NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

Miscellaneous Series No. 2

Geology Month in Scouting

October 1957

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

by

Wilson M. Laird

Grand Forks, North Dakota, 1957

GEOLOGIC FIELD TRIP IN THE MINOT AREA

By
Wilson M. Laird, State Geologist

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 Minot. Emphasis is placed on glacial phenomena on this trip, especially the glacial materials associated with the outlets of Glacial Lake Souris. The Velva Mine of the Truax-Traer Coal Co. will also be visited. This trip covers about 115 miles and follows U. S. highway 52 south and east to Bergen. Route 52 is then retraced to Voltaire. County roads are followed from there westward to U. S. highway 83 which is followed north to Minot.

The writer acknowledges with thanks the assistance of Mr. Miller Hansen and Mr. F. D. Holland, 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 possiblility 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

Geological Processes Important in the Formation of Landscape in this Area

Before discussing the geological history 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 process 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.

---

*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. In the vicinity of Minot there are several areas which exhibit terrace deposits.

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 chart, Plate 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 Antartic 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 moraine.

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 washed out on or near the glacier front are kames, kame terraces, and eskers.

Kames (see Plate 5, Fig. 1) are usually formed by stream 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 the Souris River southeast of Minot 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.

As the ice front retreated, there was frequently exposed between the ice front and the end moraine, areas where the drainage did not take place and as a result large glacial lakes formed; some of them covered many hundreds of square miles. These lakes sometimes are spoken of as pro-glacial lakes because they are formed in front of glaciers.

In this area we had several such lakes, but the largest by far was Glacial Lake Souris. At one time this lake was connected by outlets to a large lake occupying the Red River Valley. This latter lake was known as Glacial Lake Agassiz.

Among the interesting things to be seen in the Minot area are some of the long linear ridges (see Plate 5, Fig. 3) in the area north and west of Balfour in McHenry County. The exact origin of these long, relatively even-topped ridges is not known. It is thought by some that they are formed by material dropping into crevasses in the ice where the ice sheet had become rather thin and was no longer moving very rapidly. The material fell into the crevasses; and probably in part, the glacial debris was washed in by water which was running along on top of the ice. However, others think that they are in a nature of an elongate drumlin formed by material deposited beneath the ice and later overridden by the ice, giving it its long linear and slightly undulating form.

GEOLOGY OF THE AREA

Preglacial Geology

The geologic history of the Minot area is primarily one of glaciation, however, certain statements should be made concerning the pre-glacial history because formations are present here which are older than those of the material deposited by the ice.

The bedrock which is found beneath the glacial drift in the Minot area consists of two formations. The lower of these two is what is known as the Cannonball formation, and it in turn is overlain by the Tongue River formation (See chart, Plate 3). The Tongue River formation is entirely non-marine in origin and it is the one which contains the lignite which is such a valuable economic resource in this area. The Cannonball formation in this area is apparently entirely marine in origin although it very likely was deposited in brackish or near shore water. Brackish water is a term used to define water along sea coasts in lagoons or bays which is mixed with fresh water from rivers and thus lacks the normal concentration of salts found in the water of the open sea.

The Cannonball and the Tongue River formations are parts of the Fort Union group of formations which are better shown in other areas (particularly in the southwestern parts of the state) than they are here. The Cannonball formation is interesting in that it was the last incursion of a marine sea into the center of the North American continent. It was deposited at the early stages of Paleocene time (See chart, Plate 2) which was approximately 60 million years ago. As this formation is traced southward and westward it grades into non-marine continental formations which like the Tongue River are also lignite bearing. In the southwestern corner of North Dakota, these non-marine formations are spoken of as the Ludlow formation. There they underlie and are closely associated with the Tongue River formation. It is not impossible that certain portions of the basal Tongue River formation may also intertongue with the Cannonball formation. The reason that the Cannonball formation is classified as a marine formation is because it contains marine fossils, or fossils shells of animals which are known to have relatives that live only under present day marine conditions. Such fossils have been found between Sawyer and Logan.

The Tongue River formation was deposited in lakes and swamps and by streams on an alluvial plain which probably sloped gently from the sea upward and westward toward the present day Rocky Mountains. At that time the Rocky Mountains were rising, and the materials being furnished to this alluvial plain to the east were both fine and coarse in nature. In view of the fact that the North Dakota area is farther from the source of supply, the materials deposited here are rather fine grained.

Here and there over this broad alluvial plain were many swamps in which large trees grew. Many of these trees were relatives of the present day Sequoia. As these trees grew and died, they fell into the swamp where bacterial action began to decay them. However, the bacterial action failed to decay completely the trees leaving an organic, jelly-like material which ultimately solidified to form the lignite which is so abundant in North Dakota.

As time went on these materials were covered by more sediments so that great thicknesses of the Tongue River formation were built up in North Dakota. As much as a 1000 feet or more of these sediments are present to the south and west of the Minot area. In this particular area, however, the Tongue River formation is probably only a few hundred feet in thickness.

After the deposition of these materials on the flood plain, the area was uplifted and erosion began anew. Since these beds dipped toward the south and west the formations were eroded most rapidly on the northeast side. This erosion resulted in an escarpment running in a northwestward-southeastward direction across North Dakota. This escarpment is the division between the Missouri Plateau to the south and west and the Central Interior Lowland to the north and east. This escarpment was formed prior to the first Pleistocene glaciation.

Glacial Geology

After this period of erosion the glacial ice began to move down from the north. The escarpment tended to retard the flow of the ice, and the ice moved forward in lobes tending to follow channels in pre-existing topography. One such channel was apparently a valley along the course of the present day Souris River. Eventually the ice climbed the escarpment; and, impeded in its forward flow, it deposited numerous end moraines on the edge of this erosional scarp thus increasing its height. Early French explorers called this prominent physiographic feature the Coteau du Missouri. (See Plate 5, Fig. 2).

Recessional moraines of this lobe were deposited as the ice front receded northward forming numerous undrained depressions. Large depressions were also formed between the major ice front to the north and the edge of the Coteau du Missouri to the south. These depressions filled with water from the melting of the ice and these lakes overflowed when they found outlets to the south. Thus Glacial Lake Souris was formed.

There are several large outwash channels in the Minot area. The first of these and the most southerly is found south and east of the Truax-Traer mines southeast and southwest of Velva. As the ice withdrew to the north, lower outlets were found. Some of these outlets drained southward and joined the James River and thus flowed into the Missouri Valley drainage. However, as the ice front retreated lower outlets to the east were formed and at one time there were several outlets to Glacial Lake Agassiz which occupied the present Red River valley from the Glacial Lake Souris area. One of these outlets joined the Sheyenne River; others flowed to the north and east into the Lake Agassiz drainage by way of the Pembina River valley in the northeastern corner of North Dakota.

These large glacial outlets or outwash channels can be seen today in the vicinity of Velva and Bergen. They are broad channels which are floored with gravel and frequently have gravel terraces on their sides indicating that the streams carving them had higher stages at one time. Here and there small subsidiary channels such as those north of Sawyer are found where temporary channels were developed due undoubtedly to temporary blocking of the larger channels to the south and west.

In the Denbigh area, considerable quantities of sand from Glacial Lake Souris are found. These sands have been piled into dunes by the wind; therefore, a very prominant dune topography is found in this area.

Apparently very little in the way of sediments outside of the Denbigh area were deposited in Glacial Lake Souris. However, the waves did have an affect on some of the ground moraine area particularly in the old lake bottom. In many places the waves planed off the glacial till leaving it relatively flat. Glacial Lake Souris was not a very long lived lake; however, and as a result did not develop many shore features.

REFERENCES FOR ADDITIONAL READING

General References

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

Specific References on this Area

Akin, P. D., 1947, Geology and Groundwater Conditions at Minot, North Dakota: North Dakota Groundwater Studies, No. 6.

Andrews, D. A., 1939, Geology and Coal Resources of the Minot Region, North Dakota: U. S. Geol. Survey, Bull. 706-B.

Brant, R. A., 1953, Lignite Resources of North Dakota: U. S. Geol. Survey, Circ. 226.

Brown, R. W., and Lemke, R. W., 1948, Newly Discovered Outcrops of the Cannonball formation in North Dakota: Science, Vol. 107, No. 2789, pp. 624-625.

Lemke, R. W., et al., 1950-1951, Preliminary Geologic Maps of the Minot, Velva, Sawyer, Benedict, and Kongsburg Quadrangles: U. S. Geol. Survey, Open File Reports (available for inspection in Grand Forks).

MINOT FIELD TRIP ROAD LOG

0.00

Starting point. Corner of Main and U. S. highway 2. Go east on U. S. highway 2.

.40

Turn right (southeast) on U. S. highway 52 at west end of overpass.

.75

Railroad crossing.
STOP 1. Glacial till outcrop. Note the fact that this till is not very stony. This is the till of the Souris River lobe with shale practically absent but lignite chips are found. Interbedded lenses of sand and gravel and silt can be noted. Limestones and dolomites (rocks containing lime, magnesium, carbon, and oxygen) are the predominant pebble types. Note vertical fractures or breaks in this outcrop. From here on we are proceeding down the valley of the Souris River, a valley carved in Pleistocene time but prior to last glaciation. This is shown by the fact that till covers bedrock walls and underlies valley fill which is about 100 feet or more in thickness.

1.20

Coming up on glacial outwash terrace consisting of sand and gravel with boulders up to 8 feet in length. The boulders suggest that this may be a kame terrace although there is no evidence of collapsed bedding. This terrace was likely formed by a stream running in a valley at the edge of the ice sheet between the ice and the valley wall.

.70

Cross new U. S. highway 52.

.40

STOP 2. Soo Line gravel pit. Turn left into pit. Note large boulders in pit. Some boulders are as much as 8 feet long. Turn around and go back to Highway 52.

.60

Turn left (southeast) on U. S. highway 52.

.60

We are now dropping off the terrace to the valley bottom. Upper two thirds of the valley wall consist of till irregularly underlain by 1-15 feet of sand and gravel representing old kame terrace. Lower one third of the valley wall is the Tongue River formation of Paleocene age thinly veneered by till. See Plate 3 for position of Tongue River formation.

1.20

Exhumed (or uncovered) kame terrace deposit of sand and gravel exhibiting extreme deformation of bedding due to collapse of ice wall which originally held the deposit in place. Steam plant to east is Northern States Power Bison Electric generating plant.

.75

Join new U. S. highway 52.

3.35

Road to Logan to east.

3.40

Small landslide area on west. Landslides are large or small earth slippages due to an unstable condition created by erosion of the foot of the slope or by water lubricating the plane along which the slippage can take place. Landslides are usually found along valley walls and are characterized by hummocky topography.

2.50

Entering Sawyer.

.80

Valley coal mine on right.

.50

Turn left (north).

.10

Railroad crossing.

.30

Bridge across Souris River. Ten ton load limit.

.30

These gravel deposits in this rather indistinct valley show the existence of a high level diversion channel. Through this channel the melt water stream from the ice sheet flowed when part of the valley at Sawyer was temporarily blocked by ice.

.90

Turn right (east) at cemetery. You are now driving over ground moraine.

1.00

STOP 3. Due south one half mile is Black Butte which is a kame 100 feet high and one third of a mile in diameter consisting of sand and gravel with bedding roughly parallel to slope (See Plate 5, Fig. 1). Till lenses are intercalated in the gravel. There is a small undrained depression on top. A kame is a deposit of material formed when water carrying this material along the surface of the ice plunges downward into a large hole in the ice. This "plunge" hole is called a moulin. The water then flows away under the ice leaving most of the coarser material in the "plunge hole". When the ice melts, the gravel is left and forms the deposit we see here.

.60

Turn around at road crossing and return to Sawyer.

1.60

Turn left (south) at cemetery.

1.50

Railroad crossing.

.10

Turn left (east) on U. S. highway 52.

1.30

Cannonball formation on right poorly exposed. This is the only marine formation of the Fort Union group (See chart, Plate 3). This formation is much better exposed in the Bismarck-Mandan area. The rocks of this formation are the last rocks of a marine origin laid down in the interior of the North American continent. The formation consists of usually loosely consolidated sandstones and clay shale. Poorly preserved fossils such as clams and snails are found in some of these outcrops.

4.90

Entering Velva.

.70

The road now rises out of the Souris River valley into the large Velva outwash diversion channel (or spillway) filled to a depth of 50 feet of gravel. This channel is about one and one half miles wide.

2.60

One half mile to left, back of the white house, the east valley wall of diversion channel is shown. Note how the present stream has cut into the terrace gravels.

.40

Central Power Electric Co-op steam plant. This plant furnishes power for 8 REA Co-ops in Central North Dakota. Peak production is 40,000 KW per hour. Up to 660 tons of lignite are burned per day to operate the steam generator.

1.90

Voltaire.

6.20

Bergen. This town is located in another outwash diversion channel called the Wintering River channel.

4.80

Leave spillway.

.40

Turn left on gravel road toward Karlsruhe.

.30

STOP 4. (Stay in cars). Look south. Highest butte is Dogden Butte. This is the first good view we have had of the Coteau du Missouri (See Plate 5, Fig. 2). This is the northeastern edge of the Missouri Plateau. It consists of an escarpment of bedrock (probably the Tongue River formation here) capped by glacial till.

3.40

STOP 5. This elongate northwest-southeast trending ridge is one of the most interesting glacial features seen on this trip. It is called locally Hog Back Ridge (See Plate 5, Fig. 3). It was used in the early days as a road because it was relatively level and straight. Its formation is not clearly understood. Probably it was formed under the ice as the ice moved in a southeasterly direction. It is in other words, an elongate drumlin type feature. It stands above the gently rolling ground moraine visible on both sides of the ridge. The nature of the glacial till forming it suggests strongly, however, that it has been modified slightly by water as the till is very sandy and silty. It may be a crevasse filling in the edge of the melting ice sheet.

.10

Turn right (south).

.10

Turn left (east).

1.00

Turn right (south).

1.35

Cross Hog Back Ridge again. Note its continuity in a northwest-southeast direction.

2.45

U. S. highway 52, turn right.

13.70

Turn left (west).

.50

REA plant on right.

2.30

N. D. highway 41. Turn left (south).

2.00

Cross railroad tracks. We are crossing one of the higher outwash channels. This one was entered and crossed before, near the town of Velva.

2.30

Turn right (west).

4.15

Turn left (south).

.60

STOP 6. Velva Mine, Truax-Traer Coal Co. Enter mine property and proceed to the end of the pits which is about 4 miles from the entrance. The Velva Mine of the Truax-Traer Coal Co. was opened in 1927. To date this mine has produced approximately 10.5 million tons. At the present it produces about 431,000 tons per year. The stripping shovel has a 22 yard bucket and the dragline has a capacity of 6 cubic yards. The coal loading shovel has a capacity of 7 cubic yards. The average depth of overburden stripped here is 55 feet and the average thickness of the coal is 14 feet (see Plate 5, Fig. 4). This is one of the larger lignite mines in North Dakota. North Dakota is the leading lignite producing State in the nation. Electric power can be very cheaply produced from lignite, making lignite one of our State's greatest potential natural resources.
Turn around; retrace route to entrance at main road, and proceed west.

.35

Old pits of Truax-Traer mine on left.

1.10

Turn right.

1.20

Glacial till exposed on both sides of the road.

.80

Turn left (south).

.50

You are now leaving the ground moraine area and rising up into the moraine capping the escarpment.

.50

Turn right (west). Now riding on low end moraine. End moraine is the glacial material carried by the glacier and is then dumped at the edge of the ice when it melts. The edge of the ice stood just south of this point or very near this point at the time the material seen here was deposited.

5.40

Kettle hole probably formed by ice block melting in place. This is probably ground moraine.

.90

Begin end moraine.

.80

Large kettle hole. Note steep sides. These steep sides may be ice contact faces, that is, places where the till was in actual contact with the ice block.

2.90

Junction with U. S. highway 83. Note the hummocky and irregular topography of the last 2 or 3 miles. Note also the many kettle holes, some of which are full of water. This is typical end moraine and is characterized by "knob and kettle" type of topography. This moraine has been named the Max moraine. Note also the change in farming when the topography becomes more rugged. There are fewer cultivated fields and more pasture. This shows man's adaptation to his environment. Turn right (north).

2.70

Series of large kettle holes on left filled with water.

2.30

Radar base on left. Approximate edge of end moraine.

2.00

Begin true ground moraine. Ground moraine is slightly irregular topography formed by the deposition of material directly under the ice. It has more subdued topography than that of end moraine. This type of topography is spoken of as "swell and swale" topography. Here the ground moraine has probably been modified slightly by the action of the waters of Glacial Lake Souris.

9.40

Recent stream cut in till. This stream is probably a post-glacial stream as are most of the streams now draining down the escarpment into the Souris River.

1.50

Experimental farm on left.

1.40

KCJB tower on right.

.90

Minot city limits.

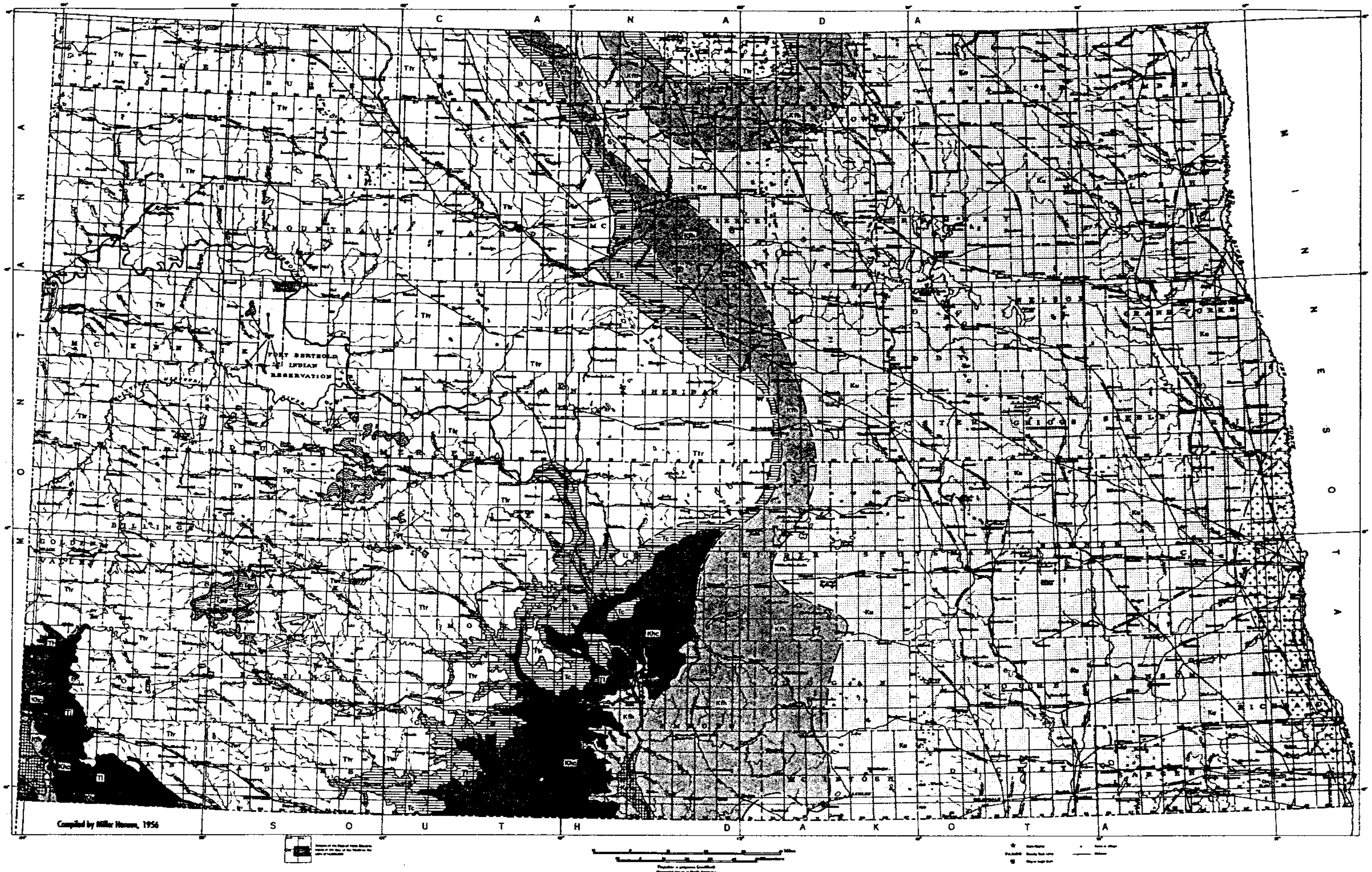
1.70

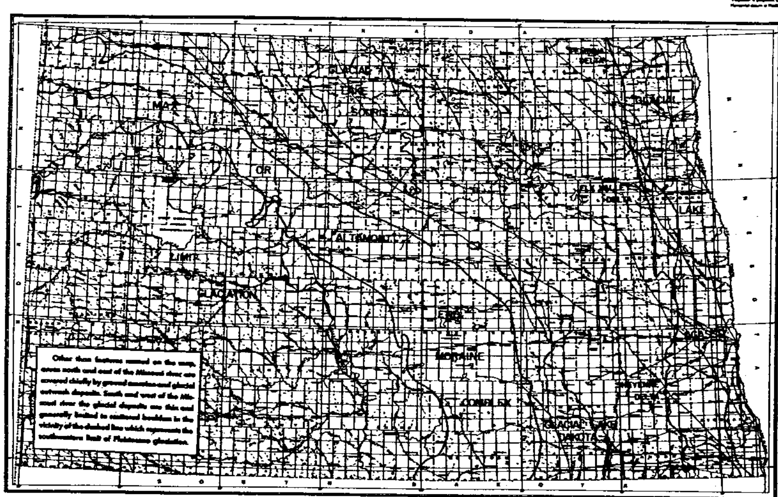
End of trip.

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

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	
	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	
		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.

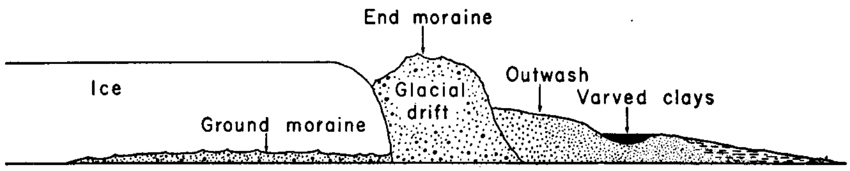


Figure 1. - Diagram showing glacial features associated with the front of an ice sheet.

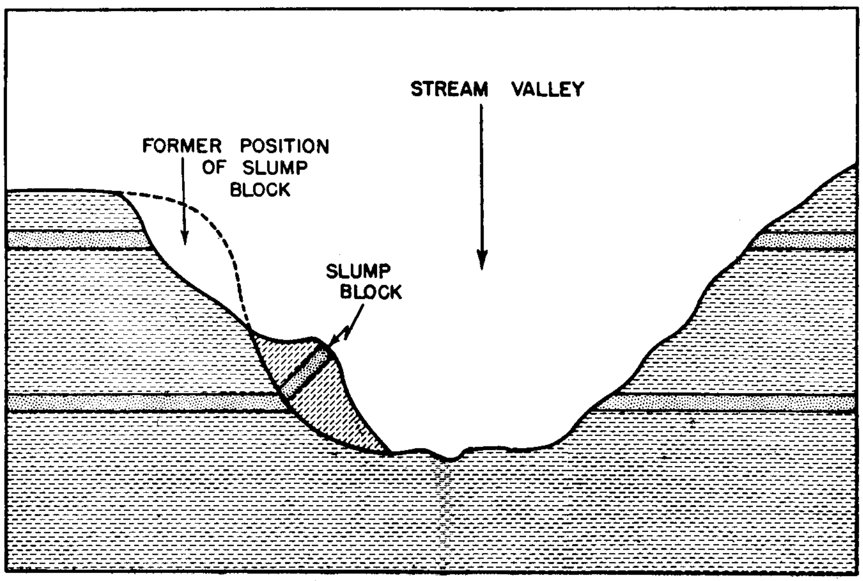


Figure 2. - Cross-section diagram showing a slump block or landslide caused by slippage on a clay or shale surface lubricated by ground water.

Fig. 1. - Black Butte, a kame 100 feet high and one third of a mile in diameter. Stop 3.

Fig. 2 - View of Coteau du Missouri. The highest point on this escarpment here is Dogden Butte. Stop 4.

Fig. 3 - Hogback Ridge looking southeast from stop 5.

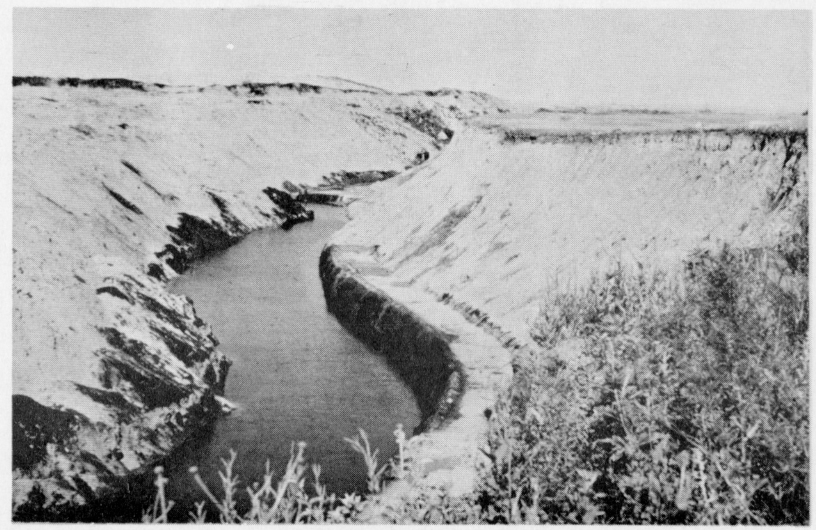
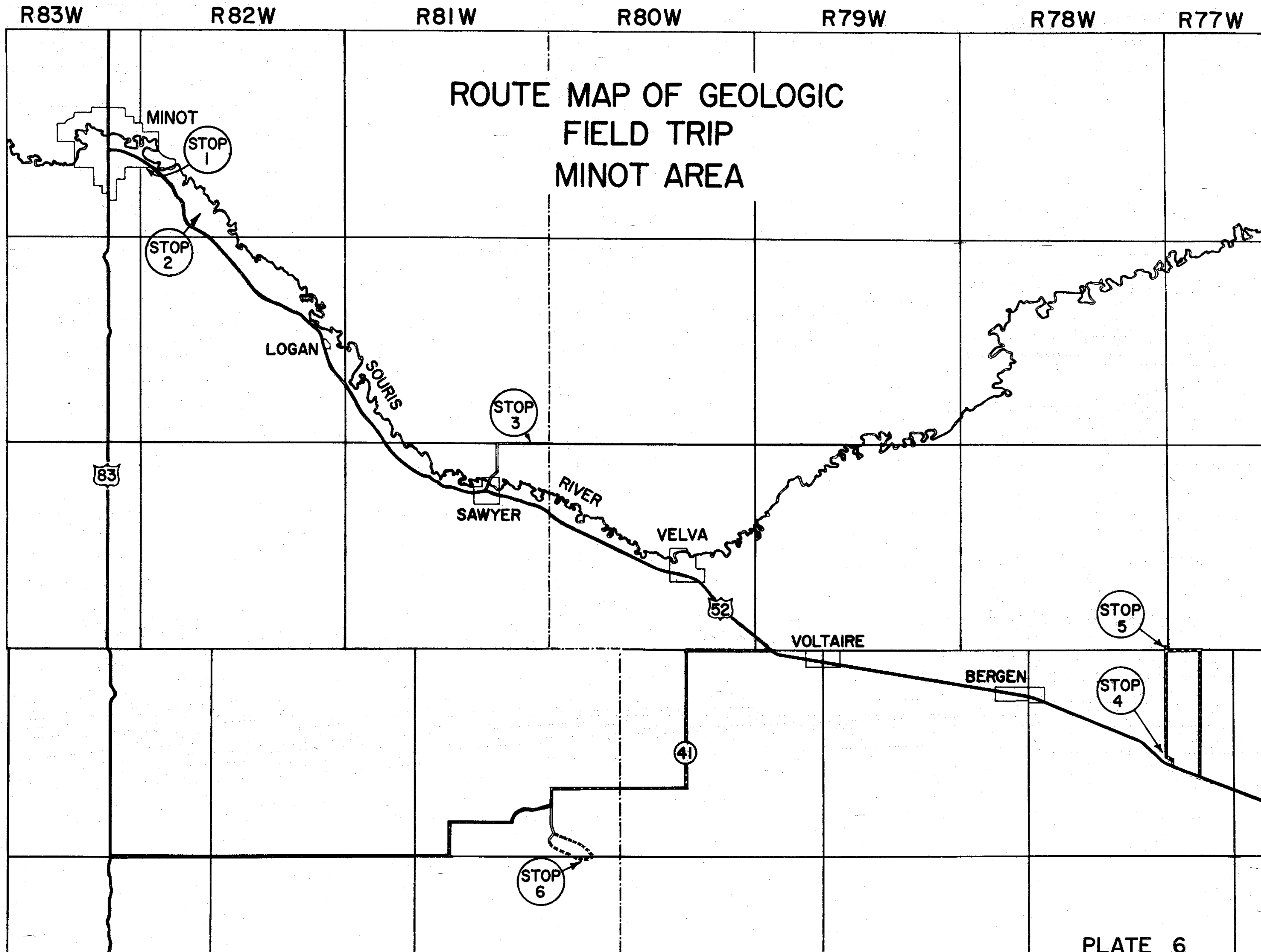


Fig. 4 - Velva mine of the Truax-Traer Coal Co. Note lignite seam near bottom of the pit. Stop 6.

MINOT AREA PLATE 5



ROUTE MAP OF GEOLOGIC
FIELD TRIP
MINOT AREA
R83W
R82W
R81W
R80W
R79W
R78W
R77W
T 155 N
T 154 N
T 153 N
T 152 N
T 151 N
MINOT
STOP 1
STOP 2
LOGAN
SOURIS
STOP 3
SAWYER
RIVER
VELVA
83
52
VOLTAIRE
BERGEN
STOP 5
STOP 4
41
STOP 6

PLATE 6