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GEOLOGY

ALONG THE

SOUTH LOOP ROAD

THEODORE ROOSEVELT NATIONAL MEMORIAL PARK

by

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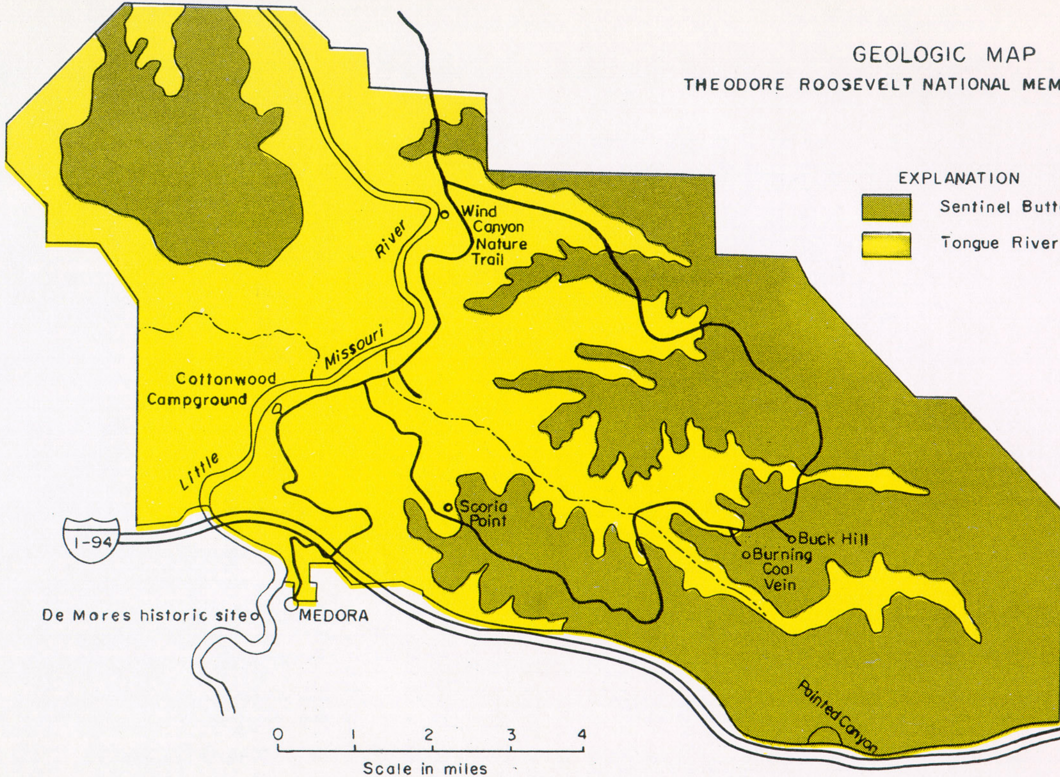

Figure 1. Map of Theodore Roosevelt National Memorial Park showing the distribution of the Tongue River and Sentinel Butte Members of the Fort Union Formation. Notice that the Tongue River Member, which lies beneath the Sentinel Butte Member (see figure 2), is exposed in the lower areas, along the Little Missouri River and in creek valleys. The Sentinel Butte Member is found at higher elevations.

GEOLOGIC ROADLOG FOR THE SOUTH UNIT, THEODORE ROOSEVELT NATIONAL MEMORIAL PARK

Introduction

On first viewing the strange shapes of the badlands, the visitor might be led to believe that some great natural catastrophe has torn the earth apart, ripping it open and exposing its interior. But the hills and valleys of these badlands were formed by agents more relentless than earthquakes or volcanoes. This land, which Theodore Roosevelt found "fantastically beautiful," was carved by running water from rain and melting snow, by wind, by frost, and by other forces of erosion.

The Sioux Indians referred to the badlands as "mako sica" ("land bad"), and early French explorers translated this to "les mauvais terres a' traverser" ("bad land to travel across"). Today, modern roads make the area easy to travel across, and the name "badlands" may not be as applicable as it once was.

The visitor who has the time to enjoy a hike or horseback ride through the badlands may experience some of the same feelings experienced by the Indians and early explorers as they crossed the area. This geologic roadlog follows the Loop Road of the South Unit of the park and includes descriptions of many of the geologic features in the badlands. We hope it will add to your enjoyment of the park.

Milepost markers, white posts located along the right side of the road, show the cumulative mileage from the Visitor Center. Mileage figures in this roadlog refer to these milepost markers. Periodic checks of the markers should make it easy for the user of the roadlog to determine where he is located. Since the roadlog follows the Loop Road in a counterclockwise direction, the user should continue ahead rather than turning left where the road forks, 6.5 miles from the Visitor Center.

The authors wish to thank Karol-lyn Knudson for her help in preparing the drawings and necessary art work.

Geologic Roadlog

Miles from Center	
	Visitor Center. The horizontal layers in the cliffs near the Visitor Center are beds of fine-grained sediment, so closely compacted that it looks and feels like rock but disintegrates in water. The layers of sediment, which are largely siltstone and claystone, were deposited in lakes, ponds, and swamps adjacent to ancient, extinct streams that flowed here during the Paleocene Epoch about 65 million years ago. Today these sediments are being washed away by the Little Missouri River.
	The beds of sediment you will see throughout the park form part of the Fort Union *Formation**. The Fort Union Formation can be further subdivided into several *members*, which differ somewhat from one another in content and appearance. Two such members can be seen in the park (figure 1). They are the Tongue River Member, which forms the cliffs here at the Visitor Center, and the Sentinel Butte Member, which you will see later. Although the Fort Union Formation is the only one exposed in the park, younger rocks can be found on nearby highlands such as Sentinel and Bullion Buttes. Older rocks, deeply buried here, are exposed at the surface about 30 miles southwest of the park (figure 2).
0.3	Medora Overlook. Notice the landslide that covers part of the parking lot at the base of the cliff. The Fort Union Formation contains considerable clay that loses its strength and becomes slippery when it is wet. On steep slopes this sediment slumps, resulting in frequent landslides and mudflows.
	Sediment the same age as the Fort Union Formation has hardened into rock in other places. In fact, some of the ledges visible in the cliff faces here are solid rock that was cemented by minerals carried in solution in water circulating through the sediment.

*Terminology found on signs in the Visitor Center and in the park. Recent North Dakota Geological Survey publications refer to these units as the Fort Union *Group*, Tongue River *Formation*, and Sentinel Butte *Formation*.

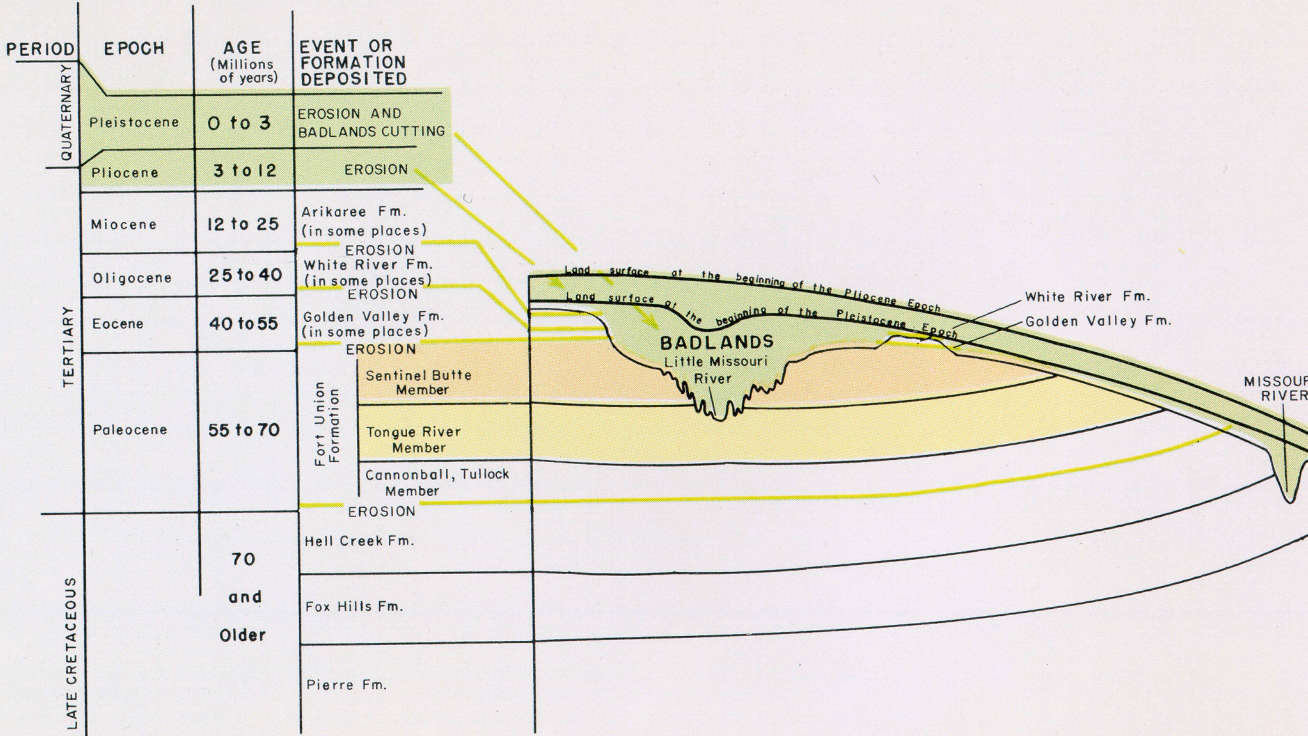

Figure 2. Cross-section showing the near-surface formations of southwestern North Dakota. The vertical scale is greatly exaggerated. The green lines represent erosional events. For example, erosion took place between the deposition of the Hell Creek and Cannonball Formations. Erosion that occurred throughout the Pliocene Epoch lowered the land surface only a small amount; but, since the beginning of the Pleistocene Epoch three million years ago, a great deal of material has been eroded away and the land surface has been lowered several hundred feet in the badlands area.

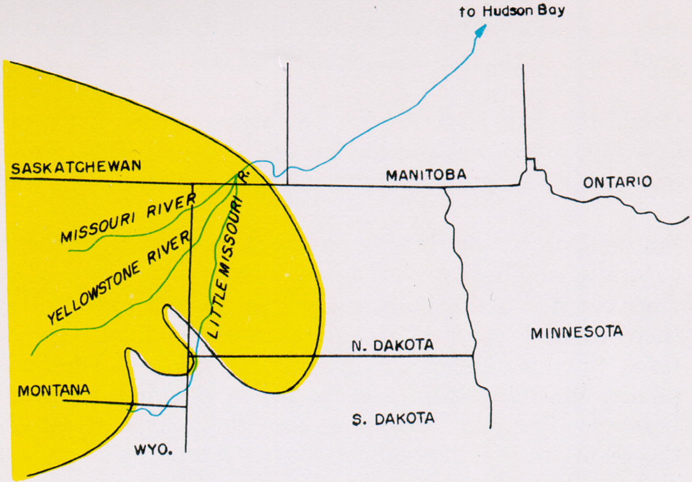

Figure 3. Map of the route of the Little Missouri, Yellowstone, and Missouri Rivers about a million years ago. In North Dakota, the Little Missouri River flowed on sediments of the Fort Union Formation, which had been deposited throughout the yellow area by different streams many millions of years earlier. The badlands had not yet begun to form at this time.

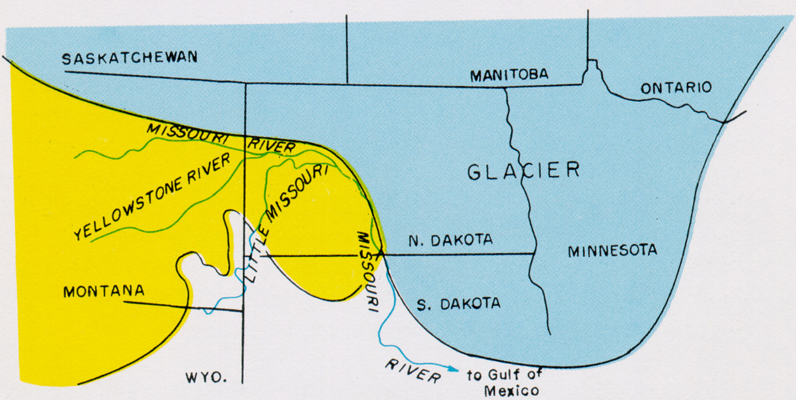

Figure 4. Map of the route of the Little Missouri, Yellowstone, and Missouri Rivers about 25,000 years ago after the rivers were diverted by a glacier. The new route of the Little Missouri River had a much steeper gradient than did the old one, so the river began to erode the Fort Union Formation away, forming the badlands.

0.5 Bed of lignite (the black material) on the right. Lignite is a low grade of coal that we will see more of later.

2.0 Cross Interstate Highway 94. The highway has been constructed in a valley that was formed by Sheep Creek. The creek eroded away sediment of the Fort Union Formation, cutting the valley.

3.1 Prairie Dog Town. Notice that the vegetation in the town is generally much shorter than in surrounding areas. The prairie dogs cut down the taller grasses to make it more difficult for their natural enemies to approach undetected. At the same time, this encourages the growth of forbs and other succulent plants, which are staples of the prairie dog diet. In some places, heavy feeding and burrowing activities may temporarily cause the plants to die. These bare spots are more vulnerable to wind and water erosion.

4.1 Overlook on the left. The flat area on which this overlook is located is a remnant of the landscape that existed here before the Little Missouri River began to carve the badlands. This late Pliocene-age surface, which is perhaps two or three million years old, extended over all of western North Dakota and eastern Montana. The largely featureless landscape at that time was interrupted by a few scattered buttes, such as those on the skyline here; but the Little Missouri River valley was shallow, with more gentle slopes, not at all like the rugged landscape here today.

The carving of the badlands began when a glacier diverted the Little Missouri River about fifty miles north of here, causing it to flow eastward (figures 3 and 4). Prior to the diversion, not only the Little Missouri River, but also the Yellowstone and Missouri Rivers, flowed north into Canada and east to Hudson Bay. As a result of its diversion by the glaciers, the Little Missouri River flowed over a shorter, steeper route than before; and, because of this, the river cut rapidly downward, causing extensive erosion and the carving of the badlands.

The erosion has not been at a constant rate. Since they began to be carved, the badlands have undergone many periods of erosion and deposition. Erosion takes place during wet periods and deposition during dry periods. During the past few hundred years, the badlands have undergone four separate periods of erosion and three periods of deposition. New gullies have been cut to their present depth since about 1936.

5.3 River Woodland sign. The cottonwood trees grow close to the river where water is most plentiful. Sage, which requires less water, grows farther from the river. Notice how the juniper and other plants grow in horizontal bands on the hillsides. The plants grow along sediment layers of the Fort Union Formation that are more moist than sediment layers above and below. Water flows through the looser, more permeable rock layers, known as aquifers, and comes to the surface wherever the rock is exposed at the surface. If sufficient amounts of water are present, springs result. Many of the bands of vegetation grow along lignite beds, which are good aquifers.

The water in the aquifers contains dissolved minerals. In some places where it comes to the surface, the water evaporates, leaving the minerals behind as a white crust of salt. The white bands that you may see on the cliff faces result in this way. These deposits are most noticeable in late summer and early autumn, when generally dry conditions promote more rapid evaporation.

5.6 Cottonwood Campground entrance.

5.8 Lignite coal vein (figure 5). Lignite is soft, low-rank coal consisting of plant fragments. The plants that formed the lignite grew in ancient swamps when the climate was much warmer and more humid that it is today (figure 6). The swamps existed along streams that were flowing generally eastward from the newly-formed Rocky Mountains during Paleocene time, about 65 million years ago. As the plants died and fell into the swamps, they began to decay due to the action of bacteria. However, before the plants could be completely decomposed, the bacterial action stopped because the bacteria "committed suicide" by filling the stagnant swamp water with their body poisons to such an extent that they died. When the streams changed course, as the Mississippi River does on its delta on the Gulf of Mexico at times, they deposited sand on top of the partially decomposed vegetation, burying it and allowing coal to form.

Figure 5. Lignite bed exposed along the Loop Rood at 5.6 miles.

Figure 6. In Paleocene time, swamps with lush vegetation covered this area that is now badlands. The subtropical climate was suitable for trees and animals such as palms and alligators. Some of the earliest mammals developed in early Paleocene time, while the Fort Union Formation was being deposited.

6.5 Begin loop drive. Continue on the road to the right.

8.8 The heavy juniper stands in this area are generally confined to north-facing slopes. South-facing slopes, which receive much more sunlight during both summer and winter, are much drier than north-facing slopes. Snow tends to accumulate on north slopes and to enter the ground when it melts.

9.3 Scoria Point. The reddish layers of "scoria" are composed of sediment that was baked by burning lignite. The term "scoria" is a misnomer, for true scoria is of volcanic origin. The scoria-like material found throughout the park is more correctly termed "porcelanite," but since the word scoria is widely used in this area, it will be used in this roadlog.

The scoria commonly contains fragments that look as though they have melted. According to one theory, these fragments were formed when the material overlying a burning coal bed collapsed, plunging it into the "furnace" and heating it to exceptionally high temperatures so that it melted. As a result of the collapsing, spaces are often present in or near beds of scoria. After the scoria cools, the spaces are convenient places in which animals can live. The spaces are favorite localities for rattlesnake dens.

Notice that the color of the scoria varies from place to place. The color of the scoria may depend on the mineral composition or grain size of the material that was baked, or it may depend on the temperature reached at different localities during the baking process. The red color apparently is due to the presence of the mineral *hematite*. Hematite is iron oxide, which is the same as common rust. All of the sediment in the park contains iron-bearing minerals, although none are of commercial value in these concentrations. Iron is oxidized more easily at high temperatures than at normal temperatures, so when the sediment is baked, hematite forms.

There is some controversy over how the lignite starts to burn. Range fires may have ignited some lignite beds, while others may have ignited spontaneously. Lightning may have ignited some of the fires. Much of the scoria is now found at elevations where the water table is too high for lignite to burn. This scoria probably formed at a time when the climate was drier and the water table was lower than it is today. This may have happened, for example, during what is known as the "hypsithermal interval" ("hypsithermal" means "maximum temperature"), a warm, dry period of time that lasted from about 9,000 years ago until about 2,500 years ago.

The lignite bed that burned here at Scoria Point is known as the HT Lignite or the HT Bed. It is named for a ranch south of Medora where it is well exposed. Where the lignite burned and formed scoria, such as right here, it is called the HT Scoria.

The HT Bed marks the contact between the Tongue River Member, below, and the Sentinel Butte Member, above. Notice the lighter, more yellowish colors of the Tongue River Member below the HT Scoria, compared to the darker gray and brown colors of the Sentinel Butte Member above.

Until now you have been traveling in an area in which the Tongue River Member is exposed. As you drove up the hill to Scoria Point, you passed into the Sentinel Butte Member.

11.3 North Dakota Badlands sign. Horizontal layers in the Sentinel Butte Member are visible on the hillside across the valley behind the sign. The layers are made of different types of sediment. The bluish gray layers are beds of silt and clay. The brownish gray layers are beds of sand that contain orange, iron-rich bands a few inches thick. The black beds immediately above the bluish beds are lignite.

Near the newly-formed Rocky Mountains in Wyoming and Montana, the Paleocene rivers and streams flowed swiftly and carried large amounts of coarse materials such as gravel. At the point where the rivers flowed from the mountains out onto the plain, they lost much of their carrying power as their velocity decreased and they deposited the coarser gravel and sand near the mountains. The finer materials, such as clay, silt, and fine sand, were carried farther eastward to the Dakotas where they were deposited as the Fort Union Formation. The deposition here was not uniform and blanket-like, but rather, as the rivers and streams meandered from side to side, they deposited materials in one area for a few years and somewhere else a few years later.

During Paleocene time, when the Rocky Mountains were forming, many volcanoes were erupting in western Montana and Wyoming. These volcanoes produced large amounts of ash, which was carried by the wind to the Dakotas. This ash collected in wet areas such as lagoons and, with the passage of time, it was transformed to clay such as you see in the bluish layers here.

12.0 Notice the lignite bed exposed in the gully on the right.

12.4 Petrified tree stump at the left edge of the road. You will be passing through an area of petrified wood for the next half mile (figure 7). Although the whole area of the park was probably forested during Paleocene time, the preservation of the wood and stumps required that the trees be rapidly buried by sediments so that they escaped decay. This might have happened when a stream changed course or flooded its banks depositing sand or silt on the trees.

After a tree was buried, ground water began to circulate through it. With the help of bacterial action, the water dissolved out the softer cellulose material of the wood. The water also carried dissolved minerals, among them silica (SiO_2). The silica was deposited in the spaces left by the dissolving out of the plant tissue. This went on for a long time so that the replacement was gradual, a molecule of plant tissue being simultaneously replaced by a molecule of silica. In this way, the original cellular structure of the wood was preserved so that, in many cases, the petrified stumps look exactly like old wood stumps except that they are stone. The petrified wood is mostly very light brown or cream colored. Abundant small pieces of it can be seen along the road. The petrified wood found in this park is not a highly colored variety such as is common in some areas. Nevertheless, we ask that our visitors not collect it in the park, so that others can enjoy seeing it in its rightful place. Petrified wood is more abundant in the Sentinel Butte Member than in the Tongue River Member.

13.4 Large, boulder-sized blocks of HT Scoria are visible along the road in this area. You are now passing out of an area in which the Sentinel Butte Member is exposed down into an area in which the Tongue River Member is exposed.

Figure 7. The petrified tree stump and log shown here are typical of petrified wood found in several places in the park. The log shown here has protected the underlying sediment from erosion and, as a result, it rests on a small, table-like pedestal.

14.4 Paddock Creek. A landslide, such as the one already seen at the Medora overlook, is visible about 100 feet up Paddock Creek to the right.

15.6 Road to burning coal bed. Turn right and travel 0.8 mile. Notice that the road is paved with gravel made of scoria fragments. Scoria is one of the few types of hard rock available in the badlands of North Dakota, and it is therefore valued as a substitute for gravel. Because it is so hard, Indians used the scoria for making arrowheads and other implements. After reading the sign and visiting the burning coal bed, return to the main road and turn right.

15.8 Pass up across the HT Scoria into an area in which the Sentinel Butte Member is exposed.

16.8 Large landslide to the right. The landslide occurred when materials on the steep slope were saturated with water from a small spring. As their weight increased due to the load of water, they overcame their bonding forces, and began to creep downward in response to the pull of gravity. Sliding material has caused the road to be closed several times in the past.

17.2 Road to Buck Hill. Turn right and travel 0.5 mile to the top of Buck Hill. Notice the lignite exposed on the left a tenth mile from the corner.

The view of the badlands from the top of Buck Hill, the highest point in the park, is impressive. Sandstone that is exposed at the top of the hill consists of grains of sand that were cemented together by minerals dissolved in the water that circulated through the sand. The sand was deposited here by an ancient, extinct river. Millions of years later, erosion of the Fort Union Formation formed the badlands. Since sandstone is more resistant to erosion than is the surrounding material, Buck Hill remained above the surrounding terrain as erosion took place. Return to the main road and turn right.

21.1 Vertical trunk of petrified, that is, silicified, tree on the right in the distance near the bottom of the valley.

21.2 Jones Creek.

22.2 Vertical trunk of another petrified tree on the right near the road.

23.0 Pass down across the HT Scoria into an area in which the Tongue River Member is exposed.

25.3 Junction with north-south road. Turn left.

25.6 Wind Canyon Nature Trail. Wind Canyon was carved by a small stream, a tributary to the Little Missouri River, that happened to become aligned nearly straight northwestward. Strong winds, which are mainly from the northwest most of the year, whip across the broad expanse of Little Missouri River bottomland, picking up sand from the river bars. The wind blows the sand into the canyon, creating a sand-blasting effect that has helped running water carve the rock into smooth, wind-eroded shapes.

26.1 Slumped area on the right with numerous tilted, table-like pedestals (figure 8). These flat, hard, sandstone slabs protect the underlying sediments from erosion until enough material is removed from beneath the slabs so that they tilt and slide off their pedestals.

27.0 Beef Corral Prairie Dog Town.

29.0 Paddock Creek.

29.6 Road junction. End of roadlog. Turn right to return to the Visitor Center.

Figure 8. The hard, erosion-resistant, sandstone slabs shown here have protected the underlying sediments from erosion so that they now rest on pedestals. With continued erosion, the slabs eventually tilt or fall off the pedestals, resulting in the unusual configurations seen here.