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Guidebook for Geologic Field Trip in the WILLISTON AREA, NORTH DAKOTA

by

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Grand Forks, North Dakota, 1957

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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 is 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 Williston, especially deposits and events which shaped the landscape in the Williston-Watford city area. The trip, about 140 miles in length, leaves on U. S. highway 2 north out of Williston and follows this highway through Ray to the "Iverson road". It follows this road to the south, crosses the Missouri River on the ferry, and continues south through Charlson and the Blue Buttes oil field to N. D. highway 23 which it follows westward into Watford City; from Watford City the trip proceeds on U. S. highway 85 back to Williston (see Plate 6).

The writer gratefully acknowledges the assistance of Mr. Louis I. Larson and Mr. C. B. Folsom, Jr., in preparing 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 emplyed 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 south and east of the Williston area, only two formations will be seen on this trip. The lower of these is the Tongue River formation of Paleocene age and the upper is the Golden Valley formation of Eocene 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 area along the Missouri and Little Missouri Rivers. 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 parts 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. Although this bed is especially well seen in the Medora area, it dips beneath the surface before it reaches the North Unit of Theodore Roosevelt National Memorial Park. Thus all of the Tongue River formation exposed in the area north of the Little Missouri River lies within the Sentinel Butte member. It is these beds which form the bedrock in the area covered by this trip.

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 in the Williston-Watford City area. However, there are several harder sandstone beds within the Golden Valley formation which cap numerous buttes, known as the Blue Buttes, east of Watford City.

White River formation.- The White River formation of Oligocene age is the youngest formation deposited in North Dakota. It consists of a thick sequence of clays and siltstones, and local deposits of hard white limestone. It is this formation which holds up some of the highest buttes of the state such as HT or Black Butte, Sentinel Butte and the Killdeer Mountains. However it too, is rather easily eroded and will not be seen along the route of this trip.

Environment and Deposition

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 partial 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 jelly-like mass that eventually formed a binder for any wood particles falling into the swamp. The weight of other sediments deposited on the site 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.

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, they scarcely warrant naming as a distinct formation (see Plate 2).

All of the 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. 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 there are rather rare usually found only as separate bones.

Physiography

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

General Principles.- Before discussing the physiography of this area, it is necessary to discuss briefly some of the processes which have gone into the making of the landscape which we see today. Generally speaking, there are any number of geological processes which could be discussed, but the two most important from the standpoint of landscape formation in this area are the work of running water and the work of glaciers.

The work of running water can be largely described as that work done by streams and running water other than streams, particularly sheetwash. When rain falls it may do any one of several things. It may sink into the ground, it may evaporate, or it may run off. If the first two things happen, it is not of immediate interest to us; but if run-off occurs, it is certainly of interest to us from the standpoint of geological work done.

Water falling on an initial slope first runs off in the form of sheetwash; however, as time goes on and initial irregularities are accentuated by the water running off in a sheet, the run-off tends to become concentrated in certain well-defined paths. These paths are used time and time again as more and more water falls on this slope until an intermittent stream is developed. A stream which flows only part of the year is classified as an intermittent stream.

When an intermittent stream cuts down deeply enough so that it intersects the underground water table, the underground water table will then feed the stream and it will flow the year around. This, then, is known as a permanent stream.

In the early stages of stream development, the cross sectional topographic profile of a stream will tend to be V-shaped. In other words, the stream is still actively cutting downward and is not swinging from side to side cutting the banks. Actually the stream itself does a relatively small amount of cutting as far as the V is concerned since it cuts only at the bottom of the V. Most of the material from the sides of the valley is brought into the stream by the processes of mass wastage which include creep, landslides, and rockfalls. This material is dropped into the stream and is carried away by the stream. The stream, therefore, acts not only as an eroding* agent but also as a carrying agent. This stage of stream development is called youth, and the stream is said to be youthful.

As time goes on the stream becomes older from the standpoint of topographic age. It reaches down to what is known as base level. This is the lowest level to which a stream can cut; and it is determined by the level of the body of water into which the stream flows or even temporarily by some other obstruction such as a layer of hard rock. Base level is reached only at the lower end of a valley, for enough slope must remain upstream to maintain the flow of water. At this stage the stream begins to swing from side to side, cutting first one bank and then the other. The end result of this is a valley which is more U-shaped than V-shaped and tends to have a rather broad flat bottom. This is the mature stage of stream development.

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*Erosion in the broadest sense includes all of the processes by which earthy or rock material is loosened and removed from any part of the earth's surface.

This bottom, of course, is first cut by the actual lateral swinging of the stream, however, it is further accentuated by the deposition of material on the stream bottom. If the area in which the stream flows is uplifted, the stream will again start downcutting and will form a new valley bottom. The sands, gravels, and clays deposited on the old valley floor will be cut away leaving banks on either side which are known as terraces. There are many well developed terraces in this area. Good terraces can be seen along Little Muddy Creek north of Williston, Cherry Creek near Watford City, and along the Missouri River.

The second major process which has been most important in the formation of the landscape in this area is that of glaciation.

A brief description of how glaciation works is in order at this point. During the Pleistocene period of geologic time (see Plates 2 and 3), to the north of us in Canada there were large accumulations of ice each year until they reached thicknesses of several miles. This was caused by the fact that there was more snow accumulating during the winter than was melting in the summer. As a result of this, large ice masses accumulated, similar in many respects to those which are found in the Antarctic continent today as well as on the ice cap of the island of Greenland.

As the ice accumulated to great thicknesses, it began to flow outward by plastic deformation within the ice mass itself. The edges of the ice sheet moved most rapidly and tended to conform to pre-existing topography. As a result of this the edge of the ice sheet became quite lobate or irregular.

As the ice moved forward, it did a considerable amount of erosion and picked up a great amount of material and incorporated it in the body of the ice. This material was ground up as the ice moved along with some of the material being ground very fine like clay. Other stones which were harder tended to resist this grinding action. Such material, when deposited by the glacier, forms an unsorted, non-stratified sediment called till. Till is composed of stiff clay full of rocks varying in size up to boulders. Of particular interest in this area is the predominance of granite and limestone boulders in the glacial till and in the outwash associated with the glacial till. These materials are not native at the surface in North Dakota; and it is apparent that they have been carried by the glacier to their present position, many hundreds of miles in some instances, south of the outcrop from which they came originally. However, most of the material which was deposited by the glacier was relatively local in origin and probably was moved, on the average, less than 25 miles.

When the edge of the ice sheet reached its maximum extent, it began to drop material rapidly (see Plate 4, Fig. 1). This was particularly noticeable at the forward edge of the glacier where the melting probably just about balanced the forward flow. This resulted in a deposit having a very characteristic knob and kettle type topography known as an end moraine. As the ice front moved backward on melting and then stopped temporarily, it left similar moraines, although somewhat smaller; these are known as recessional moraines.

Material deposited directly beneath the ice is spoken of as ground moraine. It has a swell and swale type topography and is not so pronounced in its relief as is the knob and kettle topography of the end or recessional moraines.

Water, of course, is important in modifying the effects of glaciation. As the ice melted, great floods of water washed out in front of the ice tending to carry with it much of the material which was imbedded in the ice and also that which had been deposited in front of it. This material washed out in front of the ice tends to be somewhat rudely bedded and is referred to as outwash. Other glacial features associated with material being deposited at or near the glacier front are kames, kame terraces, and eskers.

Kames (see Plate 5, Fig. 1) are usually formed by streams of water on top of the ice which flow into a hole in the ice known as a moulin or plunge hole. Some of the sands, gravels, and clays carried by the water are deposited in the hole. When the ice walls melt the material in the hole will slump, and the resulting deposit is a more or less cone-shaped mound, known as a kame.

As might be expected, kames vary a great deal in size. Kames as high as 120 feet and with a diameter of one third of a mile at the base, are known in North Dakota.

Kame terraces are found in this area, particularly along Little Muddy Creek, and they are formed somewhat as follows. As the ice was in its waning stages, the ice bodies occupying pre-existing valleys were naturally somewhat thicker than those on the upland. As a result the ice masses in these areas tended to remain longer. When they began to melt, the melting was most rapid where it was in contact with the rock surfaces. This resulted in streams forming on either side of the tongue of ice occupying these valleys. These streams as they flowed along carried with them considerable amounts of material which were deposited in the bottoms of streams. These valleys essentially had rock walls on one side and ice walls on the other. Naturally, as time went on and the ice melted, the material deposited by these streams tended to collapse and assume the angle of repose of this material.

Eskers are the result of deposition by glacial streams flowing in or under the ice. With the melting of the glacier these deposits remain as long, narrow, winding, essentially flat-topped landforms. No good examples of eskers are to be seen along the route of this trip, however.

Glacial History.- Prior to the advance of the glaciers the Missouri River flowed northeast towards Hudson Bay from a point near Culbertson, Montana, past the present towns of Grenora and Crosby, North Dakota. The Yellowstone River flowed past Williston through the present valley of Little Muddy Creek to join the Missouri River in the Crosby area. The Little Missouri River did not make a sharp bend to flow east in the area south of Watford City as it does today, but continued its northward course through Cherry Creek, Tobacco Garden Creek, and perhaps the present White Earth Valley. High-level terraces and wide valleys through the upland mark the course of these old pre-glacial rivers.

As the glaciers advanced from the north, they blocked this north-flowing drainage system and diverted the streams eastward. Till, outwash, and kame terraces are to be seen along the route of the trip within these old channels. Subsequently, these channels became the spillways for vast amounts of meltwater from the glaciers, and the valleys were cut down through the glacial deposits leaving several levels of well-defined terraces along the valley walls. Hence, some of these levels are terraces cut in bedrock by the pre-glacial streams and some are terraces formed in glacial or post-glacial deposits. In general, however, both types of terraces present the same appearance, and only close examination of the material within a terrace reveals the manner of its formation.

The principal end moraine in North Dakota is part of the great complex of terminal moraines known in South Dakota as the Altamont moraine. This great band of end moraines, lying on the pre-glacial bedrock escarpment and thus forming the Coteau du Missouri, sweeps in an arc through North Dakota and is aligned with a similar set of moraines known as the Max morainal complex which trends northwest from Max, North Dakota, to the northwest corner of the state (see inset map Plate 1). The route of this trip along U. S. highway 2 lies in the very southern edge of this great end moraine. South of U. S. highway 2 the road trends off of this moraine to the Missouri River. South of the river the glacial drift becomes, in general, much thinner and the topography does not have the knob and kettle appearance of the morainal area to the north and east.

ECONOMIC GEOLOGY

Oil is the newest addition to the mineral wealth and natural resources of the state. It has received much attention in the Williston area since the discovery of oil on April 4, 1951, in the Amerada Petroleum Corporation's now famous Clarence Iverson No. 1 well south of Tioga. In the six and one-half years since the discovery of oil in North Dakota there have been 47 million barrels of oil (a barrel of oil is 42 U. S. gallons) produced from a total of 897 wells in the state. Of this, over 44 million barrels have been produced in the fields along the Nesson anticline. Of the 40 oil fields in North Dakota today, 17 of these containing a total of 812 wells, along this great structure. The Nesson anticline is a broad, gentle, upwarp in the rocks of the earth's crust. Since oil and gas are lighter than water they migrate upward through porous layers until they are trapped by a non-porous bed at the crest or upper portion of the anticline. Although the principal oil-bearing formation is the Mission Canyon of Mississippian age, there are several oil-bearing zones in the subsurface of North Dakota. As an illustration of this fact, it is interesting to note that the discovery well for North Dakota, the Clarence Iverson No. 1, first produced in the Upper Silurian at 11,600 feet; it was then plugged back and temporarily completed in the Devonian at 10,500 feet; but was plugged back again and finally completed in December, 1951, at about 8,500 feet in the Mississippian Mission Canyon formation.

South of the turn off of U. S. highway 2, the trip goes through the Beaver Lodge, Charlson, and Blue Buttes fields. Flowing, pumping, and drilling wells are to be seen along the route. Wells being drilled are easily distinguished by the tall derrick or "rig", while flowing wells can be told from those "on the pump" by differences in the structures associated with the well (see Plate 5, Figs. 1,2). Just before leaving U. S. highway 2 the gasoline plant of the Signal Oil and Gas Company can be seen in the distance. It is interesting that while gasoline, propane, and butane are the principal products of this plant, oil and sulphur are by-products. To September, 1957, the plant has produced 76,570 barrels of oil and 27,000 long tons (a long ton is 2,240 lbs.) of sulphur.

Although oil is, indeed, extremely important, this area is richly endowed with other natural resources. Terrace sands and gravels, and "scoria" are extensively used for surfacing roads. Many lignite beds are present in the Tongue River formation, and lignite has been mined locally for many years. Many of the sands and sandstones in the area bear ground water which is of inestimable value; and although it is often taken for granted, one should not forget the minerals weathered from the underlying deposits, which when combined with the organic material of decaying plants, form the basis of the fertile soil for farming in the area.

As yet undeveloped, but a possible source of future industry are the thick deposits of salt deep beneath the surface (especially in the Charles, Opeche, and Spearfish formations; see Plate 3).

REFERENCES FOR ADDITIONAL READING

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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.

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There are field maps on the scale of two inches to the mile showing the location of all North Dakota wells listed in the price list of the North Dakota Geological Survey, mentioned above.

WILLISTON FIELD TRIP ROAD LOG

0.0

Assemble facing north on U. S. highways 2 and 85 along west edge of Harmon Park north of 11th Street.

1.2

Begin divided highway. Note the broad valley of Little Muddy Creek. Prior to the Pleistocene or glacial times, the Yellowstone River flowed north to Hudson Bay in what is now the Little Muddy Creek valley. The Missouri River also flowed north at Culbertson, Montana, past Crosby, North Dakota. When the glaciers advanced from the north they blocked this northward drainage and turned the Missouri River east, to join the Yellowstone and flow in its present course.

.3

Airport west of highway.

2.9

The highway here is on the upland surface. Note the broad valley to the east. This obviously is not a valley carved by small Little Muddy Creek.

.1

STOP 1. Pull well off the highway. BE CAREFUL OF TRAFFIC. Till in road cut just north of Grand View Motel.
Till is tough, stiff clay which is full of rocks varying in size up to boulders (over 10 inches in diameter). It is not bedded and not sorted according to size but all mixed together. Dig into the till and it is found to be brownish gray clay with many pebbles.
Note that these pebbles are of granite, quartzite, schist, and other igneous and metamorphic rocks foreign to this region. They have been transported by the glacier to this area from their place of origin in Canada.
The upland surface is all covered by till in this area (where it has not been subsequently eroded away) spread as ground moraine underneath the glacier (see Plate 4, Fig. 1).

1.4

Valley of former tributary of Pleistocene Little Muddy Creek to east. Note that the till here is lighter in color and more sandy. It has probably been partially reworked as outwash by meltwater from the glacier (see Plate 4, Fig. 1).

1.7

Note erratic boulders in fields on both sides of highway. Erratics are boulders which are foreign (or erratic) to this area that have been brought here from Canada by the glacier.

1.5

Old U. S. highway 2 goes east. Continue north.

.8

Note small low-level terraces in creek which was tributary to the Pleistocene Little Muddy Creek. Road cuts in till on sides of this valley indicate that the valley was cut in preglacial times as a tributary to the preglacial Yellowstone River which flowed north in the present Little Muddy Creek valley. This tributary valley was then filled with till and later recut by glacial meltwaters when this valley acted as a distributary for a vast quantity of meltwater. At one stage, the stream was flowing at the level of the low terraces, but it later cut farther down leaving little level benches or terraces along the sides of the valley.

.8

Look back to southwest to small outcrop of the Tongue River formation (see Plate 3).

2.1

Curve to right on new U. S. highway 2. U. S. highway 85 goes on north. Here we enter the preglacial Yellowstone River valley.

1.2

Small bridge over Little Muddy Creek.

.6

Note sand ridges and absence of till at the surface in valley bottom. The sand ridges are glacial outwash sand built into sand bars when this broad valley was carrying vast amounts of meltwater south to the present Missouri River.

2.5

Gravel pit south of highway in kame terrace. This general terrace level is more conspicuous to southeast when traveling west. It can also be well seen on old U. S. highway 2.
Kame terraces are built when streams flow along the edges of the ice which occupies pre-existing valleys. This meltwater naturally carried a great amount of material which was deposited between the old valley wall and the ice. When the ice melted, the material slumped to the angle of repose leaving a general but rather rude terrace level.
In this deposit there are big (two to three feet in diameter) boulders and a great many six inch cobbles.

2.2

STOP 2. Kame at edge of upland with much cross-bedded sand and gravel. Pull well off highway. BE CAREFUL OF TRAFFIC. Cross to north side of highway and examine the characteristics.

A kame is formed by a stream of water on top of the ice which flows into a hole in the ice known as a moulin or plunge hole. Some of the sands, gravels, and clays carried by the water are deposited in the hole. When the ice walls melt, the material in the hole will slump and form a more or less cone-shaped mound such as this.
Note the thin beds of sand and how these are cross-bedded, that is they are slanting toward each other instead of being horizontal. The fine yellowish beds are composed of silt.

Note the streak of lignite near the top of the cut. Fragments of the lignite in the bedrock were torn up by the glacier and redeposited here.
Contrast the well bedded, well sorted appearance of this outwash with the till that you have just seen. This is because the material here has been washed and sorted by meltwater instead of being merely dumped by the glacier
In this area the highway east is in ground moraine spread by the glacier (see Plate 4, Fig. 1). Ground moraine is characterized by a swell and swale type topography. Note the many rock piles of glacial erratics in the fields. There are also many low road cuts of till east of here.

2.1

Old U. S. highway 2 joins the new highway from the south.

1.5

Beaver Creek Valley and Ray ahead.

1.4

West edge of Ray.

.5

Underpass.

3.5

Gravel pit one-half mile south of road in glacial outwash gravels along small tributary of Beaver Creek.

3.4

Midway Drive-in Theater north of highway.

1.1

Town of Tioga and the Signal Oil and Gas Co. gasoline plant visible to the northeast. This plant extracts the gasoline, propane, butane, and sulfur from gas from the field separators. The sulfur is shipped out by rail, the dry gas piped to Minot, and the oil, which is a by-product, is put with the rest of Nesson Anticline oil and piped to the Mandan refinery.

1.6

Turn right (south) on the "Iverson Road" at Tioga Ferry sign. (this is one mile west of N. D. highway 40 to Tioga).
East of the road many flowing and pumping wells of the Beaver Lodge field and the collecting tanks for the wells are visible. Three kinds of tanks are seen. There are the short large tanks which are the lease storage tanks; these store the oil on the lease property before it is measured and then run into the pipeline to the refinery. The tall tanks with the stack on them and with fire in them are treaters; these separate water from the oil by use of heat and chemicals. The tall tanks without a stack are separators which separate the gas from the oil by lowering the pressure and by a series of baffle plates within the tanks. The gas then goes to the Signal Oil and Gas Co. gasoline plant and the oil into the lease storage tanks.

1.4

The Amerada Petroleum Corporation's Edward Kvam No. 1 pumping well. You will notice that some of the wells are actively pumping and some are not. This is because of the limitation of their monthly allowable quota of production or their "allowable". The State Industrial Commission regulates the amount each well can produce each month as a conservation measure based on spacing of the well, depth, and monthly consumer demand.

3.4

Turn left (east) into the site of the Amerada Petroleum Corporation's Clarence Iverson No. 1.
STOP 3. This is the discovery well for North Dakota. A granite monument at the site bears the inscription:

OIL WAS FIRST DISCOVERED
IN NORTH DAKOTA BY AMERADA
PETROLEUM CORPORATION
APRIL 4, 1951

THIS WILLISTON BASIN DISCOVERY,
CLARENCE IVERSON NO. 1
OPENED A NEW ERA FOR
NORTH DAKOTA AND REAFFIRMED
THE CONFIDENCE OF HER PEOPLE
IN THE OPPORTUNITIES AND FUTURE
OF THIS GREAT STATE

DEDICATED OCTOBER 25, 1953
TIOGA, NORTH DAKOTA

The actual well is a flowing well lying just southeast of this monument (see Plate 5, Fig. 1). Flowing wells can be easily spotted by the "Christmas tree" or set of control valves instead of a pump.
The original discovery of oil on April 4, 1957, was in the Silurian (see Plates 2 and 3) at 11,630 to 11,720 feet. However, because they later found more oil above this, the well was plugged back and completed at 8,520 to 8,528 feet in the Mission Canyon formation of Mississippian age. It tested at 677 barrels of oil per day under 3,821 pounds per square foot of pressure. As of July, 1957, after producing 158,000 barrels of oil, it still flows at over 200 barrels per day under 2,930 pounds per square foot of pressure.

.5

Turn left (south) on road to ferry.

.7

View south to Missouri River.

1.6

Road cut in pebbly till.

.8

Lignite of the Tongue River formation of Paleocene age (see Plates 2 and 3) below till in cut behind pump west of road. The oldest formation in the Williston area is the Tongue River formation which is young geologically speaking even though it was deposited about 60,000,000 years ago. The river bluffs to be seen ahead are of this formation. Actually this is the upper part of the Tongue River or the Sentinel Butte member. The Tongue River formation composed of shale, sandy and lignitic shale, and lignite, was deposited on a broad plain on which ran many sluggish streams through swamps and marshes. Decaying vegetation of these swamps formed the lignite after the gases were driven off. What remains is mostly carbon and some woody plant material.

2.4

Road west to Williston. Continue south.

.3

Road to east. Follow signs to ferry since the ferry landing changes depending on river conditions. If the river is low this road should be followed to the landing.
Continue ahead over hill to Stop 4, however, and return to this road if necessary.

.3

Road curves to right around buttes of the Tongue River formation.

.8

Note Thompson Lake or Garrison Dam Reservoir flooding the bottom land.

.5

"Scoria" pits east of road.

.2

Turn left off road and drive to pits.
STOP 4. "Scoria" pits (see Plate 5, Fig. 3).
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; this caused 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 burnin g 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. Most of the deposit here is especially sandy. There is also much of the melted glassy type.
"Scoria" is extensively used as road gravel and occasionally as a unique pottery glaze.

.2

Turn left (south) on road to ferry. (Or return north two miles to road to east if conditions demand.)
After leaving pits at Stop 4 you are traveling on a sloping terrace of former Missouri River when it flowed at a higher level.

1.1

Turn right (west) and follow winding road to ferry which lands at different points depending on conditions. On the bottom lands here there are numerous pits in gravel deposits of the Missouri River. The ferry leaves the north bank on the hour and the south bank on the half hour.

Ferry ride across Lake Thompson (old Missouri River).

From south landing the lowest well to be seen to the northeast is Amerada's J. G. Viall Tract 1, No. 2. This well is located on the north bank but by directional drilling it was completed out under the river almost one-fourth mile away. Now under 15 feet of water to the east is the Investors Oil Co. U. S. A. No. 1 well. The valves for this well are controlled by divers; but when winter sets in, it will be necessary to build a mound of some sort for location of the "Christmas tree".

South ferry landing.

.6

Turn right (west) past Amerada's Bert Boots No. 1 well (NW 1/4 SE 1/4, Sec. 32, T. 154N., R. 95W.). This well and those to the south of here are in the Charlson field.

.2

Turn left (south). The cut banks of the stream just west of the corner are Missouri River terrace deposits of silt.

.25

Small wooden bridge. Following winding road to south. This road affords an excellent view of the Sentinel Butte member of the Tongue River formation (see Plate 5, Fig. 4).

.65

Thick yellow sandstone in the Tongue River formation.

.3

Bluff of typical Tongue River east of road with "scoria" bed near the bottom. Behind and to north of hillock of "scoria" is the lignite which burned to form the "scoria". When fire burned the lignite so far back from the outcrop that it could no longer get oxygen, the fire was smothered. Erosion later exposed this outcrop so that the lignite bed which burned to form the "scoria" is now seen.
Note the gullied badland type of erosion. 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 with soft rocks and where there is little plant cover to protect the land surface from torrential downpours.
Also note the limonitic sandstone which caps pedestal rocks farther up the road. This sandstone is cemented rather hard by iron oxide or limonite ($Fe_2O_3.2H_2O$) which imparts the yellow and brownish colors to the rocks.

.5

In bluff east of creek note "scoria" at levels on the hillside where lignite is visible to the south at the same level.

.7

Till on top of Tongue River below the Hunt Oil Co. John Isaacson No. 2 well.

.05

Cattle guard.

.2

Top of hill. Look back to north to Missouri River bluff of the Tongue River formation. Note high ground of the Max end moraine (see inset map, Plat 1) in the distance to north.

.3

Note till and abundant erratic boulders on both sides of road. Blue Buttes capped by the Golden Valley formation of Eocene age can be seen on the horizon to south beyond the Amerada camp.

.25

Cattle guard. Texas Company office and camp west of road.

.35

Turn left (east).

.1

Turn right (south) over culvert.

.1

Turn left (east).

.1

Amerada Petroleum Corporation, Watford office.

1.8

Turn right (south).

.3

Charlson, N. Dak. The low swell to the south is a small recessional moraine.

2.7

Turn right (west).

.2

Turn left (south). South edge of the Charlson oil field. The wells ahead are in the Blue Buttes field. A field is named whenever the oil pool is not continuous with a named field.

3.4

Carman corner. Cross N. D. highway 23.

1.8

Many erratic boulders in field.

.3

Cattle guard.

.3

Entering wide level valley. This is part of the old drainage system of this area in Pleistocene times. Here the streams were flowing at this high level before those most favored by a complex set of conditions, cut down to their present level.

.5

Cattle guard.

.2

"Scoria" pit west of road.

.2

Cattle guard.

.3

Good view of isolated buttes east of road with cap of thick sandstone of the Golden Valley formation of Eocene age.

.5

Cattle guard.

1.0

Turn right (west). The well one half mile east of corner on the north side of the butte sits in Golden Valley sandstone. These are the Blue Buttes for which the oil field was named.

1.0

Turn left (south).

1.0

Turn left (east). If time permits, your trip leader will guide you to a drilling well in this area.

1.0

Turn right (south).

1.1

Turn right (west).

.15

STOP 5. Lignite seam in low road cut north of road.
This seam of brownish lignite is about 18 inches thick. It is underlain by gray clay called underclay. This is the soil in which the swamp vegetation that formed the lignite grew.

1.8

Butte of Golden Valley formation to south.

1.0

Turn left (south) on N. D. highway 23.

2.4

STOP 6. Butte of Sentinel Butte member, Tongue River formation, where road curves around the butte. This is an opportunity to observe the shales in the Sentinel Butte. Note the various colors of the shale and the nature of the bedding. Note also the gullied or rivulet erosion by rainwater. While the shale seems fairly hard now, it is easily eroded when wet.

1.3

"Scoria" pit east of road.

1.3

Highway curves right (west) at Johnson's Corner.

1.0

For next few miles there are low cuts of Tongue River shale, lignite, and "scoria" on both sides of the road. Note that most of the low buttes and hills have a cap of "scoria" since this resistant rock protects them from erosion. Also observe the red color in the field south of the road caused by "scoria"in the soil.

3.2

Watford City on horizon to the west. Here we are entering a broad, high-level, pre-Pleistocene valley. This valley was a tributary of Cherry Creek. The Little Missouri River once flowed north through Cherry Creek and Tobacco Garden Creek to the Missouri River (see Plate 6). With the advance of the ice from the north these pre-glacial streams were block and diverted eastward.

Tobacco Garden Creek has re-established its flow in its pre-glacial valley, but Cherry Creek flows northeast near Watford City and then makes a sharp bend to the southeast and empties into the Little Missouri. Between here and Watford City we will cross Cherry Creek twice.

As you ride along watch for the flat spaces that indicate terraces of the Little Missouri-Cherry Creek-Tobacco Garden Creek drainage system.

1.0

Bridge.

.5

Bridge.

.4

Bridge.

.6

On the north side of the highway there are low cuts in sand of the old valley bottom.

.3

Bridge. Note the hills of the Tongue River formation to north at the edge of the valley.

.5

Road cuts in cross-bedded sand south of the highway.

.6

Here we are on a Tongue River bedrock high area within this old valley system.

.8

Bridge.

1.3

Bridge over Cherry Creek.

1.2

Outcrop of cross-bedded Pleistocene sand.
Ahead is the broad pre-glacial valley of Cherry Creek.

1.5

Cross-bedded Pleistocene sand on both sides of highway.

1.5

Bridge over Cherry Creek. Hill to south is a small kame. A kame is a hill of sand and gravel which was deposited by a stream plunging into a hole in the glacier. When the ice melted it left this isolated conical hill.

.1

Watford City park and picnic grounds to south of highway.

.3

East edge of Watford City. The town is built on a Tongue River bedrock high with Pleistocene terraces high on the side of the hill. West of town is another wide valley which carried Cherry Creek at one time. The Pleistocene geology of this area has never been studied in any detail and the exact history of this old drainage system is not fully known. For instance, it is not known when Cherry Creek changed its course around Watford City or exactly why. On the other hand, the bedrock high of Watford City may have been an island in a large river.

.5

Turn left (south) through town.

.4

Junction with U. S. highway 85. Turn right (west) on U. S. highway 85 and N. D. highway 23.

.45

Silt and sand deposited in terrace (kame terrace ?) of old Little Missouri-Cherry Creek drainage.

1.0

Cross-bedded sand.

.3

Broad valley of old Cherry Creek-Little Missouri River well seen here.

.8

Going up out of pre-glacial valley.

.3

STOP 7. Cross-bedded Pleistocene sand. This is well cleaned and sorted sand deposited at the edge of the old drainage channel. Some of these clean sands may be wind blown and wind deposited sands associated with dry periods in glacial times. Examine the grains with a magnifying glass or hand lens. Most of the sand is the mineral quartz (SiO_2). Most sand is of this mineral but commonly the grains are coated with clay and cannot be well seen.

.2

Back on the upland. To the north are buttes of the Tongue River formation. To the south is the broad valley of Cherry Creek.

.6

Cross-bedded sand deposits. From here west is the rolling swell and swale topography of ground moraine. The ground moraine in this area has been extensively reworked by water, however; and there are many local deposits of sand with a few pebbles in the sand.

.2

Great Northern Railroad tracks.

1.5

Arnegard to north.

.4

Tongue River shale crops out in low cuts on both sides of the road.

.2

Bridge over Timber Creek which empties in the Missouri River to the north.

3.8

High buttes visible on horizon to south and northwest are all in the Tongue River formation.

.3

Road north to Rawson.

3.9

Bridge over Lonesome Creek which flows northwest to join Charbonneau Creek which in turn empties into the Yellowstone River.

.9

Highway turns right (north).

1.2

Hill into Lonesome Creek valley.

.2

Bridge over Lonesome Creek.

.5

Highway curves right.

.3

Railroad tracks.

.4

Entering Alexander.

1.4

Ragged Buttes on both sides of highway are capped by thick brown sandstone in the Tongue River formation.

1.4

N. D. highway 23 turns west to Fairview and Sidney, Montana. Continue north on U. S. highway 85.

3.1

Note terraces in Camp Creek ahead northeast of highway curve.

.5

Bridge over Camp Creek. Highway climbs onto upland.

2.4

Look back to southeast and note old high level terraces in the Camp Creek valley.

3.6

Dropping down off the upland over a series of hills. Dissection of the upland by smaller streams near a large river is very common.

3.7

Highway descends through cuts in the Tongue River formation.

.5

Terrace west of road.

.3

Terrace deposits east of road. This terrace is partly a cut terrace (that is, a terrace cut in till by the river) and partly a depositional terrace; because there are deposits of both till and outwash gravel along the south bluff of the Missouri River. The Missouri River normally hugs its south bank through this part of its course. However, it changed course during flood stage and now flows below its left or north bank. During the ice jam in March, 1943, it nearly returned to its former course along the south bank but was prevented from doing so by extensive rip rapping which had been placed in its former course by the U. S. Army Corps of Engineers.

.5

Look back to southeast to the terrace levels.

1.7

Williston Irrigation Substation, Agricultural Experiment Station, North Dakota Agricultural College. Elevation: 1852 feet.

1.0

South end, Lewis and Clark Memorial Bridge over Missouri River. The bridge is about 70 feet above the water. The gradient (slope) of the river is about .8 feet per mile in this area.
There is till in terrace along the north bank of the river below the bridge.

.6

Riding on till terrace.

1.5

Junction with U. S. highway 2. Turn right (east) on U. S. highways 2 and 85. Here you are on the upland level.

.5

Note in the foreground to the southeast the gradual rise of the terrace to the upland surface.
We are riding on a cut terrace at about the level of the partial cut terrace on the south bank of the river barely visible at treetop level to south.

1.5

Here we are going off this terrace level. Note that there is till in the cuts on both sides of the highway. Thus the surface on which we have been riding since the junction with U. S. highway 2 is a terrace cut by the river in till which filled the pre-glacial Yellowstone River valley.

.7

On a lower terrace level here. Note the higher level to the north.

.3

Valley Drive-in Theater.

.3

Bridge.

.4

West edge of Williston. Here we go up on to a terrace of the high-level Yellowstone River on which Williston is built.

1.1

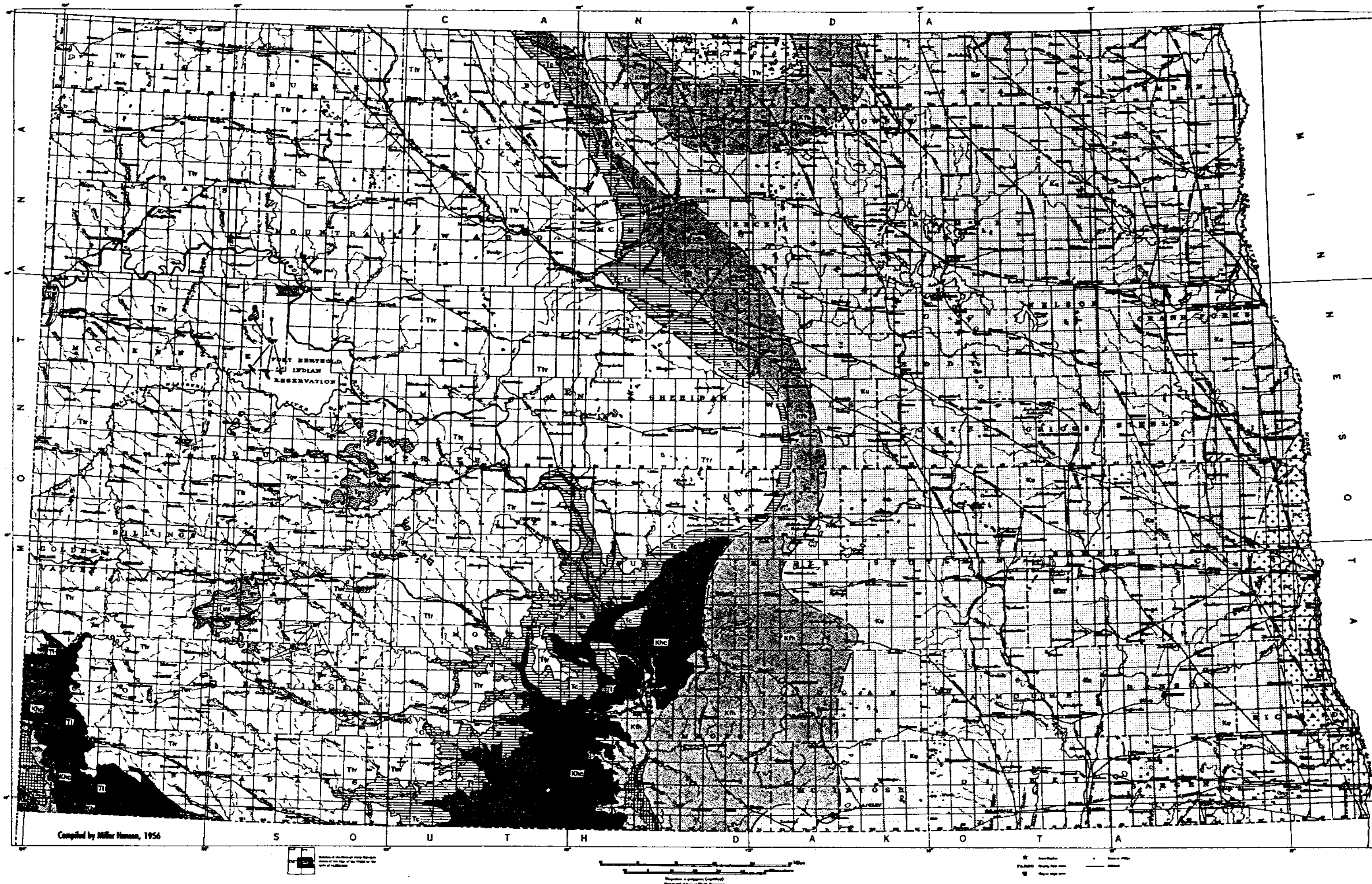
Highway turns left (north) through town.

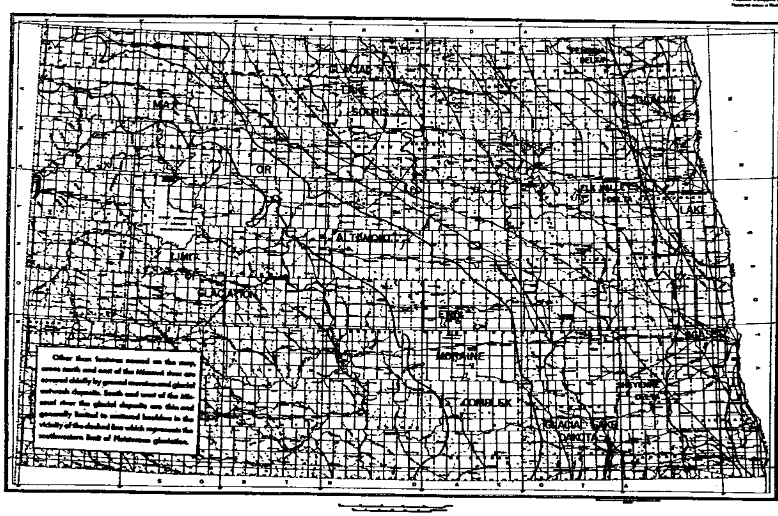
END OF LOG

NORTH DAKOTA GEOLOGICAL SURVEY

GEOLOGIC MAP OF NORTH DAKOTA

WILSON M. LAIRD, State Geologist





MAJOR GLACIAL FEATURES OF NORTH DAKOTA

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

Symbol	Name	Age
Twr	White River	Oligocene
Tgv	Golden Valley	Eocene
Ttr	Tongue River	Paleocene
Tc	Cannonball	
Tl	Ludlow	
Khc	Hell Creek	Cretaceous
Kfh	Fox Hills	
Kp	Pierre	
Ku	Chiefly Pierre, includes Colorado and Dakota groups.	
P€	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	
	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	
MISSISSIPPIAN		"AMSDEN"	
		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	

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.

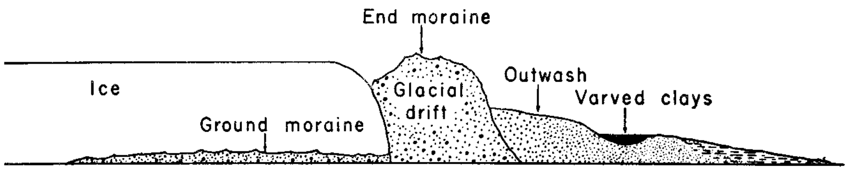


Figure 1. - Diagram showing glacial features associated with the front of an ice sheet.

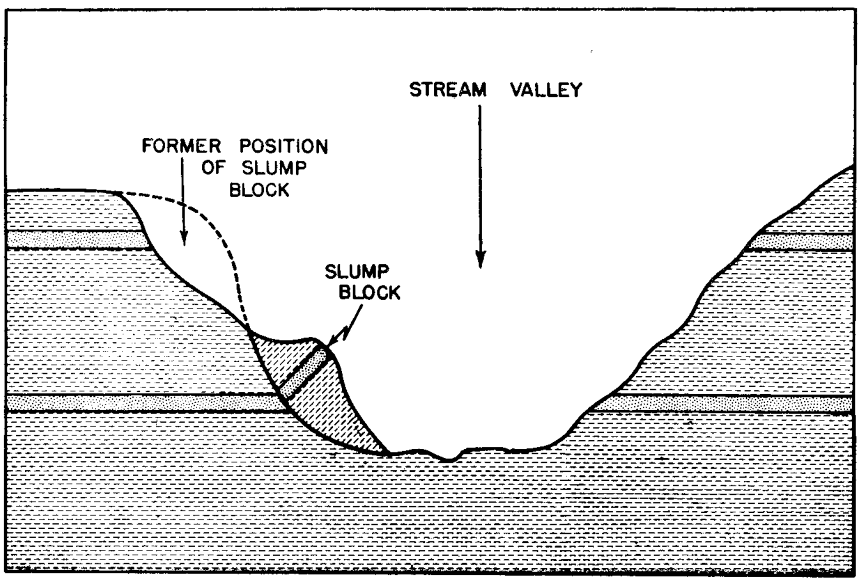


Figure 2. - Cross-section diagram showing a slump block or landslide caused by slippage on a clay or shale surface lubricated by ground water.

PLATE 4

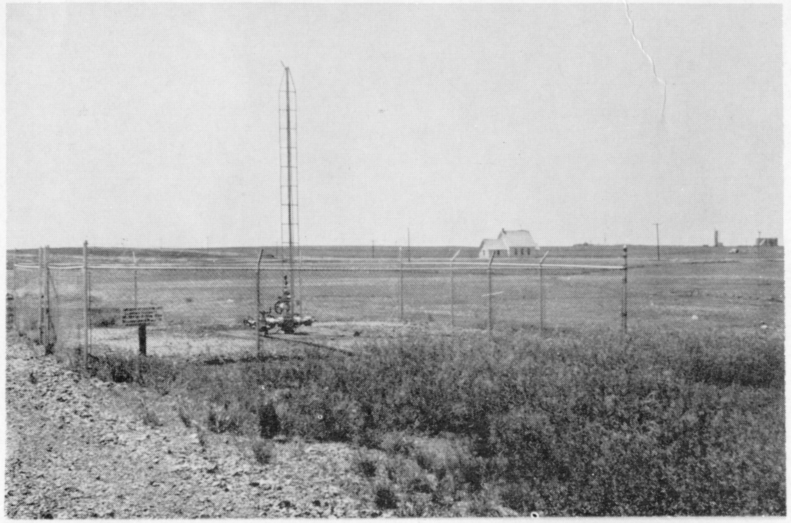


Fig. 1 - "Christmas tree" of flowing oil well. This is the Amerada - Clarence Iverson No. 1, the discovery well in North Dakota. Stop 3.

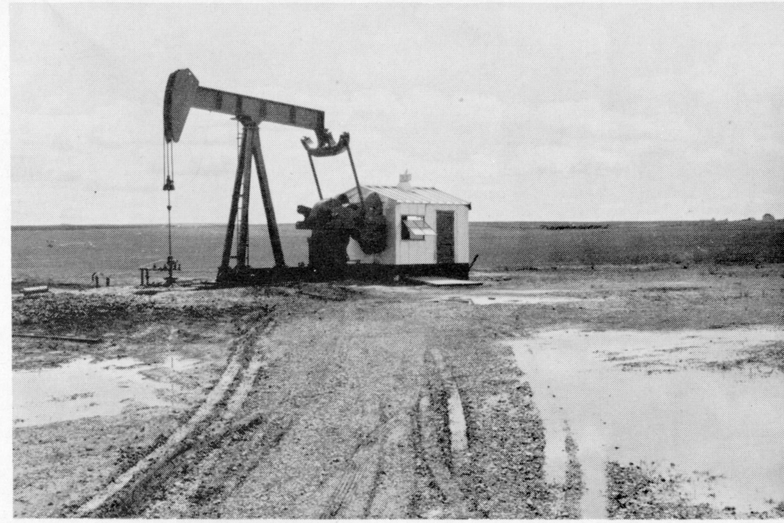


Fig. 2 - Pumping oil well in the Beaver Lodge Field.

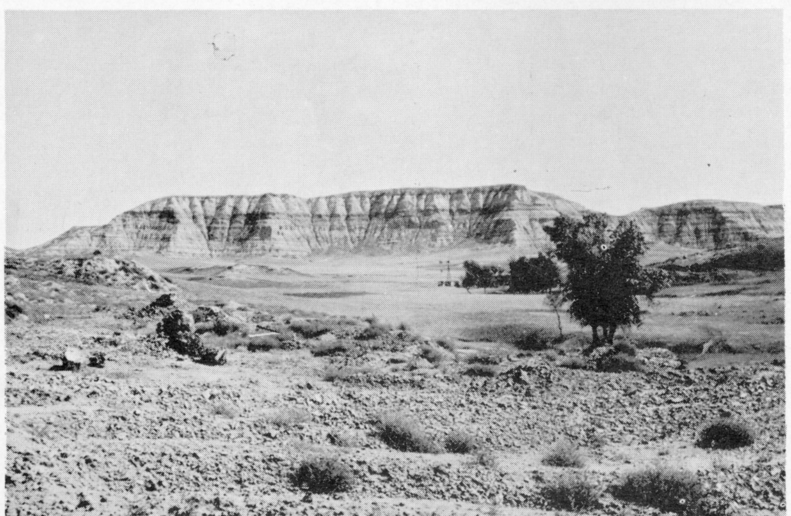


Fig. 3 - "Scoria" pit with bluffs of the Tongue River formation in background. Looking northeast from stop 4.

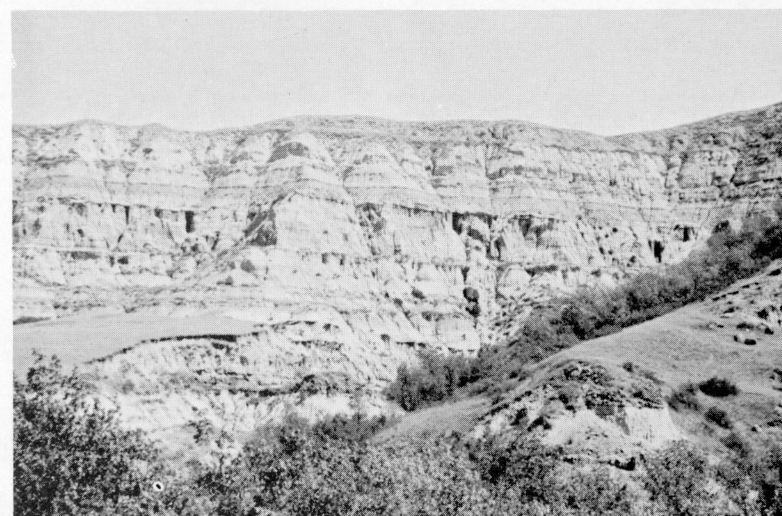
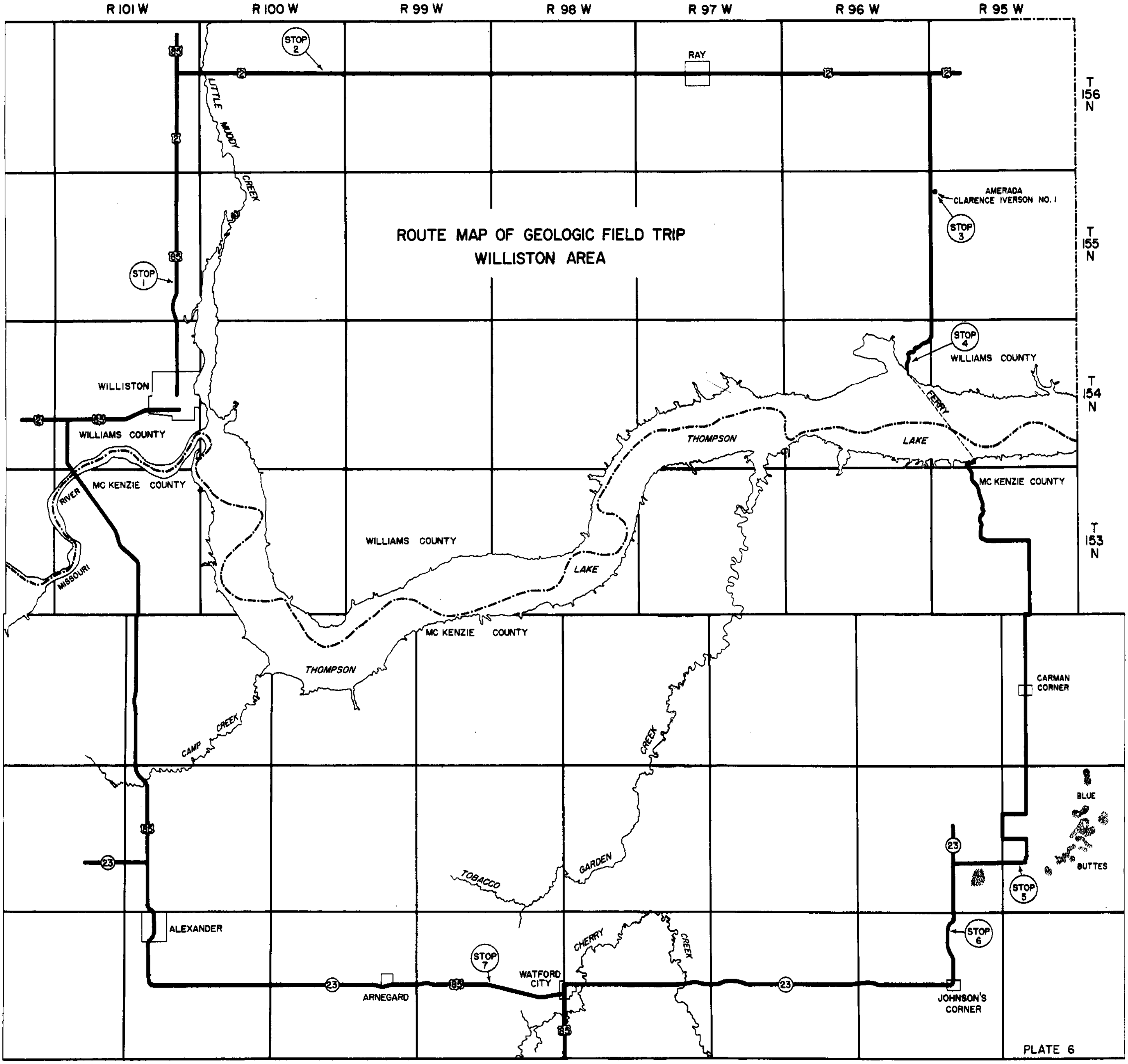


Fig. 4 - Bluffs of the Tongue River formation showing rivulet or badland type of erosion along road south of Missouri River ferry. Note small terrace remnant at left.


ROUTE MAP OF GEOLOGIC FIELD TRIP
WILLISTON AREA
R 101 W
R 100 W
R 99 W
R 98 W
R 97 W
R 96 W
R 95 W
T 156 N
T 155 N
T 154 N
T 153 N
T 152 N
T 151 N
T 150 N
STOP 1
STOP 2
STOP 3
STOP 4
STOP 5
STOP 6
STOP 7
RAY
AMERADA
CLARENCE IVERSON NO. 1
LITTLE MUDDY CREEK
WILLISTON
WILLIAMS COUNTY
MC KENZIE COUNTY
MISSOURI RIVER
THOMPSON LAKE
FERRY
CAMP CREEK
GARDEN CREEK
TOBACCO
CHERRY CREEK
CARMAN CORNER
BLUE BUTTES
ALEXANDER
ARNEGARD
WATFORD CITY
JOHNSON'S CORNER
23
85
2
PLATE 6