Walking the Mesozoic

National Park Service
U.S. Department of the Interior

Dinosaur National Monument

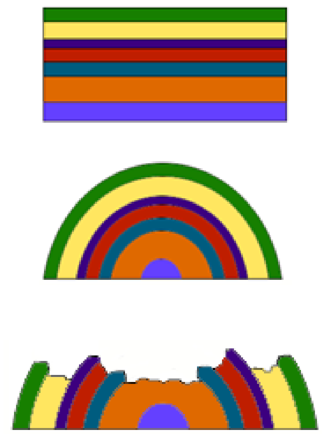
A Fossil Fanatic's Guide to the Fossil Discovery Trail

The Mesozoic Era lasted from about 250 million to 65 million years ago. It saw the evolution, terrestrial dominance, and eventual extinction of the dinosaurs. Here at Dinosaur National Monument the well exposed Mesozoic rocks record the amazing story of how life and the land changed over the course of almost 200 million years. This brochure offers a more in depth look at the fossils and geology seen along the Fossil Discovery Trail.

Getting Started

For much of the Mesozoic, western North America was hot and dry, and the area around what is now Dinosaur National Monument alternated between desert dunes and broad river plains. The mountains that are here now had not been born, so this area was flat enough to be periodically flooded when sea level rose. Then in the Cretaceous (about 145 million years ago), a chain of volcanoes that had formed out in the Pacific Ocean slammed into North America. Mountains rose, seas were born and erased, and the land bent and broke. The climate turned warm and humid, and the sea advanced, flooding North America down the middle.

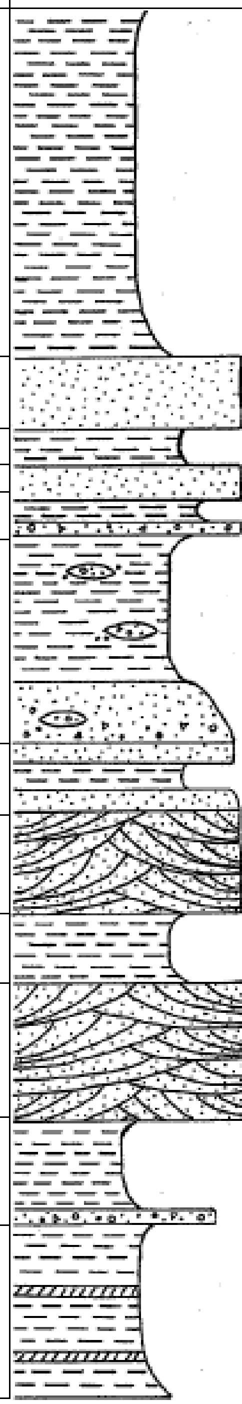
The rocks in this part of Dinosaur National Monument are almost all sedimentary. They were created when loose sediment like sand or mud was buried so deep underground that it became rock. Different sediments produce rocks of different strengths; you will be able to see that some layers have resisted erosion and stand up in ridges and cliffs while others are so badly eroded you can't even tell they're rock. Take a look at the figure to the right. The block of horizontal rocks you see at the top gets folded into a shape called an anticline (middle). After a time, the top is eroded away, but the weak rocks erode more than the strong rocks (bottom). That's why there are so many ridges in Dinosaur National Monument. The erosional valleys between the ridges are called strike valleys. Split Mountain, the major topographic feature on the Utah side of the park, is an anticline, just like the one illustrated above. If you were to walk from the outermost layer towards the center, you would be traveling back in time. Taking the Fossil Discovery Trail (and, if you wish, the Sound of Silence Trail) allows you to do just that.



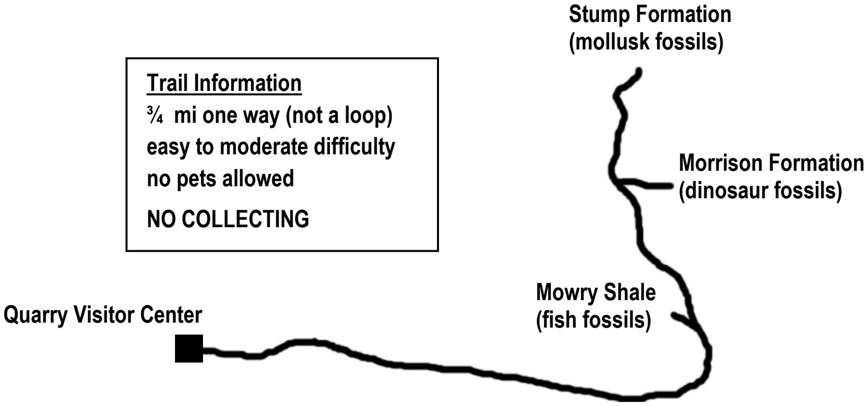
Something you will see again and again is a transgressive-regressive sequence. This refers to the advance and retreat of oceans as sea level rose and fell. Imagine standing in one place for tens of millions of years. At first you might be on a sandy beach, and the rock that will form from the sand you're standing on is a strong sandstone. Forty million years later, the sea has advanced toward you. Now you are underwater, on the mud at the bottom of an ocean, which will eventually form a weak shale. After a while, sea level falls, the sea retreats again, and once more you are on a sandy beach. In the rock record, this translates to alternating layers of sandstone and shale. When you walk through the Mesozoic, you can actually see this alternation. It tells us how high sea level was here at the time each rock was formed.

In order to begin your tour, park at the Quarry Visitor Center. The trail begins to one side of the building. Be sure to bring plenty of water, sunscreen, and a hat on the trail. Remember that the first rock units you see are the youngest.

This diagram is called a stratigraphic column. Geologists use it to summarize a set of rock layers in a given area: their ages, compositions, and how easily they erode. The oldest layers, the ones that were laid down first, are at the bottom, just as they would be in outcrop (if they haven't been folded, faulted, or overturned). There are different symbols for different kinds of rock: sandstones are filled in with dots, shales with horizontal dashes, and so on. In the lithology column, the farther out to the right a rock unit sticks out, the harder it is, so those units represent the tall ridges you will see along the trails. Note how the alternation of sandstone and shale reflects the transgressive-regressive sequence discussed on the previous page.

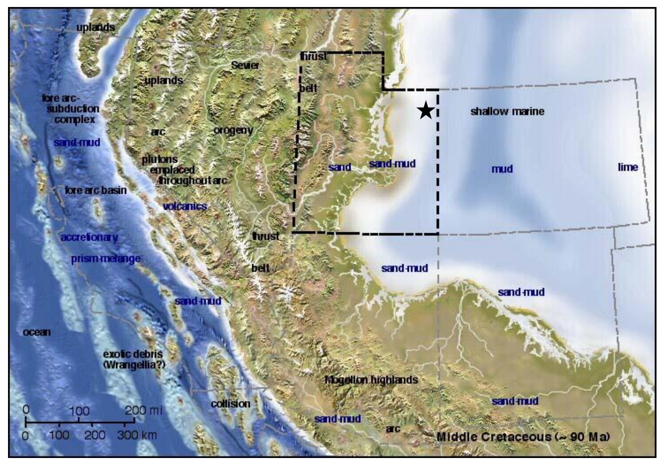
Trail	Period	Rock Unit	Thickness m (ft)	Lithology	Description
	CRETACEOUS	Mancos Shale	1450-1700 (4800-5600)		Dark grey, silty to clayey, marine shale that weathers light grey to light yellow. Minor siltstone and sandstone in the upper part with layered bentonite (ca. 90 Ma) and a few limestone beds in the lower part. Locally fossiliferous. Top not exposed in DNM.
FOSSIL DISCOVERY TRAIL		Frontier Sandstone	30-90 (100-300)		Brown sandstone, siltstone, and shale, marine fossils, and local coal.
		Mowry Shale	10-65 (33-220)		Hard, grey, fissile, siliceous shale.
		Dakota Sandstone	12-30 (40-100)		Light-grey to –yellow sandstone.
		Cedar Mountain Formation	0-60 (0-200)		Colorful clay- and siltstone, some sandstone. Local conglomerate.
		Morrison Formation	200-300 (650-1000)		Multicolored mud- and siltstone, with bentonite, sandstone, and conglomerate. Dinosaur fossils.
	JURASSIC	Stump Formation	21-37 (70-120)		Siltstone and shale over sandstone.
		Entrada Sandstone	12-49 (40-160)		Pink to yellow-grey eolian sandstone.
SOUND OF SILENCE TRAIL		Carmel Formation	0-43 (0-130)		Dark red sandy silt- and mudstone.
		Glen Canyon Sandstone	180-200 (600-650)		Pink to grey-yellow eolian sandstone.
	TRIASSIC	Chinle Formation	60-140 (200-460)		Red to grey siltstone, sandstone, and shale with local basal conglomerate.
		Moenkopi Formation	150-240 (500-800)		Mostly red to brown, green, and grey siltstone and shale with thin gypsum beds. Ripple marks, reptile tracks, marine invertebrate fossils.

Part I: Fossil Discovery Trail



Mancos Shale

The trail begins near a prominent sandstone ridge. Before you begin, if you look far down the ridge to your left, you can see grey and yellow hills lying up against it. Those hills, which can best be seen from the road on the way into the park, represent the **Mancos Shale**. This rock was originally mud and silt on the bottom of a shallow sea that covered the intermountain west. The picture to the right shows an approximation of this environment. This sea must have been here for a long time: the Mancos is 5,000 feet thick—thicker than all the rest of the Mesozoic rocks in Dinosaur put together! It doesn't look quite so thick right here because it has been so thoroughly eroded. Shales are generally weak rocks; throughout this trail you will notice that they don't usually form nice outcrops or ridges the way a sandstone might. This particular shale is dark grey but turns light grey and yellow when it is exposed to the elements. The Mancos contains fossils here and there; some of them—certain clams and ammonites, especially—are important *index fossils*. Index fossils are geographically widespread over a certain time period, which allows geologists to accurately determine the age of the rock that contains them. It's a little like how everyone in your extended family can tell that a picture was taken in 2003 because that was the only year you had such a bad haircut.



Fossilized ammonite shell.

Frontier Sandstone

Now look at the steep ridge in front of you. This is the **Frontier Sandstone**, which was once a beach on the Mowry Sea during the Cretaceous. Paleontologists analyzed grains from the tops of the numerous anthills at the foot of the ridge, and found that the ants have actually collected a few small fossil shark teeth to use in their anthill! Other than that, though, this layer doesn't contain many fossils.

As you walk along the ridge, look up at the darker areas of the ridge. You may be able to see ripples like those you might see at the beach, preserved on the steep surface. You might also see concretions near the trail, which look like round brown boulders. They look loose, but they are anchored at the bottom, and some of them are broken. One of them has a pretty star-shaped crack in the middle of it. These were formed in the sand, long before it became rock, by minerals hardening around a focal point.

The trail runs along the ridge and then turns left around a large boulder—on its dark underside you can see a few petroglyphs, although more recent visitors have, lamentably, also felt compelled to leave their mark on the rock. The petroglyphs were made by the Fremont people, who lived in this area between 650 and 1400 C.E. You may notice that the petroglyphs tend to be made on darkened rock surfaces, to stand out. This red or black sheen is called desert varnish, composed of chemicals produced by microbes living on the surface. There is still debate over what else is involved—maybe evaporating water, maybe particles of clay—but this feature is widespread in arid areas, and desert-varnished rocks were popular places to carve petroglyphs. If petroglyphs are of interest to you, there are good examples (with less vandalism) elsewhere in the park. Consult a map of the park to find these sites.

Mowry Shale

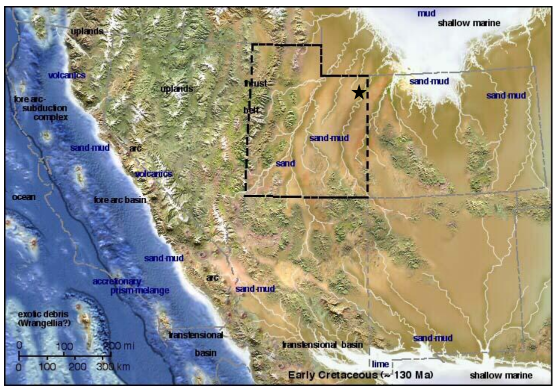
Just before the next obvious sandstone ridge, you can see a silvery grey layer of shale, which looks mostly like a wide silver stripe on the ground. This is the **Mowry Shale**. It consists of mud and silt that was deposited at the bottom of the Mowry Sea, before it began to retreat. Much of the mud is actually weathered ash from volcanoes erupting in Idaho—that's why the rock is silver. The Mowry Shale is chock-full of fish and shark fossils, mostly just isolated scales and bones. This is likely because the ash in the water caused massive die-offs, and deep currents pulled the decomposing bodies apart and scattered the bones and scales. This probably happened many times over: each time the volcanoes erupted, tons of ash fell into the sea and more fish bits were mixed in with the bottom mud. There are also occasional leaf fossils in this layer—the leaves must have blown out to sea and then sunk to the bottom. The Fossil Discovery Trail marks a stop in the Mowry, where visitors can sift through a pile of silver shale chips, looking for fossils. Try your hand at finding some; they might be more subtle than you expect. Fish scales usually look like dark or gold circles in the rock; see the example to the right.

Dakota Sandstone

The next sandstone ridge, with rust-colored stains near the trail, is the **Dakota Sandstone**. The Dakota formed in swamp and river environments, although it is still part of the transgressive-regressive sequence you've been walking through (see intro). On the left side of the trail there is one Dakota ridge; on the right side there are two. Encountering this kind of variation is not uncommon for geologists. Don't let it bother you.

Cedar Mountain Formation

On the other side of the Dakota is the grayish-purple ridge of the **Cedar Mountain Formation**, which was deposited in a variety of freshwater environments, including rivers, lakes, ponds, and floodplains. This is the layer where paleontologists at Dinosaur National Monument recently discovered a new species of sauropod (long-necked herbivores), including the *only* complete Cretaceous sauropod skull from North America. That's 80 million years with only one surviving skull! It also contains many other types of fossils, although it's not as fossiliferous as the Morrison Formation (up next).



The new sauropods were found in a river deposit. This is what the area might have looked like when they were fossilized. Notice the river running very close to DNM.

Morrison Formation

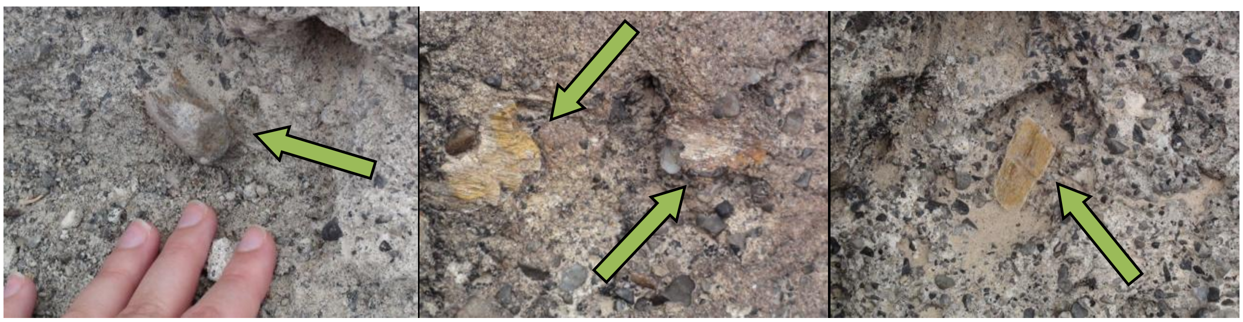
The next ridge along the trail, quite similar in appearance (and origin) to the Cedar Mountain ridge, is part of the **Morrison Formation**. In fact, these two formations look so much alike that for a long time, many geologists lumped them together into one. There's actually a 20 million year gap between the two! Near the path are popcorn-textured hills made of weathered volcanic ash blown in from what is now California. These rocks expand and contract as they absorb and lose rainwater, which is usually a problem for man-made structures in the area. The instability of these mudstone hills is the reason the old Quarry Visitor Center started to fall apart and had to be torn down and rebuilt.

Popcorn texture.

Earl Douglass was an employee of the Carnegie Museum of Natural History. He was looking for dinosaur bones here, and in 1909, he struck paleontological gold. He found what is now the Carnegie Quarry, and directed its excavation from 1909 to 1922, producing 700,000 tons of material that he shipped back to the museum in Pittsburgh. In the middle of these excavations, in 1915, the government created Dinosaur National Monument to protect the quarry, although at first (until 1938) it only covered the 80 acres right around the quarry. Other excavations were carried out by various organizations, mostly universities and museums. The Quarry Visitor Center was built in 1957 over the quarry face, which now contains 1500 visible bones still in their original positions in the rock.

The Morrison formation is one of the most prolific dinosaur-producing sites in the world: the quarry has so far yielded bones and partial or complete fossil skeletons from about 500 individual dinosaurs belonging to ten different species. Also included in the rock are fossilized crocodiles, freshwater turtles, freshwater mollusks, and petrified wood. There are over 400 Morrison fossil localities in the park. The formation extends over one million square kilometers, from Nebraska to Montana to New Mexico.

A spur trail leads off the main path to the right, up the ridge of the resistant Morrison layer. Along the spur you can see dinosaur bones in place, all naturally exposed; this is very similar to what Earl Douglass found in 1909. Begin at the bottom of the trail by training yourself to see bone chips. When the outermost layer of bone is exposed, it looks familiar, more like the assembled skeletons you've seen in museums. But they can be cream- or rust-colored and spongy- or fibrous-looking if what you're seeing is the inner part of the bone.



Bone fragments along the spur.

Once you know what you're looking for, you'll see them everywhere, and they get larger as you go up the spur. But watch out for the clay balls (shown at right); these round white bits might look like bone at first, but they're just part of the rock. You can tell they're not bone by touching them—bone doesn't feel chalky, and these do. As you go farther and farther up the trail, the bones become larger and more recognizable. Some of the larger ones are marked with white painted circles or arrows, but there are many that are not labeled. The three most striking sauropod bones are as follows: the arm bone of a juvenile, just above the level of the trail proper; a row of vertebrae, about ten feet above the spur; and part of a leg, near the turnaround loop at the top. Remember to look both up and down, and watch your footing!

Clay ball.

NOTE: **PLEASE STOP** at the turnaround loop. Do not climb past the low wall at the end of the spur. Do not climb up the ridge face. Besides the obvious risk to you, you might easily damage the fossils, and there is loose rock that can make it dangerous for people on the spur below you as well.

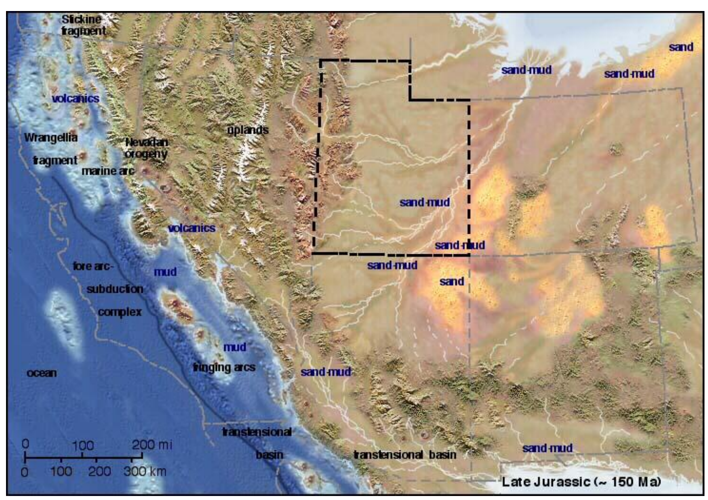
UNIONOIDS

When you return to the trail, pause a moment and look for mussels. All along the Morrison, fossils of freshwater unionoid (yoo-nee-AH-noid) mussels are visible; the best place to see them is at the bottom of the spur, just as you are about to continue along the path: there is a large boulder, flat side towards the path, covered with fossil unionoids. Note how the shells are all in identical orientations: concave down. This position is stable in flowing water; the current catches the edge of concave-up shells and flips them over. None of these fossils are in "butterfly" pairs, so they must have died and rotted away before their shells washed downstream and were deposited in a calm area. Mollusks get growth rings just like trees; it isn't possible to count them on these particular fossils, but other Morrison unionoids of this size with visible growth rings are 10-12 years old.

The very specific reproductive process of these kinds of mollusks, which still exist in rivers today, gives us a lot of information about the environment they lived in, and, by extension, the environment beyond the stream. Many saltwater mollusks reproduce by broadcast spawning: each sex sends out a cloud of eggs or sperm, and wherever an egg and a sperm happen to meet, they produce a larva that eventually settles to the bottom. But this method doesn't work in rivers—not if the clams want to *stay* in the river, and not end up in the ocean. Instead, the males send out bundles of sperm into the water which the female takes in and uses to fertilize her eggs. Once she has growing larvae inside her (75,000-3,000,000 per brooding cycle), she attaches them to a fish, where they can grow without washing downstream. Some modern-day species have evolved an enlarged mantle they use as a lure; others spit the eggs out in a web of mucus that looks appetizing to predatory fish. One way or another, the larvae end up on a fish's fins or gills, living off the host's cells until they are big enough to drop off, settle to the bottom, and begin life as a bona fide bottom-dwelling mussel.

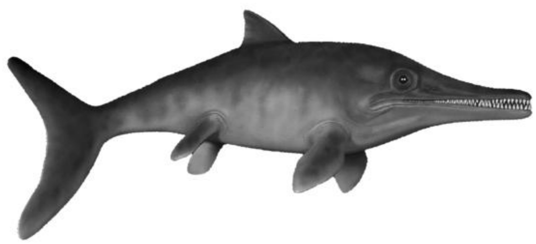
Their presence in general implies a permanent river (because they're 10-12 years old) with a large fish population and clear water (because they're filter feeders—they'd choke on muddy water). Their presence in the Morrison, specifically, tells us that the fossil fish record is very poor. Fish fossils (aside from the occasional scale) are one of the least well-represented groups in the Morrison. Because of the mussels, we know that the fish *were* there, and were not preserved. This is an illustration of how the most seemingly insignificant fossils can give us the most information. The dinosaur fossils you just saw tell us nothing about the river. We need the mussels for that.

(above) Unionoids! Sometimes you have to look carefully to be able to see the clam shapes.



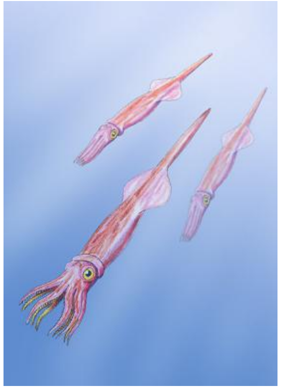
(right) The dinosaurs found in the Morrison probably lived and died in an environment like this one.

Stump Formation
Follow the path all the way to its end; it dead-ends against a sandstone wall, which is the beginning of the **Stump Formation**. This layer was deposited as part of another transgression-regression sequence. In this area it contains lots of marine fossils, mostly mollusks, although a complete ichthyosaur skeleton was found in the Stump sandstone outside the park. In the area around the end of the trail, you can find some mollusk fossils. In addition, you may be able to find belemnite fossils: picture a squid with a bony head. The bone fossilizes into something that looks like a long bullet. They are sometimes lying on the ground in this area.



Ichthyosaur.

Stump mollusk fossils.



An artist's reconstruction of live belemnites.

Fossilized belemnite, with a dime for scale.

This is as far down the Mesozoic as you can go on the Fossil Discovery Trail. If you wish to see the rest of the section, go back to the Visitor Center and drive two miles into the park on the main road, and you will see a sign for the Sound of Silence trail. Park there and we'll pick back up in the Morrison.

CREDITS
Belemnite illustration: Dmitry Bogdanov
Belemnite photo: DanielCD
Ichthyosaur/ammonite illustrations: Sedgwick Museum of Earth Sciences
Paleogeographic maps: Ron Blakey (http://jan.ucc.nau.edu/~rcb7/paleogeogwus.html)
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