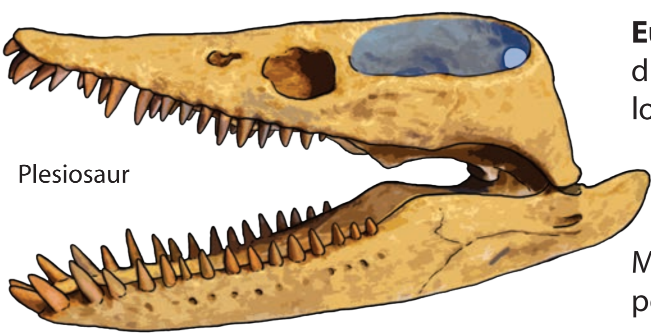
Komodo dragon

Most other reptiles, birds, and dinosaurs, are called **diapsid** because they have two fenestrae.

Mammals and therapsids (mammal-like reptiles) are called **synapsid**, because they have one large temporal opening.



Sea otter

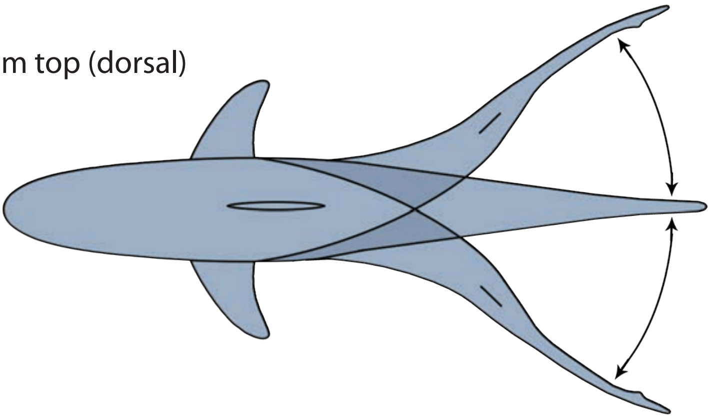


Plesiosaur

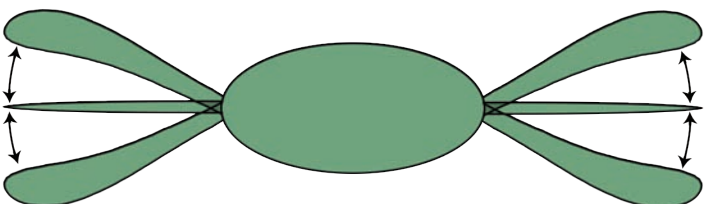
Euryapsids are thought to be diapsids that have lost their lower temporal fenestra, and have a single small fenestra located higher up on their head – a trait many extinct Mesozoic marine reptiles possessed.

Mosasaurs propelled themselves through the water in a shark-like fashion. Their streamlined bodies were pushed forward by the stiff, back and forth motion of their tails. For a long time it was thought that their whole body snaked through the water like an eel.

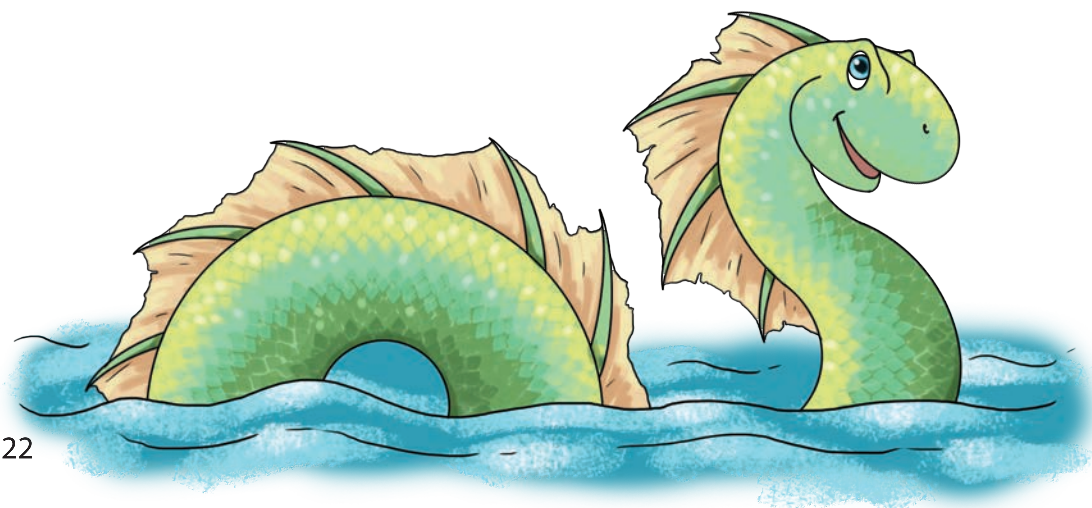
Shark, view from top (dorsal)



Plesiosaurs, on the other hand do not have a long tail for swimming – only flippers. Perhaps their motion underwater was more similar to that of a sea turtle. As much as science-fiction would have us believe, plesiosaurs were not able to curve their necks like a swan or goose, in Loch Ness Monster fashion. Their necks were much more restricted in their motion.

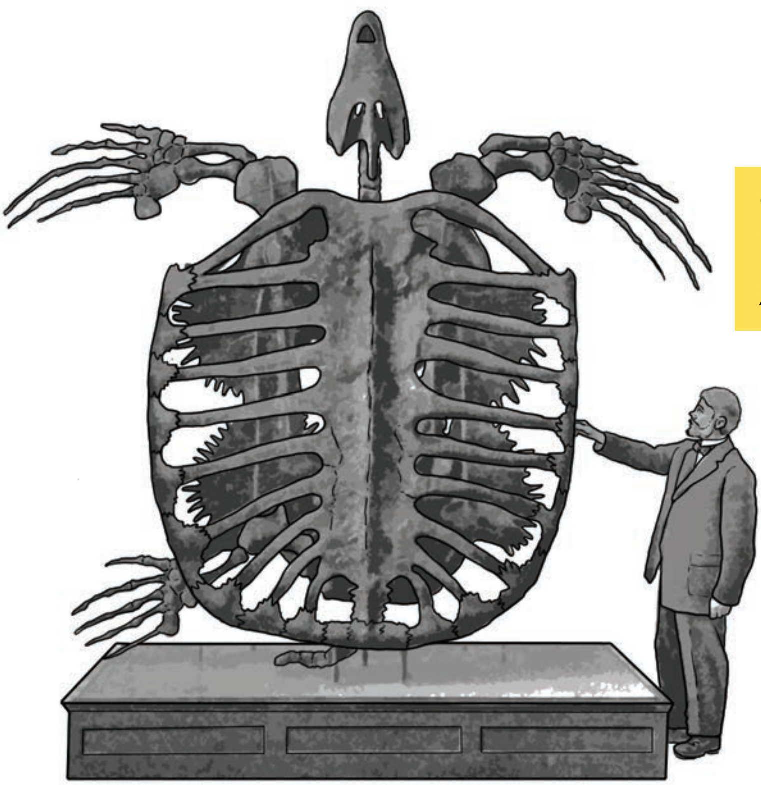


Turtle, view from front (anterior).



Archelon

How would you like to go swimming next to a sea turtle the size of a Volkswagon Beetle? The "ruler turtle" *Archelon* certainly lived up to its name, and is one of the largest sea turtles discovered. Rather than a solid shell like you would find in a snapping turtle, the ribs that make up the **carapace** (top shell) acted more like struts or rafters in a roof, holding up a leathery shell. It would have looked similar to the leatherback sea turtles alive today, but much larger at 4 meters in length.



George R. Wieland standing beside the Yale Peabody Museum's specimen of *Archelon* (YPM 3000).

Hesperornis

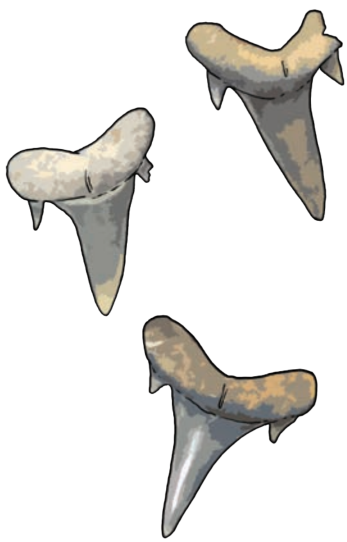
The "western bird" *Hesperornis* was a genus of bird adapted to life in the water. It was flightless, with wing bones reduced to mere twigs. The feet were very large and lobed, much like modern-day grebes, yet they also had teeth in the rear portion of the beaks. The first *Hesperornis* was found in Kansas by Othniel Charles Marsh in 1871. These birds were often reconstructed in a pose similar to penguins, however it is doubtful this large, 1.8 meter long bird was able to walk on land.

Hesperornis skeleton

Closeup of Cretaceous sea mural, previously on display at the North Dakota Heritage Center & State Museum.

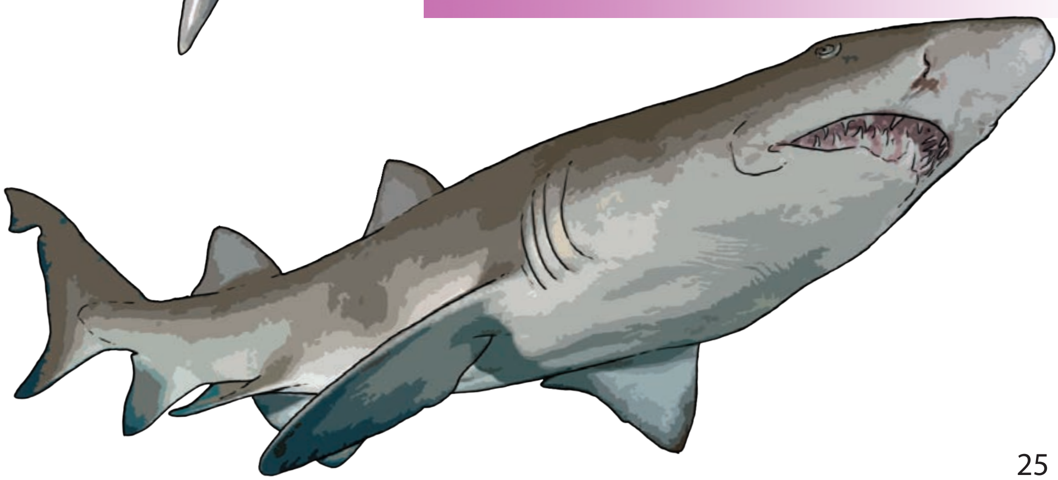
Carcharias

Sharks first evolved 450 million years ago, so it comes as no surprise that they inhabited the prehistoric seas of North Dakota. Soft tissue such as skin and muscle rarely fossilize, so trying to deduce the exact shapes of fins and bodies can be difficult. With sharks it tends to be even more so, as their skeletons are made from cartilage – the same connective tissue that makes up the flexible portions of your nose and ears. The most common parts of sharks to fossilize are teeth, and teeth they have in abundance! *Carcharias* is a type of sand tiger shark. Their teeth have a long, narrow central cusp which is flanked by smaller lateral cusplets. Modern sand tiger sharks can grow between 2-3 meters in length, and feed on a variety of bony fish, other sharks, and skates.



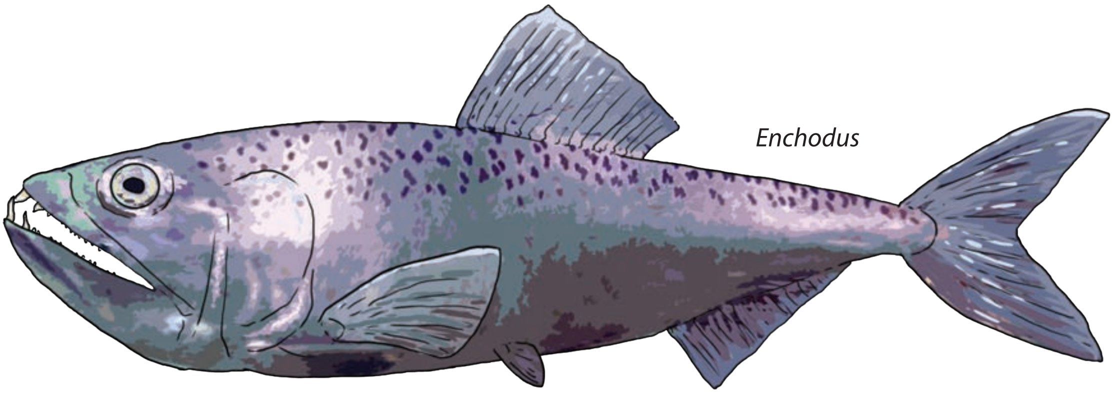
Carcharias teeth, NDGS 1045, 1046, 1048, Pierre Formation, found in Griggs Co.

Carcharias have been called sand tiger sharks, bull sharks, grey nurse sharks, and ragged-tooth sharks. All these names add to confusion. They're not related to tiger sharks as the name implies, but they are related to the great white shark.



Enchodus

The remains of *Enchodus* are commonly found in the Pierre shale of North Dakota. It was a medium sized bony fish, growing up to 1.5 meters long. It is often referred to as a "saber-toothed salmon" because of the 5 centimeter long teeth jutting out of the front of its mouth. While they were predatory fish, they were also feasted upon by other predators such as sharks, fish, mosasaurs, and birds.

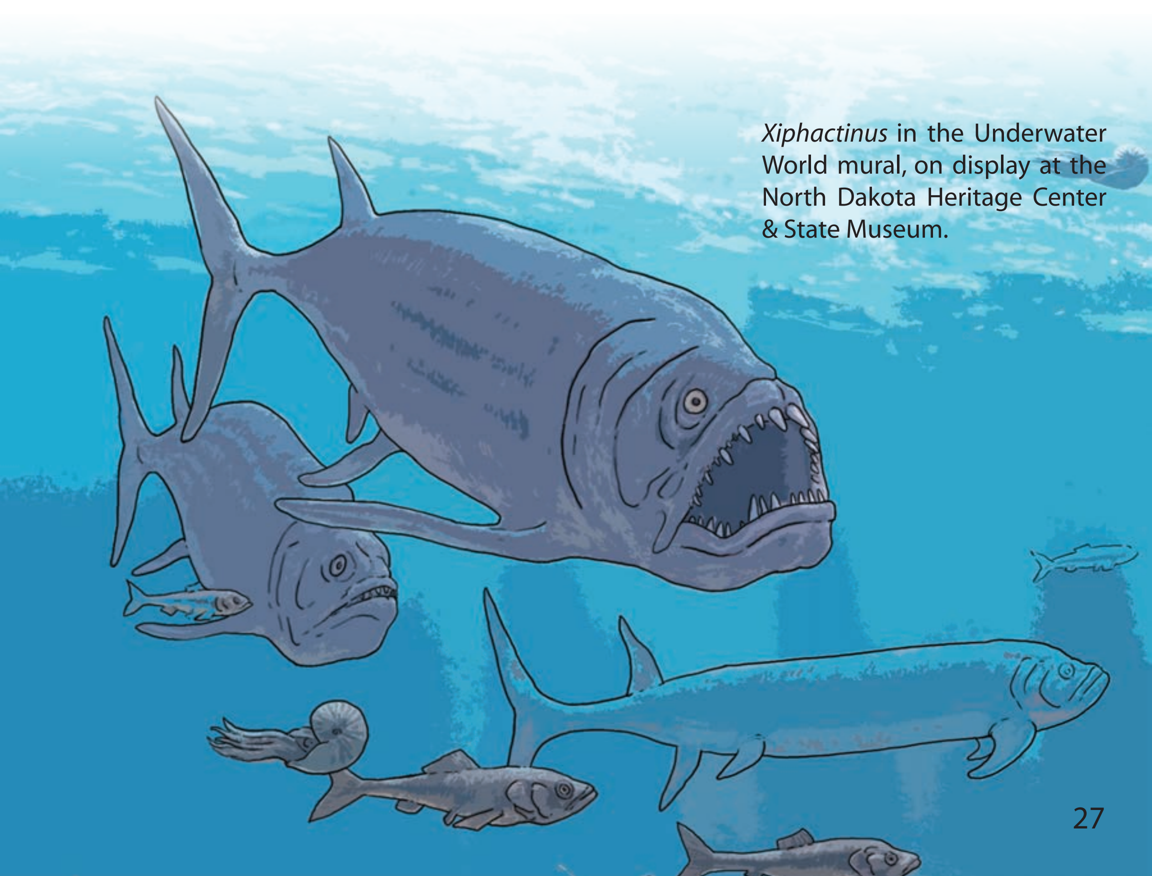


The vertebrae below were part of a scavenged skeleton found on the 2018 Pembina Gorge public fossil dig. In typical fashion, they were uncovered on the last hour, of the last day of digging! Not too far from these bones was a partial backbone of another fish, *Xiphactinus*.

Xiphactinus

There always seems to be a bigger fish. *Xiphactinus* was a large predatory fish that lived in the Western Interior Seaway. These fish could grow up to 6 meters long, and had mouths full of pointed teeth. They had voracious appetites, and fossils have been found containing their last meals within their gut cavity. Like *Enchodus*, *Xiphactinus* was also a bony fish.

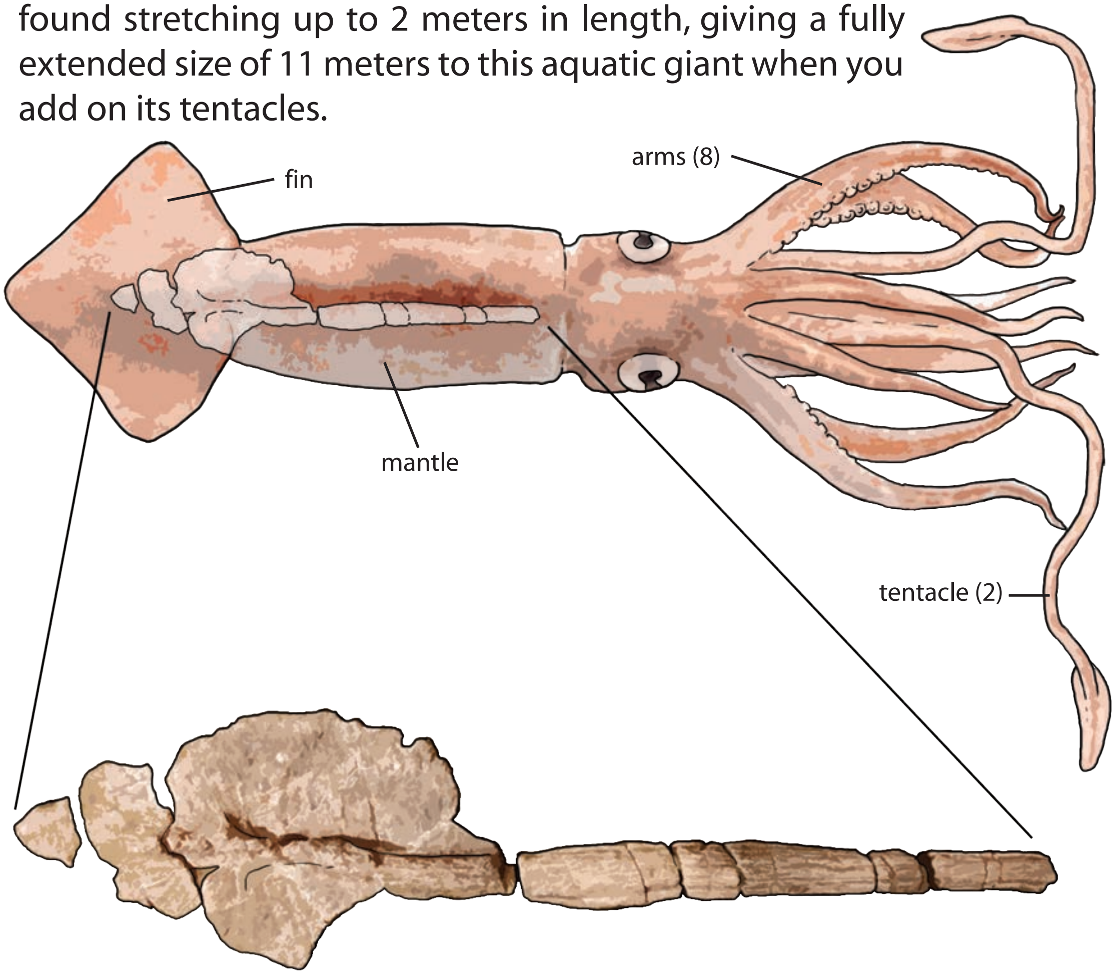
"Fish-Within-A-Fish" *Xiphactinus* FHSM VP-333, having eaten the fish *Gillicus* at the Sternberg Museum of Natural History.



Xiphactinus in the Underwater World mural, on display at the North Dakota Heritage Center & State Museum.

Tusoteuthis

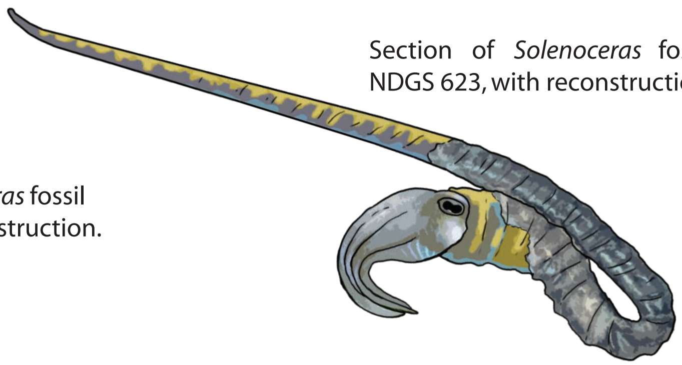
Just because the previous monsters of the sea all had backbones doesn't mean *Tusoteuthis* was spineless – in a matter of speaking, anyways. Squid, along with other cephalopods (meaning "head-foot"), are grouped in the phylum Mollusca. This giant squid may have lacked a skeleton, but it did have a rigid support system in place called a **"gladius"** or "**pen bone**." You may be more familiar with the external secreted shells of the nautilus or ammonite; *Tusoteuthis'* "shell" was on the inside of its mantle. Gladius have been found stretching up to 2 meters in length, giving a fully extended size of 11 meters to this aquatic giant when you add on its tentacles.



You can check out a smaller pen in squid bought from the grocery store. Pick up a fresh (or frozen) squid, and part of the preparation and cleaning will involve removing the thin, translucent support structure from the mantle area. Calamari, anyone?

Didymoceras

Latin for "paired horns," *Didymoceras* was an extinct genus of ammonite, also in the class Cephalopoda (along with its bigger cousin *Tusoteuthis* – twice removed). *Didymoceras* looks different than your typical spiral-coiled ammonite, and is called a "**heteromorph**." The shells of these animals bend and coil around in loose whorls, into an ever widening corkscrew. The inside of the shell would have been similar to other ammonoids however; as the animals grew, they would secrete another living chamber, thus increasing the size of their shell. A tube connecting all the internal chambers together, called a **siphuncle**, enabled *Didymoceras* to adjust its buoyancy, allowing it to drift in the water. Other ammonites from the Pierre shale of ND include the straight-shelled *Baculites*, and the saxophone-looking *Solenoceras*.



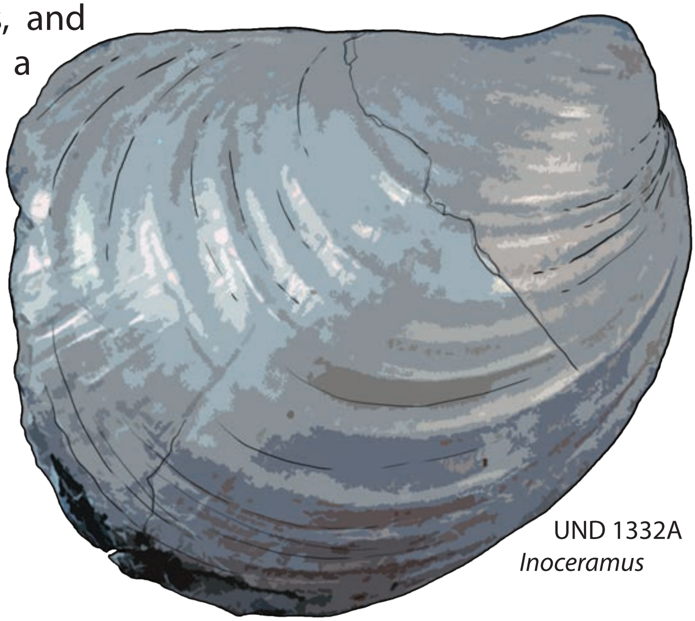
Section of *Solenoceras* fossil NDGS 623, with reconstruction.

Didymoceras fossil and reconstruction.

Segment of *Baculites* NDGS 4058 with iridescent nacre (mother-of-pearl).

Inoceramus

Not all **bivalves** (molluscs with two shells, like clams) are small. One genus found in ND could grow very large: *Inoceramus*. They had very distinct growth ridges, and their shells exhibited a pearly luster that often survives fossilization. It is speculated that the large size may give the soft mantle of the animal more surface area for filter feeding in murky environments.



UND 1332A
Inoceramus

Gastropoda

Another group of soft-bodied molluscs are the snails, found within the class Gastropoda. *Trachytriton* and *Margaritella* are two genera of snails that have been found within the Pierre shale of North Dakota. The shells of *Trachytriton* are heavily ribbed around the spire, as well as transversely, giving the shell an almost plaid appearance.

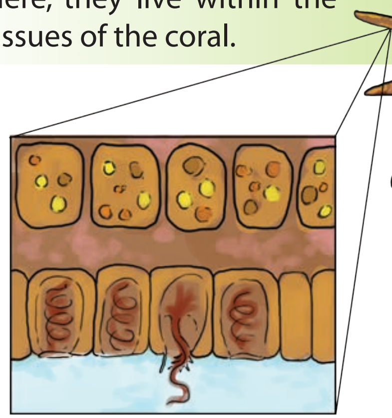
Trachytriton
NDGS 625

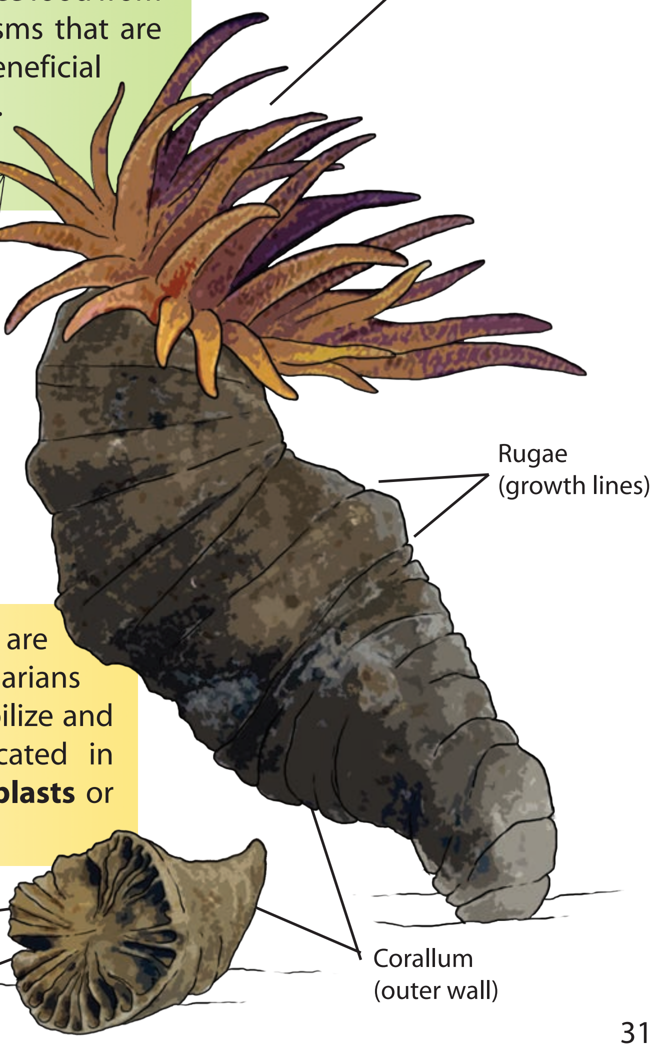
Margaritella shells, clockwise from lower left, NDGS 4059, 4060, 4061, 4062.

Coral

What we think of as fossil coral is actually the "skeleton" of a coral polyp. A horn coral cone was built from calcium carbonate, and was added to as the animal grew larger – thus giving the coral a cone-like appearance; small at the bottom, large at the top. Corals are from the phylum Cnidaria (ni-dar-ee-ah; the "c" is silent), named for the stinging cells used to capture prey. Other animals in this phylum include jellyfish and sea anemones. Horn corals had a ring of small tentacles that encircled their mouth, and were **sessile** (immobile) animals.

Zooxanthellae (zoo-ah-zan-thel-a) are photosynthetic (able to produce food from sunlight) single-celled organisms that are often found in **symbiotic** (beneficial to both organisms) situations. Here, they live within the tissues of the coral.

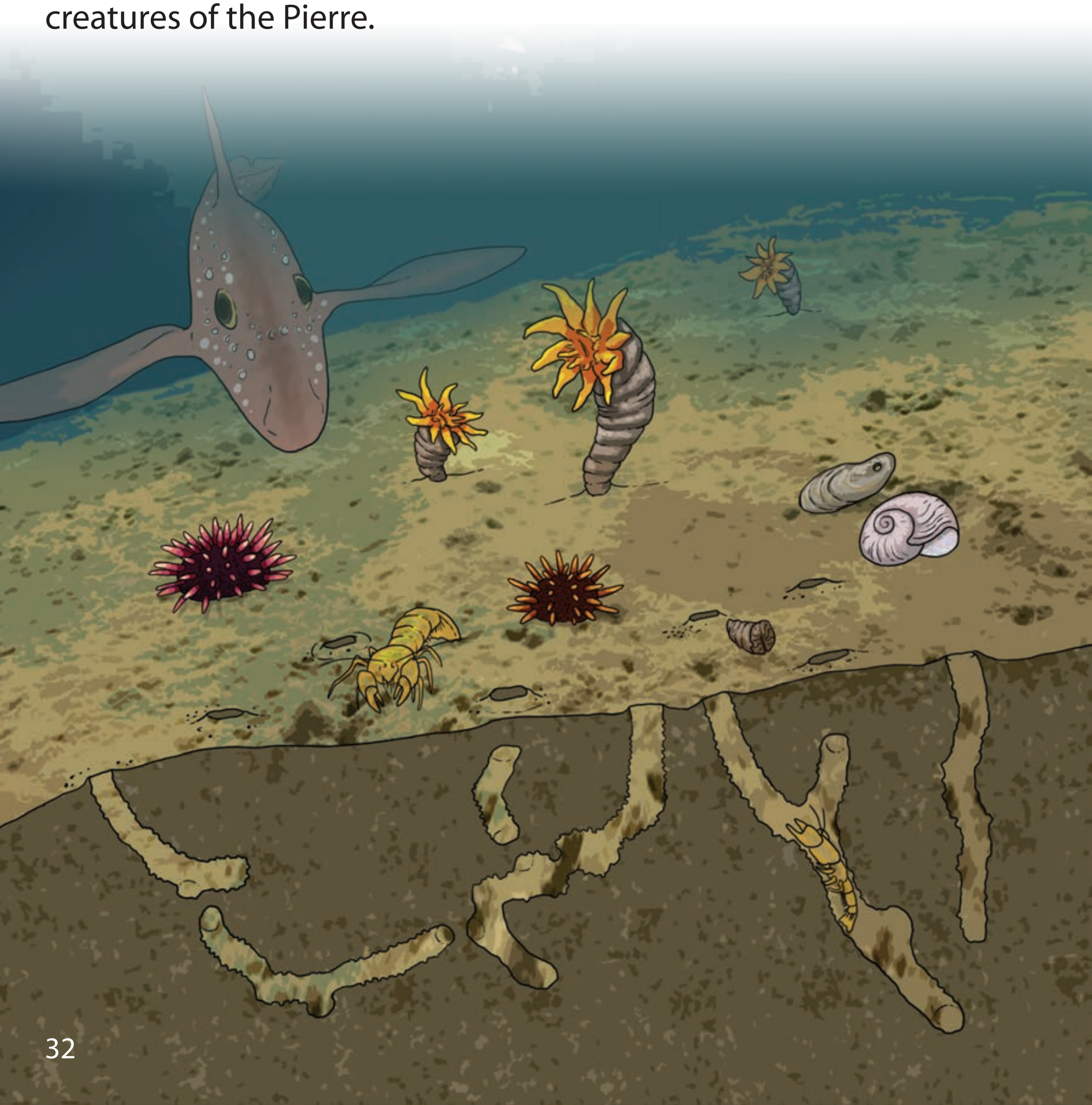




Nematocysts (ne-ma-to-sist) are the stinging capsules that cnidarians use in self defense, or to imobilize and capture food. They are located in specialized cells called **cnidoblasts** or **cnidocytes**.

Fox Hills

The extensive shales of the Niobrara and Pierre Formations are a legacy of deeper, calmer waters. About 68 million years ago the Pierre Sea withdrew from the western half of North Dakota. The new land was called the Hell Creek delta – similar to the river deltas of Louisiana and Mississippi today. The delta was home to many plants and animals, including dinosaurs, crocodiles, mammals, and birds. The silty-sandy characteristics of the Fox Hills Formation are the remains of the receding Pierre Sea, and are made up of prehistoric shorelines, beaches, and calmer deltas and lagoons. This shoreline habitat was also teeming with life, albeit different from the deep-sea creatures of the Pierre.

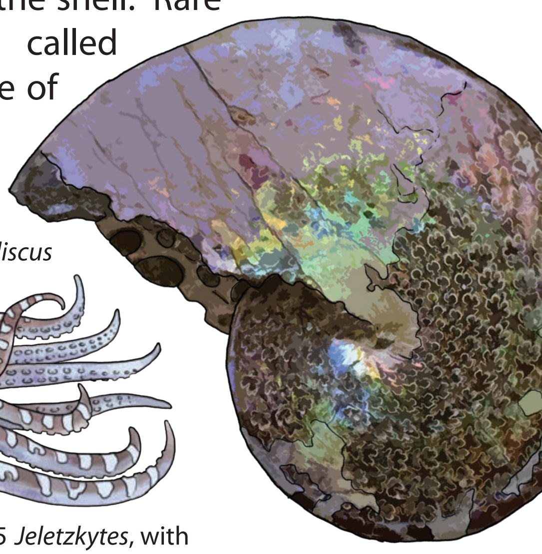


Invertebrates

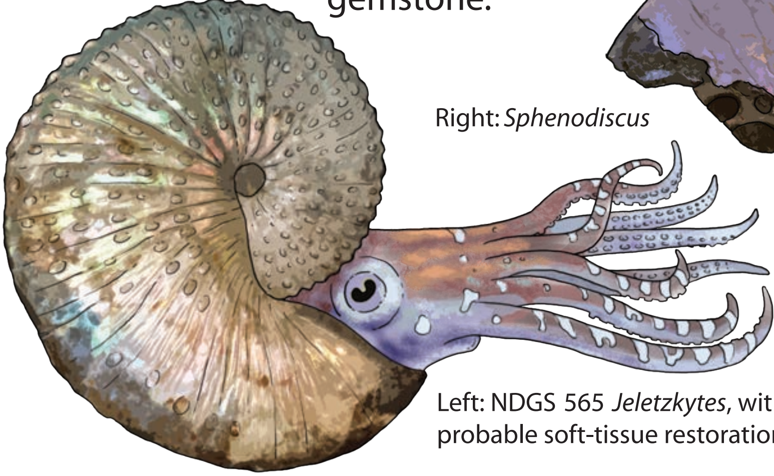
Many types of **invertebrates** (animals without a backbone) lived within the warm shallows of the Fox Hills Sea; bivalves, snails, sea urchins, ammonites, and even lobsters and horseshoe crabs. Snails found a great body plan, and stuck with it, so it is no surprise that we find snail fossils in the Fox Hills. *Euspira* is a snail that still has descendants alive today – a group of gastropods called "Moon Snails."

Moon Snail

Jeletzkytes and *Sphenodiscus* are ammonites (similar to *Didymoceras* mentioned earlier). These cephalopods both had shells covering their soft bodies, but they are very easy to tell apart. *Jeletzkytes nebrascensis* had a compact, ridged shell. If examined closely, the coiling nature of the shell isn't uniform - like *Didymoceras*, it too was a heteromorph ammonite. *Sphenodiscus lenticularis* had an extremely smooth laterally compressed shell, and was a "regular" coiled ammonite. Both types of ammonite have been found with intact mother-of-pearl, **nacre**, an iridescent form of aragonite (calcium carbonate) that makes up the shell. Rare geologically altered nacre is called "ammolite," and is considered a type of gemstone.



Right: *Sphenodiscus*



Left: NDGS 565 *Jeletzkytes*, with probable soft-tissue restoration.

Callianassa & Ophiomorpha

Trace fossils generally have different names than the creature that made them, because it is often difficult to connect who dug a burrow, left a coprolite, or chewed on a leaf to the actual animal that did the deed. In this case, *Ophiomorpha* is a burrow left by the ghost shrimp *Callianassa*. The shrimp makes its home within soft ocean sediment, and adds a layer of fecal pellets to the wall to prevent the tunnel from collapsing. In the fossil *Ophiomorpha*, this translates to a very bumpy surface. The delicate exoskeleton of *Callianassa*, while rare, can also fossilize.

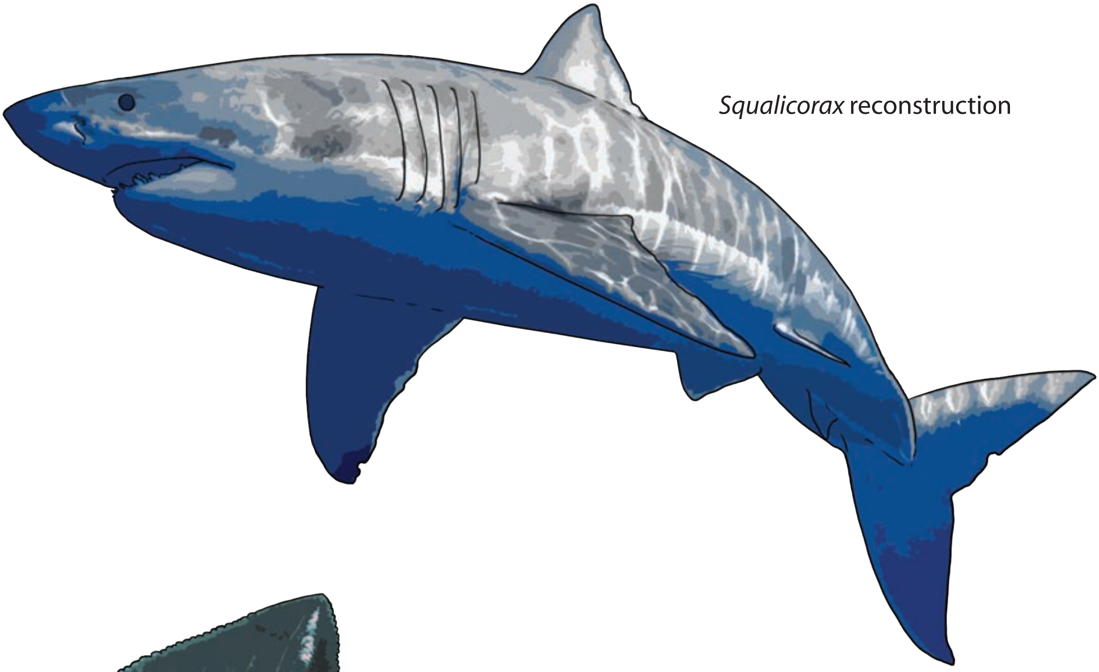
Callianassa shrimp reconstruction. Males have one claw much larger than the other. They are called "ghost shrimp" because their bodies are transparent.

Callianassa shrimp claw, NDGS 619

Ophiomorpha shrimp burrow - notice all the bumps from fecal pellets?

Chondrichthyes

The word "chondrichthyes" is greek for "cartilage fish," and is a class that includes sharks, rays, skates, and chimaeras. These are animals that have a skeleton made from cartilage rather than bone. So as with *Carcharias* earlier in this book, we must rely on teeth for identification. Some teeth found within the Fox Hills Formation of North Dakota belong to a shark called *Squalicorax pristodontis*. The name *Squalicorax* is Latin and Greek for "shark-raven," which is appropriate for this coastal scavenger-predator. It could grow up to 5 meters in length, and is from a group of sharks referred to as "mackerel sharks." This group also includes species of sharks such as *Cretoxyrhina*, the great white, and *Carcharocles megalodon*. Unlike the needle-like teeth of *Carcharias*, *Squalicorax* had a more rounded, serrated tooth.



Squalicorax reconstruction

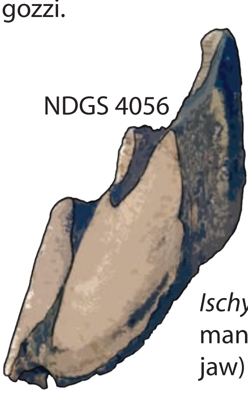
Squalicorax pristodontis tooth from Bowman Co., SLU 1832, measuring 2cm wide.

A fish with many faces

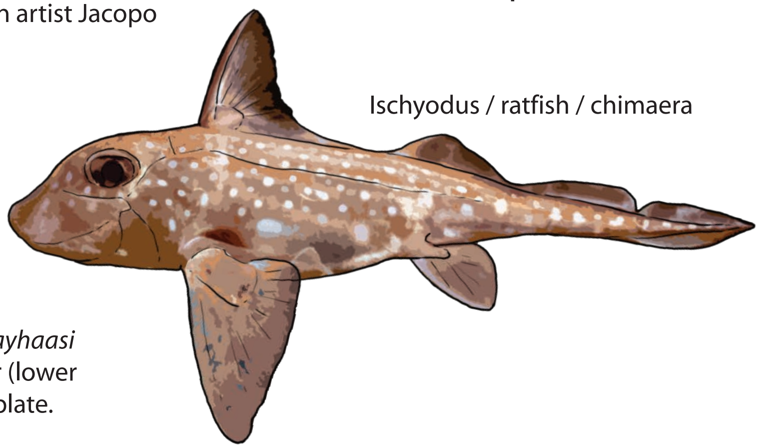
Most people are more familiar with sharks, skates, and rays (together a subclass called "**Elasmobranchii**"), and less so with chimaera. While the chimaera's closest living relative is the shark, they branched off from each other during the Devonian, some 400+ million years ago in a subclass called **Holocephali**. Sharks rely on movements of their tail for propulsion through the water; ratfish use their large **pectoral** (chest) fins. The word "chimaera" refers to a creature from Greek mythology (chimera) which blended together parts from different animals. Generally it took the form of a lion, with a secondary goat-head, and a serpent for a tail. This blending of features can be seen in the names for the cartilaginous version of chimaera: rat-fish, rabbit-fish, and elephant-fish.

Chimera drawn ~1600 by Italian artist Jacopo Ligozzi.

NDGS 4056



Ischyodus rayhaasi mandibular (lower jaw) tooth plate.

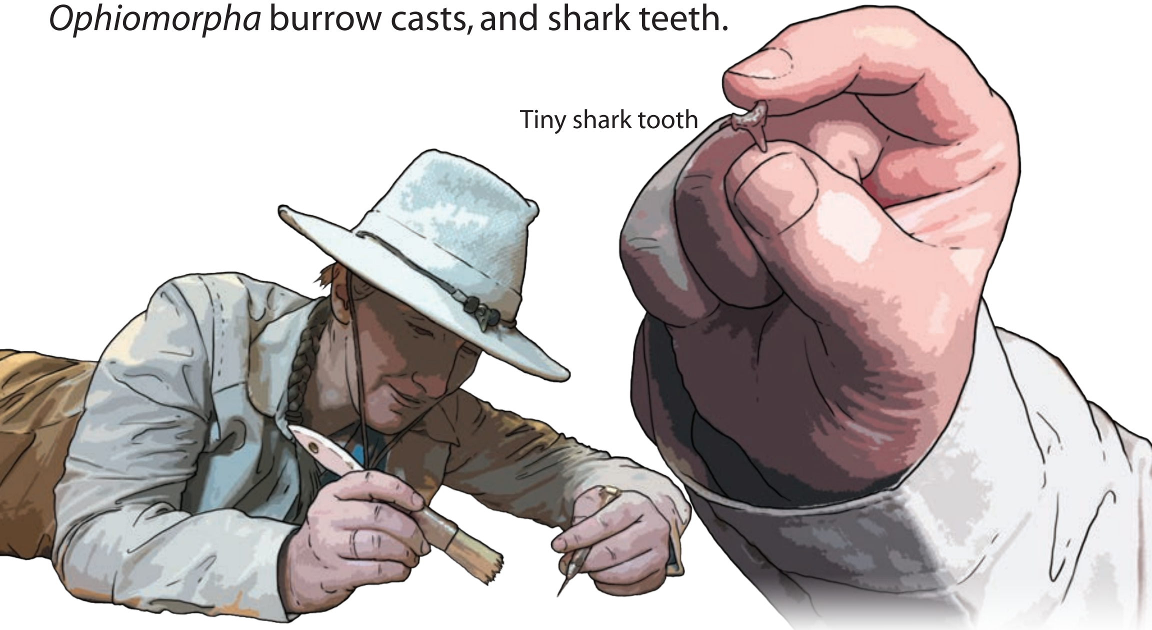


Ischyodus / ratfish / chimaera

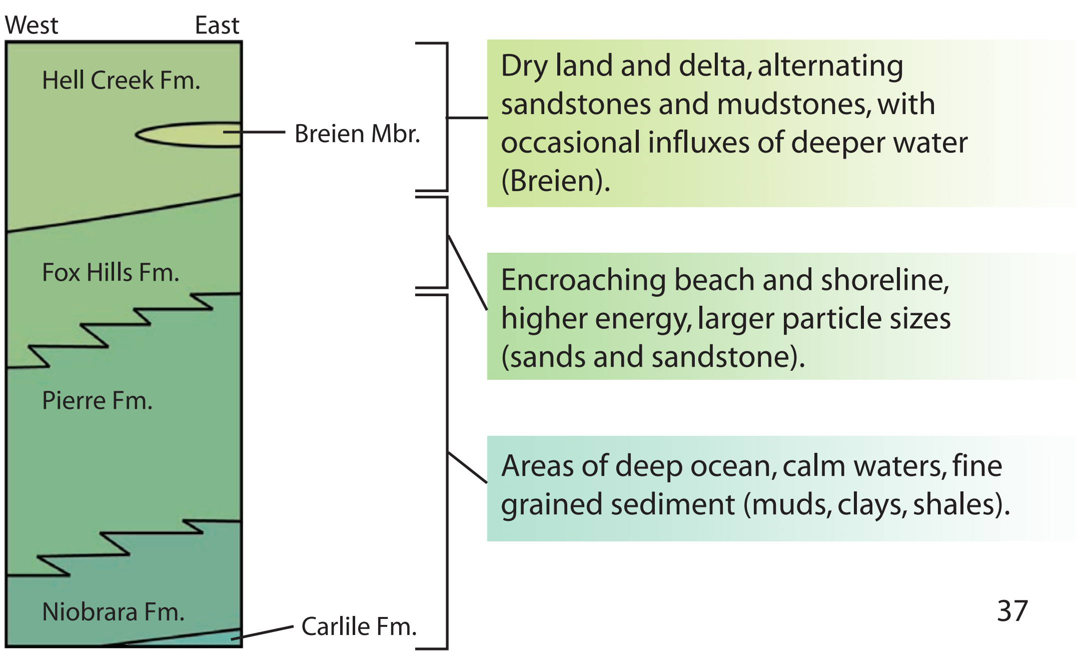
Tooth-plates from a prehistoric ratfish, *Ischyodus rayhaasi,* have been found in Logan County, North Dakota. The animals had large eyes and pectoral fins, a dorsal spine in front of the dorsal fin, and a long whip-like tail. Modern chimaera inhabit deeper sections of the ocean – the North Dakota variety apparently favored shallow seas filled with one of their food sources, molluscs.

Breien

As the Cretaceous seaway moved west, pushing back the delta, the marine sediments deposited in the Hell Creek Formation were called the Breien Member. Small outcrops of the Breien have contained *Ophiomorpha* burrow casts, and shark teeth.



There are little "fingers" of the Breien Member sandstone that can be found sandwiched between layers of the Hell Creek Formation mudstone, showing the movement of the Western Interior Seaway.



Cannonball Sea

The last sea to cover North Dakota was called the Cannonball Sea. Because this body of water occurred after dinosaurs went extinct, it will be covered in more detail within the Paleo Primer which focuses on the Paleocene Epoch of time.

But that, as they say, is a story for another time...

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