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By Wilson M. Laird, *State Geologist*
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Geology of the North Unit Theodore Roosevelt National Memorial Park

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GEOLOGY OF THE NORTH UNIT THEODORE ROOSEVELT NATIONAL MEMORIAL PARK

By Wilson M. Laird, *State Geologist*

Abstract

The North Unit of the Theodore Roosevelt National Memorial Park is at the edge of the glaciated portion of the Missouri Plateau. Because of this situation there are a number of interesting drainage changes which have taken place in and nearby the Park. These changes and their influence on the topography of the Park area are considered in some detail.

The geologic processes responsible for the formation of various land forms are described. Several diagrams and photographs illustrating the drainage changes and the geologic processes at work in the Park are included.

A list of references for further reading is appended at the end of the report. A road log describing the geologic features to be seen along the roads of the Park is also given. A short statement of the more interesting historical highlights of the region is included.

Location of the Park

The Theodore Roosevelt National Memorial Park was established by an Act of Congress April 25, 1947. The Park erected by that original act was extended by Acts approved in 1948. At the present time, it consists of 65,648.50 acres of federally owned land on three separate units. One of these is near Medora which has been covered by another report,[1] another near Watford City and the Elkhorn Ranch site about midway between the two along the Little Missouri River. This report deals with the unit near Watford City which is known as the Theodore Roosevelt National Memorial Park-North Unit. It is located largely in the southern part of T. 148 N., Rgs. 99 and 100 W., and in the northern part of T. 147, Rgs. 99 and 100 W. U.S. Highway 85 passes along the east side of the park area with the park entrance about 15 miles south of Watford City.

Acknowledgements

The work that has been done on this report has been materially aided by a number of individuals. Notably, my greatest appreciation should be expressed to Mr. Emmett R. Schmitz, formerly a graduate student at the University of North Dakota. Mr. Schmitz wrote his

[1]Laird, W. M. The geology of the south unit Theodore Roosevelt National Memorial Park: N. D. History, Vol. 17, pp. 1-18, 1950. Reprinted as Bull. 25, N. D. Geological Survey.

Master's thesis on this and adjacent areas and some of the geological interpretation contained in this report has been derived from his work.

I have been materially assisted by Mr. Robert Roehrich, student draftsman of the North Dakota Geological Survey.

Mr. Ben Bay, Custodian of the North Unit of the park as well as the various seasonal rangers of the North Unit have been most helpful in many ways. Thanks also are hereby expressed to Mr. John Jay, Superintendent of all Units of the Theodore Roosevelt National Memorial Park, and Mr. Chester Brooks, Historian of the Theodore Roosevelt National Memorial Park, both of Medora, North Dakota.

Purpose of this Report

This report is written so that the visitor may gain some appreciation of the geology and the history of this beautiful Park. To do this it has been found necessary to tell something of the general geology of the area of which this Park is a part. A few paragraphs are also given describing some of the geologic processes which have been important in

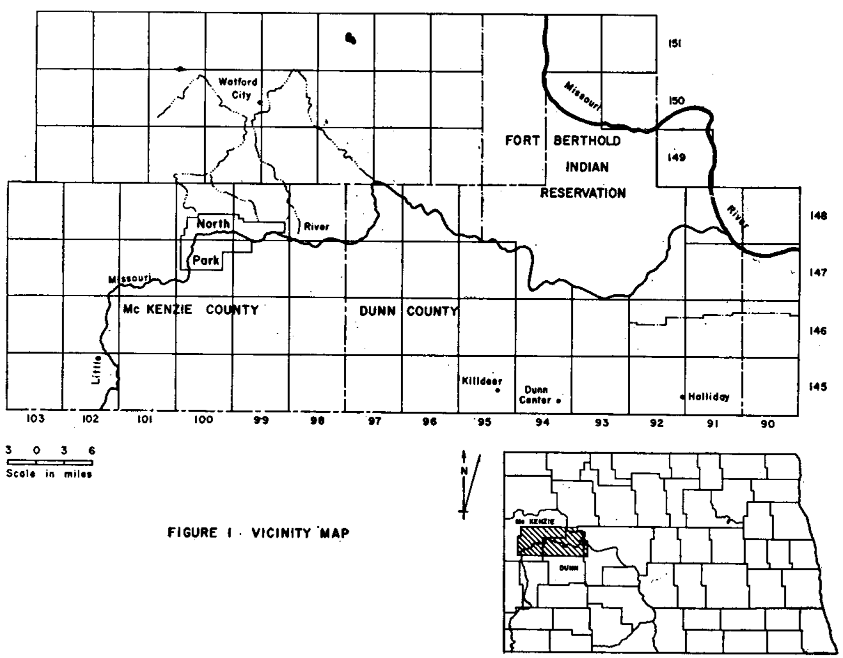


FIGURE 1

Diagrammatic sketch map showing the location of the North Unit of Theodore Roosevelt National Memorial Park.

the formation of the land forms which you will see about you. The road log is appended to give you some idea of things to look for as you travel along the roads of the Park.

There are a number of points of historic interest included within the boundaries of this North Unit. A short statement should be made relative to these items as they too, add to the interest of the visitor.

On figure 2 you will see some of these points of historic interest noted. Also included are some other interesting places such as the Long X trail along which those spending more time in the Park will want to hike to get better acquainted with this region.

The Long X nature and hiking trail was named for the Long X Ranch which lies about three miles north of the start of this trail. The Long X Ranch was the end of the trail for the cattle drives in 1883 and 1884 which started in Texas and ended in this area.

Those of the readers who are familiar with the history of Theodore Roosevelt and his ranching activities in the Badlands area will remember the episode of the stolen boat. In the early spring of 1886 some thieves stole Roosevelt's boat from its moorings near the Elkhorn Ranch some distance upstream (south) from the North Unit. After the discovery of the theft, Roosevelt and two of his ranchhands, Sewell and Dow, constructed another boat and set off down the river in pursuit of the thieves. On this trip they camped in what is now the North Unit although the exact place of camping is not known. Some of the early settlers in this area tell of a rock near the river bank which bore Roosevelt's initials. The thieves were finally overtaken and captured near the mouth of Cherry Creek about 12 miles east of the North Unit. The mouth of Cherry Creek can be located on Plate I of this report.

The Indians were naturally the first inhabitants of this area and remains of an encampment are known across the river from the Squaw Creek campgrounds. This was supposed to have been the site of a Gros Ventre camp site. The Badlands were a favorite camping place for the Indians as there was plenty of shelter and firewood to say nothing of the availability of cottonwood bark to feed the horses when all other available feed was covered by the snow. Game also was more abundant in the Badlands. However about this particular campground relatively little is known as yet due to lack of detailed exploration.

On the south bank of the river on the high plateau area overlooking the Park are what are called tepee rings for want of a better term. These are rings of stones about the same size placed roughly in a circle. It is supposed that they were placed there to hold down the skins making an Indian tepee but because of their scattered distribu-

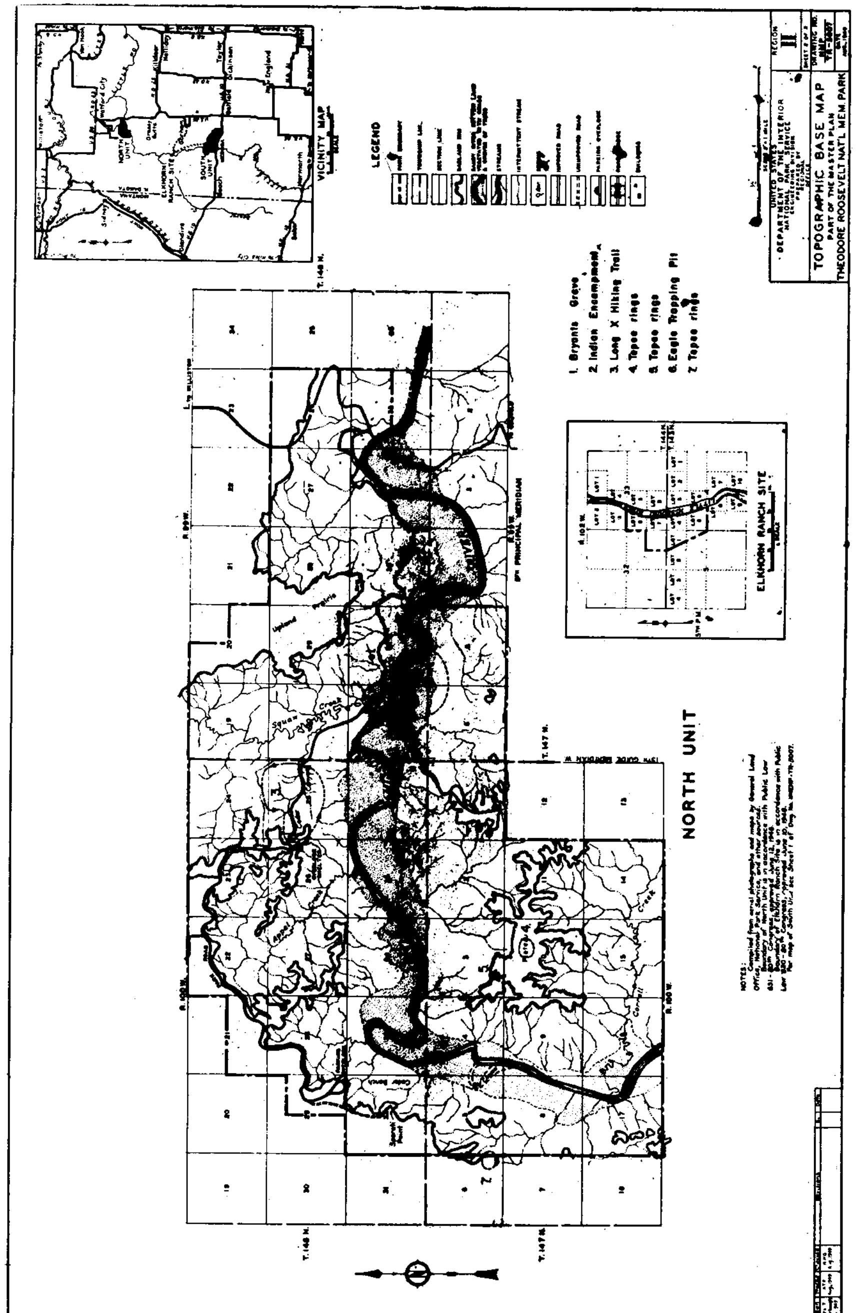


FIGURE 2

Base map showing historic points of interest in the North Unit, Theodore Roosevelt National Memorial Park.

tion and rather unlikely situation as a place to camp there is some doubt if this is the entirely correct interpretation.

Also on the south bank of the river near the edge of the plateau are pits which were apparently dug by the Indians for the purpose of catching eagles. These are therefore known as eagle pits. They were used by the Indians probably in somewhat the following fashion. The pit was dug and covered with sticks and branches making a sort of camouflage. Bait in the form of a live rabbit was placed on top to attract the eagles. When the eagle lighted on the bait he was caught by the Indians crouching inside the pit.

The Indians would catch the eagle by the legs and pull some of the tail feathers out for use in his war bonnet. Eagles feathers were much prized for this purpose and the scratches and other assorted wounds obtained in catching the eagle were regarded as a small payment to make if the catch was successful. Eagle feathers were much in demand for the war bonnets and in addition to the decoration he obtained from the feathers, the Indian was also more respected for the bravery he had shown in obtaining the feathers in the first place.

To the north of the Squaw Creek campground in the rough terrain bordering the cliffs making the side of the valley is the unmarked grave of "Scrap Iron Bill" Bryant, a cousin of the famous poet William Cullen Bryant. He operated a sawmill in the area where the campgrounds now are located from about 1912 to February 1915 when he died. The spot where he is buried is one chosen by himself before he died as he loved the country so much he wanted to be buried there. The spot which he chose is one which is unlikely to be disturbed by wild beast, man or the advance of civilization as was his wish.

Regional Geologic Setting of This Area

Originally, this area is a part of the Missouri Plateau. According to Fenneman[2] "the Missouri Plateau comprises all that part of the Great Plains province which lies north of the High Plains to an undetermined boundary in Canada. Its southern limit is the Pine ridge. . . well shown on the geological map because of the high formations which underlie the High Plains of the south are absent in the north . . . Along its eastern boundary, the Missouri Plateau is itself being consumed by the gradual westward spread of the Central Lowland. Here the two provinces, Central Lowland and the Great Plains are separated by an indefinite escarpment. . ."

A good description of the northern Great Plains is given by William C. Alden.[3] "The Northern Great Plains rise gradually westward from

[2]Fennemen, N. M., Physiography of the Western United States, McGraw Hill Book Company, New York, p. 61, 1931.

[3]Alden, William C., Physiography and glacial geology in eastern Montana and adjacent areas. U. S. Geological Survey Prof. Paper 174, P. 3, 1932.

altitudes between 1800 and 2400 feet above sea level on the Coteau du Missouri, east of the Missouri River in North Dakota to 5000 or 6000 feet at the foot of the Rocky Mountains. The Rocky Mountain front in general rises above the prairies, and a short distance back from the front are peaks rising to altitudes of 9000 or 10,000 feet in Glacier National Park and 11,000 to 13,000 feet or more in The Big Horn Mountains and the rugged region north and east of Yellowstone Park. In this connection, attention may be called to the fact, which is probably already familiar to many, that the country east of the mountains, though known as the northern Great Plains is far from being smooth, flat surface. It is true that there are some flat tracts and large gently rolling areas. And that to an observer on a high point in the mountains, the whole vast plain looks as flat as a floor in contrast with the boldness of the mountain ridges. This impression is, however, due to the fact that the features are much smaller and lower than the mountains and that the details are lost in the hazy distances. Particularly, outside of the drift covered part of the plains – that is, in most of the plains regions south and west of the Missouri River there are large areas of very rough country. Typical badlands occur in the breaks along the Missouri and Yellowstone Rivers, where there is deep and thorough dissection, and in the larger inter-stream tracts ridges rise in places 500 to 1500 feet above the valley bottoms, with many bold cliffs and picturesque towers and pinnacles, especially where the eminences are capped with sandstone.

"The Missouri and Yellowstone Rivers flow for the most part in rather narrow young valleys bordered by lines of abrupt bluffs 100 to several hundred feet in height. In many places on the Missouri River below Great Falls, Marias River, the Teton, the lower Musselshell, and the Little Missouri the inner valleys are narrow gorges approached with difficulty except on the main graded roads".

The section of the Missouri Plateau in which the North Unit of the Theodore Roosevelt National Memorial Park is found is that portion of the Missouri Plateau which has been glaciated. The glacial effects of this area are not particularly evident from the standpoint of glacial deposition, but the glacier did make marked changes in the drainage of this area which, in fact, is the backbone of the story of the recent geology of the Park area. Here and there in the Park area are found evidences of the former glacier. These include small amounts of glacial drift as well as glacial erratic boulders consisting of rocks foreign to this area. However for the most part, deposition of glacial materials can be disregarded in this area as the amount of the material is relatively small.

TERTIARY	RECENT	ALLUVIUM	
	PLEISTOCENE	GLACIAL DRIFT	
	PLIOCENE	PRE-PLEISTOCENE GRAVELS	
	MIOCENE		
	OLIGOCENE	WHITE RIVER	
	EOCENE	GOLDEN VALLEY	
	PALEOCENE	SENTINEL BUTTE	FORT UNION GROUP
		TONGUE RIVER	
		LUDLOW ≷ CANNONBALL	
CRETACEOUS		HELL CREEK (BREIEN)	
		FOX HILLS	MONTANA GROUP
		PIERRE	
		NIOBRARA	COLORADO GROUP
		CARLILE	
		GREENHORN	
		BELLE FOURCHE	
		MOWRY	DAKOTA GROUP
		NEWCASTLE "MUDDY"	
		SKULL CREEK	
		FALL RIVER	
		FUSON	
		LAKOTA	
JURASSIC		MORRISON	
		SUNDANCE	
		PIPER	
TRIASSIC		SPEARFISH	
PERMIAN		MINNEKAHTA	
		OPECHE	
PENNSYLVANIAN		MINNELUSA	
		"AMSDEN"	
MISSISSIPPIAN		HEATH	BIG SNOWY GROUP
		OTTER	
		KIBBEY	
		CHARLES	MADISON GROUP
		MISSION CANYON	
		LODGEPOLE	
		ENGLEWOOD	
DEVONIAN		LYLETON	QU'APPELLE GROUP
		"NISKU"	SASKATCHEWAN GP
		DUPEROW	
		SOURIS RIVER	BEAVERHILL LAKE GROUP
		DAWSON BAY	
		PRAIRIE EVAP	ELK POINT GROUP
		WINNIPEGOSIS	
		ASHERN	
SILURIAN		INTERLAKE GROUP	
ORDOVICIAN		STONY MOUNTAIN UPPER	
		STONY MOUNTAIN LOWER	
		RED RIVER	
		WINNIPEG	
CAMBRIAN		CAMBRIAN	

GEOLOGIC COLUMN FOR NORTH DAKOTA

NORTH DAKOTA GEOLOGICAL SURVEY

TABLE I

Table of formations of North Dakota

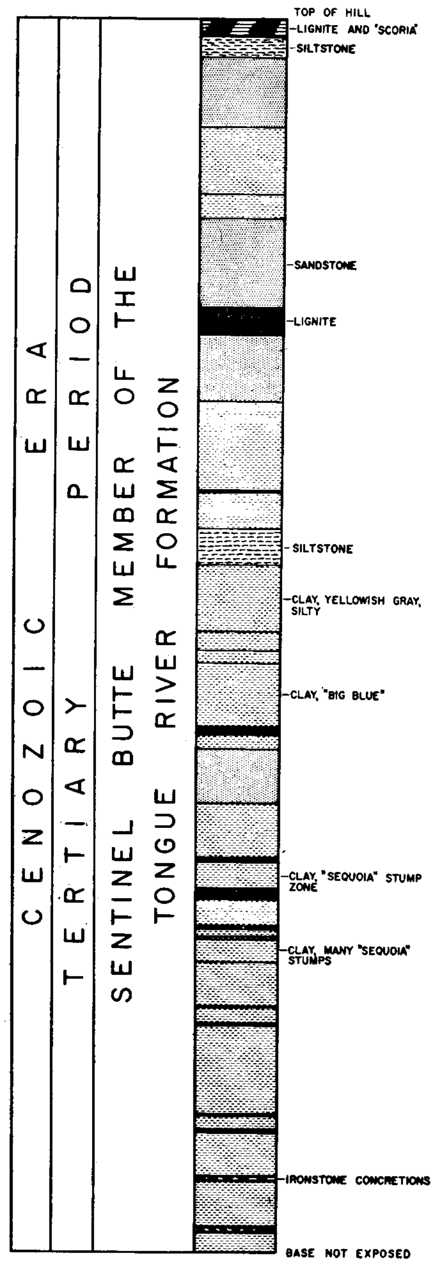


FIGURE 3. Geologic section measured in the SW¼ NE¼ Section 33, T.148N., R.99W. illustrating the nature of the Sentinel Butte member of the Tongue River formation.

FIGURE 3

Geologic section measured in the SW/4 NE/4 Section 33, T. 148N., R. 99W. illustrating the nature of the Sentinel Butte member of the Tongue River formation.

Geology

This area, geologically speaking, is near the center of the famous Williston Basin. This is an area of down-sinking which has progressively sunk lower and lower during most of the geologic time since the end of the Pre-Cambrian which was roughly 500 million years ago. (See Table I)

This down-sinking was a very slow process, however, and would not be perceptible to the human eye had anyone been there at the time. As the area sank, it became more and more filled with sediments. Most of these sediments were washed into this basin from highlands located to the north, northeast, and perhaps at times to the west. Greatest amounts of down-sinking took place during the Ordovician, Devonian, Mississippian, and probably Cretaceous times. The down-sinking probably continued even into the Tertiary period, most notably in the Paleocene, although the effects of the down-sinking are not so well known and not so easily noted in this latter-named period.

In all, a total of greater than 15,000 feet of sediments, most of them shallow-water deposits or continental deposits were laid down in the Williston Basin. The last sediments that were deposited, namely those of the Paleocene period, are, in this area, entirely continental in origin. There were some beds of marine origin deposited during the Paleocene, but they are exposed to the east and southeast of the area of this report. It is the beds of the Paleocene period which should be described most fully, as these are the sediments which one can see in the Park area proper.

These beds have been named the Tongue River formation from the Tongue River in Montana. This is one of the formations of the Fort Union group. Formations which immediately overlie and underlie the Fort Union group are as follows:

- Cenozoic Era
  - Eocene Period
    - Golden Valley formation
  - Paleocene Period
    - Fort Union group
      - Tongue River formation
      - Sentinel Butte member
      - Cannonball - Ludlow formations
- Mesozoic Era
  - Cretaceous Period
    - Hell Creek formation

The beds of the Tongue River formation have been previously noted as all non-marine or continental in origin. They were deposited on land, probably when this area was considerably lower in elevation than it is now. Very likely, at the time of deposition of these beds, this area was not far from sea level. Probably if we could trace them eastward and if the deposits were still in existence, we might conceivably trace them into a marine formation. This is, of course, something that we will never know as the marine beds, if they were ever present, have been eroded away.

These beds were deposited on what can be called an alluvial plain which sloped eastward from the then newly-formed Rocky Mountains. On this alluvial plain, there were many rivers wandering back and forth depositing sediments here and there. From time to time, certain portions of the area became shut off from deposition by streams and great swamps developed in which trees and other plants grew. As these trees and plants died, they fell into the swamp where they were later turned to lignite by partial decomposition by bacteria and the pressure of overlying sediments. As the streams continued to flow to the sea, more and more sediment was deposited on this area until probably a total thickness of greater than 1000 feet of sediment now called the Tongue River formation was deposited. These strata consist largely of fine-grained sands, shales, clays, lignites, and some bentonitic clays.

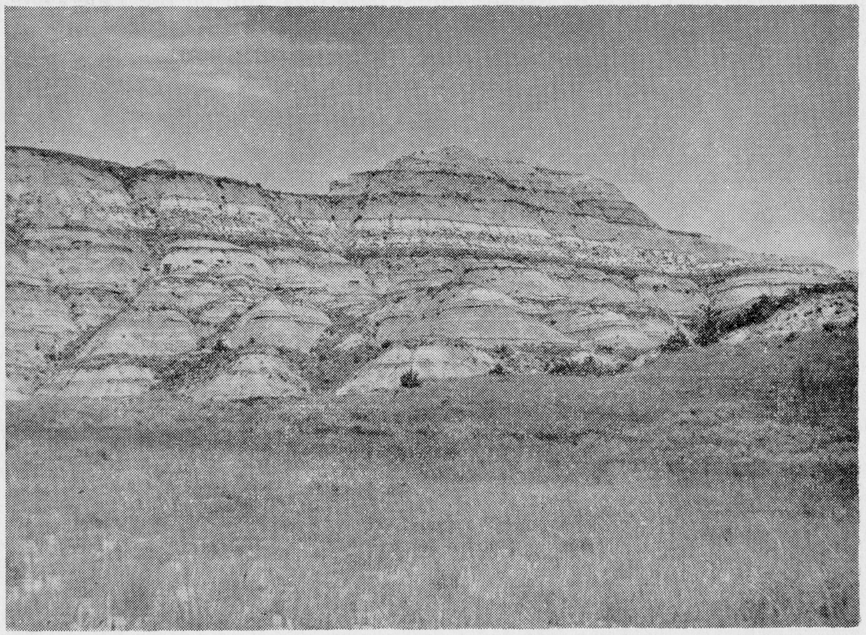


Figure 4

View of the section measured for Figure 3.

The Tongue River formation the North Unit is represented entirely by the Sentinel Butte member which is the upper part of the Tongue River formation. The Sentinel Butte is characterized by being darker in overall color and having fewer lignites than the remainder of the Tongue River formation. With fewer lignites to burn, there are consequently fewer "scorias" and thus the red color is not as prominent in the North Unit as it is in the South Unit of the Park where the lower portion of the Tongue River which contains more lignite beds is exposed.

At the same time that this material was being deposited on this alluvial plain near the sea, there were volcanos erupting to the west in what is now the present-day Rocky Mountains. These volcanos threw out a tremendous amount of ash and other materials which settled down to earth far to the east of the volcanos themselves. These volcanic materials gave rise to the types of clays which we classify as bentonitic or swelling clays.

There are several different strata in the Sentinel Butte member in the North Unit which deserve description because they are so prominently displayed. Undoubtedly, the most spectacular bed in the Park is

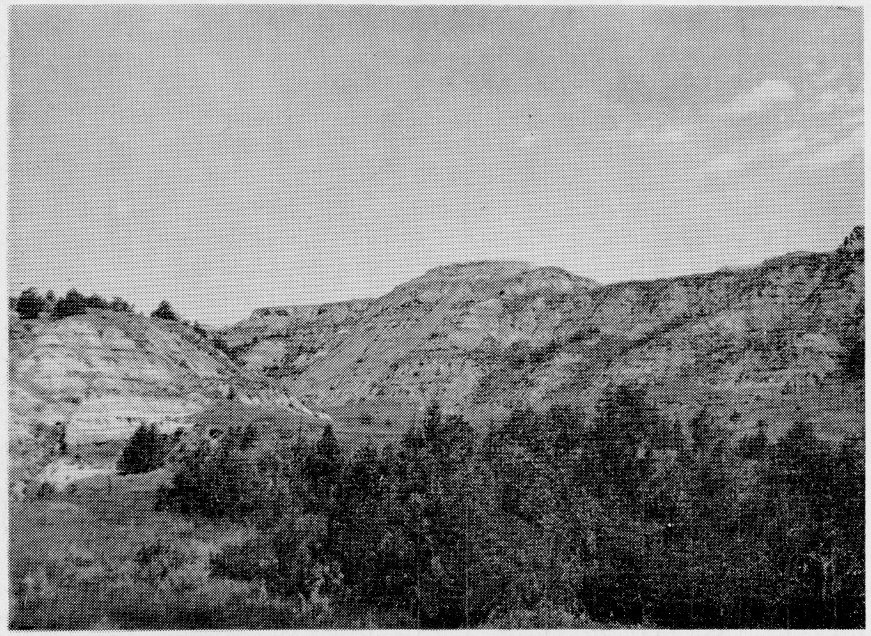


Figure 5

View of the "Big Blue" bentonitic clay bed in the NW/4 Section 25, T. 148N, R. 100W. Note how the clay has "flowed" down hill when it was wet.

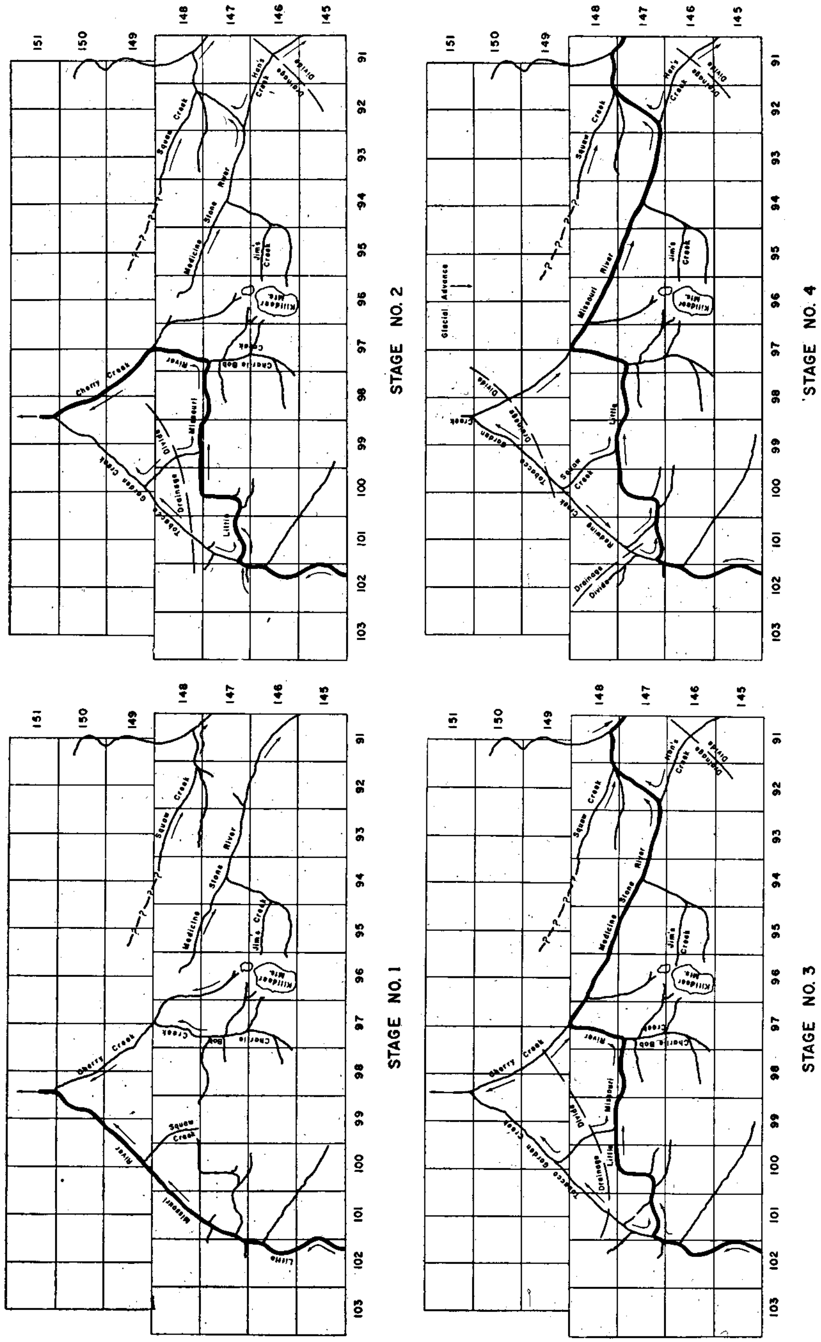
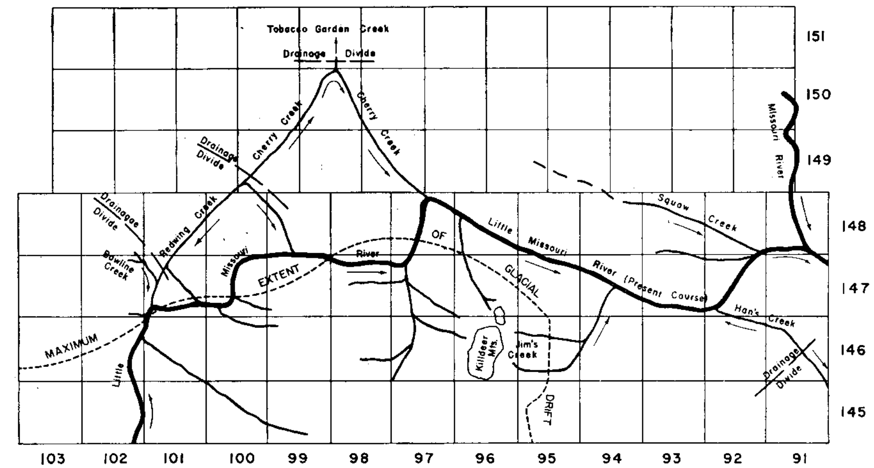


PLATE 1

Diagrammatic maps showing the various shapes in the evolution of the drainage of the lower course of the Little Missouri River.



STAGE NO. 5

the blue bentonitic clay prominently displayed below the first observation point after leaving the Squaw Creek Campground. This bed can be traced with the eye for miles up and down the river and for some distance to the north. Because it is bentonitic, it is plastic and when wet "flows" down hill. Numerous places can be seen on the sides of the buttes where this "flowage" has taken place. This clay is very sticky when wet. When it dries, the surface of the clay shows a characteristic palygonal cracking due to the weathering which is frequently found in bentonitic-type clays. This clay has been locally spoken of as the Big Blue Bed.

Above the Big Blue are two other yellow—or buff-colored beds separated by a slightly darker shale. These yellow beds are siltstones and silty clays and like the blue clay underlying them, they too can be traced with the eye for long distances.

Toward the top of the buttes is one of the more prominent red beds of the area. This is a "scoria" formed when the underlying lignite burned and baked sands and clays above it. As there are fewer large lignite beds in the North Unit, there are consequently fewer "scorias". It should be noted that this is incorrect geologic usage of the term "scoria", but it is used locally for the beds described above. True scoria is an igneous rock.

Other interesting features in the Park are the sandstone concretions. These might be readily mistaken for fossil logs. In most cases they are not fossils, but are simply hard sandstone beds usually in the form of elliptical, round, or irregularly-shaped masses. The formation of these particular concretions is not entirely clear. However, it seems that very likely the formation is due to the deposition of some cementing material usually calcite or other limey material around the sand grains. Perhaps the reason why this limey material was deposited irregularly instead of uniformly, is that these particular zones of sand were originally more permeable and allowed the water to pass through them more readily. Therefore, as the water passed through these zones, readily, it may have deposited material which it was carrying in solution, cementing the sands in these spots more readily than elsewhere where the water was not passing so freely. In any event, the concretions make rather interesting sights on the sides of the buttes.

Evidences of the life of this particular area during the time of the deposition of these rocks can be seen in the plant fossils as well as the gastropod and pelecypod shells which are found scattered here and there in the rocks in the Park. There are relatively few of these fossil-bearing localities readily found.

Physiography

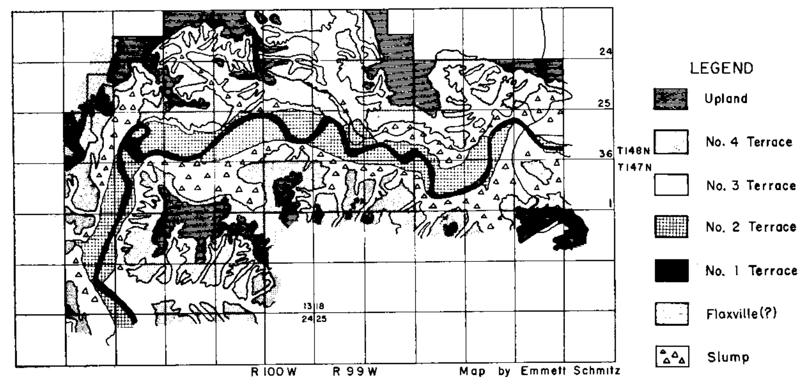
In order to understånd the scenery you see about you in the North Unit, it is necessary to call upon your imagination extensively. Most of the land forms you see about you are very young, geologically speaking.

Going back to the Pliocene which was about 1,000,000 years ago, this area was a broad rolling plain much like that you can see now in the uplands west and north of the North Unit of the Park. On this surface were somewhat higher hills forming drainage divides. One of these old divides is represented by the present day Killdeer Mountains. On this old surface were numerous streams of which the biggest in this area was the Little Missouri.

Now let us set the scene for the beginning of many drainage changes. The Killdeer Mountains were a drainage divide with streams flowing west from it to join the Little Missouri and streams flowing east to join some streams (including possibly a pre-glacial Missouri River), the exact courses of which are not now known. The Little Missouri at that time was flowing northeastward past Watford City to join the Yellowstone which in turn flowed northward to join the Big Missouri near Crosby. From near Crosby the combined streams flowed northeastward toward Hudson Bay. This level of the Little Missouri and its tributaries as well as the tributaries of various streams flowing eastward at this time from the Killdeer Mountains make the

present No. 4 terrace level. The gradient of this terrace level declines east and west from the Killdeer area.

Then, at the end of the Pliocene and at the beginning of the Pleistocene there was a broad regional uplifting of the land surface causing renewed downcutting by the streams. This downcutting was particularly active on the east side of the Killdeers with the result that this stream (the Medicine Stone River) ate through, by headward erosion, or lengthening its course by erosion at its headwaters, at a narrow place in the divide at the present site of the Little Missouri River course. Thus, this stream captured first the tributaries of the Little Missouri and finally the Little Missouri itself. At this time the Little Missouri first began to flow in its present course. Probably, the reason the stream on the east side of the Killdeers could cut more rapidly was that it probably had the advantage of a steeper gradient and a lower local baselevel and thus flowed faster which enabled it to downcut more rapidly. The story of these drainage changes are somewhat more complicated than herein described but the details are not entirely necessary here. The steps in the changes are outlined in the maps of



MAP SHOWING TERRACES ALONG LITTLE MISSOURI RIVER IN THEODORE ROOSEVELT NATIONAL MEMORIAL PARK NORTH UNIT

PLATE 2

Map showing the terraces along Little Missouri River in Theodore Roosevelt National Memorial Park North Unit.

the various stages in Plate II. These maps were first prepared by Emmett Schmitz.

About this time, the glaciers were forming in Canada and a climatic change was taking place resulting in increased precipitation in all of North America. This increased the flow of the Little Missouri in its new course and caused greater downcutting. It was at this time that the valley was cut most deeply and because the sides of the valleys were oversteepened by this rapid downcutting they began to slump extensively. This slumping was slow when considered from the standpoint of a human lifetime but geologically speaking, it happened overnight.

Then the glacier arrived in this area. While the ice probably stood in this valley, it did little erosive work and left practically no deposits except a few scattered boulders called glacial erratics. After it receded from the valley, it did block the eastward-flowing drainage for a time and thus caused extensive remodeling of the valley landscape.

When the drainage was blocked, a lake began to form and after reaching its maximum height (about the top of the No. 3 terrace) it must have stayed there for some time. Into this lake poured great amounts of sediment carried by the streams and by sheetwash from the surrounding hillsides. This material was reworked by the lake waves and the fine bedding we can see in some of the gully sides was the result.

This alluvial fill extended up the middle parts of some larger tributary streams such as Squaw Creek. However, the streams themselves were doing some lateral cutting so the Number 3 terrace along the sides of the tributary valleys and at their heads is actually a cut rather than a fill terrace.

After the formation of terrace Number 3 the lake was drained and the river meandered or wandered back and forth at a somewhat lower level cutting terrace Number 2 in the deposits of the Number 3 terrace. This terrace is about 25-30 feet plus or minus below terrace Number 3. Its surface is definitely a cut surface as it is somewhat irregular topographically and old meander scars can be seen on it. It still floods in very high water.

The present stream (terrace Number 1) is flowing about 15-20 feet below terrace Number 2. The stream can be seen to be meandering widely at the present level. Near the Sperati overlook the stream has cut through one of its meanders leaving a meander scar. In times of high water, it is filled forming what is called an oxbow lake. The stream undoubtedly has done this many times at all levels on which it has flowed.

An alternate hypothesis to consider for the formation of these terraces, particularly the prominent Number 3 terrace, is that they were formed at various times when the stream was overloaded without the necessity of having a lake present. In other words they were formed at times when the stream was not able to carry its entire load and thus deposited the part it couldn't carry along its course.

There are various ways a stream could be overloaded. There could be a decrease of water causing less run off. This could have happened after the ice front retreated and the glacial melt water declined in amount or it could be that there was less precipitation after the ice front retreated.

Another cause of deposition might be excessive load which was more than the stream could carry. This would cause deposition even if the amount of the water in the stream remained constant.

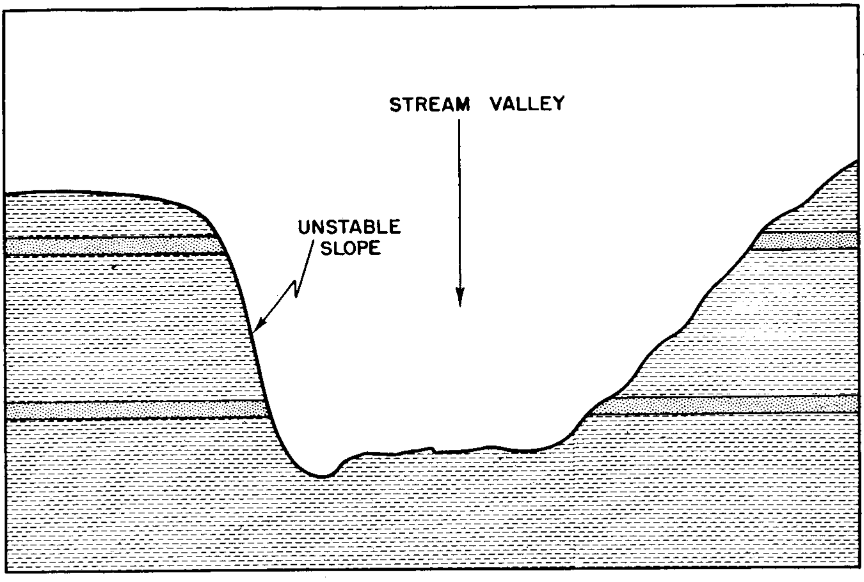
As can be seen, it might be possible to cause these terraces without there actually having been a lake in this area. However one point which strongly suggests ponding in the center portion of the valley at least is the laminated bedding shown in some parts of the Number 3 terrace. Then too, this terrace level is very even and does not show the meander scars and similar features present on lower terraces where the stream is known to have meandered widely.

Geologic Processes Important in Formation of Land Forms in the Park

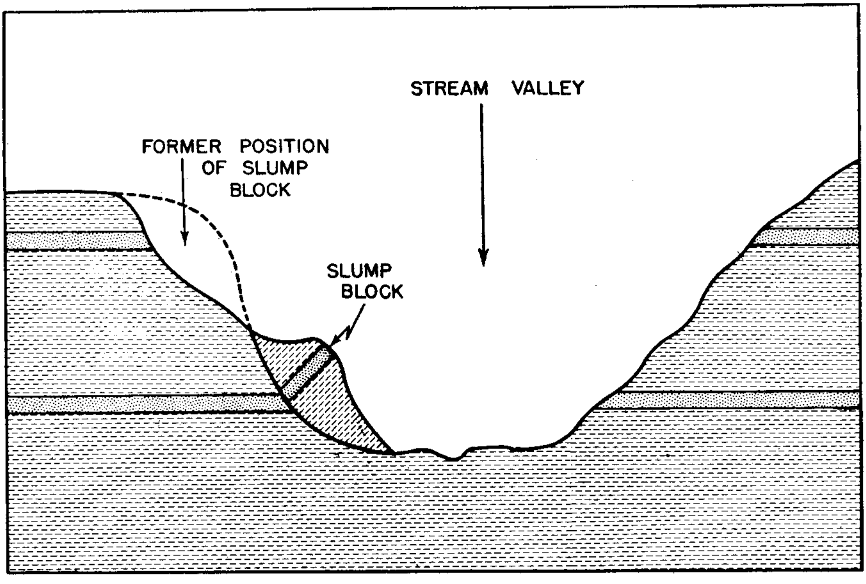
There are two geologic processes making land forms in the North Unit which deserve more than passing mention. These are slumping on a large scale and fluted weathering of the butte sides. Neither of these processes is peculiar to this area only but they have played important parts in the formation of its scenery.

Slumping

Slumping is due to unstable conditions of the sides of the hills. This unstable condition may be created a number of ways but here apparently it was due to oversteepening of the banks by the stream cutting at the bottom of the bank. When water falls as rain on this unstable slope, it sinks in and adds weight to the already unstable part thus increasing its instability. The water also tends to lubricate the planes or surfaces along which the slipping will later take place.



CONDITION BEFORE SLUMPING TAKES PLACE



CONDITION AFTER SLUMPING TAKES PLACE

FIGURE 6

Diagrams showing conditions before and after slumping takes place.

When the block gets too heavy, it finally starts to move. It may move very rapidly or it may and probably does move quite slowly. In any event, the strata in the block which has moved are frequently little disturbed in the movement except to cause them to be tilted into the bank. This type of slumping gives rise to a kind of topography known as hummocky topography as it is so irregular. An excellent example of this can be seen at the Sperati or furthest west overlook on the North Unit Park road as well as many other places in the Park.

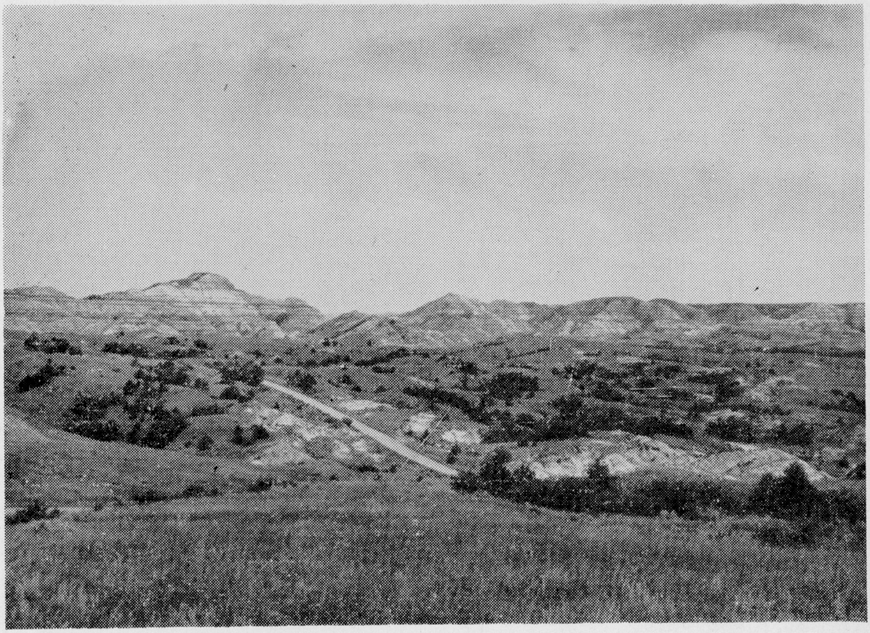


Figure 7

General view looking east across the slump area in Section 33, T. 148N., R. 99W. Note the hummocky nature of the topography accented by the growth of juniper trees.

Fluted weathering or rivulet erosion

The sides of many of the buttes can be seen to be extremely gullied or minutely dissected by running water. Unless you were present here during a rain, you actually would never see water running down these little gullies. This type of erosion produces forms which are spoken of, rather incorrectly perhaps, as fluted weathering. More correctly, it should be called rivulet erosion.

Figure 8

Closer view of the slump area in Section 33, T. 148N., R. 99W. The beds in the slump block to the left dip into the hill at an angle of roughly 45 degrees.

Apparently, the way this process works is that sheetwash running more or less uniformly off the sides of the butte tends ultimately to concentrate into tiny gullies due to initial irregularities of the slope. After they are established, these tiny rivulets tend to remain and grow with each rain.

As they grow, they cut back into the butte until finally two rivulets meet at their heads. The divide between them is now very narrow and more subject than ever to fast wearing away by erosive action. Finally this divide between the two rivulets is entirely cut through and thus a small portion of the butte side is separated from the main butte. Thus the butte is destroyed little by little by the action of running water and at the same time by separating small parts off the main butte in this fashion the sides of the butte tend to remain quite steep and at approximately the same angle with the horizontal.

This type of erosion is most common in arid or semi-arid regions where the slopes are poorly protected by plants. It is also a characteristic of areas where the rainfall tends to come in large amounts in short spaces

of time. In other words, this type of topography is most commonly seen in arid or semi-arid areas where there is little plant cover to protect the land surface from torrential downpours.

Preface to Road Log

In following the road log outlined below, you will see a number of geological features which are described in other sections of this report. Keep your eyes open for the various terrace levels. Briefly, these are the number 1 terrace or the present stream, the number 2 terrace about 15 feet above the present stream, the number 3 terrace about 25 feet above number 2 and the number 4 terrace which is at varying heights above the number 3. Also note the great amount of slumping on both banks of the river. This is the cause of the steeply dipping beds along the road. You will also see sandstone concretions and peculiar weathering shapes and forms. We hope that from this short geologic report you will learn something of the geology of this fascinating area.

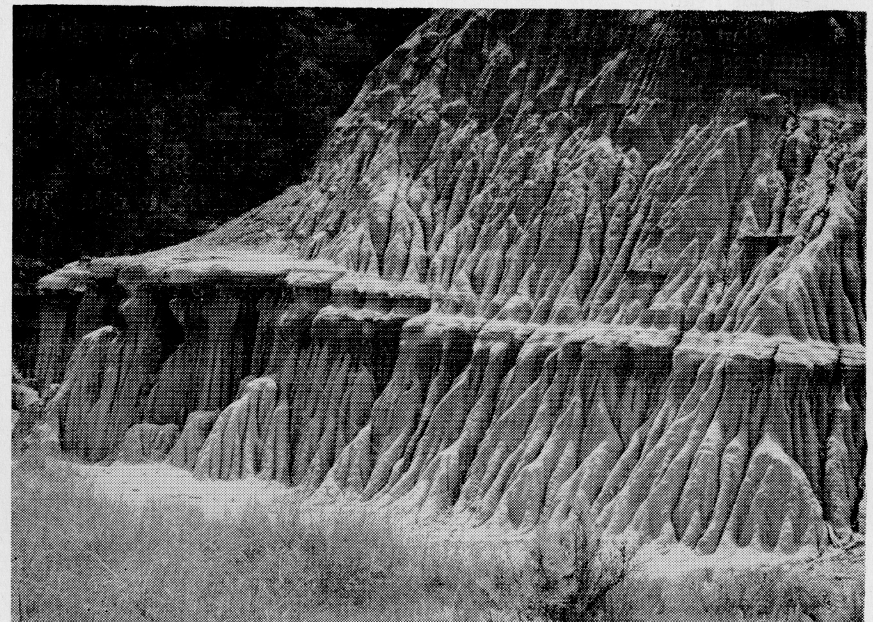


Figure 9

View of fluted weathering or rivulet erosion in a poorly consolidated sand in the NW/4 NE/4 Section 31, T. 148N., R. 99W.

ROAD LOG

Theodore Roosevelt National Memorial Park North Unit

(Numbers on left refer to distances from Park Entrance)

0.00 Entrance. Set speedometer at 0.

0.1 Road to left of Park headquarters.

0.3 You are riding over the Number 3 terrace. Note slump blocks to your right.

0.6 Road starts up over slump block.

0.7 Note lignitic black shales straight ahead.

1.0 Number 3 terrace again. This terrace is most prominent in the Park. Note the bedded or laminated nature of the terrace deposits resting on the bedrock under this terrace. This flat surface probably represents cutting by water action when the stream ran at a higher elevation than now. It might also be cut by wave action when a lake temporarily occupied this valley.

Note how the terrace extends up the tributary valleys. Good exposure of undisturbed Sentinel Butte formation to the right. Note the sandstone concretions (round or irregularly shaped sandstone masses) in the beds near the base of the cliff.

1.3 Cross small bridge. Note bedded terrace material in side of ravine on your right.

1.6 Start over anothed slump area. Rusty-looking small chips on right are ironstone or limonite concretions.

1.7 Note lignite in slump block in road ditch to right. Note that the beds in the slump block dip into the hill. See the section of this report on slumping for explanation of what happened here.

Note large iron-stained sandstone concretions just ahead to right.

1.9 Begin Number 2 terrace. Note small rain-eroded columns to right. The beds of the Sentinel Butte are very easily eroded.

2.1 Here the Number 2 terrace has practically regraded or eroded away the Number 3 terrace. Only small remnants of Number 3 terrace are here near the bluffs.

2.3 Note small pillar on right formed by the sandstone concretion serving as a protective cap keeping the soft material immediately below it from being rapidly eroded away.

2.5 You are on Number 3 terrace again. Look back to your right and you can see that this terrace is formed both of alluvial material and cut in the bedrock itself.

2.7 Slump blocks to right.

2.8 Ironstone concretions abundant to right.

2.9 Excellent view of slump block dipping into cliff straight ahead. The slump block you are now driving past has slipped down the hill at least 150 feet by actual measurement. This measurement was made by matching beds in the slump block with those on the cliffs which are not disturbed by the slump. Some small erosional caves can be noted on this cliff also. These features erode away rapidly and form just as fast.

3.5 Cross small ravine. Note how the Number 2 level is extending itself up into the Number 3 level. Eventually it will destroy the Number 3 terrace and higher levels.

3.8 Note the red rock in the hill ahead of you and to your right. This is locally called "scoria" and is formed when the lignite burns and bakes the overlying rocks turning them red in color.

4.0 Road is crossing slump block in Number 3 terrace.

4.3 Road crosses small gully. This is an extension of Number 2 terrace into Number 3 terrace.

4.6 Road is on top of another slump block. Note "scoria" in cliffs to right.

4.8 You are at edge of Number 3 terrace and about to drop down on to the Number 2 terrace. Note the sandstone concretion in the cliff to your right. Also note the fluted appearance of the soft easily eroded sandstone. These flutings are due to erosion by water running down the face of the cliff. These flutings are important in the formation of these steep sided cliffs.

5.1 Bridge and entrance to Squaw Creek camp and picnic ground to left. The Squaw Creek campground is a good place to see the river in action and to get some idea of how sediments are carried and deposited by running water. The sand and silt carried by the high water is left when the water goes down and shows the current ripple marks of the water. The banks of the stream are constantly changing by being eroded here and built up by deposition there.

The Little Missouri is a heavily-loaded stream but it carries a great deal of material in high water. It is probably still deepening its bed in spite of the high amount of sediment it carries.

Across from the camp ground is an abandoned school. Near this school are deep but very small diameter pits which were dug by the Indians and used as cache pits to store their food. Also nearby but outside the Park boundary are tepee rings. All this suggests repeated occupancy of this area by the Indians prior to the advent of the white man.

To the north of the Squaw Creek campgrounds in the rough terrain bordering the side of the valley is the unmarked grave of "Scrap Iron Bill" Bryant, a cousin of the poet William Cullen Bryant.

5.4 Start up grade. This is contact between Number 2 and Number 3 terraces. Note the sandstone outcrop in road cut to left.

5.5 Road to Squaw Creek campgrounds to left. Good view of Squaw Creek to right. Most prominent terrace is Number 3 terrace but the Number 2 terrace can be seen to have made considerable inroads into it. The top of the cliff ahead of you and to the left probably is a remnant of the Number 4 terrace. The Number 4 terrace in the Park proper is not well shown as it has been badly eroded and slumped. Therefore it appears to be a number of different levels. Furthermore as it represents several streams not entirely governed by the same conditions it might be expected to have varied levels.

5.8 Note harder sandstone beds to left. Also note fluted weathering.

6.0 Trail up Squaw Creek to right.

6.2 Good view of Number 3 terrace up Squaw Creek to right.

7.1 Note you have followed Number 3 terrace up to this point in the ravine. This shows how intricate this terrace is and how it extends up every draw. It has a very high gradient (drop in feet per mile).

7.5 You are now on what remains of terrace Number 4. Very irregular here as you can see.

7.6 Note gray clay on right. Note how it has "flowed" down hill.

8.0 Note lignite in cliff to right.

8.1 Note "scoria" to left.

8.3 You are now above all the terraces and are on the upland plain.

8.4 Lookout. Get out of the car and walk to left to lookout house. The view is grand and the walk will do you good. At the lookout you will see below you an excellent exposure of the blue clay you have seen in the sides of the cliff previously. This blue clay is a bentonitic clay which is very plastic and which swells three or four times its regular size when wet. This member is herein locally called the "Big Blue" and can be traced for many miles up and down the river as well as to the north.

A good "scoria" outcrop is visible to the west.

The Number 1 terrace is the present stream. The Number 2 terrace is just above the Number 1 terrace and is wooded. Above it and extending up into the ravines (i.e. just below the lookout) is the Number 3 terrace. Number 4 terrace is just below lookout and is poorly developed.

Note the thin lignite just below lookout house to the west.

The lookout house is made of local sandstone. Note the irregular ripple cross bedding in the sandstone blocks. This suggests that the sand forming this rock was deposited when currents were actively moving the sand about.

9.0 At this point the road is very close to the Number 4 level which is just below the road on the left.

9.4 Road at Number 4 level here. The level well developed to right. Also note extensive outcrops of "Big Blue" bentonitic clay bed to right. The yellow beds to the right are also prominent in this area. They are siltstones and silty clays.

10.3 Looking straight ahead for several miles you can see a valley running northeastward. This is the Number 4 level and this valley was part of the Little Missouri valley when it flowed northward to Hudson Bay prior to the drainage changes outlined in another part of this report. You can see in this view and later views how gradually the Number 4 level grades into the upland and vice versa. This is because they developed together for a long time without interruption, geologically speaking. Then came rejuvenation of the streams with rapid downcutting and the later levels were cut into the upland Number 4 terrace.

12.9 Note disc-shaped sandstone concretion on right.

13.1 On left note how cedars grow well on north side of bluffs but hardly at all on the south side of the bluffs. This is probably due to moisture staying longer on the north side as sun doesn't strike north facing slopes so directly.

14.5 Sperati Point-parking overlook. End of the road log. Get out and enjoy the magnificent view. Immediately below you is one of the most obviously slumped areas in the Park.

Note the cut off portion of the stream. This is called a meander scar or when it has water in it an oxbow lake and is due to the stream changing its course. The stream has done this many times in its lifetime.

All terrace levels are present in this view but the slump area accounts for most of the Number 3 level.

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