NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

Miscellaneous Series No. 1

Geology Month in Scouting

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Guidebook for Geologic Field Trip in the VALLEY CITY AREA, NORTH DAKOTA

by

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and

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GEOLOGIC FIELD TRIP IN THE VALLEY CITY AREA

By
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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 are 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 choosen 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 Valley City. Along the route outlined, glacial features will be emphasized as they are the most prominent geologic phenomena present. Erosional features produced by running water will also be shown. The trip covers about 85 miles and goes north and west to the Bald Hill Dam. From there the route is north and east crossing the Sheyenne River to Route 32. Route 32 is followed southward to Route 10 which is followed westward to Valley City.

The writers wish to acknowledge with thanks the help of Col. Dana Wright of St. John, North Dakota, in supplying historical notes used in preparation of this guidebook.

What is Geology?

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

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

Secondly, there is also the possibility of interest in geology from the professional standpoint. Geologists are employed by State and Federal Surveys 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 material on which our civilization rests.

GEOLOGY

Geological Processes Important in the Formation of Landscape in this Area

No attempt will be made to discuss all the geological processes which have been important in the formation of landscape in this area. The work of running water and glaciation which have been instrumental in the formation of the landscape of this area will be discussed specifically.

The geological work done by running water is obvious to even the most casual observer. Particularly it should be pointed out that the valley of the Sheyenne River is a valley which has been primarily excavated by running water. Water as it runs down hill digs into the rocks and wears away or erodes the rocks as it passes along. Thus, the stream valley is deepened. This process is further aided as far as the widening of the valley is concerned by landslides (slump), creep, and other methods of mass transport of material. The results of slumping (see Plate 4) are visible on some of the valley sides along the Sheyenne River as is shown by the hummocky and irregular topography visible in many places. Hummocky topography is typical of areas where landslides have occurred.

Undoubtedly the work of running water was most important prior to the descent of the glaciers into this area. At that time a system of drainage was probably quite well developed and the topography was quite irregular, perhaps in some instances quite similar in appearance to the present day Badlands in western North Dakota.

The second most important geological process which has effected this area is that of glaciation. During the recent ice age which extended back approximately one million years during a period of geologic time called the Pleistocene, large amounts of ice piled up to the north in present day Canada. In fact some of the ice masses in that area were probably several miles in thickness similar to the present day Antarctic ice sheet or the ice cap on the island of Greenland.

As the ice accumulated to great thicknesses, it began to flow outward in all directions, particularly toward the south. This flow is due to plastic deformation within the ice mass itself. In other words, the ice acted as a plastic mass rather than as a brittle solid particularly in the lower part of the ice sheet.

As these tongues of ice proceeded southward, they naturally chose the lines of least resistance. In most cases these lines of least resistance were along lines of pre-established drainage in the area over which the ice was travelling. The irregular or lobe-like nature of the edge of the ice sheet was emphasized by the ice following up these old river valleys such as the Red River valley in eastern North Dakota and western Minnesota and also undoubtedly the preglacial Sheyenne River.

As the ice moved along it picked up a great deal of material by eroding and gouging the land surface over which it was passing. The ice sheet incorporated this material into the ice mass itself. Much of the material in the ice mass was derived within a relatively few miles of the place where it was finally deposited. In other words, most of the material was not carried great distances. Some of the more resistant material particularly the limestone and granite pebbles in the till in North Dakota, however, was carried many hundreds of miles.

When the ice front stopped and did not make any further forward advance, melting became the dominant process. When the edge of the ice sheet stood long enough in a certain area, it deposited a great deal of material at the edge of the ice sheet. This material was frequently pushed by the slight, temporary forward advances of the ice front and as a result around the edges of the lobes material dumped directly by the ice and the material washed out from the ice frequently are formed into irregular masses. These irregular hills are spoken of as end moraines. End moraines have what is known as knob and kettle type topography. In most instances the kettles or depressions are undrained and contain lakes or swamps. This type of topography is most characteristic of the area west and north of Jamestown. Material deposited beneath the ice directly and forming a swell and swale type topography is spoken of as ground moraine. This type of topography has a more subdued appearance than end moraine. Both these types of moraine are quite evident in the Valley City area.

The water flowing from the melting ice washed out a great deal of glacial debris in front of the end moraine giving rise to outwash plains and also to terraces along the edges of the ice tongues that were confined to the valleys. Frequently these latter types of gravel and sand deposits are spoken of as kame terraces.

As the edge of the ice was frequently irregular and water was flowing on the top of the ice sheet as well as through and under it, glacial material was transported along well defined trends. When the ice melted and the debris deposited in these channels in and on the ice were let down on the underlying land surface, these deposits gave rise to irregular features consisting of hills of gravel or long linear ridges. The former are spoken of as kames, the latter are spoken of usually as eskers or crevice fillings. These gravel deposits are of considerable interest, because they have some economic value not only as aggregate for concrete but also as road material to improve secondary roads.

GEOLOGY OF THE AREA

Preglacial Geology

Inasmuch as the bedrock formations in this area are poorly exposed, they will not be discussed at any great length. In any event, they are of relatively little concern in the formation of the landscape in this area.

The bedrock exposed here, particularly in the Sheyenne River valley is a formation of Cretaceous age (see Plate 2) known as the Pierre shale (see Plate 3). This shale has been named for its occurrence near Pierre, South Dakota. It is a gray, usually calcareous shale which was laid down during Cretaceous time in a great seaway stretching practically the entire length of North America. The Cretaceous period is a division of geologic time which was roughly 55 million years in duration and ended about 60 million years ago. Originally it was a clay mud which was later consolidated into a rock which is called shale. The Pierre contains fossil remains in this area but these remains are generally poorly preserved. Among the fossils found are Inoceramus which was a clam, Discoscaphites, a cephalopod (ammonite) which is a cousin of the Chambered Nautilus and also Baculites which was also an ammonite, and a cousin of the Chambered Nautilus.

The only exposures of the Pierre shale which are found in this area are in the valley sides. Usually they are badly slumped as the Pierre is very slippery when wet.

Glacial Geology

To start the story of the glacial history of this area it is necessary to give a brief review of the preglacial topography in this particular area. This topography as has been mentioned previously, was more or less of an irregular erosional type probably somewhat similar to the appearance of the North Dakota Badlands today.

This topography was formed by running water and probably at that time the Sheyenne River in this area had much the same course as it has now. However, it is quite likely that the valley was not quite so deep as it is now.

After the beginning of the accumulation of the ice to the north, the glacier began to flow southward in various lobes as has been mentioned previously. One lobe covered this area and covered both in the valley and on the upland area. Undoubtedly, however, the ice was deeper in the valley than it was on the upland and as a result when the ice melted the uplands were exposed first as the ice was thinner there.

Material shoved in front of the ice left an end moraine such as that found on the "Alta" ridge or the Fergus Falls moraine which is traversed in the course of the field trip. This moraine is located about five or six miles east of Valley City and extends in a general north-south direction.

The material washed down in front of the ice formed an outwash plain and piles of this material in the form of kames and similar features are found, generally speaking, north and east of Valley City. The material deposited beneath the ice, called ground moraine, is found in the general area east of the Sheyenne River for ten or twelve miles with the exception of the "Alta" ridge.

As the ice melted, the material it contained was let down without any particular arrangement. This material is spoken of as ablation moraine which is very thin and just mantles the surface as can be seen in the cut just east of Valley City on U. S. highway 10.

In the valley, kame terraces were left by the water flowing from the ice. The way these were formed is something as follows: As the ice melted, the last remnants of the ice sheets occupied the valleys. As the edges of this residual tongue of ice were thinner, melting took place along the edges of the ice sheet first. This led to streams coursing along the edges of the ice tongue in the valley. Probably these water courses were on either or both sides of the ice tongue. In other words, these temporary streams were flowing in valleys with ice on one side and land surface on the other. The water of these streams was carrying a considerable amount of material that was derived from the melting of the ice. This material was deposited in the bottom of these half ice, half bedrock valleys. After the ice entirely melted the material slumped down and formed irregular terraces on either side of the valley itself. After the ice was entirely gone from this area the stream development proceeded with considerable speed and excavated the valley and the deposits in the valley quite rapidly.

It is not known exactly what the original course of the Sheyenne River valley was but it is presumed that in this region it was very similar to that which is now followed by the stream. This stream when flowing at an upper level now represented by indistinct terraces approximately 20 to 30 feet below the general level of the ground surface, probably served as an outlet to glacial Lake Souris of the Minot area. After abandonment of this river as an outlet to Lake Souris, the stream later entrenched itself below the terrace represented by the former Lake Souris outlet. Probably this stream was encouraged in its entrenchment by the melting of the ice to the north so that the greater volume of water was supplied to the stream, thus increasing its power and ability to erode. Quite possibly the stream was entrenched below its present depth and at this time the extensive slumping (see Plate 4) along the valley walls took place. This slump can be seen at the Lake Ashtabula bridge near the east abutment.

Later deposition by the stream in the valley itself caused the terraces to be developed in the stream. It is in these stream terraces that the river is now entrenched.

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).

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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

Campbell, M. R., and others, 1915, Guidebook of the Western United States, Part A, Northern Pacific Route: U. S. Geol. Survey, Bull. 611.

Hard, H. A., 1913, System of Eskers and Kames in Eastern Barnes County: North Dakota Agr. Coll. Survey, 6th Bienn. Rept., p. 39-43.

Willard, D. E., 1909, Jamestown-Tower Quadrangles: U. S. Geol. Survey, Folio 168.

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VALLEY CITY FIELD TRIP ROAD LOG

Start at corner of 2nd Street Northeast and Central Avenue North. Facing west on Second Street Northeast north of Northern Pacific Railroad depot. (One block north of U. S. highway 10). Turn north (right) on Central Avenue North.

.60

Ball park to east; Sheyenne Memorial Hospital to west.

.05

Turn right (east).

.30

Turn left (north). Note the extensive gravel terraces to the southeast.

.30

Soo highline underpass.

.20

Cross Sheyenne River.

.30

Cross Soo tracks and turn left (west).

.30

Glacial boulders on right. Hills beyond of Pierre shale.

.35

Road forks. Continue straight ahead on left fork.

.40

STOP 1. Outcrop of Pierre shale. Note the very fine grained nature of this rock and the thin bedding. Zones of yellowish colored shale are also present. This yellow color is due to iron sulfate. It is also mixed with gypsum which secondary in its deposition. Poorly preserved fossils have been found in this outcrop. This is near the base of the Pierre formation as the yellow streaks mentioned above are known only in the basal part of the Pierre formation in this area and at other exposures in eastern North Dakota.

.20

Gravel pit in glacial material on hill to north. Note abundance of glacial boulders.

.90

Fish hatchery gates to south. Flood plain of Sheyenne River. Hill to north of road is Pierre shale masked by glacial drift. Road cuts through overlying drift.

.60

Turn right up the hill. Note glacial till in road cuts.

.50

Upland level is gently rolling ground moraine. Ground moraine is material deposited directly beneath the ice. 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.

.20

Turn left (west).

.20

Turn right (north).

1.00

Small end moraine which trends to north and west. End moraine is a ridge-like deposit of glacial material deposited at the forward edge of the ice where melting just about balanced the forward flow of the ice.

1.00

Turn west.

1.10

Church on south.

.90

Turn right (north) east of farm buildings.

1.00

STOP 2. Good view of Sheyenne valley. Note the poorly defined terrace level along the river about the elevation of the red barn across the valley (see Plate 5, Fig. 1). Note also the gravels in ditch on your right. These gravels have the appearance of ablation moraine glacial materials let down right where the ice melted. At the same time the fine particles were washed away leaving the coarser materials behind.

.20

Terrace gravel on east or right side. The terraces along the river were made when the Sheyenne flowed at a higher level in Pleistocene times than now; later as the river receded it cut into its former deposits leaving terraces on the sides of the valley.

.10

Turn right (east).

.70

STOP 3. Take road to right up into parking lot. View over Bald Hill Dam. The Bald Hill Dam was constructed as a multiple purpose project. It will stabilize stream flow, help prevent floods and serve to supplement municipal water supplies and assist in pollution abatement down stream. The dam is an earth fill dam 1650 feet long with a concrete spillway and control works. The reservoir is approximately 27 miles in length and has a maximum width of one half mile. Immediately behind the dam the lake is about 40 feet deep at normal full pool level and the depth decreases about 1 foot for every additional river mile upstream from the structure. Construction of the dam under the supervision of the U. S. Corps of Engineers was started in July 1947 and was formally dedicated on September 21, 1952. Observe the slumping on west side of river. Leave parking lot.

.30

Note gravel terrace to east (see Plate 5, Fig. 2).

.40

Turn left (south).

1.30

Turn left (east).

1.90

Turn left (north).

3.60

Cattle guard.

.50

STOP 4. Camp Ritchie. Camp Ritchie is the State Conservation Training Center originally begun by the North Dakota Wildlife Federation. In 1955 it was taken over by the Barnes County Soil Conservation District Supervisors with the help of the State Association. Here teachers are trained in the methods used in the solving of problems affecting conservation of our natural resources. These courses are taught under the sponsorship of the several teachers colleges in the State. Note the work of the waves on the soft clay till and shale in the banks of the lake. These are wave cut cliffs. Turn around and retrace route (south).

2.00

Turn left (east).

2.00

Turn left (north) travelling on ground moraine.

3.30

Come up on small end moraine.

.20

School on left (west).

.60

Good coarse till on east. Till is material deposited by the glacier which forms on unsorted, unstratified sediment. It is composed of stiff clay full of rocks varying in size up to boulders. Note the large boulders in this deposit of till.

.30

Fine sand and silt. This appears to be outwash or material deposited in small preglacial lake. Gravel pit near top of hill on east side of road. Sand and gravel found in irregular thin patches along here. This is probably an outwash plain with some of the material removed by subsequent erosion.

3.90

End moraine (?).

.30

Slump zone in Pierre. Pierre exposed near base of the hill. Gravels and silts and sands are found in depressions behind slump zones. These sands, silts and gravels are probably outwash.

.10

Ashtabula bridge and picnic grounds.
This is the Sibley crossing of the Sheyenne River. In July 1863 General Henry H. Sibley passed this way enroute to punish the Indians after the Sioux outbreak in Minnesota in 1862. Although the Sioux had left the Devils Lake region, Sibley pursued them and drove them west across the Missouri River south of Bismarck before he returned this way in August. General Sibley did not camp here; but after Ft. Totten was established in 1867, the government kept a stopping place for mail carriers on the flats now covered by water northwest of the old bridgesite.

.30

Pierre shale outcrop in ditches on both sides of road.

.80

Turn right (north).

.60

Begin end moraine. Note hummocky topography and boulders.

.40

Going down off end moraine.

.70

Small end moraine.

1.80

Turn left (west).

2.10

Turn right (north).
Camp Corning on northeast corner is a camp site occupied July 16-17, 1863, by General Sibley on his northward march.

1.00

Turn right (east).

3.10

Turn right (south).

1.00

Turn left (east).

1.10

Upper cut terrace level. Gravel pit on south.

.60

Lower cut terrace level.

.40

Bridge near Danceland.

.40

Till in cut to south of road.

1.80

Turn right (south).

.40

Begin end moraine.

.60

Turn left (east).

1.20

School on south.

.80

This is the last of the end moraine; start ground moraine.

4.20

Turn south on N. D. highway 32.

3.90

Gravel in flat valley. Looks like this was a distributary for the glacier.

3.30

Road west to KXJB-TV tower.

2.90

Church on west side of road.

3.60

Kame gravel on west side of road. Rather fine grained material.

.60

Camp Arnold Historic Site west of highway. The Sibley expedition occupied this site on the night of August 14, 1863. Two of his soldiers, James Ponsford and Andrew Moore were buried here (see Plate 5, Fig. 3).

1.70

Kames on both sides of road.

2.50

Northeast corner of Oriska.

1.00

Junction U. S. highway 10.

.50

Till outcrop on both sides of highway. Note that the high ground on horizon ahead trends north-south. This is an end moraine.

2.80

Start up east side of small end moraine as shown by pot-holes and knobs. This has been called the Fergus Falls moraine.

2.00

Going down west side of the Fergus Falls moraine.

2.50

Look to north. Large kame deposit of cross-bedded sand and gravel. More sand and silt than gravel. The kame deposit is about 50 feet thick. The hill to the northeast with the tower on it is of similar origin.

.70

Soo Line underpass.

.20

Ablation moraine on south.

.30

Landslide south of highway. Here gravels of the ablation moraine are sliding on the underlying Pierre shale. This was caused by cutting away the toe of the slope; the gravels and the Pierre shale then slip when the shale becomes wet. Fragments of fossil clam shells and coiled nautiloids are easy to find in the Pierre shale at this road cut.

1.15

Bridge over Sheyenne River.

.45

Corner of U. S. highway 10 and Central Avenue North.

.10

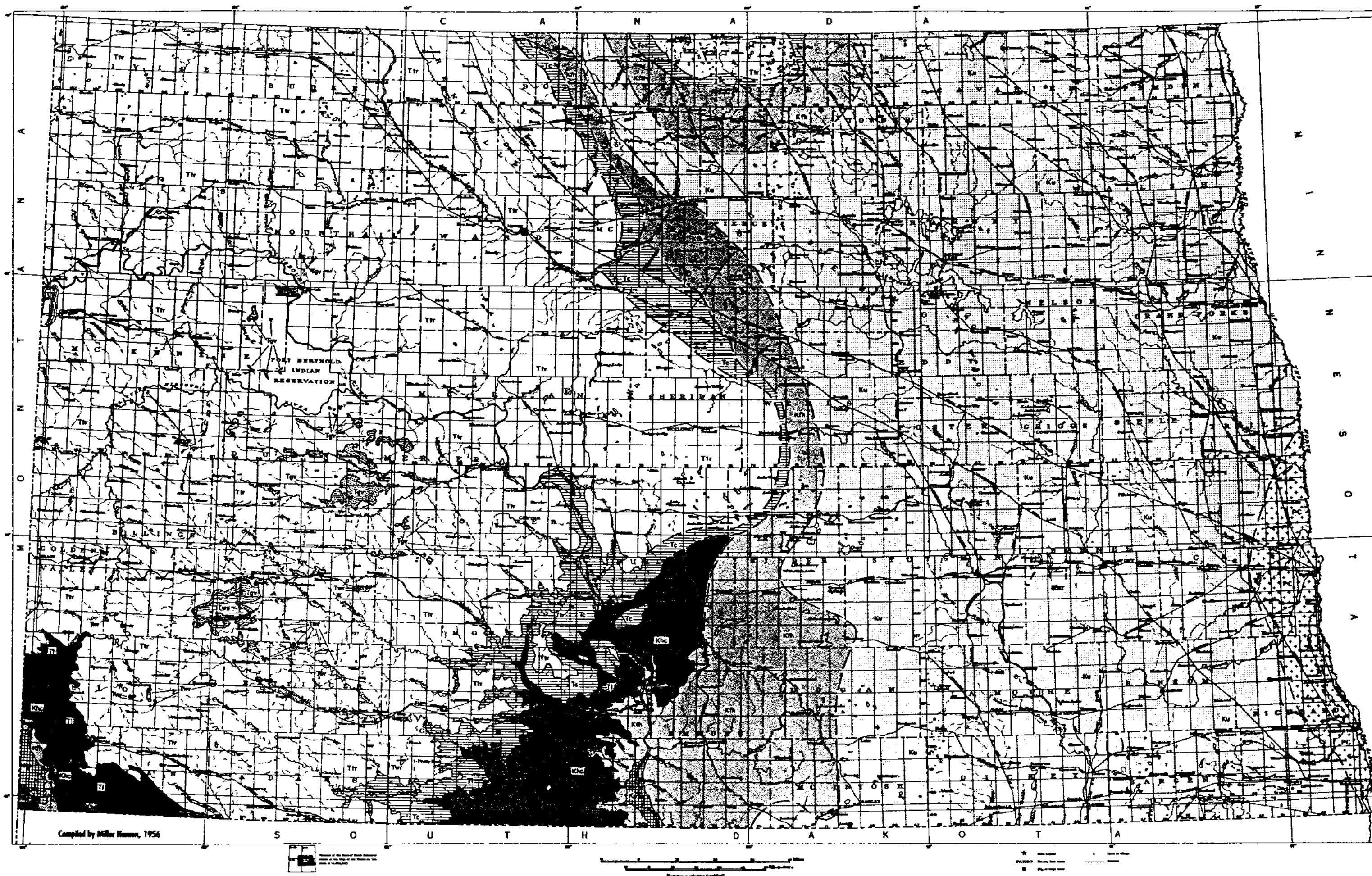
Starting point - corner of Second Street Northeast and Central Avenue North.

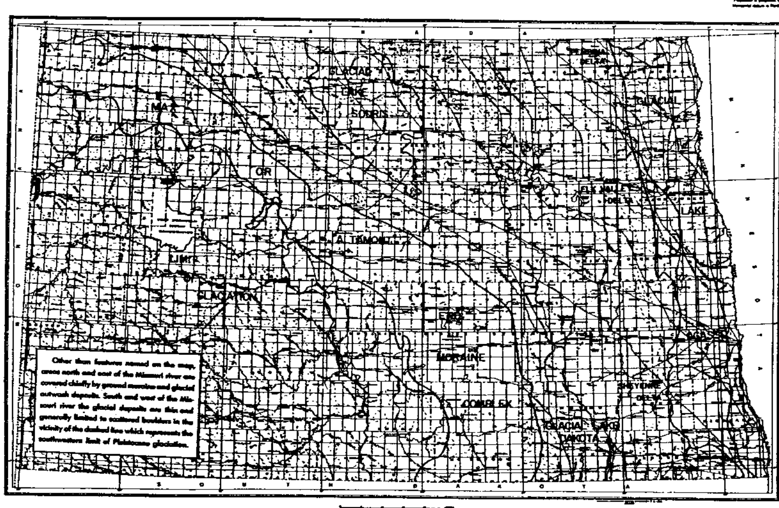
PLATE I

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.	
PC	Igneous and metamorphic rocks	Pre-Cambrian
	Known contacts	
	Inferred contacts	

TABLE OF GEOLOGIC TIME

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

PLATE 2

TERTIARY	RECENT	ALLUVIUM	
	PLEISTOCENE	GLACIAL DRIFT	
	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.

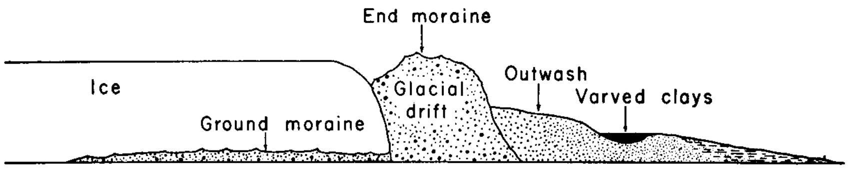


Figure 1. - Diagram showing glacial features associated with the front of an ice sheet.

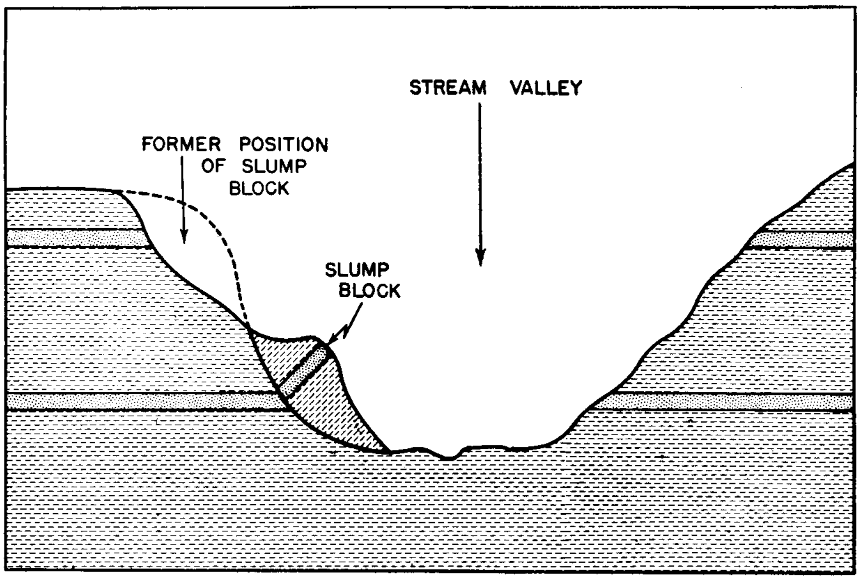


Figure 2. - Cross-section diagram showing a slump block or landslide caused by slippage on a clay or shale surface lubricated by ground water.

Fig. 1 - View of Bald Hill Dam and Lake Ashtabula from stop 2. Farm across valley sits on Pleistocene terrace of the Sheyenne River.

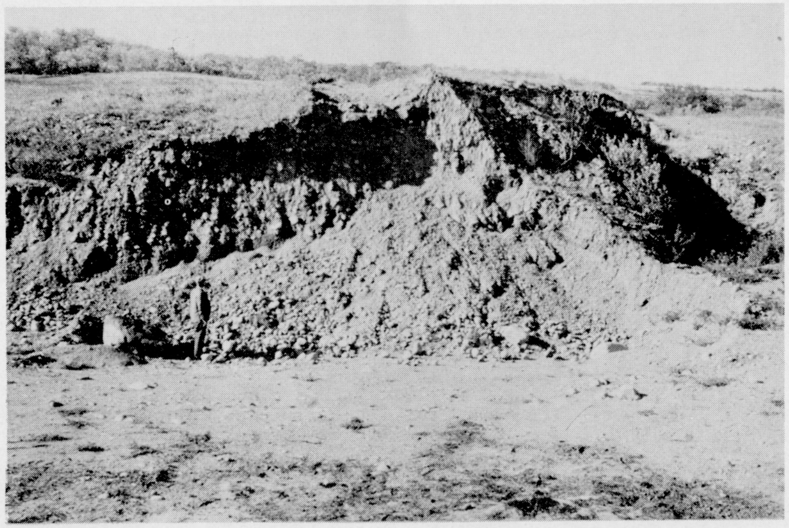
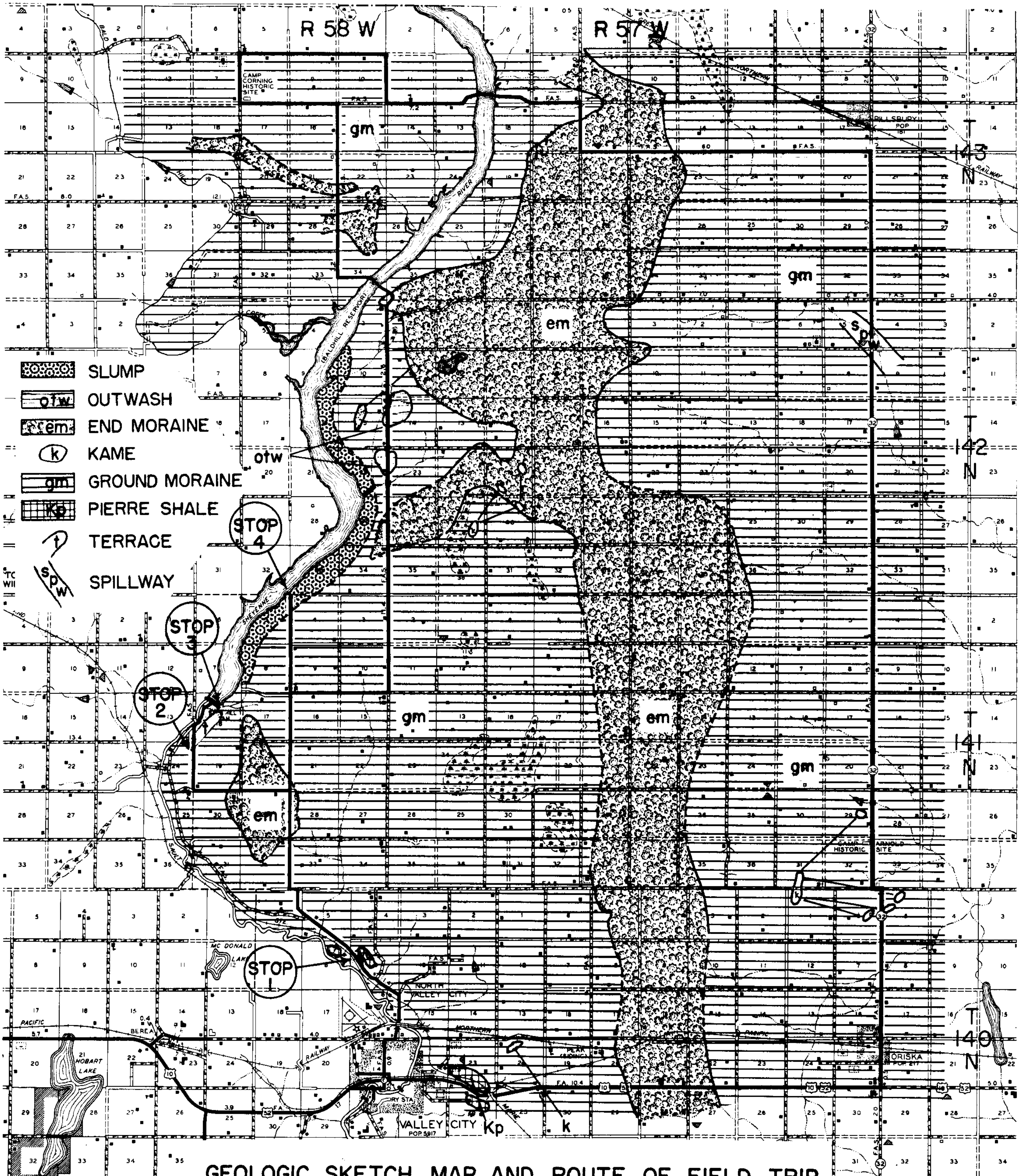


Fig. 2 - Pleistocene terrace gravel of Sheyenne River east of road near Bald Hill Dam between stops 2 and 3.

Fig. 3 - Sibley trail marker at Camp Arnold historic site, four miles north of Oriska.



GEOLOGIC SKETCH MAP AND ROUTE OF FIELD TRIP VALLEY CITY AREA

PLATE 6