NORTH DAKOTA GEOLOGICAL SURVEY

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Guidebook

for

Geologic Field Trip

in the

DICKINSON AREA, NORTH DAKOTA

by

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Grand Forks, North Dakota, 1957

GEOLOGIC FIELD TRIP IN THE DICKINSON AREA

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INTRODUCTION

Purpose

This guidebook is one of a series prepared specifically for use by Boy Scouts of America during the month of October, 1957, which has been designated "Geology Month in Scouting". This guidebook series provides guides to field tours to points of geological interest around various cities in North Dakota. They will be useful not only to the Boy Scouts but to other individuals who are interested in the geology of the particular area in which they live and to tourists who may be interested in some of the most interesting geological features in the state. These guides cover in a general way the geological processes important in landscape formation in the area. For obvious reasons no extensive discussion of geological principles are included in the reports. Each trip route was chosen because it best and most conveniently portrayed the geologic events of the particular area, and is only one of many that could be taken in that vicinity. After following this logged route it is hoped that the individual will take other similar excursions in the area identifying similar phenomena illustrated by this trip.

The road log included herein is designed to show as many different geologic phenomena as possible within reasonable driving distance of Dickinson, especially deposits and events which shaped the landscape in the badland areas of western North Dakota. The trip, about 165 miles in length, leaves on N. D. highway 22 and tours the Little Badlands southwest of Dickinson. It then proceeds west on U. S. highway 10 through Medora to the top of Sentinel Butte and returns.

The writer gratefully acknowledges assistance rendered by Dr. John R. Bergstrom during the preparation of this guidebook.

What is Geology?

The word "geology" is taken from two Greek words which mean literally "earth study". One might ask the reason for this study.

In the first place, everybody should be interested in geology simply because of the fact that it concerns the earth on which we dwell. Therefore, if we are intelligent human beings, we should wish to know as much as we possibly can about the planet on which we live. One of the really interesting things about geology is that it shows man's adaptation to his environment as clearly or more clearly than any other subject available to him.

Secondly, there is also the possibility of interest in geology from the professional standpoint. Geologists are employed by State and Federal Surveys and in teaching as well as by oil and mining companies. Although the profession of geology is not a large one compared to other professions, it is an extremely important one, as it is the geologists who locate for us the basic raw materials on which our civilization rests.

GEOLOGY OF THE AREA

General Statement

The Williston Basin was originally a shallow depression in the igneous and metamorphic rocks of the earth's crust which has been invaded many times by the sea since Cambrian (see Plate 2) time. The North Dakota part of the Williston Basin was a plain of igneous and metamorphic rocks with numerous residual hills on it. The early shallow seas lapping up on to this plain, which sloped gently to the west, were supplied with sand and clay by rivers which emptied into them from the area to the north and northeast. These seas deposited many formations (see Plate 3) of great thickness as the shallow basin continued to sink slowly throughout geologic time.

Near the end of the Mesozoic the seas retreated from the basin,and North Dakota has been land and received continental sediments for the last 80,000,000 years except for a brief length of time in the Paleocene. These sediments add up to approximately 15,000 feet in the deepest part of the Williston Basin in North Dakota near Tioga.

Only the formations above the Niobrara are well exposed at the surface in North Dakota. Information on the subsurface formations comes principally from wells drilled for oil since the discovery of oil in the Williston Basin in April, 1951. Study of the strata, their extent, kind of rock, and fossil content constitutes the field of stratigraphy.

STRATIGRAPHY

Although older formations are exposed east of Dickinson, only three formations will be seen on this trip. The lowest of these is the Tongue River formation of Paleocene age, the middle is the Golden Valley formation of Eocene age, and the uppermost formation is the White River of Oligocene age.

Tongue River formation - The Tongue River formation consists of shales, clays, sandstones, silts, sands, and lignite. In general, the shales and clays are gray to brown, the sandstones tend to be light yellowish-orange to buff and tan, and the lignite is dark brown to black. The interbedded strata showing many different colors on the hillsides add much to the scenic beauty of the Medora area. Frequently, the lignites have burned, baking and fusing the overlying clays, shales, and sands into a red to brownish red color. This baked and fused material is locally called "scoria", but should more correctly be called "clinker" since true scoria is an igneous rock associated with volcanoes. Although in this area the exposed part of the formation totals only about 620 feet, the total thickness of the Tongue River formation is about 1000 feet.

The upper part of the formation has been named the Sentinel Butte member of the Tongue River formation. While it is commonly difficult to separate the two, part of the formation in the Medora area, the Sentinel Butte member, is darker gray and presents, in general, a more somber aspect than the beds below. The color change takes place at about the level of a prominent "scoria" which has been designated the "L" bed for the purpose of mapping and tracing in the field. This bed is especially well seen from the observation point over-looking the Badlands. Here it will be noticed that the "scoria", being more resistant to erosion than the underlying beds, forms a general level for the tops of many

buttes and pinnacles to the north.

In the immediate vicinity of Dickinson it is very difficult to separate the Sentinel Butte member from the lower member of the Tongue River formation, but it is presumed that in this area most of the beds are in the Sentinel Butte shale.

Golden Valley formation - The Golden Valley formation consists of about 200 feet of sands, silts, shales, and clays that are commonly cream, tan, or light gray. Hence, in general, this formation is much lighter in appearance than the Tongue River below. Since these beds are especially easy to erode, they are not often exposed around Dickinson. However, there are several very hard brown sandstone beds within the Golden Valley formation which cap numerous buttes in the Dickinson area. Typical of this is Davis Butte northeast of Dickinson which is held up by one of these hard sandstone layers. Several of the clays in the Golden Valley formation are of ceramic quality and can be used for making pottery and bricks.

White River formation - The White River formation is made up of three unnamed members. The lower member is white sand and sandstone overlain by bentonitic clay. Above the lower member is the middle member which is composed of tan clay which weathers a decided pink. The upper member is composed of shales at the base overlain by siltstone and sandstone. The three members total about two hundred feet in thickness.

The White River formation unconformably overlies the Golden Valley; that is, the Golden Valley formation was eroded at the end of Eocene times, and the White River formation was deposited on this irregular erosional surface.

The clay at the top of the lower member of the White River formation plays a prominent part in the formation of the Little Badlands. This clay, which is about sixteen to twenty feet thick, shrinks and cracks upon drying, resulting in a rough shell of weathered material three to four inches thick (Stop 3). This outer shell appears as a jumbled mass of irregular, warped, clay fragments which is quite resistant to further erosion. Buttes capped by this clay present a peculiar rounded appearance resembling a haystack. These "haystack" buttes are characteristic of the Little Badlands area southwest of Dickinson. Also prominent in this area is the middle pink member of the White River formation which forms steeper-sided buttes.

Near the top of the formation in the Little Badlands area is a thicker, tan to light gray, sandstone which caps many of the highest buttes in this area, for example, Golden Butte (Stop 2).

On the top of Sentinel Butte is an unusual deposit within the White River formation. This is a tan, hard, calcareous (limy) claystone which weathers nearly pure white. In some places this rock contains so much lime ($CaCO_3$) that it may be classified as a limestone.

Since the White River is the youngest formation which has been deposited in North Dakota, it caps many of the highest buttes in the state, such as HT or Black Butte, Bullion Butte, Square or Flattop Butte, Sentinel Butte, and the Killdeer Mountains.

Environment of Deposition

All of the formations described above were deposited on a vast alluvial plain which sloped gently eastward from the newly formed Rocky Mountains.

Across this plain wandered sluggish streams carrying the finer material eroded from the new mountains. In some places the slope of the land was so low that huge swamps were formed. Lush vegetation, growing in a mild climate in these swamps died and fell into the water. There it partially decayed, but poisonous conditions caused by the release of gases soon prevented further decay. The decay by bacteria caused destruction of the wood so that, as it is preserved today, it looks like it was chewed up. Parts of the plants not destroyed collected underwater in a jellylike mass that eventually formed a binder for any wood particles falling into the swamp. The weight of other sediments deposited on the side of the old swamp, after a change of conditions, compacted the vegetal matter to form the lignite which is one of the great natural resources of North Dakota.

Prior to Oligocene time the entire area was slightly uplifted causing erosion instead of deposition. In some places a considerable thickness of the Golden Valley formation has been removed. Thus an irregular erosion surface was formed on the Golden Valley formation as will be seen at Stop 4 (see also Plate 5, Fig. 4). During the Oligocene there were numerous large fresh-water lakes. Clayey limestone such as can be seen on top of Sentinel Butte (Stop 7) was deposited in some of these lakes in addition to clays, shales and gravels.

Following the Oligocene, renewed uplift in the Rocky Mountains caused a thin veneer of gravels to be deposited over western North Dakota. While a few local deposits of these still exist in some places, they scarcely warrant naming as a distinct formation (see Plate 2).

All three formations of this area contain fossils; however, they are rarely abundant at any one spot. Woody material and impressions of plants are present in some of the lignite and lignitic shale. Occasionally, impressions of leaves can be found in the baked clay or "scoria". Petrified stumps and logs are rather common in certain zones of the Tongue River formation. Some of these trees were the genus sequoia and are closely related to the redwoods which grow in California today. You have probably seen many homes and business establishments where these fossil trees are displayed. Well preserved fresh-water snail and clam shells can be found in the shales of the Tongue River formation in the bluffs along the Little Missouri River. The White River formation is famous for its fossil mammals and fish; however, these are rather rare and are usually found only as separate bones. Well preserved fossil fish have been found in the clayey limestone on top of Sentinel Butte, but the outcrop has been searched so thoroughly that a specimen found there today would indeed be a treasure.

PHYSIOGRAPHY

Physiography is the study of the landforms and their development. This trip lies entirely within the Unglaciated Missouri Plateau Section of the Great Plains Province. However, there are a number of smaller features which are worthy of note.

During the Pleistocene great continental ice sheets advanced from the north covering a large part of the United States. All of North Dakota except the southwest quarter of the state was covered by the ice at one time or another in the Pleistocene. The glaciers deposited vast amounts of material on the rest of the state, greatly modifying the landscape. However, in this Section only

the indirect results of glaciation are to be seen. An example of this is the terraces to be seen along the Little Missouri River in the Medora area. In Pleistocene times the major streams in this area were flowing at a much higher level than they do today. Because of the large amount of meltwater and rain water associated with the edge of the glacier which lay to the north, they were then much larger streams. As the streams flowed northward at their former high level, they deposited sand and gravel along the bottom of the stream just as the Missouri or the Little Missouri do today. In the Williston area, the north flowing streams were pushed out of their courses by the advancing ice and made to seek new channels to the east. Since then they have cut to lower levels and left gravel terraces at high levels along their valleys. Such terraces can be seen in the South Unit of Theodore Roosevelt National Memorial Park. In the Park the road goes up and down several of these terrace levels. In some places the terraces were not built of material deposited on the stream bottom, but were cut in the bedrock of the valley. In general, however, both cut and depositional terraces present the same appearance.

For convenience of tracing, these terraces have been numbered as shown in the diagram below. The No. 1 level is that of the present stream. Terrace No. 2 is in the lowlands and flats along the present stream, about 15 feet above stream level (No. 1). About 27 feet above the No. 2 level is terrace No. 3. The No. 4 level is a cut terrace at some distance above terrace No. 3 and below the upland surface which has been designated level No. 5.

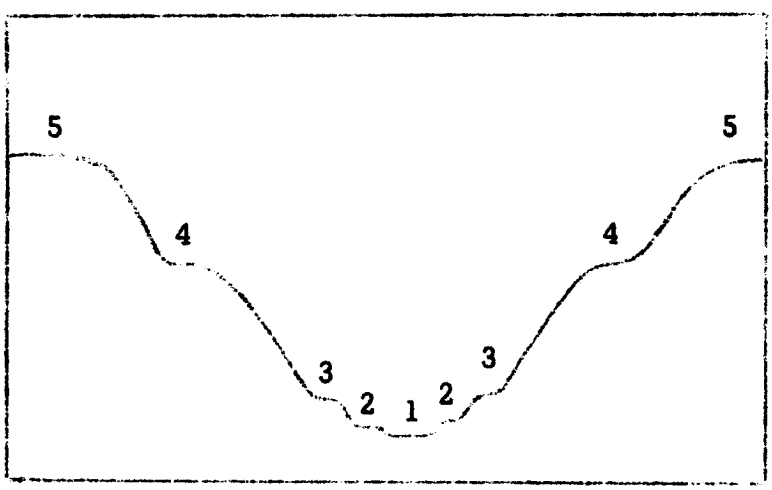


Diagram showing the various terrace levels along the Little Missouri River near Medora.

Especially distinctive of this part of North Dakota are the Badlands. Badlands, from the words of the early French explorers mauvais terres, meaning literally bad lands, are formed in semi-arid climate where occasional very heavy rains erode poorly cemented or consolidated formations. In such a region, commonly nearly devoid of vegetation, erosion, instead of carving hills and valleys of the ordinary type, has cut the land into an intricate maze of narrow ravines, sharp crests and pinnacles. Without the convenience of modern roads, travel across such a region by the early explorers was almost impossible, hence the name. As you view the Badlands from the No. 5 or

upland level near the east edge of the Park, contrast this array of erosional features with the grasslands and farmlands of the Dickinson area. In the latter area the major streams have not yet cut so deeply into the upland surface.

In the badlands areas note that especially resistant layers hold up the higher levels above the gullied sides of the buttes. These resistant layers may be harder sandstone, or, as is commonly the case, "scoria layers".

ECONOMIC GEOLOGY

There are many natural resources of this area; only a few of these will be mentioned here.

Some of the harder sandstone layers in the Golden Valley formation have been used in building walls and foundations in the Dickinson area. Clays in the Golden Valley and White River formation are widely used for ceramic purposes and for making brick. Terrace gravels and "scoria" are used for graveling roads. Beside its use as fuel many by-products, such as creosote tars, waxes, highway surfacing and roofing materials, and wood stain are derived from lignite. The organic matter in lignite and lignitic shales has also concentrated the rare elements uranium and germanium in these beds. However, a profitable method of extraction of these valuable substances has not yet been developed.

Producing wells in the Fryburg oil field can be seen from the highway west of Belfield. The Fryburg field has produced 649,350 barrels of oil since its discovery in 1953 in the Mission Canyon formation of Mississippian age at about 9,400 feet (see Plate 2). Discovery of oil in the Leach Oil Corporation's Wm. Kalanek No. 1 well west of Dickinson has heightened drilling interest in the Dickinson area.

Many of the sands and sandstones in the area bear groundwater which is of inestimable value; and although it is often taken for granted, one should not forget the minerals weathered from the underlying bedrock, which when combined with the organic material of decaying plants, form the basis of the fertile soil for farming in the area.

REFERENCES FOR ADDITIONAL READING

General References

Emmons, W. H., Thiel, G. A., Stauffer, C. R., and Allison, I. S., 1955, Geology, Principles and Processes: McGraw-Hill Book Co., Inc., New York, Fourth Edition. (General text on physical geology).

Dunbar, C. O., 1949, Historical Geology: John Wiley & Sons, Inc., New York. (General text on historical geology).

Flint, R. F., 1957, Glacial and Pleistocene Geology: John Wiley & Sons, New York, (Advanced college text which, however, contains a wealth of readable information on glacial geology).

Hainer, J. L., 1956, The Geology of North Dakota: North Dakota Geol. Survey, Bull. 31. (General booklet on the geology of the state).

Longwell, C. R., and Flint, R. F., 1955, Introduction to Physical Geology: John Wiley & Sons, Inc., New York. (General text on physical geology).

Stovall, J. W., and Brown, H. E., 1954, The Principles of Historical Geology: Ginn and Co., Boston. (General text on historical geology).
Willard, D. E., 1921, The Story of the Prairies: Ihling Bros. Everard Co., Kalamazoo, Michigan. (Although out of date this book contains the geological story behind landscape formation in North Dakota).

Publications on the geology of North Dakota are available from the North Dakota Geological Survey, Campus Station, Grand Forks. A list of these publications and their price is available on request.

Topographic maps of certain areas in North Dakota are available from the U. S. Geological Survey, Denver Federal Center, Denver, Colorado. A map index to the areas mapped is available from this address on request.

Specific References on this Area

Benson, W. E., 1951, Geologic Map of North Dakota Southwest of the Missouri River: U. S. Geol. Survey, Prelim. Map, 1:500,000.
_____, 1952, Geology of the Knife River Area North Dakota: U. S. Geol. Survey, Open File Report (available for consultation in Grand Forks).
Bergstrom, J. R., 1952, The General Geology of Uranium in Southwestern North Dakota: North Dakota Geol. Survey, Rept. of Invest. No. 23.
Brant, R. A., 1953, Lignite Resources of North Dakota: U. S. Geol. Survey, Circ. 226.
Brown, R. W., 1948, Correlation of Sentinel Butte Shale in Western North Dakota: Amer. Assoc. Petroleum Geologists, v. 32, p. 1265-1273.
Caldwell, J. W., 1954, Surface Structure of Western Stark County and Adjacent Areas of North Dakota: North Dakota Geol. Survey, Rept. Invest. No. 14.
Clarke, F. F., 1948, Southwestern North Dakota Clay Deposits, Stark, Slope, and Billings Counties, N. Dak.: U. S. Bureau Mines, Rept. Invest. 4219.
Goplen, A. O., 1946, The Career of Marquis de Mores in the Bad Lands of North Dakota: North Dakota History, v. 13, nos. 1 and 2.
Laird, W. M., 1950, The Geology of the South Unit Theodore Roosevelt National Memorial Park: North Dakota History, v. 17, no. 4 (reprinted as North Dakota Geol. Survey, Bull. 25).
Leonard, A. G., 1908, Geology of Southwestern North Dakota with special Reference to the Coal: North Dakota Geol. Survey, Fifth Biennial Rept.
_____, 1911, The Cretaceous and Tertiary Formations of Western North Dakota and Eastern Montana: Jour. Geology, v. 19, p. 507-547.
_____, 1922, The White River Formation in North Dakota: Univ. North Dakota, Quart. Jour., v. 12, p. 216-219.
Petter, C. K., 1956, The Late Tertiary History of the Upper Little Missouri River, North Dakota: Unpublished master's thesis, Univ. of N. Dak.
Quirke, T. T., 1918, The Geology of the Killdeer Mountains, North Dakota: Jour. Geology, v. 26, p. 255-271.
Summers, G. E., and others, 1954, Guidebook, Southwestern North Dakota Field Conference: North Dakota Geol. Society.
Tychsen, P. C., 1950, Geology and Groundwater Hydrology of the Heart River Project and the Dickinson Area, N. Dak.: U. S. Geol. Survey, Circ. 34.
Yen, T. C., 1948, Paleocene Fresh-water Mollusks from Southern Montana: U. S. Geol. Survey, Prof. Paper 214.

0.00 Assemble south of Stark County Courthouse facing west on Third Street East.

.25 Turn left (south) on N. D. highway 22 (Third Avenue West) at stoplight.

.25 Junction N. D. highway 22 and U. S. highway 10. Continue south on N. D. highway 22.

.10 Northern Pacific Railroad underpass.

.50 Bridge over Heart River.

.70 Turn right (west) on gravel road past abandoned airport.

.90 Continue west as main road curves south.

.10 Turn right through gate into clay pit. STOP 1. Clay pit in Golden Valley formation of Eocene age which is the light colored clay on top of the Heart River bluff. The darker shales of the bluffs below are the Tongue River formation of Paleocene age.

Commonly the exact contact between the two formations is difficult to pick. We know that, in general, the Tongue River formation (especially its upper member, the Sentinel Butte shale) is dark gray more somber colored shales and that the Golden Valley formation is usually lighter gray to white shale. Since they are both continental deposits there commonly was channeling at the end of the Paleocene or early in Eocene time, and part of the total section is commonly missing. In other places the contact seems to be gradational. In this pit the contact is placed above the sandstone ledge at the point just north of the gate. The darker Tongue River silts form the bluff below and the light silty clay above is the Golden Valley formation. An orange color often displayed by the Golden Valley formation can be seen better at a distance from the farm home to the west.

Note that none of the beds of the Tongue River or the Golden Valley can be traced very far laterally. This is especially common in continental deposits. Bite a little of the finest clay you can find between your front teeth. Note that it is gritty. Hence it is silty clay; pure clay is so fine grained that it has the consistency of chocolate candy. The extreme top of the bluff is held up by a thin zone of firmly cemented siltstone.

The light gray or white clay was formerly used for brick at the brick plant in Dickinson now torn down. Some is still being crushed powder fine and being used as a "fattener" in mortar for brick and block laying. The dark gray clay just below the orange layer has been used in pottery glazes.

Note the broad bends of the river below. These meanders are characteristic of a stream with a low gradient fall in feet per mile). Here at Dickinson nearer the headwaters of the Heart River, the flood plain is much narrower than at Mandan.

Hill to southwest capped by hard Golden Valley sandstone (designated the BQ bed) formerly used in laying up many of the basements in the older homes locally.
Turn around and return to highway 22.

1.00

Turn right (south) on N. D. highway 22. Highway in Golden Valley formation.

2.60

Road cuts in silty shales of Golden Valley formation. There are numerous small exposures along highway.

1.50

Dickinson airport; elevation 2589 feet.

1.00

Valley of Dry Creek ahead where crossed by highway is in the Tongue River formation, but the contact between it and the Golden Valley formation is obscured.

1.10

Turn right (west) on gravel road. The hills to south are in the Golden Valley formation, and the gravel road goes up on Golden Valley again about one-half mile west (See geologic map, Plate 6).

3.00

Small hill south of road in Golden Valley.

.40

The contact with the White River formation of Oligocene age is just ahead. Note change in color of road.

.70

All the hills on the horizon and in the foreground are White River formation. White Butte where we will stop later in the trip lies to the northwest. Our immediate destination is Golden Butte with the transmitter tower on it.

.10

Turn left (south).

2.00

Turn right (west).

2.00

Turn left (south) toward Golden Butte.

1.20

Cattle guard. Continue ahead up butte; since it is difficult to stop and start up hill, we will examine the White River section on the way down.

.50

Turn around on summit of Golden or Brown's Butte at KDIX-TV transmitter tower and pause before descending. Elevation 2935.2 feet (foot of tower); tower is 621 feet tall. The butte rises about 250 feet above the road to the north. The butte is locally called Brown's Butte after the landowner on whose property it is located, but reputedly it was named Golden Butte at the time the tower was built.
The valley of Antelope Creek to the south is in the Golden Valley formation. The middle member of the White River formation holds up the buttes beyond. Far to the south can be seen East Rainy and West Rainy Buttes also held up by White River formation.

To the north (about 60 miles) can be seen the Killdeer Mountains in the White River formation, and to the NNE are Davis Buttes northeast of Dickinson capped by Golden Valley formation (probably by the BQ bed).

.20

STOP 2. Exposure of the White River formation, north side of Golden Butte. The White River formation is made up of three members. The lower member is white sand and sandstone overlain by clay which makes the "haystack" buttes of the Little Badlands. Here this forms the slopes at the base of the butte. Overlying the lower member is the middle member which is composed of tan clay which weathers a decided pink. The upper member is composed of shales at the base overlain by siltstone and sandstone.
It is this greenish gray sandstone at the top of the upper member which forms the "rim rock" of the butte. Note the darker gray appearance of this sandstone where weathered in natural exposures to east. The hollows in this sandstone are formed where greenish clay chunks have washed out of the sandstone. Break some of the sandstone and find the green clay.
Walk down the section to the middle pink member of the White River formation which is exposed on the curve below. On the way down note the cross bedded, shaly, softer sandstone near the base of the upper member above the pink sandstone of the middle member. Examine closely the pink member and note that although the middle member of the White River formation has been called clay, it too is quite gritty.

.30

Cattle guard.

1.20

Turn left (west).

1.00

Lowland ahead is in the lower member of the White River formation characterized by white sand and sandstone. The top of this member is marked by 16 to 20 feet of light gray to brownish gray bentonitic clay. Pure bentonite is a type of clay which has the property of swelling when wet. Clays which have a greater or lesser bentonite content are common in North Dakota. It is these purer clays which make the sticky mud locally referred to as "gumbo". The clay of this zone is particularly bentonitic and is so impermeable (won't pass water) that it is quite resistant and caps the little "haystack" buttes characteristic of the Little Badlands. These are well shown north of the road.

1.00

Crossroads; continue west.

2.80

Scenic School No. 3 north of road.

.50

Turn right (north) toward South Heart.
You are entering the heart of the Little Badlands. Typical White River badlands (note difference in appearance of these "badlands" and those along the Little Missouri River which we will see later in the trip) are here developed on the lower member of the White River with the upper clay zone capping "haystack" buttes.

.50

Road curves around butte with yellow claystone at the base. This is the "WR" bed in the White River formation.

.40

"Haystack" buttes well shown ahead.

.30

STOP 3. "Haystack" east of road at north edge of badlands. White sandy clay capped by bentonitic clay at the top of the lower member of the White River formation. Note that this clay has a rough shell three to four inches thick formed when the surface of the clay shrinks and cracks. This outer crust appears as a jumbled mass of warped clay fragments, adhering to one another, with the smaller pieces slaking off and forming little talus slopes at the base of the exposure. Dig through this crust and test the underlying clay with your teeth. Is it sandy or silty ?
On the surface east of this butte are patches of ironstone or limonitic concretions which have weathered from the shale. These are concentrations of the mineral limonite ($Fe_2O_3 \cdot 2H_2O$) which cements the rock (commonly sandstone) together and makes it harder and more resistant to weathering. The cliffs to the east are in the pink middle member of the White River formation.

.10

Road turns straight north.

.40

Drive slowly. Thin lower member of the Golden Valley formation in low hill northeast of this point. Note the orange color characteristic of the lower member just below the small shed.
The creek bluff just east of the road ahead is in the Tongue River formation. Thus the Golden Valley formation must be very thin at this locality. Since the White River formation comes down the stratigraphic column very near the Tongue River formation this indicates that there was considerable erosion below the White River. Such an erosion surface is called an unconformity. Thus the White River is unconformable on the Golden Valley and erosion has here removed almost the entire thickness of the Golden Valley. Just a few miles north, this is not true.
The road ahead is in the Tongue River formation.

.80

Small bridge. Tongue River in bluff to east with Golden Valley above. Hill in Golden Valley.

.80

School to east is on Golden Valley as is hill beyond. The Tongue River-Golden Valley contact is just east of the road but is obscured.

2.00

Lignitic zone in the Tongue River in ditch east of road below house.

1.10

Road turns east one mile then north again.

1.80

Tongue River shale east of road.

1.45

Turn right (east) at south edge of South Heart before crossing railroad tracks.

.65

Turn right (south). Hills ahead in Golden Valley formation.

1.40

Going on to the Golden Valley formation. Contact with the underlying Tongue River on which we have been riding is covered.

1.60

Up on to White River. Contact covered.

.15

Turn left (east). White Butte ahead.

1.15

In the buttes south of the road the unconformable contact between the Golden Valley and the White River above is at the top of the yellowish-orange shale. The white sand is the base of the White River formation. Note how in some places the white sand cuts well down into the yellowish-orange layer.

.20

STOP 4. White Butte is the isolated butte north of the road. Walk southeast to the butte south of the road.

The hard brown rock scattered over the surface close to the road is silicified lignitic shale weathered from the Golden Valley formation.

As you approach the butte, notice how the white sand cuts downward across the bedding planes into the orange shale. This is really gray shale which has been stained by limonite. Check some of the gray lignitic shale below the orange shale with your teeth. Is it clay or silt?

The large gray rubbly blocks are blocks of conglomeratic sandstone (not unlike that we saw on Golden Butte much higher in the section) which have tumbled down from the top of the butte where they form the cap rock except for a little bentonitic clay on top. The similarity of this sandstone to that we saw higher in the section indicates that similar conditions were repeated during the Oligocene time.

Continue east.

.80

Road goes up on to White River formation.

1.00

The rim of the hill we are on is dark brown to gray micaceous sandstone (the "BQ" bed) high in the Golden Valley. Hence we are near the White River-Golden Valley contact here.

.20

Sandstone ("BQ" bed) in road and just beside road to north.

.90

Turn north.

The bluff of Ash creek just south of corner is in the Golden Valley.

2.00

Lignite and lignitic shale in Tongue River formation just southeast of corner. Going down on to flood plain of the Heart River.

.70

Bridge over Heart River. Butte of Golden Valley to southeast.

.40

Railroad crossing.

1.20

Turn left (west) on U. S. highway 10.

1.30

Lignite of the Tongue River formation in road cuts. There are a number of exposures of lignite or lignitic shale in the road cuts along U. S. highway 10. In some cases weathering has caused minor surface slump which obscures the actual lignite. The resultant brownish or brownish black streak which marks the presence of coal is called a coal "blossom" or coal "bloom" or "smut".

Lignite is brownish black coal which is made of decomposed vegetal matter. In Paleocene time (See Plate 2), trees and shrubs flourished in and around the many swamps which dotted a broad alluvial plain. As this vegetation died, it fell or was washed into the swamp where bacterial action partially decayed it. During this process, and following its subsequent burial, lignite was formed by devolatilizing (or driving off the gases) and by compaction.

3.70

STOP 5. "Scoria" pits at corner. Road to South Heart goes south from highway. Pull well off the highway.

True scoria is an igneous rock associated with volcanoes. The "scoria" of North Dakota is a sedimentary rock formed of shales and sandstones baked to a brick or pottery-like color and nature by burning of the underlying lignite bed. The heat and gases from this underground burning alters the shale or sandstone to "scoria" or "clinker" as it is called locally. "Scoria" derives its name from the fused, glassy nature of some of the rock where the heat was most intense causing the early settlers to believe that it was true scoria. It has been called "clinker", because it "clinks" when tapped, walked on, or driven over in the road, and also because it is the result of burning. There are coal seams burning in North Dakota today northwest of Amidon and in the South Unit of Theodore Roosevelt National Memorial Park.

Some of the "scoria" is sandier than other (altered sandstone); some is very much like pottery because it is baked clay; and some is fused, twisted, and glassy like "clinkers" in the furnace. Some of the baked clay contains impressions of leaves preserved as fossils.

"Scoria" is extensively used as road gravel and occasionally as a unique pottery glaze.

9.70

Junction of U. S. highway 10 with U. S. highway 85, east edge of Belfield. Continue west on U. S. highway 10.

6.30

East boundary of the South Unit of Theodore Roosevelt National Memorial Park. Antelope are commonly to be seen in the park field north of the highway.

1.60

Cedar Canyon and trading post north of highway. Square or Flattop Butte on horizon to the southwest.

1.60

STOP 6. Drive off highway to right into Badlands observation point. This will be only a brief observation and picture stop. Note that the wall is made of "scoria" and petrified wood from the Tongue River formation, but do not chip or take any.

Visible to the north are a number of buttes capped by a thick red "scoria" bed. For tracing and mapping purposes this prominent bed has been designated the "L" bed. It separates the upper, darker gray, somber shales of the Sentinel Butte member from the lighter beds of the rest of the Tongue River formation below.

2.20

Going down into Badlands of the Little Missouri River. The early French explorers called such areas mauvais terres meaning, literally "bad lands"; because the intricate maze of narrow ravines and sharp crests and pinnacles made travel across such a region almost impossible. This type 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.

.80

Turn right into east entrance to scenic drive through the South Unit, Theodore Roosevelt National Memorial Park. The park consists of three units, this one near Medora, another one 16 miles south of Watford City, and Roosevelt's Elkhorn Ranch site about midway between the other two on the west side of the Little Missouri River. The Theodore Roosevelt National Memorial Park was established by an act of Congress on April 25, 1947; and as extended by subsequent acts, the Park now consists of 65,648.50 acres.

.50

Good examples of gullying action or rivulet erosion to be seen here.

.10

Clay-capped buttes on both sides of the road.

.40

Zone of fossil Sequoia stumps north of road.

.40

Good examples of gullying.

.10

Note sandstone concretions north of road.

.40

Note small bench held up by gray clay. Note also fossil stumps to the north.

.20

Parking overlook. In the general view to the north and west, note the level below the upland surface. This is probably the No. 4 level (See diagram, p. of this guidebook). Note the clinker below the overlook and in the distance.

.10

Dark gray and purple lignitic shales to the north.

.10

Excellent view to south. The highest subupland level is the No. 4 terrace and that below it is the No. 3 terrace.

.10

Log-like concretions at road side to the north. Thin zone of these concretions extends to the east here for a short distance.

.10

Road south to observation point. Good stand of "badlands cedar" (really Rocky Mountain red cedar) whose scientific name is Juniperus scopulorum.

1.00

Note extensive gullying on the sides of the buttes to the north.

.10

Sandstone concretions south of the road; note how they cap erosion pillar to the south by protecting the underlying shale from erosion.

.10

Outcrop of clinker to the north. This is an excellent example of pseudo-columnar jointing in rock. This jointing arises as a series of tension cracks around polygonal columns formed when the "scoria" was cooling. This is similar to the columnar jointing in many lava flows (such as in Yellowstone National Park), hence the name "pseudo" columnar jointing.

.10

Note level to north. This level is part of the old high level stream cut surface or No. 4 terrace level.

.20

Clinker outcrop showing some of the unburned coal still present with ash at the top.

.90

Massive sandstone concretions on the south side of the road.

.70

View to west over Little Missouri Valley.

.60

Eastern edge of No. 3 terrace level (see diagram p.).

.30

Eastern edge of No. 2 terrace level.

.10

Road to east to Pleasant Valley and the Park Headquarters. Turn left.

.15

Road to south to picnic area. Turn left.

.05

Edge of the No. 3 Terrace. You have been traveling on the No. 2 level.

.20

You have been on Terrace No. 3. Here you are beginning to go up onto the No. 4 terrace level.

1.90

Edge of Terrace No. 4.

1.80

Turn right (west) on U. S. highway 10.

1.00

Turn right (north) just east of school in Medora. The town was named for the wife of the Marquis de Mores (See below), formerly Medora von Hoffman of New York. The town is built on Terrace No. 2.

.20

The brick building on the right is the Catholic church built in 1884 by the Marquis for his wife.
Turn left (west).

.10

On the right is the Rough Rider Hotel. Theodore Roosevelt stayed here occasionally while he was ranching in North Dakota, and later his cavalry troop in the Spanish-American War became known by this name.

.10

On the left is De Mores Memorial Park containing a statue of the Marquis.

.20

Intersection of street with U. S. highway 10. Continue west on U. S. highway 10. To the north is the brick chimney and foundations of the packing plant built by the Marquis de Mores in 1883. The plant was abandoned in 1886 and destroyed by fire in 1907.

The career of the French nobleman and his lovely American wife, the daughter of a wealthy Wall Street businessman is a fascinating saga in North Dakota history. The Marquis' plan was to buy and slaughter cattle here on the range in Medora, and ship them to eastern markets in ice-filled refrigerator cars in order to avoid the usual loss of weight and quality involved in shipping live cattle. With this idea in mind he founded the town of Medora, built a lovely home to be seen standing southwest of this point across the river, built the abbattoir or slaughter-house, and numerous icing stations between Medora and Chicago. Partly because of adverse pressure of eastern beef growers and partly because of an apparent consumer preference for grain fed over range fed beef, the Marquis' Medora venture failed. The Marquis also operated a stage-coach line from Medora to Deadwood, South Dakota, in the Black Hills from October, 1884, to May, 1885. At first this was a successful venture but eventually failed because actually the Medora route was not the best nor shortest route to the Black Hills, because the route through Pierre received the government mail contract, and because the beginning of deep vein mining of gold instead of placer mining ended the prospecting rush and cut down on passenger traffic to the Black Hills. The handsome, mustachioed Marquis in wide, white hat, fringed leather hunting coat over a blue yachtsmans shirt tied at the neck with a yellow silk cord, leather chaps supported at the waist with a cartridge belt bearing two long barreled Colt revolvers, and carrying a French double barreled gun made a picturesque figure of a plainsman as he rode forth on his numerous hunting expeditions. This wealthy, foreign nobleman and his talented, stately and aristocratic wife, (who also was an excellent shot and horsewoman) was not popular with all of the local ranchers and frontier "hangers-on", but his employees were loyal to him and characterized him as a kind and generous man. In Roosevelt he found a man of similar tastes and character; and, although they had differences of opinion, Roosevelt occasionally dined with the Marquis and Marquise at their home and they worked together in business matters of the cattlemen's association.

The Marquis de Mores was murdered in 1896 at age 38 by North African tribesmen while on a political mission there. Madame de Mores last visited the town founded in her honor in 1903; but since her death in 1921, her sons visited Medora several times.

.20

Bridge over Little Missouri River. Terrace levels No. 1, 2, 3, and 4 are readily visible from this point.

.10

Entrance to De Mores State Historical Site. The 26 room chateau of the Marquis is preserved intact as a museum. It is suggested that if time permits this would make a most interesting individual stop on the return trip.

.40

Little Missouri Station of Northern Pacific Railroad to south of road. Little Missouri was the only settlement in the Badlands when Roosevelt and De Mores arrived here in the spring of 1883.

.20

Andrews Creek bridge. The highway here follows up the No. 3 terrace level.

13.4

Conical butte, held up by "scoria", with cross put up by Lutheran Layman's League of the German Lutheran Church of Beach in 1957. The highway is in the lower member of the Tongue River formation while the top of the butte is in the Sentinel Butte member of the Tongue River formation. The contact is about half way up the slope at a prominent "scoria".

2.20

Turn left (south) at west edge of the town of Sentinel Butte.

.30

Railroad crossing.

2.00

Prominent dark red "scoria" north of road.

.60

Cattle guard above picnic area.

.20

Very prominent "clinker" ridge ahead with the thick sandstone which supports Sentinel Butte seen to south of it (See Plate 5, Fig. 1).

.80

Lignite of the Sentinel Butte member of the Tongue River formation at road level.

.10

Thick Oligocene (?) White River sandstone by road. It is this resistant sandstone which holds up Sentinel Butte.

.20

STOP 7. Summit of Sentinel Butte; elevation 3,430 feet.
Sentinel Butte is really composed of two prominences with a saddle between them; the top totals about 450 acres. On the way up you have seen the shales, siltstones, lignite and "clinker" of the Sentinel Butte member of the Tongue River formation. Here on top of the butte at the surface is tan but white weathering, thinly bedded (laminated), hard calcareous (limy) claystone of the White River formation. This whitish rock contains so much lime ($CaCO_3$) that in some places it may be classified as a limestone. Fossil fish of Oligocene age have been found by splitting this rock along the bedding planes, but so many people (including expeditions from the U. S. National Museum in Washington, D. C.) have searched for these fossils that the outcrop is depleted. Between this upper claystone and the shales of the Sentinel Butte member is about 60 feet of brownish gray sandstone which is the resistant rock which holds up Sentinel Butte. Although it is usually classified as part of the White River formation, it may be Eocene instead of Oligocene in age.
To the south, the broad valley in the Tongue River formation was formed by the North Branch of Garner Creek. This is a small stream now; but in Pleistocene times it undoubtedly carried much more water, as there was likely increased rainfall around the edges of the glacier to the north. Similarly Andrews Creek and its tributaries formed the valley to the north of Sentinel Butte.

To the east can be seen Flattop or Square Butte and to the southeast in the distance is Bullion Butte with Black Butte, highest point in North Dakota at 3468.1 feet, in the far distance to the south - southeast.

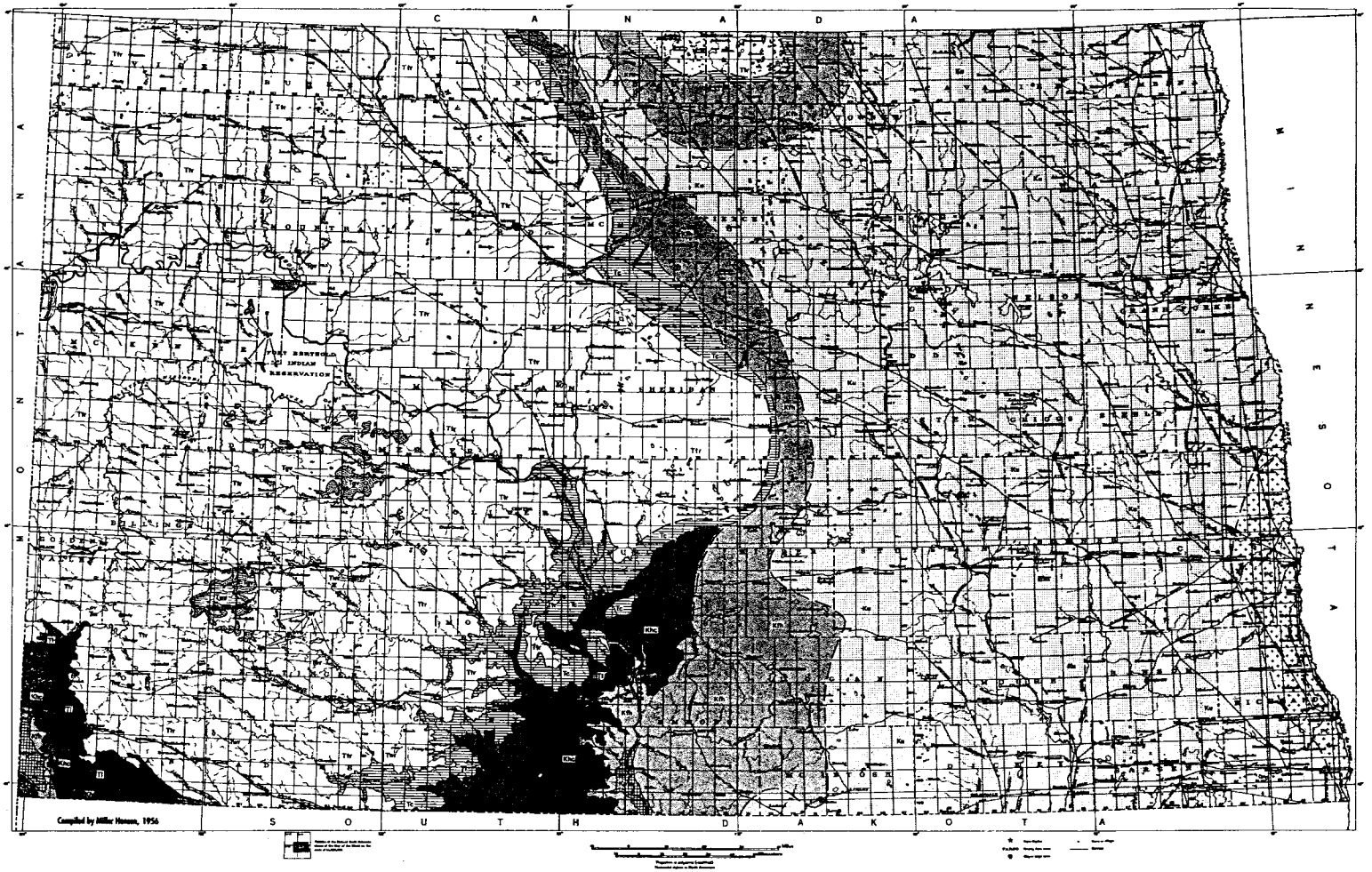
Drive from the western promontory to the east on Sentinel Butte. STOP HERE and observe scattered loose stream gravels of cloudy white agate composed of silica (SiO_2). The age of these is not known; they may be Oligocene or they may be younger (Miocene-Pliocene) in age (See Plate 2). The pits on the surface and sides of the butte are uranium prospect pits. In prospecting for uranium a detailed survey of the area is made with a Geiger counter or scintillometer. These do not read directly in terms of the uranium contained but only record its radioactivity. After radiometric check in the field, an unweathered sample is dug and sent to a chemical laboratory for assaying. There has been a considerable amount of uranium prospecting in southwestern North Dakota. Some few of the many lignites in the Tongue River formation are especially radioactive. There are several theories to explain this, but the most plausible explanation seems to employ the known liking of uranium for carbon. Hence ground water carrying tiny amounts of uranium and percolating downward through the sediments hits the carbonaceous (carbon-bearing) lignites and their impervious under-clay (the clay in which the swamp vegetation grew) and tends to concentrate the uranium in the lignite. The clayey limestone and limy claystone (clay derived from volcanic ash) in the White River formation on top of Sentinel Butte have been found to have an unusual amount of radioactivity, and have been thought to be the source of the uranium. Unfortunately no method has yet been devised for extracting the valuable pure uranium from the other mineral matter in North Dakota rocks. Retrace route down Sentinel Butte and return to Dickinson.

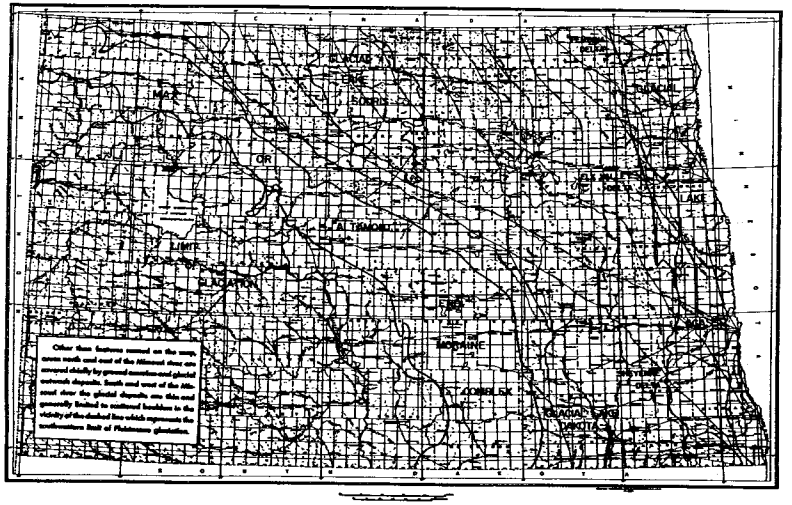
End of road log.

NORTH DAKOTA GEOLOGICAL SURVEY

GEOLOGIC MAP OF NORTH DAKOTA

WILSON M. LAIRD, State Geologist





Sources of Data

All Cretaceous and Tertiary contacts in the northwestern part of the state are taken by permission of the Director, U. S. Geological Survey from an unpublished bedrock map of northwestern North Dakota by Richard W. Lemke, Geologist, U. S. Geological Survey. The area mapped by Mr. Lemke lies north of 47°30'00" north latitude and is bounded approximately on the east side by the 100°00'00" west longitude line.

The south-central and southwestern portions of the map have been prepared from the same sources listed on the North Dakota Geological Survey "Preliminary Geologic Map of North Dakota", published in 1952. Additional information has been obtained from well logs and North Dakota Ground Water Studies.

As new information becomes available, all inferred contacts will be extensively refined.

LEGEND

Twr	White River	Oligocene
Tgv	Golden Valley	Eocene
Ttr	Tongue River	
Tc	Cannonball	Paleocene
Tl	Ludlow	
Khc	Hell Creek	
Kfh	Fox Hills	
Kp	Pierre	Cretaceous
Ku	Chiefly Pierre, includes Colorado and Dakota groups.	
PC	Igneous and metamorphic rocks	Pre-Cambrian

Known contacts

Inferred contacts

TABLE OF GEOLOGIC TIME

Time Units	Years ago	Approximate Duration of time	Approximate Percentage of Total time
Phanerozoic Eon	(to beginning)		
CENOZOIC ERA			
Tertiary Period			
Recent Epoch	11,000		
Pleistocene Epoch	1,000,000		
Pliocene Epoch	12,000,000	11,000,000	
Miocene Epoch	25,000,000	13,000,000	
Oligocene Epoch	35,000,000	10,000,000	70,000,000 ≠ 2%
Eocene Epoch	60,000,000	25,000,000	
Paleocene Epoch	70,000,000	10,000,000	
MESOZOIC ERA			
Cretaceous Period	130,000,000	60,000,000	
Jurassic Period	165,000,000	35,000,000	130,000,000 ≠ 3%
Triassic Period	200,000,000	35,000,000	
PALEOZOIC ERA			
Permian Period	235,000,000	35,000,000	
Pennsylvanian Period	260,000,000	25,000,000	
Mississippian Period	285,000,000	25,000,000	
Devonian Period	325,000,000	40,000,000	350,000,000 ≠ 9%
Silurian Period	350,000,000	25,000,000	
Ordovician Period	410,000,000	60,000,000	
Cambrian Period	550,000,000	140,000,000	
Cryptozoic Eon			
PRECAMBRIAN ERA			
Late Precambrian	1,035,000,000	3,500,000,000	
Early Precambrian	3,850,000,000		

PLATE 2

TERTIARY	RECENT	ALLUVIUM	
	PLEISTOCENE	GLACIAL DRIFT	
	PLICCENE	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 / LOWER	
		RED RIVER	
		WINNIPEG	
CAMBRIAN		CAMBRIAN	

PLATE 3 - GEOLOGIC FORMATION TABLE FOR NORTH DAKOTA. ONLY THE FORMATIONS ABOVE THE CARLILE ARE EXPOSED AT THE SURFACE; THE OTHERS ARE KNOWN ONLY FROM WELLS.

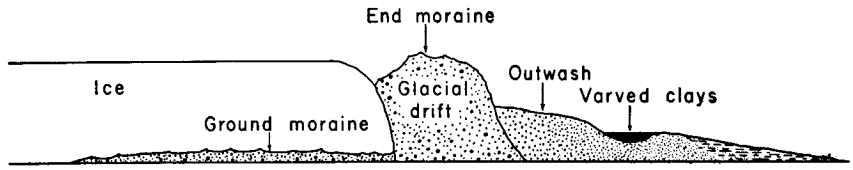


Figure 1. - Diagram showing glacial features associated with the front of an ice sheet.

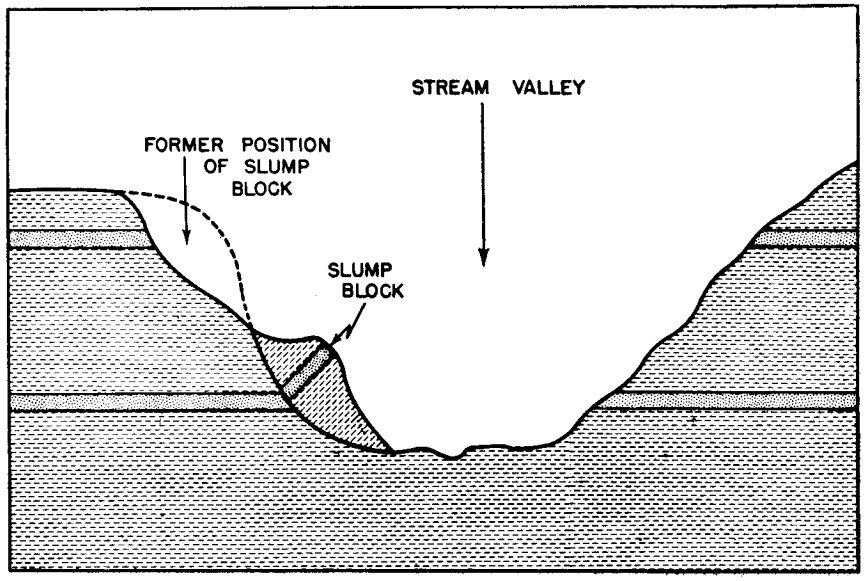


Figure 2. - Cross-section diagram showing a slump block or landslide caused by slippage on a clay or shale surface lubricated by ground water.

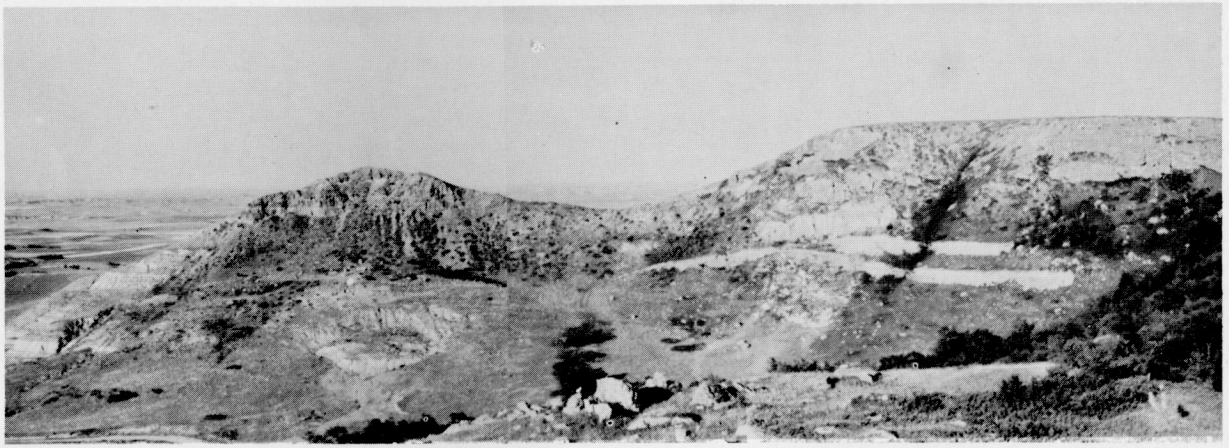


Fig. 1 - Looking east to "scoria"-capped northeast ridge of Sentinel Butte with the Badlands of the Little Missouri River in the distance. To the right is shown the resistant sandstone which holds up Sentinel Butte. Note the landslide in the soft Sentinel Butte shales, below the prominent "scoria" ridge toward the left center of picture.

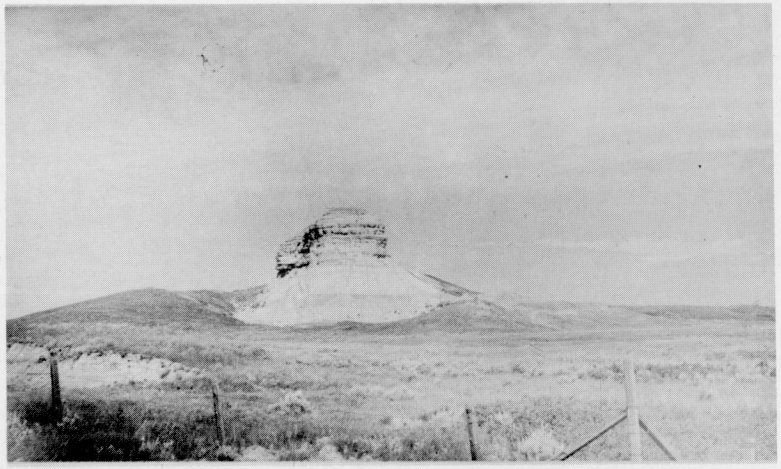


Fig. 2 - White Butte southwest of Dickinson, stop 4. The butte is of the White River formation capped by bentonitic clay.

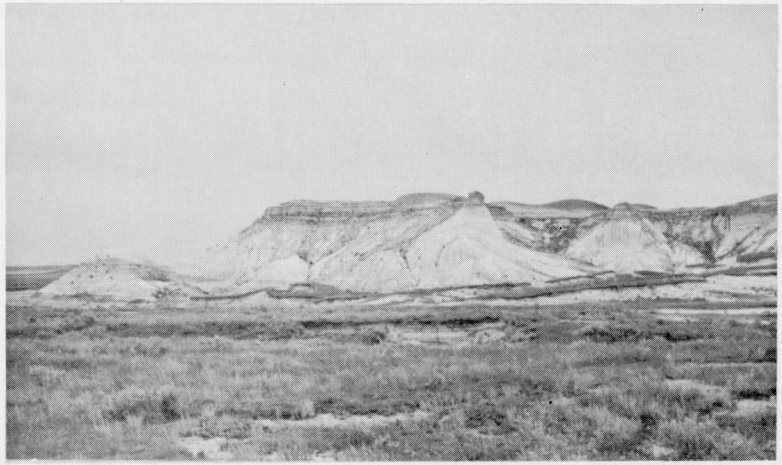
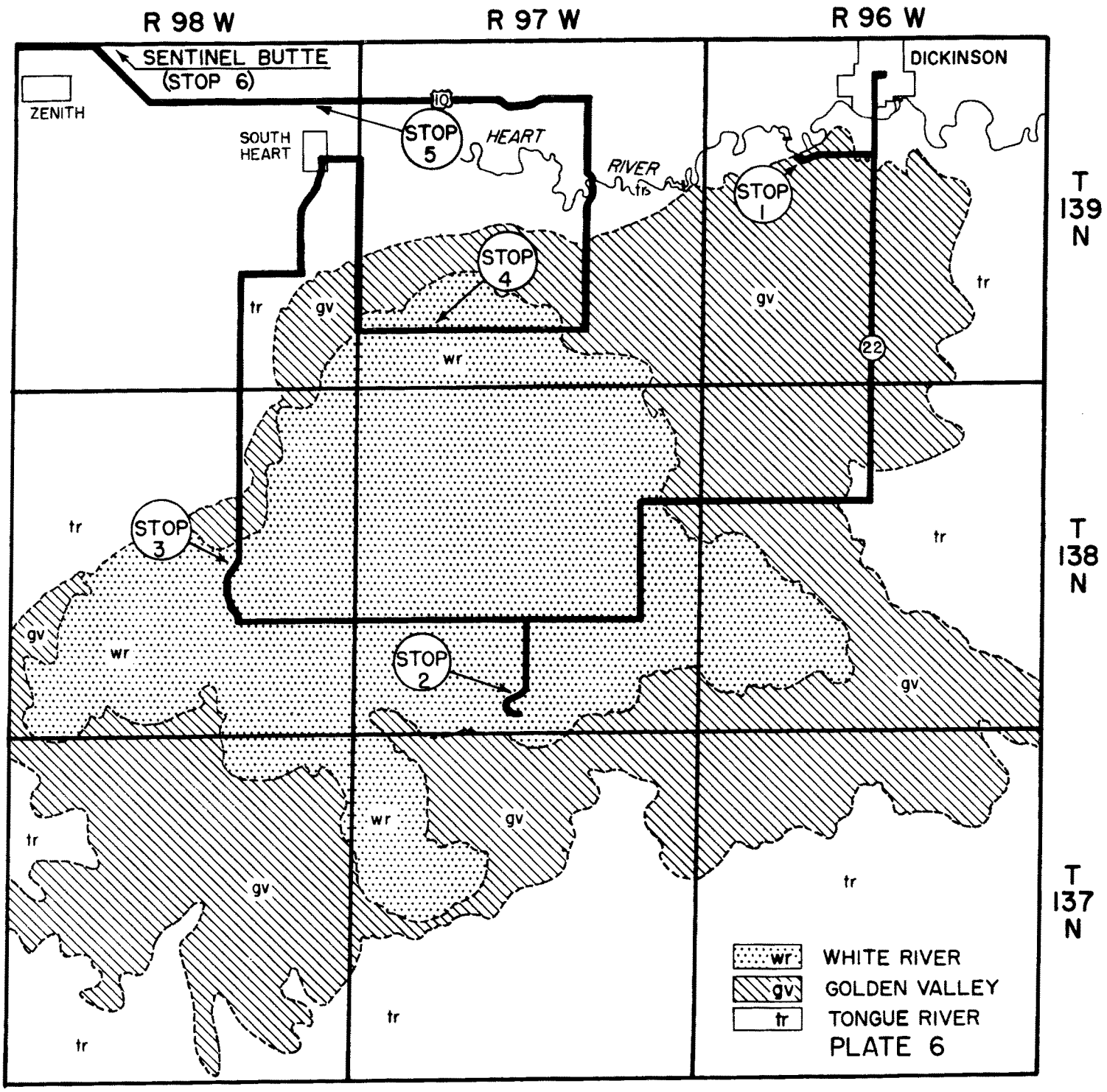


Fig. 3 - Buttes of White River formation unconformably overlying the Golden Valley formation, Little Badlands, stop 4. Slanting contact is shown at the left of picture.



GEOLOGIC MAP AND ROUTE OF FIELD TRIP
DICKINSON AREA