Walking the Mesozoic

National Park Service
U.S. Department of the Interior

Dinosaur National Monument

Geological Blast through the Past

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 both the Fossil Discovery and Sound of Silence Trails.

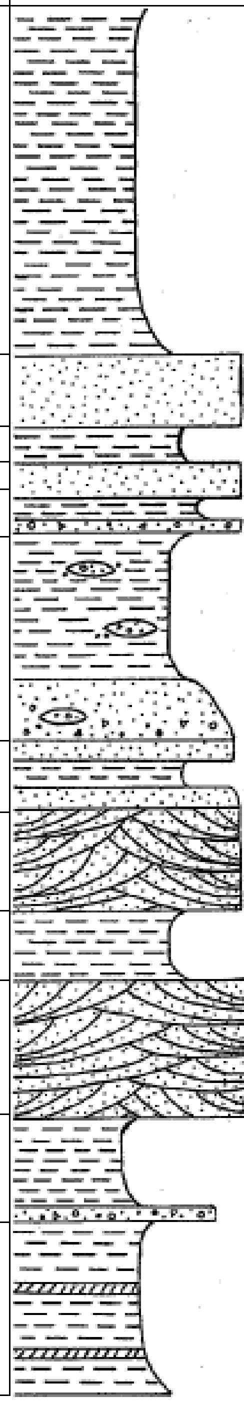
Getting Started

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.

Walking the Mesozoic

The Mesozoic section in Dinosaur National Monument is 3,000 meters thick and covers the Late Triassic through the Middle Cretaceous. Rocks of this age are well-exposed along two trails: the Fossil Discovery Trail allows you to walk from the Mancos Shale (Middle Cretaceous) to the Stump Formation (Middle Jurassic), and the Sound of Silence trail will take you from the Morrison Formation (Late Jurassic) through the Moenkopi Formation (Late Triassic). The stratigraphy is profoundly affected by the large Split Mountain Anticline, which plunges to the southwest. The beds on the limb of the anticline where you will be walking dip sharply (about 70°) to the south, and because the trails run perpendicular to strike, you will be able to walk through a thick section over a relatively short distance.

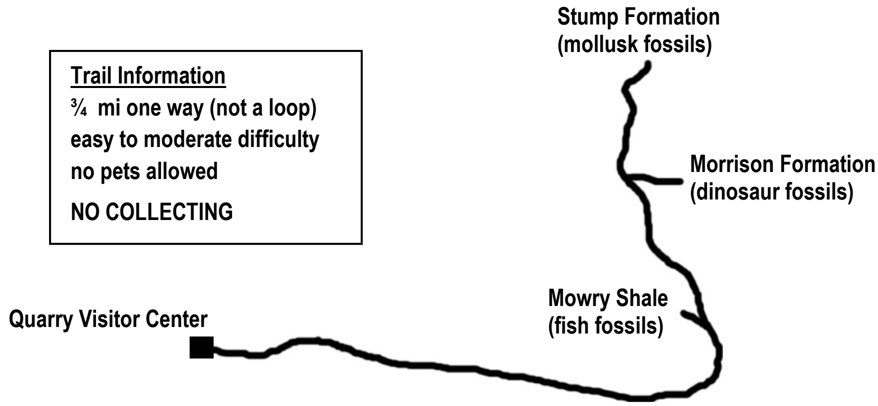
Trail	Period	Rock Unit	Thickness m (ft)	Lithology	Description
FOSSIL DISCOVERY TRAIL	CRETACEOUS	Mancos Shale	1450-1700 (4800-5600)		Dark grey, silty to clayey, marine shale that weathers light grey to light yellow. Minor siltstone and sandstone in the upper part with layered bentonite (ca. 90 Ma) and a few limestone beds in the lower part. Locally fossiliferous. Top not exposed in DNM.
		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.
FOSSIL DISCOVERY TRAIL / SOUND OF SILENCE TRAIL	JURASSIC	Morrison Formation	200-300 (650-1000)		Multicolored mud- and siltstone, with bentonite, sandstone, and conglomerate. Dinosaur fossils.
		Stump Formation	21-37 (70-120)		Siltstone and shale over sandstone.
SOUND OF SILENCE TRAIL		Entrada Sandstone	12-49 (40-160)		Pink to yellow-grey eolian sandstone.
		Carmel Formation	0-43 (0-130)		Dark red sandy silt- and mudstone.
	JURASSIC / TRIASSIC	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.



Remember that this is a national monument. Certain routine geo-educational proceedings, such as taking samples away from a site or using a rock hammer on an outcrop, are not permitted. Bring plenty of water, sunscreen, and a hat on the trails.

Part I: Fossil Discovery Trail

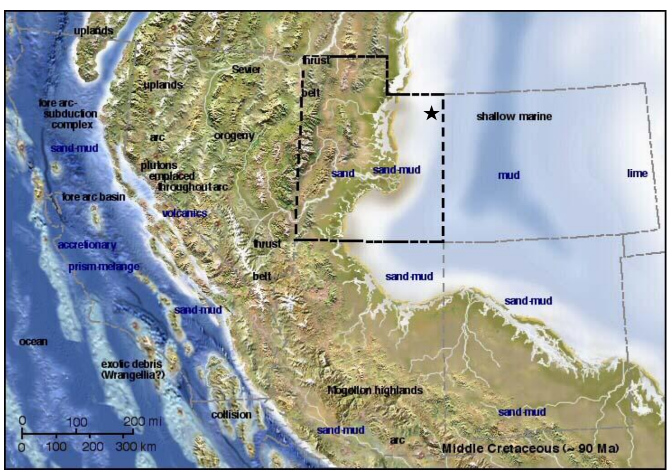
It is not permitted to leave the trail in this area. Please stay on the established trail. Obey all posted signs.



Mancos Shale

The trail begins by the Quarry Visitor Center, near a prominent sandstone ridge. Before you begin, if you look several hundred meters west down the ridge, you can see grey and yellow hills lying up against it and extending out to the southwest. These hills, which can best be seen from the road you took into the park, are the **Mancos Shale**. In the Upper Cretaceous, a shallow epicontinental sea covered the intermountain west; the Mancos was deposited on this sea floor, and is locally fossiliferous with bivalves, brachiopods, cephalopods, bryozoans, echinoderms, protozoans, and trace fossils. Certain of these—for example, inoceramid clams and baculites (ammonite cephalopods)—are important index fossils for the region. Note the thickness of this unit: it is thicker than all of the other Mesozoic rock units combined.

Mancos Shale
Upper Cretaceous (100-80 Ma)
1450-1700 m thick
Dark grey, silty to clayey marine shale that weathers light grey to light yellow. Minor siltstone and sandstone in upper part, with layered bentonite, few limestone beds in lower part. Locally fossiliferous. Top not exposed in DNM.



Paleogeographic setting in the Middle Cretaceous, about 90 Ma.

Frontier Sandstone

The sandstone ridge to the north of you is the **Frontier Sandstone**, a regressive unit deposited as the Mowry Sea retreated to the north. It is informally divided into two members. The upper part is the light

Frontier Sandstone
Upper Cretaceous (100 Ma)
30-90 m thick
Brown sandstone, siltstone, and shale; marine fossils and local coal.

brown, resistant sandstone you see in front of you, which tends to form hogbacks and flatirons in the area. Immediately below the sandstone are dark grey pre-regression fossiliferous shales and siltstones, which are visible further north along the trail, on the other side of the ridge. These members tend to weather into hills. Examination of pebbles and grains gathered from the tops of the abundant anthills at the foot of the ridge reveals that, in fact, these harvester ants have recovered a few small shark teeth weathered out from the Frontier. Aside from that, though, the upper Frontier is not very fossiliferous within Dinosaur National Monument. On your way east along the trail, notice ripple marks high up on the ridge, highlighted by patches of desert varnish (we'll come to that in a minute). You might also be able to see large concretions near the trail. They are difficult to distinguish from boulders that have simply fallen from the ridge, but they are fixed in place, usually a darker brown, and spherical except where they have been split. One concretion in particular sports a beautiful star-shaped fracture in its center, filled in with precipitated minerals.

Where the trail bends to the north and cuts through the ridge, you can see a large boulder with a few petroglyphs on its eastern face. These were made by the Fremont people, who inhabited this area between 650 and 1400 A.D. The rust-colored sheen on the rock is desert varnish. Although some debate exists about its exact genesis, it is certainly a thin (<100µm) layer of manganese and iron oxides. The most widely accepted idea is that these are a byproduct of microbial metabolism, and, according to some, the varnish is formed when clay minerals either stick to the oxides or partially erode out of the underlying rock to react with them. Petroglyphs are frequently made on desert varnish surfaces; when the thin top layer is chipped away, the relatively pale rock beneath it stands out nicely from the darker surround. As you can see, more recent people have unfortunately felt the need to leave their mark on the rock as well. 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

Mowry Shale
Middle Cretaceous (110-100 Ma)
10-65 m thick
Hard, grey, fissile, siliceous shale.

Between the Frontier and the next obvious sandstone ridge, you will see a silvery grey layer of shale: the **Mowry Shale**. It is a marine deposit from the oldest transgression of the shallow Cretaceous seaway. Much of it is volcanic ash from what is now Idaho, interbedded with unsilicified dark shales. The abundance of disarticulated fossil fish scales and bones may be the result of massive die-offs related to the ash falls. The presence of neritic fauna fossils (bony fish, ammonites, and sharks), together with the lack of benthic fauna fossils indicates an anoxic environment on the bottom of the sea. Occasional leaf fossils have been found in the shale, which must have blown out to sea and sunk to the bottom, so land cannot have been too far away. The Fossil Discovery Trail marks a stop where visitors can sort through a pile of silver shale chips and look for fossils, especially fish scales.

Dakota Sandstone

Dakota Sandstone
Middle Cretaceous (110 Ma)
12-30 m thick
Light grey to light yellow sandstone.

The next sandstone ridge, with some reddish cross-bedding visible where the trail cuts through it, is the **Dakota Sandstone**. The Dakota formed in paludal and fluvial environments in a transgressive-regressive sequence. This sequence is also visible in the overlying Frontier and Mancos. It is generally light grey, white, or light yellow, medium- to coarse-grained, with some cross-bedding, and generally not fossiliferous.

Cedar Mountain Formation

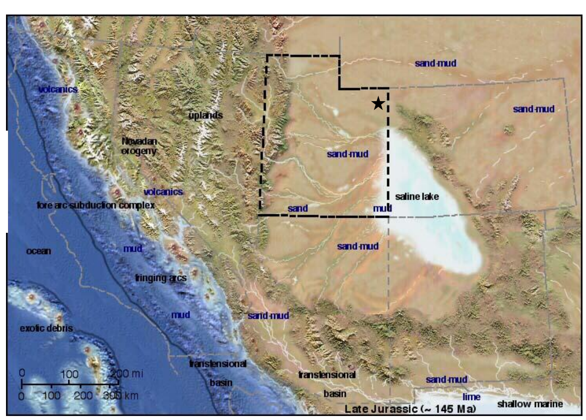
Cedar Mountain Formation
Middle Cretaceous (120 Ma)
0-60 m thick
Colorful clay- and siltstone, some sandstone. Local conglomerate.

On the other side of the Dakota is the **Cedar Mountain Formation**, which is composed of clay- and siltstone, sandstone, and some conglomerate, deposited in rivers, lakes, ponds, and floodplains. The grayish-purple sandstone ridge is its most obvious manifestation along the Fossil Discovery Trail. Within the boundaries of Dinosaur National Monument, the Cedar Mountain has not yielded quite so many dinosaur fossils as the famous Morrison Formation, although outside our boundaries it has actually been quite prolific. It is lithologically similar to the Morrison, and paleontologists working in the park have uncovered a few fossils, foremost among them a new sauropod, *Abydosaurus mcintoshi*. The specimens recovered include the only Cretaceous sauropod skulls from the entire Western Hemisphere!

As you proceed along the trail, try to identify the contact between the Cedar Mountain and the older Morrison. There is a 20 million year gap between the two formations, but the contact is very obscure—there is no unconformity or erosional surface visible. There is a resistant caliche layer at the bottom of the Cedar Mountain which is usually included in that formation, but the exact timing of its deposition and cementation is uncertain; it may be Morrison-age sediments that were cemented during Cedar Mountain times. The contact is so poorly manifested that the Cedar Mountain and Morrison are sometimes mapped together as "Undifferentiated Upper Jurassic and Lower Cretaceous."

NOTE: The reddish-grey, runneled hillside to your left (to the west) as you continue along the trail is just overburden dirt and parking lot fill from the construction site on top of the neighboring hill. It is not a natural feature. Please disregard.

Paleogeographic setting in the Early Cretaceous, about 130 Ma. Approximate deposition of the Cedar Mountain.



Paleogeographic setting in the Late Jurassic, about 145 Ma. Note the relative aridity of the environment towards the end of the deposition of the Morrison.

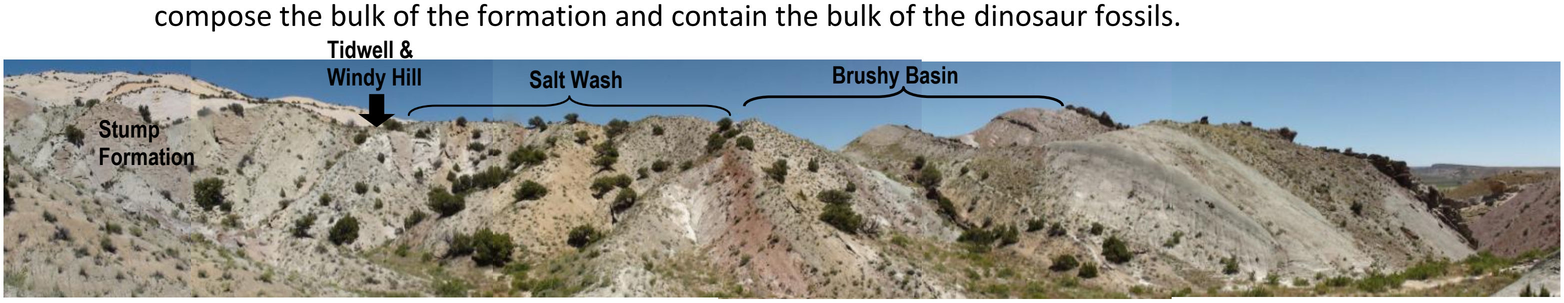
Morrison Formation

The next ridge along the trail, quite similar in appearance to the Cedar Mountain ridge, is part of the **Morrison Formation**. Deposition of Morrison sediments took place in a variety of freshwater settings: rivers, lakes, ponds, floodplains, deserts, hypersaline lakes, etc. The popcorn-textured hills near the path are bentonite; volcanic ash from what is now California blew to this area and was lithified. These rocks absorb rainwater and expand, which is usually a problem for man-made structures built on them. The instability of the bentonite hills is the reason the old Quarry Visitor Center was structurally compromised and had to be torn down and rebuilt.

Morrison Formation
Late Jurassic (152-144 Ma)
200-300 m thick
Multicolored mud- and silt-stone, with bentonite, sandstone, conglomerate.
Dinosaur, reptile, mammal, amphibian, and fish fossils.

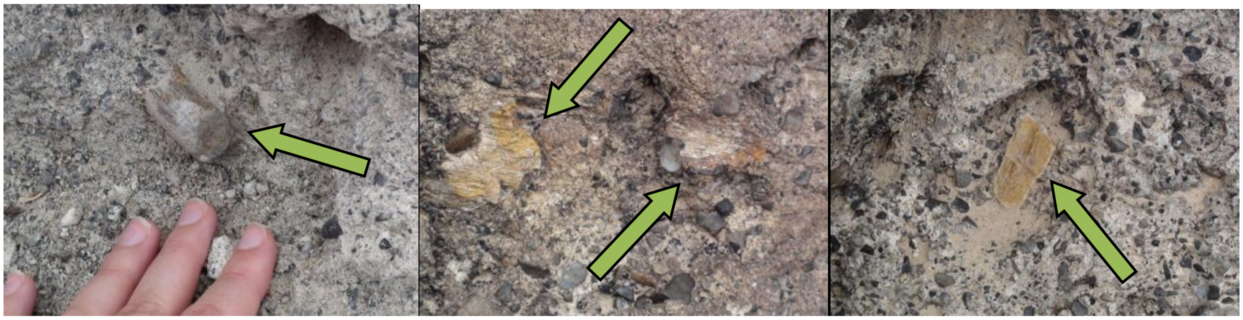
In 1909, Earl Douglass, an employee of the Carnegie Museum of Natural History, discovered what is now the Carnegie Quarry while prospecting for dinosaur bones in this area. It was excavated by the Carnegie Museum from 1909 to 1922, producing 700,000 tons of material to be shipped back to Pittsburgh. Dinosaur National Monument was created in 1915, although at that time it included only 80 acres immediately surrounding the quarry. Subsequent years saw excavations by the U.S. National Museum and the University of Utah. In 1938 the monument was expanded to its present size. The Quarry Visitor Center was built in 1957, over the fluvial sandstone face that now contains 1500 bones exposed and preserved in situ. The bone-bearing layer of the quarry is now mostly exposed, allowing park paleontologists to focus on sites elsewhere in the monument. This formation is one of the most prolific dinosaur-producing rock units in the world, and the Carnegie Quarry is one of the largest and most fossil-rich quarries anywhere in the Morrison. The quarry eventually yielded bones and partial or complete fossil skeletons from about 500 individual dinosaurs (10 species), crocodiles, freshwater turtles, sphenodont reptiles, freshwater bivalves, and carbonized wood. There are over 400 Morrison fossil localities in the park. The formation extends over approximately one million square kilometers, from Nebraska to Montana to New Mexico.

The Morrison is divided up into four members: from oldest to youngest, Brushy Basin, Salt Wash, Tidwell, and Windy Hill. The latter two are quite thin, whereas the former two compose the bulk of the formation and contain the bulk of the dinosaur fossils.



The Morrison Formation displays increasing aridity of environment from bottom to top: the Salt Wash is mostly thick fluvial sands, while the older Brushy Basin contains much less fluvial sand and much more mud and silt.

A short spur trail leads off the main path to the right (east), along the face of a resistant sandstone layer. This is the same sandstone that contains the Carnegie Quarry. Along the spur you can see dinosaur bones in situ, all naturally exposed. Begin at the bottom of the spur by training yourself to see bone chips. Some of them show the smooth outer surface of the bone, which looks familiar to most of us, but many of these are fragments that display the inner part of the bone, and they can be cream- to ochre-colored and spongy- or fibrous-looking.



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 chalky round white clasts look like bone at first, but they're only a sedimentary feature, ripped up and rounded when water sluiced over a bed of clay. As you progress up the spur, 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 humerus of a juvenile, just above the level of the trail proper; a string of articulated caudal vertebrae, about ten feet above the spur; and part of a large femur, near the turnaround loop at the top. Remember to look both above and below eye level, 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 onto 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.

When you reach the bottom of the spur and are ready to continue on the path, look for a large boulder with its flat side towards the path. One part of the surface contains a small orange, curved surface with veins snaking across it. This is an impression of part of a turtle shell. The rest of the surface is covered with casts of mussel shells.

Unionoids

All along the spur, casts of unionoid bivalves are visible; they are the most abundant fossil in the sandstone. The best place to see them is on the flat surface of this boulder. This piece of sandstone is worth closer examination, because these fossils tell us quite a bit about the paleoenvironment. They are natural casts of the inner (concave) surface of the shell; the actual fossilized shell material has been eroded away.

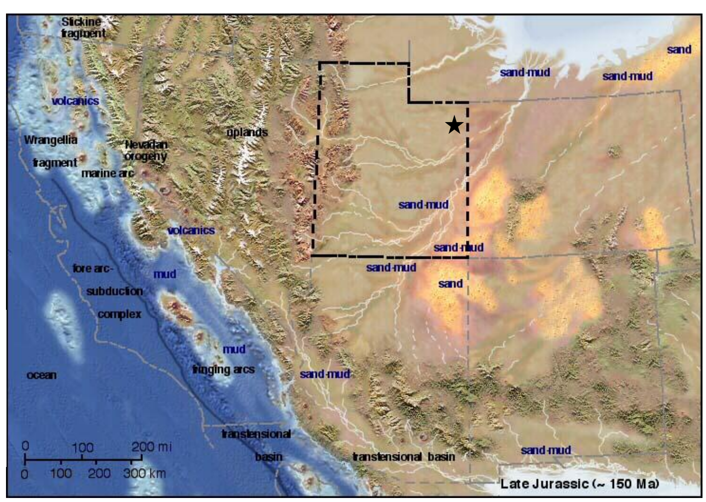
First of all, note the identical orientations of the shells: concave down. This position is hydrodynamically stable: the edges of any concave-up shells are caught by the current and flipped over. None of these fossils are “butterflies”—all the valves have been separated—and they are all preserved on a single bedding surface rather than in life position within the sediments, so they must have died and become disarticulated prior to their transport. The concentration of shells in this area (likely tens of thousands throughout the entire layer) indicates a massive die-off, probably during a sustained drought. It is not possible to count growth rings on these particular fossils, but other Morrison unionoids of this size with visible growth rings are 10-12 years old.

Unionoids still exist today and are the major group of clams living in freshwater rivers. Like other mussels, they are filter feeders and require relatively clear water. Their presence in this sandstone implies that the river usually had a low suspended sediment load.

Possibly the most interesting aspect of living unionoids is their reproductive biology. Many marine mollusks reproduce by broadcast spawning: each sex sends out a cloud of gametes (eggs and sperm), and wherever a pair 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, male unionoids 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 eject the eggs 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.

In summary, then, the presence of unionoids in the quarry sandstone implies a permanent river with a large fish population and clear water. They also tell us that the fossil fish record is biased. No fish fossils have yet been found in the sandstone, but because of the mussels, we know that the fish *were* there in some abundance, and were just not preserved. The unionoids in front of you illustrate how the most seemingly insignificant fossils can give us the most information. The dinosaur fossils tell us nothing about the river’s quality, biology, or permanence. We need the mussels for that.

Unionoid casts in situ. (above)



Paleogeographic setting in the Late Jurassic, about 150 Ma, around the time that deposition of the Morrison began. (right)

Stump Formation

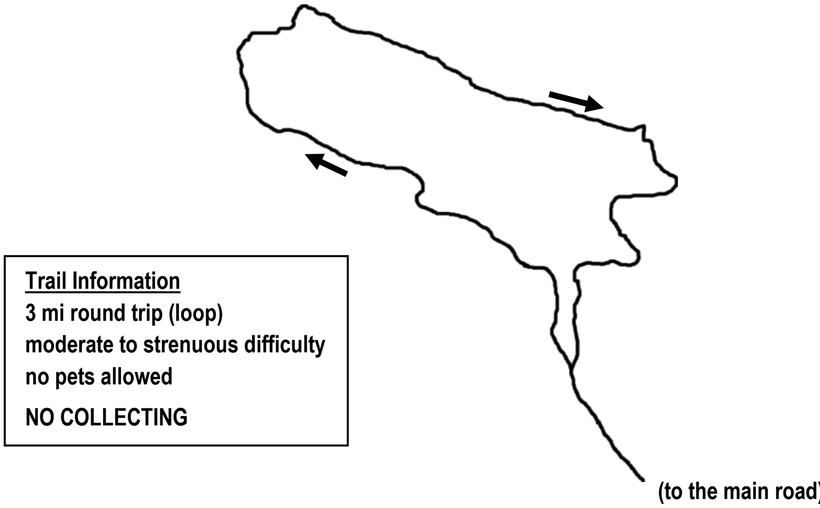
> **Stump Formation**
> **Middle-Upper Jurassic (175 Ma)**
> **55-70 m thick**
> **Siltstones, shales, and sandstones.**

Follow the path all the way to its end; it dead-ends against a sandstone wall, which is the top of the **Stump Formation**. This formation represents the latest Jurassic sea intrusion from the Arctic. The overlying Redwater Member is light- to olive-green, fissile, glauconitic siltstone and shale, and is locally rich with brachiopods, bivalves, echinoderms, and cephalopods, especially belemnites. The resistant light grey Curtis Member, below the Redwater, is medium- to coarse-grained, cross-bedded sandstone, which contains neritic fauna fossils such as belemnites and ichthyosaurs, as well as fossilized bivalves, brachiopods, and bottom-dweller traces.

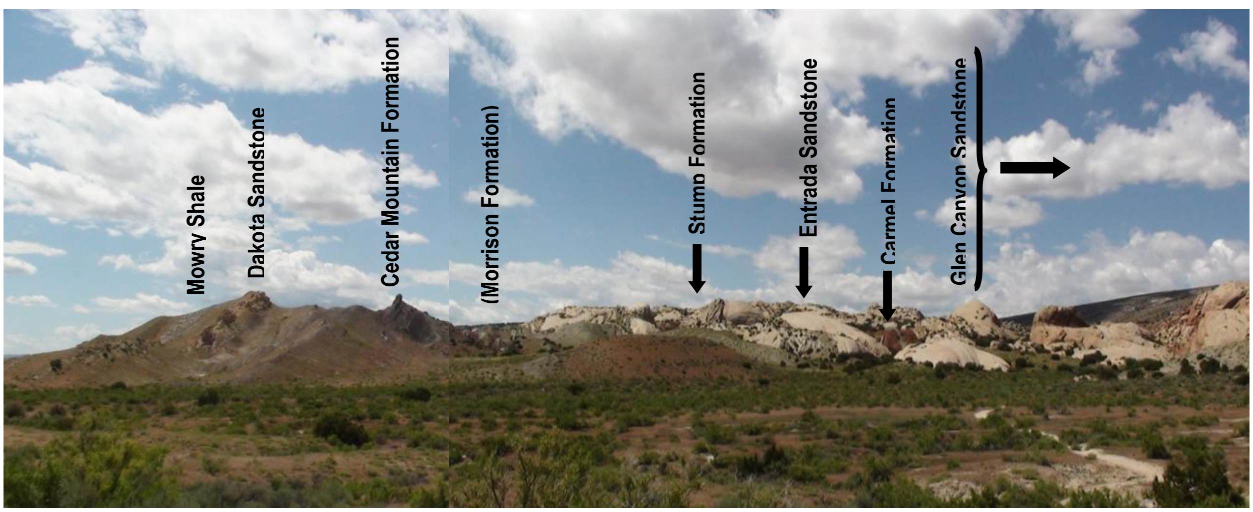
Stump mollusk fossils.

This is as far down the Mesozoic section as you can go on the Fossil Discovery Trail. To see the lower part of the section, including the rest of the Stump Formation, return to the Visitor Center and drive two miles farther into the park. You will see a sign for the Sound of Silence Trail. Park there and we'll pick back up in the Morrison.

Part II: Sound of Silence Trail



The Mesozoic section resumes at the Sound of Silence trailhead. On the Fossil Discovery Trail we went as far down as the top of the Stump Formation in the Upper Jurassic. This trail begins in the Morrison, although it does not outcrop very visibly in this area. There are outcrops to your left (west) that can help you orient yourself: you should be able to recognize the Mowry, Dakota, and Cedar Mountain/Morrison units.



View of Mesozoic outcrops to the west of the Sound of Silence trail.

Again, remember that this is a national monument. Certain routine geo-educational proceedings, such as taking samples away from a site or using a rock hammer on an outcrop, are not permitted. Bring plenty of water, sunscreen, and a hat on the trails.

Morrison Formation

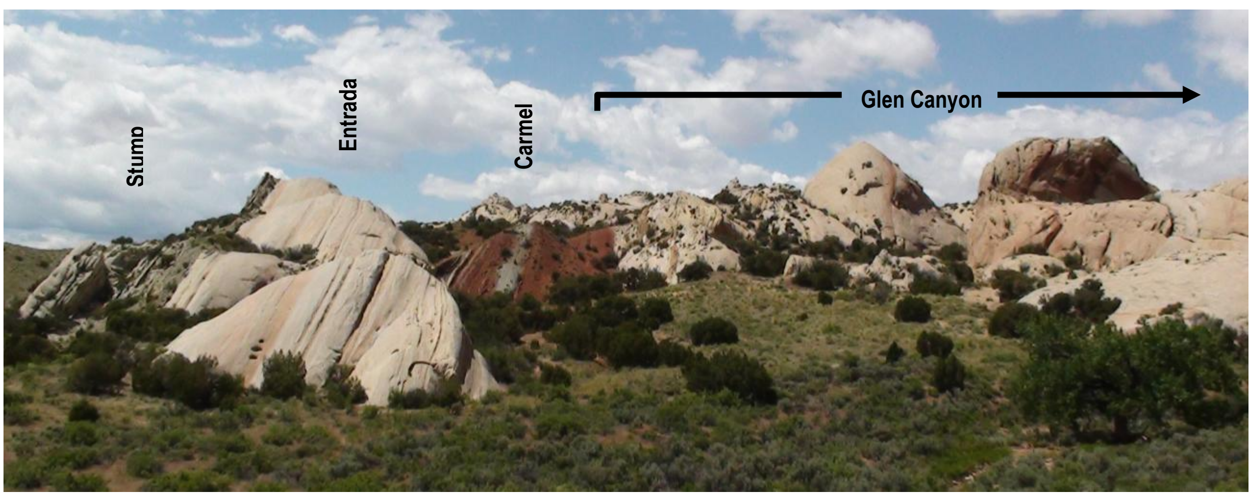
The **Morrison Formation** was covered extensively in the first part of this pamphlet, when we encountered it along the Fossil Discovery Trail. It was deposited in a variety of freshwater and terrestrial settings that reflect increasing aridity towards the top of the formation. It is divided into four members, two of which (Brushy Basin and Salt Wash) compose most of the formation and contain most of the myriads of fossil bones in it.

> **Morrison Formation**
> **Late Jurassic (152-144 Ma)**
> **200-300 m thick**
> **Multicolored mud- and silt-stone, with bentonite, sandstone, conglomerate. Dinosaur fossils.**

Stump Formation

The first low (<10 ft) sandstone ridge you pass on your right is part of the Stump Formation. This formation represents the last Jurassic sea intrusion from the Arctic; it was very shallow, probably not exceeding 90 m in depth in its eastern part. The overlying Redwater Member is light- to olive-green, fissile, glauconitic siltstone and shale. The resistant light grey Curtis Member is medium- to coarse-grained, cross-bedded sandstone, which contains complete fossils of neritic fauna—a complete ichthyosaur skeleton was found outside the boundaries of the park—and fossilized bivalves and bottom-dweller traces. The Stump as a whole contains abundant marine bottom invertebrates, including clams and brachiopods. As you pass through the Stump you will see two separate sandstone layers, one composing the low wall mentioned earlier, the other lying up against the older Entrada Sandstone, with shale in between.

> **Stump Formation**
> **Middle-Upper Jurassic (175 Ma)**
> **55-70 m thick**
> **Siltstones, shales, and sandstones.**



Part of the Mesozoic section in Dinosaur National Monument, looking west off the Sound of Silence trail.

Entrada Sandstone

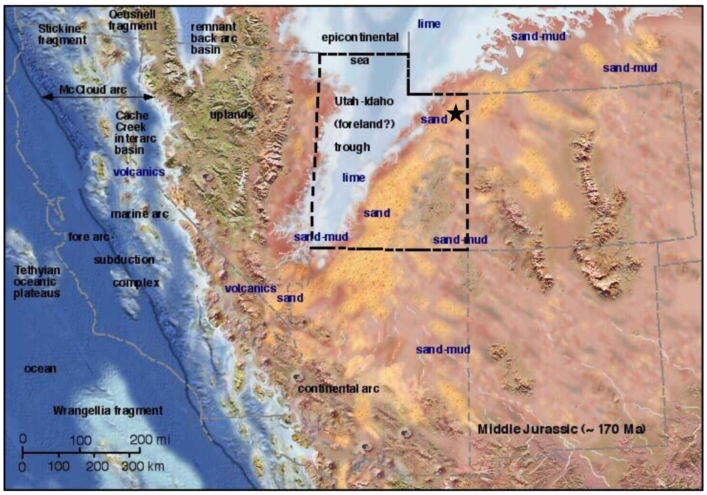
On the next large, rounded outcrop just off the trail to your right you can see the contact between the lowest member of the Stump—the grey, planar sandstone—and the **Entrada Sandstone**, which is rounded and yellow with fine red layers. You can also see the contact further off the trail to your left. The Entrada is a thick fine- to medium-grained sandstone with large-scale eolian cross-beds, and it is not fossiliferous in Dinosaur National Monument. It is the same sandstone that forms the spectacular arches and spires in Arches National Park in southern Utah.

> **Entrada Sandstone**
> **Middle Jurassic (150 Ma)**
> **12-50 m thick**
> **Pink to yellow-grey eolian sandstone.**

Carmel Formation

On that same outcrop to your left (best seen from further down the trail), you can see the contact between the Entrada and the underlying **Carmel Formation**, a thin, dark red unit of sandy silt- and mudstones. It is softer than the surrounding rock, and tends to form strike valleys. Where it is visible, the contacts with the sandstones on either side are striking. The Carmel was formed during a Jurassic sea intrusion from the Arctic; because it did not connect to either the Pacific Ocean or the Gulf of California, the water did not circulate well. The lack of currents meant that sediments accumulated rapidly, and the sea became shallow, warm, and saturated with $CaCO_3$. On the eastern and southern edges of the seaway, gypsiferous red beds imply brackish or lagoonal waters. This formation contains invertebrate fossils, as well as rare theropod dinosaur footprints on what were once tidal flats.

Carmel Formation
Middle Jurassic (155 Ma)
19-40 m thick
Dark red sandy silt- and mudstone.



Paleogeographic setting in the Middle Jurassic, about 170 Ma.
This map lies between the Carmel and the Glen Canyon periods, and you can see that the sea is beginning to intrude from the north.

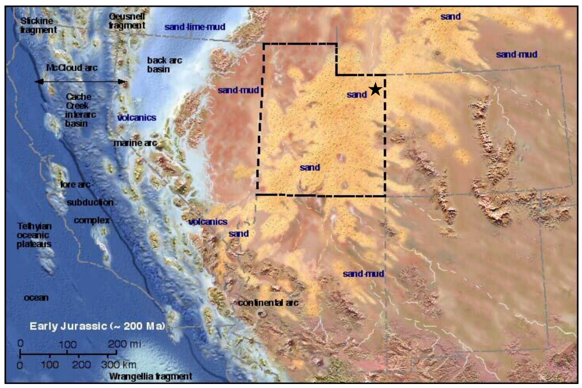
Glen Canyon Sandstone

Below the Carmel Formation is the **Glen Canyon Sandstone**, a resistant unit that strongly resembles the younger Entrada. It is well exposed along the margins and the nose of the Split Mountain Anticline, forming prominent ridges with sweeping cross-beds. Most of it was deposited in an enormous Early Jurassic sand sea. According to some, it was the largest sand sea in the history of the planet, covering much of the western United States. In Dinosaur National Monument, the top and bottom thirds of this unit show evidence of wetter environments, usually with abundant tracks. In one remote canyon, hundreds of *Brasilichnium*, tracks made by small mammal-like reptiles, are preserved on the exposed lee side of a fossilized dune. Nearby are tracks made by other large vertebrates (as yet unidentified) and a large scorpion. These are probably the record of a single night's activity; there was apparently enough dew that night to preserve the tracks long enough for them to be buried the next day.

Glen Canyon Sandstone
Upper Triassic, Lower Jurassic (200 Ma)
180-200 m thick
Pink to grey-yellow eolian sandstone.

Thin, discontinuous, horizontally-bedded layers of mud, sand, and/or carbonates represent interdunal deposits, some of which may have been characterized by permanent or semi-permanent bodies of water. Carbonate spring mounds have been found, along with the first snail fossils in the Glen Canyon, which suggests that at least some of these bodies of water were fed by freshwater springs.

Elsewhere, parts of the Glen Canyon are known as the Aztec, the Nugget, or the Navajo. The group as a whole is responsible for the spectacular rounded and cross-bedded outcrops visible along this trail. When you get closer to the outcrops, you may notice the pockets in the face of the stone. These are the result of concretions that formed in the loose sediment: much later, they weathered into protrusions and eventually fell out, leaving behind pockets that were enlarged by wind.

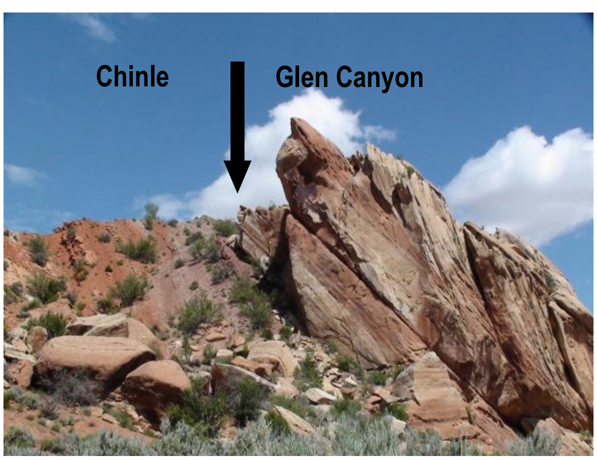


Paleogeographic setting in the Early Jurassic, about 200 Ma. Deposition of the Glen Canyon.

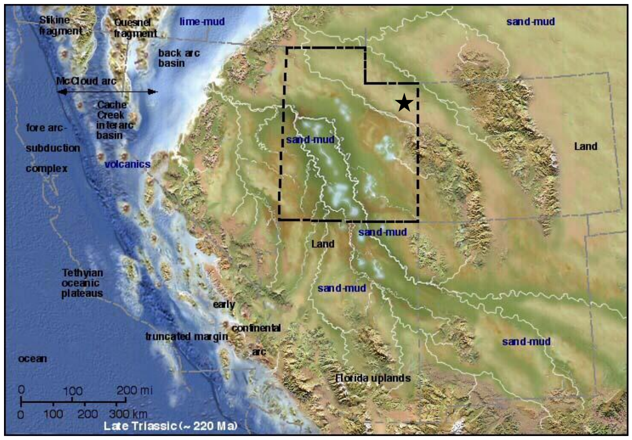
Chinle Formation

Chinle Formation
Upper Triassic (210 Ma)
60-140 m thick
Red to grey siltstone, sandstone, and shale, with local basal conglomerate.

When the trail makes a major curve to the right, watch on your right for the contact with the **Chinle Formation** (pictured below), whose upper part is mostly easily erodible red siltstones and shales. The top part of the Chinle is subdivided into several informally named members: the red siltstone layer, the upper member, the ochre member, and the mottled member. It was deposited in a coastal plain river system, and so the deposits vary between fluvial, deltaic, lacustrine, etc., and the consequent rapid lateral facies changes can be problematic in mapping and analysis. It also contains some ash from the volcanic arc to the west of the Triassic continent. The Chinle is the formation famous for its fossilized flora and fauna in Petrified Forest in Arizona; it does not look to be as prolific in Dinosaur National Monument, although neither has it been extensively studied. Many bones and bone fragments have been found, which indicate a rich variety of reptiles and amphibians. The trace fossil record in this formation is abundant and diverse, including burrows and trails of snails, insects, crayfish, and freshwater horseshoe crabs. The formal basal unit of the Chinle is the prominent Gartra Member (sometimes referred to as the Shinarump), a thick grey coarse-grained to conglomeratic sandstone with some cross-bedding.



After a time the trail begins to travel in a strike valley formed by the upper Chinle, and you will be able to examine the Gartra more closely when you reach the point in the path where boulders have fallen across the path. The resistant Gartra tends to form ridges and caps, in contrast to the soft upper Chinle.

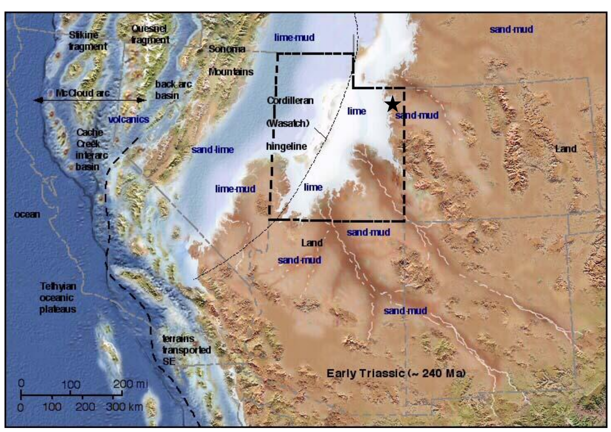


Paleogeographic setting in the Late Triassic, about 220 Ma. Deposition of the Chinle.

Moenkopi Formation

> **Moenkopi Formation**
> **Lower Triassic (220 Ma)**
> **150-240 m thick**
> **Mostly red to brown, green, and grey siltstone and shale. Ripple marks.**

When you pass through the Gartra you will find yourself in the **Moenkopi Formation**, a mostly red siltstone/shale unit. It was deposited in a near-shore continental to marine environment; the presence of gypsum beds points to periods of high aridity, possibly on tidal flats. The trail winds through badlands topography, where it is possible to see the thin gypsum beds from the trail. When you emerge from the badlands, you will be able to see more clearly how this formation has weathered into a strike valley. On the other side of the valley, there is a golden band visible right next to the white sandstone hills; this is the Park City Formation. The hills are formed by the massive white Weber Sandstone, which forms part of the spectacular river canyons elsewhere in the park. Both these latter units are Permian in age, but they are worth mentioning.



Paleogeographic setting in the Early Triassic, about 240 Ma. Deposition of the Moenkopi.

You have now passed through the entire Mesozoic section of Dinosaur National Monument. Should you choose to continue on the trail (which is a great hike but will take longer than simply turning around); the loop will eventually take you back towards the road, crossing directly over ridges of the Gartra Member and the Glen Canyon. Pay attention to signs: there is one fork in the trail where to continue on the Sound of Silence loop, you should go to the right.

CREDITS

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All other figures and photos courtesy of National Park Service.

FURTHER READING

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