NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

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Guidebook for Geologic Field Trip in the DEVILS LAKE AREA, NORTH DAKOTA

by

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GEOLOGIC FIELD TRIP IN THE DEVILS LAKE AREA

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INTRODUCTION

Purpose

This guidebook is one of a series prepared specifically for use by the 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 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 herein is designed to show as many different geologic phenomena as possible within reasonable driving distance of Devils Lake. Particular attention will be directed to the glacial phenomena of the area and the history of Devils and Stump Lakes. As shown on Plate 6, this field trip begins at the junction of U. S. highway 2 and N. D. highway 20 at Devils Lake and proceeds south on 20 to the junction with N. D. highway 57. County roads to the south and west off 57 are followed to a junction with U. S. highway 281. Highway 281 is followed south to Sheyenne where the route turns east on a county road to highway 20 on which the return trip is made to Devils Lake. The total mileage on this trip is about 80 miles.

What is Geology?

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

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

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

GEOLOGY

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 times 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 then will 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.

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 Greeland.

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. One of these tongues or lobes extended down into this area guided by the valley of the Red River. This was a valley in preglacial times as it is now, although it was much different in appearance.

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. 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 (see Plate 5, Figs. 2 and 4). 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 has 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. Such deposits can be seen in the vicinity of Warwick. In fact, this area is one of the outstanding areas in which to demonstrate outwash in North Dakota. 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 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 in the Seven Mile Coulee area, 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.

One of the interesting things about the gravel in this particular area and one of the things which makes the gravel considerably less valuable is the presence of great amounts of Pierre shale pebbles. Shale pebbles break down on weathering and are thus useless for concrete aggregate. The Pierre shale is the bedrock formation in this area and several outcrops of it will be seen in the course of the field trip.

GEOLOGY OF THE AREA

Preglacial Geology

The preglacial geology of this area will be described only briefly in view of the fact that there is relatively little known and not a great deal of it can be seen.

The bedrock of this area is the Pierre Shale (see geologic map, Plate 1). This formation was deposited during the later part of Cretaceous time (see chart, Plate 2 and Plate 3). The Pierre formation consists of a gray, calcareous, fine grained, rather evenly but thinly bedded shale which in many places contains fossils. So far in this area, no fossils have been found, partly because there are relatively few outcrops. Also these outcrops have not been extensively studied for the occurrence of fossils.

This formation was laid down in a great inland sea which extended the entire length of North America from the Arctic to the Carribean. The deposits consist of very fine sediments such as clays and silts in this particular area, but westward, towards the source of the sediments which was located in the vicinity of the Rocky Mountains, the materials become coarser. While this formation is not known to contain oil or gas in North Dakota, its equivalents in the southwestern corner of North Dakota and in Wyoming and Montana do contain oil and gas.

From the end of Cretaceous time up to the recent there was apparently little or no deposition in this particular area. In other words, the main geological process going on was that of erosion of the land surface by running water.

The exact preglacial topography of this area is not known. However, if we compare in our minds the probable appearance of this area without the glacial cover, with other unglaciated areas, we probably would get some idea as to what the preglacial topography looked like. In preglacial time, the country was rolling with some rather sharp sided buttes. Very likely, the country may have looked something like southwestern North Dakota or northwestern South Dakota does today.

Undoubtedly, the preglacial stream patterns were dendritic or in other words the streams and tributaries make a pattern on a map more or less like the branches of a tree and the main trunk. Unquestionably, present day Devils Lake was a part of a preglacial valley which has been partially buried by the ice and the material which the ice carried. Where this particular drainage system led is not known at the present time; however, from the general alignment of it, it would appear that the headwaters of this preglacial drainage system were somewhere in the Turtle Mountain area. Probably at one time this system was part of a river which joined up with either the Sheyenne River or the Red River.

The shale exposures found in the sides of the hills, particularly around Sully's Hill indicate that these were high areas during preglacial time. Due to the fact that the hills were high, they hindered the forward progress of the ice and thus the ice tended to stop at these particular points. As a result the height of the preglacial bedrock highs was increased by the deposition of considerable amounts of glacial till on top of these areas.

Glacial Geology of the Area

The glacial features of the area are chiefly the result of one of the most recent advances of the ice sheet. Very likely the material forming most of the moraines in this area was deposited during the latest advance of the Pleistocene ice.

Two major end moraines are found in this area. These have been named the North Viking moraine and the Heimdal moraine in publications of the North Dakota Geological Survey. The North Viking moraine is the one which is most prominent in the area of this particular field trip. It is the one which curves around and is part of the Sully's Hill area which is immediately south of Devils Lake. The morainal material is quite irregular topographically, and in areas such as the Crow Hill area west of Fort Totten, probably some of the most typical end moraine topography in North Dakota occurs. Included in the end moraine are large depressions which are known as kettles. There seems to be little question that these kettles were formed by the inclusion in the glacial drift of large blocks of ice which, when they melted, allowed the material around them to collapse leaving a kettle or hole in the morainal area. Interspersed here and there in the recessional moraine areas are eskers, crevice fillings, kames and similar glacial water laid deposits.

The ice was carrying considerable amounts of material and was melting rapidly. As it melted it swept great amounts of outwash in front of the ice sheet forming what is known as the North Viking outwash plain. This plain extends from just south of Sully's Hill Game Reserve in a southeasterly direction toward the Sheyenne River.

One interesting thing is that in the area immediately south of Sully's Hill Game Reserve the Heimdal moraine and the North Viking moraine are essentially joined, separated only by the valley of the Sheyenne River. Apparently this has a very decisive effect upon the course of the Sheyenne; because as it passes through this area the valley is much narrower, and terraces which are present in other parts of the valley do not exist where the stream cuts through the moraine.

The Sheyenne River is an extremely interesting stream in the Devils Lake area. There are at least two different terrace levels above the main stream. Undoubtedly, these upper terrace levels were associated with the discharge of Glacial Lake Souris when it discharged into the Lake Agassiz basin by way of the Sheyenne. At a later date the stream apparently cut down through these terraces and most of the present day flats are composed of recent alluvium. As can be seen, these moraines for the most part tend to run either in an east-west or in a northwest-southeast direction. The northwest-southeast direction is the most predominant in this particular area.

It will also be noted that the end moraines tend to loop around the Sully's Hill Game Reserve. Sully's Hill was the high point and undoubtedly caused the moraines to be draped around on either side of it.

As the ice front retreated in a northward direction, more and more of the landscape north of Sully's Hill and the North Viking moraine was exposed. Apparently the ice front traversed the area quite rapidly and did not remain long enough in any one place to form a strong recessional moraine. As a result the area of the present day Devils Lake was exposed. Devils Lake and Stump Lake are definitely post-glacial lakes. At one time the water in these lakes was considerably higher, perhaps 20 feet higher than it is at the present. When these lakes were at or near their maximum levels they undoubtedly drained through several different drainage ways into the Sheyenne River.

As time went on and settlers moved into the area, the amount of run-off entering the lake was reduced due to cultivation of the land surface, and the lake has declined to its present low level. Quite probably, however, the main cause for the decline of the lake was climatic. Recent climatic records show that there has been a trend toward less precipitation coupled with a trend toward higher temperatures. These lakes have had other early lower levels as is evidenced by the stumps in the bottom of Stump Lake. Some of these stumps indicate trees of considerable size suggesting that a long period of time elapsed before the lake rose again. At one time fishing was a popular sport in this area, and there was regular boat service between Devils Lake and Minnewaukan.

As the drier years came on the present lake practically ceased to exist and it is only in recent years that the lake level has risen. If present plans mature, it appears that sometime in the future the lake will be raised as much as four or five feet above its present level by waters which will flow into the Lake from Missouri River diversion projects. This will provide an adequate water supply for the city of Devils Lake and also improve the recreational facilities of the area.

REFERENCES FOR ADDITIONAL READING

General References

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

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

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Stovall, J. W., and Brown, H. E., 1954, The Principles of Historical Geology: Ginn and Co., Boston. (General text on historical geology).

Willard, D. E., 1921, The Story of the Prairies: Ihling Bros. Everard Co., Kalamazoo, Michigan. (Although out of date this book contains the geological story behind landscape formation in North Dakota).

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

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

Specific References on this Area

Aranow, S., 1957, On the Postglacial History of the Devils Lake Region, North Dakota: Jour. Geol., Vol. 65, pp. 410-427.

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Branch, J. R., 1947, The Geology of the Flora Quadrangle: North Dakota Geol. Survey Bull. 22, 35 pp.

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Simpson, H. E., 1912, The Physiography of the Devils-Stump Lake Region, North Dakota: North Dakota Geol. Survey, Sixth Biennial Report, pp. 103-157.

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DEVILS LAKE FIELD TRIP ROAD LOG

0.00

Starting point - junction of U. S. highway 2 and N. D. highway 20 in Devils Lake. Go south on N. D. highway 20.

.50

Old shore line of Devils Lake.

2.50

Old shore line behind houses on west.

2.30

Route 20 turns east. Proceed south on N. D. highway 57.

.70

STOP 1. Pole showing various lake levels (see Plate 5, Fig. 1). This pole indicates that the water in these lakes was once much higher than now. Likely the decline in water level is due largely to climatic changes and to the breakup of the land after settlement.

2.00

Concrete cement block and pipe plant.

1.00

Cut on south side of road. Glacial till overlying gravel composed largely of Pierre shale pebbles.

.70

STOP 2. Outcrop of Pierre shale formation covered with Pierre gravel overlaid by glacial till. This section is Pierre shale from the bottom of the road ditch 20 feet up the face. Forty seven feet of stony clay till lies above, containing pebbles of limestone, granite and Pierre shale, and a few boulders. Near the top is a small slump scar (see Plate 4, Fig. 2).
The Pierre shale is a formation (named for exposures at Pierre, South Dakota) laid down during Cretaceous time (see Plates 2 and 3) on a sea bottom which must have been very muddy. This was approximately 60,000,00 to 100,000,000 years ago. In preglacial times this formation was eroded and broken up. Some of the large gravel size fragments are included in the glacial till as the ice undoubtedly picked this loose material up when it rode over this region and then deposited it as till.
The glacial till is formed mostly of clay with large and small rock boulders in it. These rocks may be granite and other igneous and metamorphic rocks, limestone, dolomite, and Pierre shale fragments. None of these rocks except the Pierre shale is found at the surface in this part of North Dakota. They were carried here from their outcrop areas; some of the outcrops are several hundred miles to the north.

.70

Outcrop of Pierre shale overlain by gravel and till.

.70

Good outcrop of glacial till. Pierre shale in road cut.

.60

Good outcrop of Pierre shale and Pleistocene glacial gravel, composed mostly of Pierre shale pebbles.

.90

Road left to Fort Totten, continue on highway 57.
Fort Totten was established as a military post in 1867 and was named for General Gilbert Totten, then Chief, Corps of Engineers, United States Army. The reservation was established through a treaty with the Sioux. The original fort, built of logs, still stands half a mile south of the brick buildings that replaced it in 1868. The bricks for the fort were made from clay found on the reservation. After the garrison was withdrawn in 1890, the military property was turned over to the Indian school.

1.80

Start Tokio (?) end moraine. End moraine is formed at the edge of the ice sheet where melting is quite rapid. When the amount of melting balances approximately the forward advance of the ice, the material the ice is carrying is dropped and tends to be dumped in piles forming irregular "knob and kettle" topography. Frequently detached blocks of ice are covered by the glacial debris. When these melt they form steep sided holes in the moraine which are called "kettles".

1.20

Turn south (left) on gravel road.

.40

STOP 3. Sharply crested morainic ridges and steep-sided kettle holes. (see Plate 5, Figs. 2 and 4).

.85

Kettle hole to south.

1.65

Turn left (south).

.40

Turn right (west).

2.10

Turn left (south) on U. S. highway 281.

2.00

Road west to Oberon. Continue south on U. S. highway 281. The road is traversing recessional moraine and ground moraine. Recessional moraine is generally the same as end moraine and is formed in much the same fashion. However, it usually is not as large or as massive as end moraine. Recessional moraines mark short halts in the backward movement of the ice front. Ground moraine characterized by a "swell and swale" type of topography is formed by material dumped directly beneath the ice and is molded to a greater or lesser extent by the ice passing over it.

3.10

Begin outwash plain. When the ice melts, the water flowing outward from the ice carries the material dumped by the ice. Usually the result is an outwash plain outside the end moraine.

.40

Small patch of ground moraine just to east.

2.00

No. 1 or lower terrace along Sheyenne River. These gravel deposits indicate that the stream flowed at a higher level when these gravels were deposited.

Perhaps these gravels were associated with the channel draining Glacial Lake Souris which was a glacial lake in the Minot area.

.60 Sheyenne River.

.20 STOP 4. Outcrop of the Pierre shale east side of road.

.50 North limits of Sheyenne. The town is on #2 or higher terrace.

.20 Turn left in Sheyenne.

1.40 End #2 terrace. The road now ascends up on to recessional and ground moraine.

.60 Good view to north over Sheyenne valley, showing #2 terrace.

3.10 Kettle hole to right (south). Good recessional moraine.

2.10 Area to south is mostly outwash plain.

1.20 Terrace gravel on both sides of road. Probably #2 or higher terrace along the Sheyenne River.

.40 Glacial till on south side of road.

.20 Alluvial flat of Sheyenne River. The deposits along the stream are of relatively recent origin. These are classified as Recent or alluvium deposits.

.30 Sheyenne River.

.90 Outcrop of Pierre shale overlain by glacial drift.

.90 End terrace and proceed on outwash plain. Terrace looks more like cut terrace here on top with very little sediment. A cut terrace is an erosional plain cut by the stream wandering back and forth cutting laterally in its valley. Outwash plain is pitted, indicating that ice blocks were buried. When they melted they left holes or pits.

3.60 Begin recessional moraine.

.50 Kettle hole. Note boulders on hill to north.

2.50 STOP 5. Begin outwash plain. This outwash plain is known to contain underground water in abundance. This water someday may be used as a source for irrigation water or as a source for municipal or industrial supply.

2.50

N. D. highway 20, turn left (north).

1.10

Benson - Eddy County line.

.40

Railroad crossing

.20

Road to Warwick.

.40

Glacial till to west. Small island of ground moraine surrounded by outwash.

.20

Road now on outwash.

3.60

STOP 6. Outcrop on east side of road on east end of Free Peoples Lake. About 15 feet of glacial till overlain by 7 to 8 feet of bedded sands and silt overlain by 5 feet of outwash with Pierre shale pebbles. (See plate 5, Fig. 4).

.40

Start recessional moraine. Note boulders on hill to east.

1.30

Ground moraine.

1.80

Begin end moraine.

.50

Kame or esker gravel deposit. Mainly Pierre shale pebbles in the gravel.

1.70

On old lake bottom. Islands were present here and there in old lake.

2.10

End lake - start ground moraine.

3.10

Outwash on lake beds. End ground moraine.

2.50

End lake, start ground moraine.

1.80

Start lake. Probable beach.

1.10

Gravel pit in old beach.

.10

Railroad crossing.

.30

Junction with N. D. highway 57. Turn right (north).

4.90

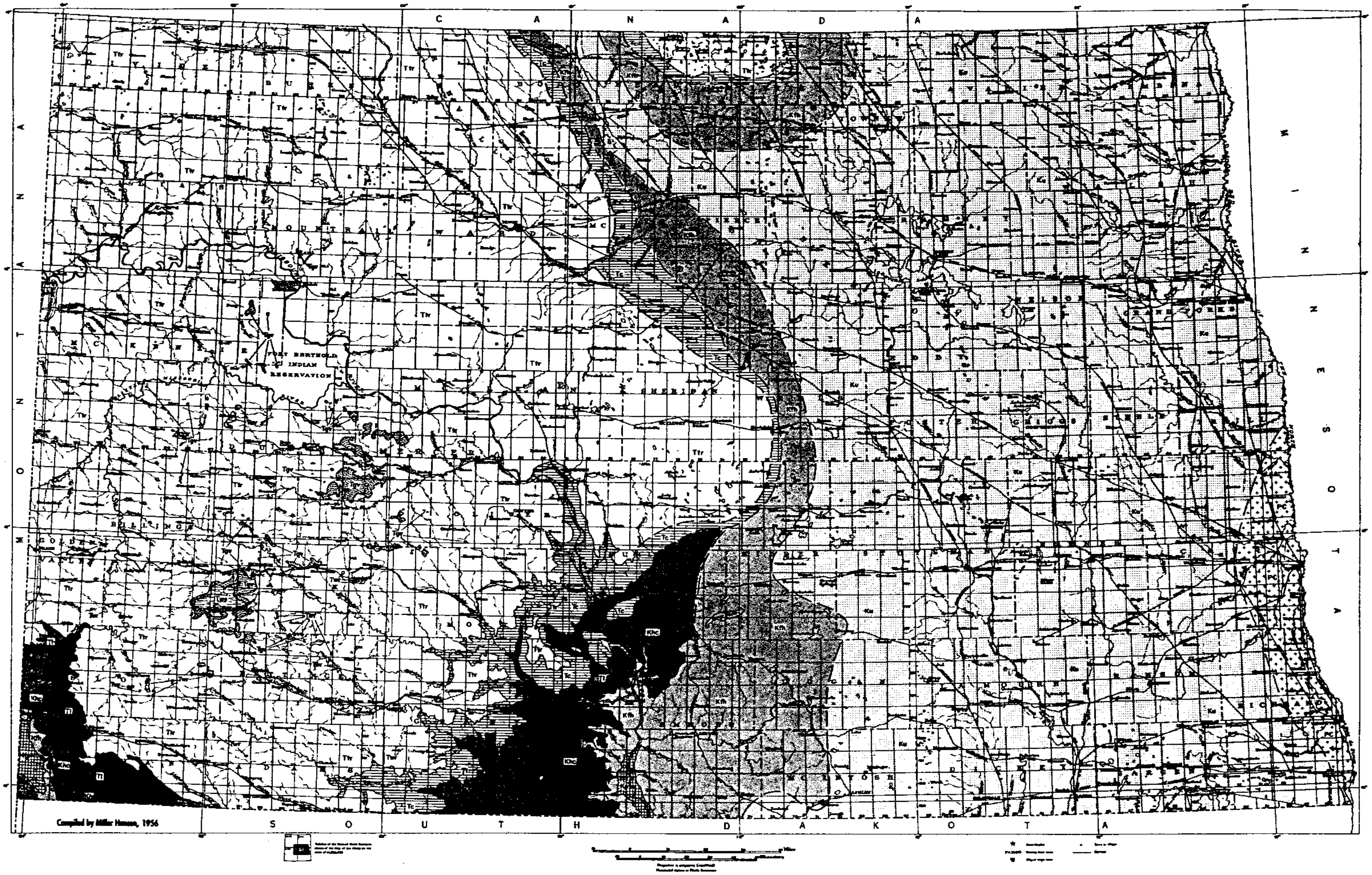
Junction with U. S. highway 2. End of trip.

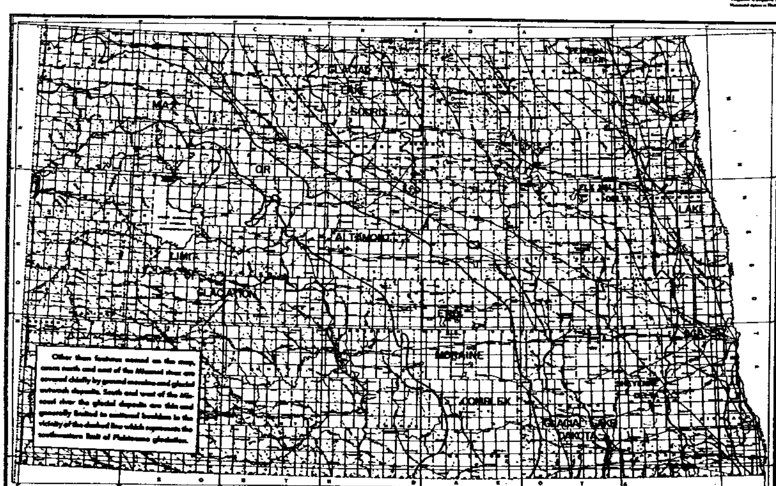
PLATE I

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	
	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.

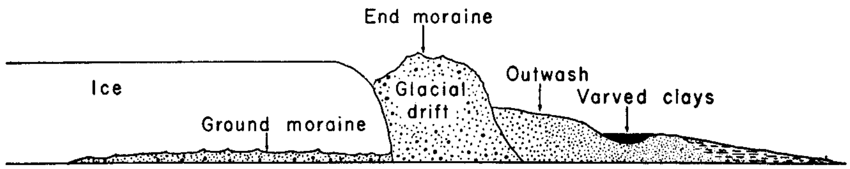


Figure 1. - Diagram showing glacial features associated with the front of an ice sheet.

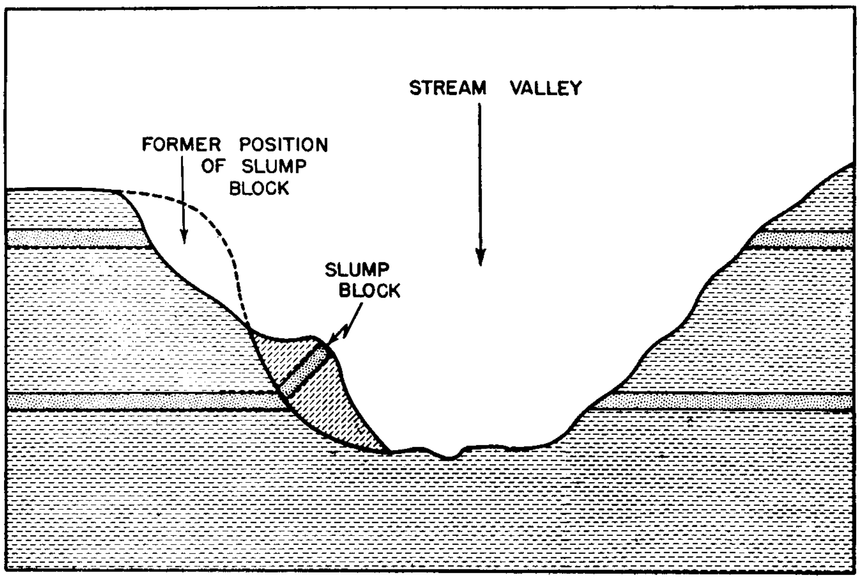


Figure 2. - Cross-section diagram showing a slump block or landslide caused by slippage on a clay or shale surface lubricated by ground water.

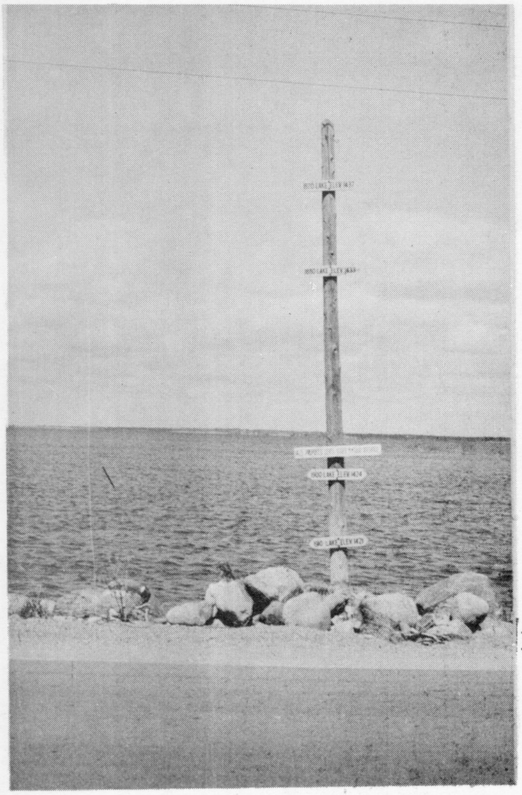


Fig.1

Fig.2

Fig.3

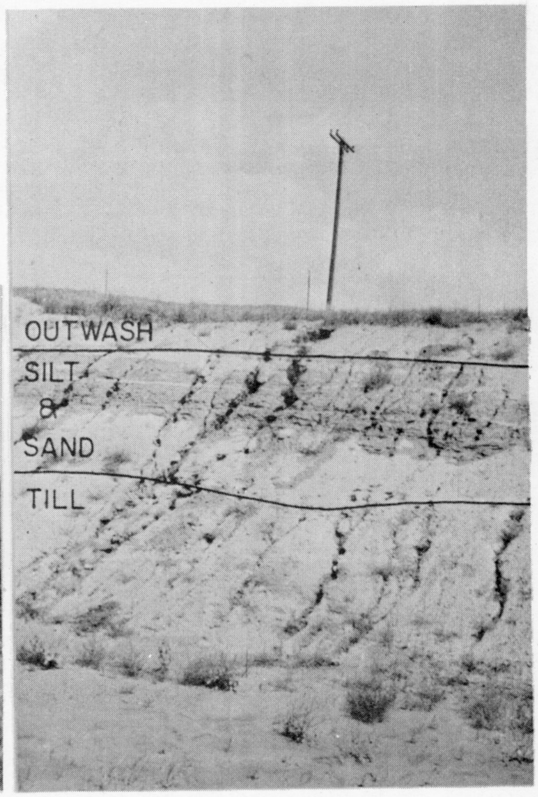


Fig.4

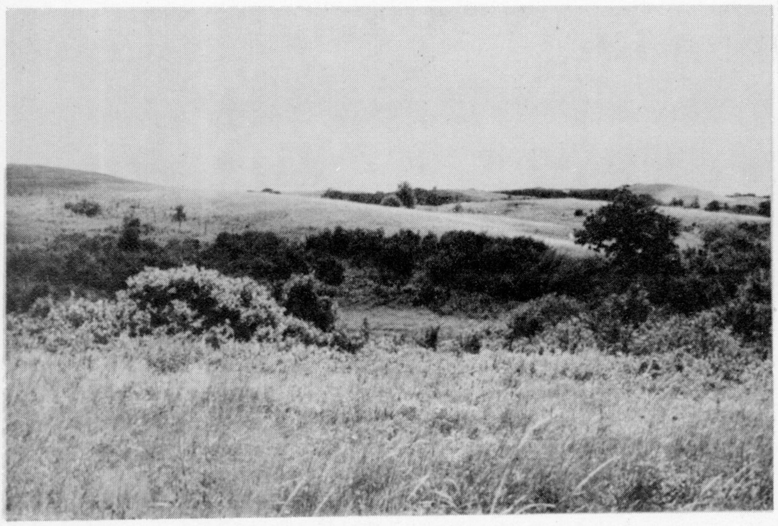
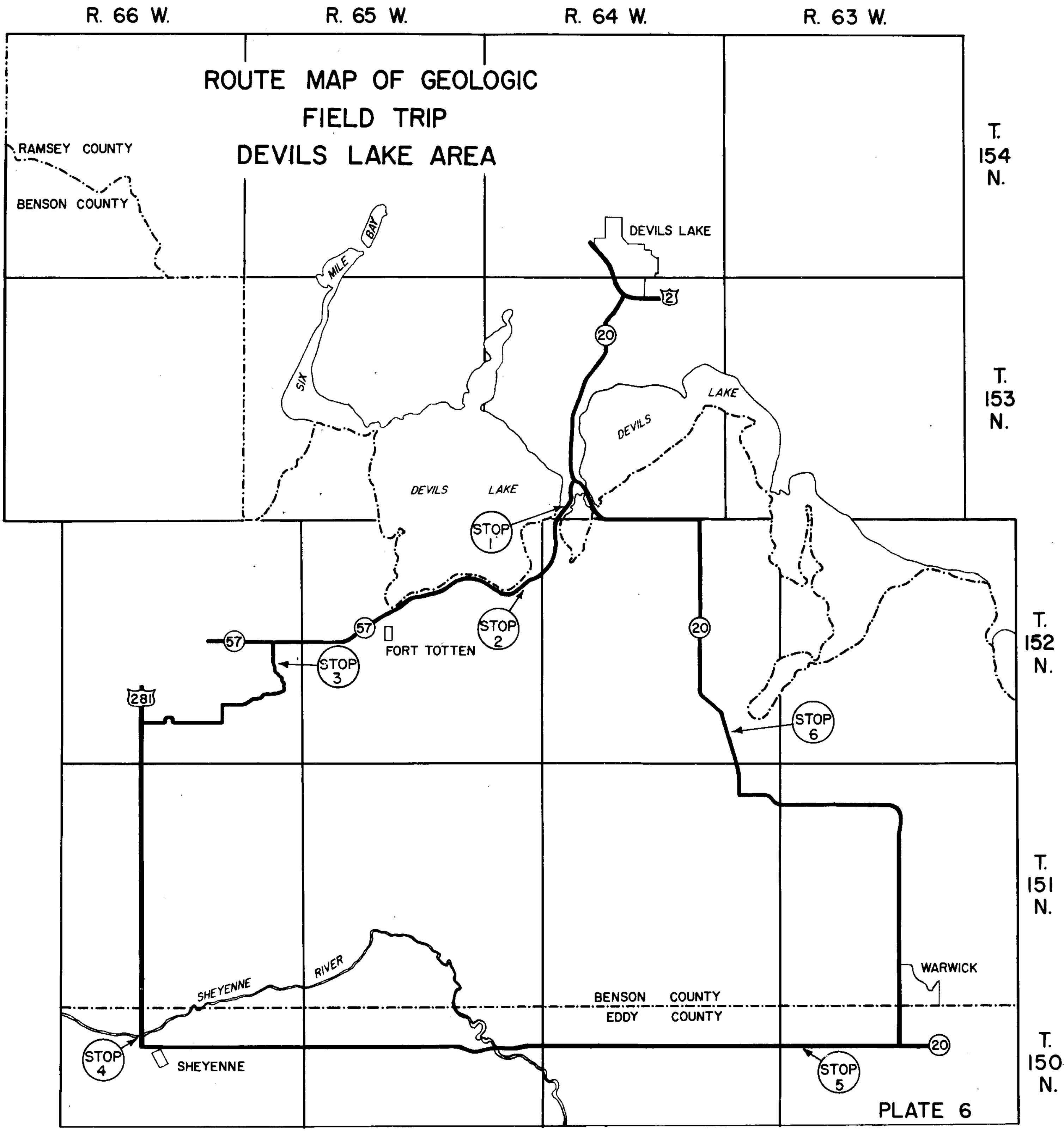


Fig. 1. - Pole showing various past levels of Devils Lake. Stop 1.

Fig. 2. - End moraine forming Crow Hills. This is part of the North Viking moraine. Near stop 3.

Fig. 3. - Outcrop at the east end of Free Peoples Lake. Glacial till is at the bottom of the outcrop overlain by sand and silt which is the dark band. The uppermost part of the exposure is outwash gravel. Stop 6.

Fig. 4. - Kettle hole in the Crow Hills, North Viking moraine. Near stop 3.


R. 66 W.
R. 65 W.
R. 64 W.
R. 63 W.
ROUTE MAP OF GEOLOGIC FIELD TRIP DEVILS LAKE AREA
T. 154 N.
T. 153 N.
T. 152 N.
T. 151 N.
T. 150 N.
RAMSEY COUNTY
BENSON COUNTY
SIX MILE BAY
DEVILS LAKE
DEVILS LAKE
DEVILS LAKE
2
20
STOP 1
STOP 2
57
57
FORT TOTTEN
STOP 3
281
20
STOP 6
SHEYENNE RIVER
WARWICK
BENSON COUNTY
EDDY COUNTY
STOP 4
SHEYENNE
STOP 5
20
PLATE 6