GUIDE TO THE GEOLOGY OF North-Central NORTH DAKOTA

by John P. Bluemle

revised edition 1988

GUIDE TO THE GEOLOGY OF NORTH-CENTRAL NORTH DAKOTA

Benson, Bottineau, Eddy, Foster, McHenry, Pierce, Ramsey, Rolette, Sheridan, Towner, and Wells Counties

by

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revised

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North Dakota Geological Survey

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ILLUSTRATIONS

INTRODUCTION

Why did part of northern Minnesota end up in the Turtle Mountains? Why do you suppose you find so many more sloughs around McClusky than near Harvey, a few miles to the northeast? What are the long, exceptionally straight ridges in the Velva area if they aren't old railroad grades? Did you know that some of the largest sand dunes in North Dakota are found in the Denbigh area? Geologists are concerned with the above questions. Their science, geology, is the study of the earth, the science that attempts to learn how and when rocks have formed, when the earth began, how it has evolved, and what is going on within it today. This may seem to be an impossible undertaking, but we do have some of the answers to many of these questions, and solutions to other questions are being found every day.

Geologists with the North Dakota Geological Survey study the mineral resources of the state and make their findings available to the public. This guidebook describes the geology of north-central North Dakota*. It has several accompanying roadlogs so that you can visit the areas described. Geologic educational aids available to North Dakota schools and other organizations include taped lectures and collections of selected slides, which may be borrowed free of charge. Members of the Survey staff give illustrated lectures on arrangement. Rock and mineral collections are available to schools. Numerous technical maps and reports on North Dakota geology are also available, at nominal costs.

Further information may be obtained from the North Dakota Geological Survey, University Station, Grand Forks, North Dakota 58202-8156.

GEOLOGIC TIME

Geology necessitates our thinking in terms of millions of years, not days, months, and years as we are accustomed. Although time is a fundamental consideration in all geological research, it is sometimes difficult to comprehend the immensity of geologic time. The earth is about 5 billion years old. If all of those 5 billion years were compressed into a single imaginary year, the earliest life would have appeared in late April of that year. Dinosaurs would have come on the scene in mid-December and lasted only six of our imaginary days. The Ice Age would have begun in North Dakota at 8:40 p.m. on December 31 and ended only two minutes before midnight. Primitive man would have arrived on earth about 10:20 p.m. in the midst of the Ice Age. At 20 seconds before midnight, Christ was born, and at 10 seconds, Leif Ericson discovered America. So, as you can see, the two thousand years since the birth of Christ may seem like a long time to most of us, but to the geologist they are only an instant in the history of the earth.

GENERAL GEOLOGY

Introduction

The part of the earth we live on is only a thin skin, known as the crust, which encases a huge volume of denser materials known as the mantle and core. The crust is built from solid materials, known as rocks, which vary widely in density, chemical composition, color, hardness, and origin. Some rocks have come from deep within the earth; others have formed at the surface. The mantle and core consist of a

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* Benson, Bottineau, Eddy, Foster, McHenry, Pierce, Ramsey, Rolette, Sheridan, Towner, and Wells Counties.

great amount of matter, some of it extremely dense and hard. Tremendous pressures bear down on much of the interior and, for this reason, some of the mantle and core materials behave more like liquids than solids. Certainly, at the earth's core, the rocks are mobile, probably something like very dense plastic. The temperatures within the earth are also great.

The popular concept of a rock is that of a hard, compact substance such as granite. However, not all rocks fit this concept and the geologist includes in his classification of "rocks" such things as loose beach sand, layers of partially-cemented sand such as is found in the North Dakota badlands, and glacial "till" consisting of a mixture of uncemented materials ranging in size from clay to large boulders. In general, the term "rock" implies an aggregate of mineral crystals or grains that have formed by natural processes.

Minerals

The basic components of rocks are minerals such as the silicates, oxides, and carbonates of the metallic and alkalic elements within the crust. Quartz, for example, is silicon dioxide (SiO_2), calcite is calcium carbonate ($CaCO_3$), and pyrite is iron sulphide (FeS). Although a large number of minerals occur--about 2,000 have been identified--only a small number are abundant in rocks. For this reason, the select few that are common are known as the "rock-forming minerals."

Perhaps the most common mineral is quartz, a colorless silicate with a complex crystal structure. Glass is made from pure silica sand. The fact that glass cannot be scratched by a knife blade indicates that it is harder than steel and that's why diamond, a form of carbon that is the hardest of minerals, can be used to cut glass. Because minerals differ in hardness, this physical property may be used to distinguish between minerals that are otherwise similar. Color, luster, and specific gravity are other properties of importance to the mineralogist (one who works with minerals). Minerals can be distinguished by their particular properties.

Rocks

Rocks are made of combinations of minerals. The three varieties of rocks are *igneous*, *sedimentary*, and *metamorphic*. The igneous rocks (from the Latin, *ignis*, "fire") were once hot, molten rock matter known as *magma*, which subsequently cooled to a firm, hard material, much as water freezes to ice. Some of the deepest crustal rocks in North Dakota are igneous granites. The granites are buried under 300 to 15,000 feet of younger rock so they cannot be seen in-place (that is, in the position in which they formed) any place in the state. However, igneous boulders are scattered on the surface of the ground throughout the part of North Dakota that was glaciated. These boulders were transported to their present locations from Canada, mainly Ontario, by the glaciers.

Sedimentary rocks (from the Latin, *sedimentum*, "settling") have been derived from preexisting rocks by the processes of erosion. Rain, ice, and wind are powerful destructive forces that constantly tear down the earth's surface and reduce its topography. The particles worn from any eroded rock mass are eventually carried by rivers and streams to lakes and seas. In North Dakota, sedimentary rocks such as limestone, sandstone, and shale, all of which were deposited in water, lie above the igneous rocks. They formed when sediments washed into the seas that covered the state during much of the past 600 million years. In the same way, topsoil today is washed from the Red River Valley and deposited in Hudson Bay, or from the North Dakota badlands and deposited in the Gulf of Mexico. Such sedimentary rocks are as much as 15,000 feet thick in parts of western North Dakota. Figure 1 includes a cross section showing how the sedimentary rocks thicken westward toward the deeper parts of the Williston Basin. The Williston Basin of western North Dakota was once a sea in which thick sediments were deposited, much as sediments are being deposited today in the Gulf of Mexico.

All of the rocks already mentioned may be subjected to changes that alter or modify their texture, mineralogy, or chemical composition. Rocks that have changed are known as metamorphic rocks (*metamorphic* means "to have changed"). They began as one kind of rock and were changed to another kind. The change to metamorphic rocks may have been accomplished by heat, pressure, or the action of magmatic gases. For example, when heat and pressure are applied to limestone, the limestone may change to marble. In the same way, shale changes to slate. The only metamorphic rocks that can be found in North Dakota were carried here from Canada by glaciers.

ROCKS IN NORTH-CENTRAL NORTH DAKOTA

In general, two kinds of sedimentary rocks are found in north-central North Dakota: bedrock and glacial drift. The bedrock, which is much older than the glacial deposits forms the surface on which the glacial sediments was deposited throughout the area. Where glacial deposits are absent, bedrock can be seen. In north-central North Dakota, the oldest bedrock that can be seen is shale of Cretaceous age about 100 million years old in Eddy and Foster Counties where the Sheyenne and James Rivers have cut through the glacial sediment cover. In the western part of the area are scattered exposures of bedrock that include sandstone, shale, and lignite that ranges in age from late Cretaceous to Tertiary, as young as about 50 million years old.

The glaciers that advanced over North Dakota several times during the Pleistocene Epoch covered all but the southwest corner of the state. Consequently, the area north and east of the Missouri River is characterized mainly by landforms related to glaciation. A veneer of glacial deposits covers glaciated areas southwest of the Missouri River where the landscape is largely erosional.

During the past two to three million years, glaciers repeatedly overrode north-central North Dakota. The last of these glaciers melted about ten thousand years ago. There were times between glaciations when the area was as free of glacial ice as it is today, but the entire period (two or three million years ago--until ten thousand years ago) is known as the Pleistocene Epoch or "Ice Age." Figure 2 shows the glaciated area of North America.

Sand, silt, gravel, and clay are among the materials deposited by glaciers. Boulder piles and "stony" fields report "the glacier was here!" Before the Ice Age, all of North Dakota had buttes and large-scale, wind- and water-sculptured scenery similar to the area west of Mandan today. When the glaciers overrode north-central North Dakota, they planed off the more rugged features and filled in the valleys with loose, ground-up deposits that had been carried southward in the ice. The landscape in the glaciated part of North Dakota is *constructed* (deposited by the ice), but the landscape of the unglaciated part of the state is *eroded* and was worn down by running water and wind action. Included in the glacial deposits are boulders of all sizes that were broken from the Canadian Shield area northeast of Winnipeg. The fertile soils of North Dakota derived these minerals from rocks ground up by the glaciers. Bacterial action and

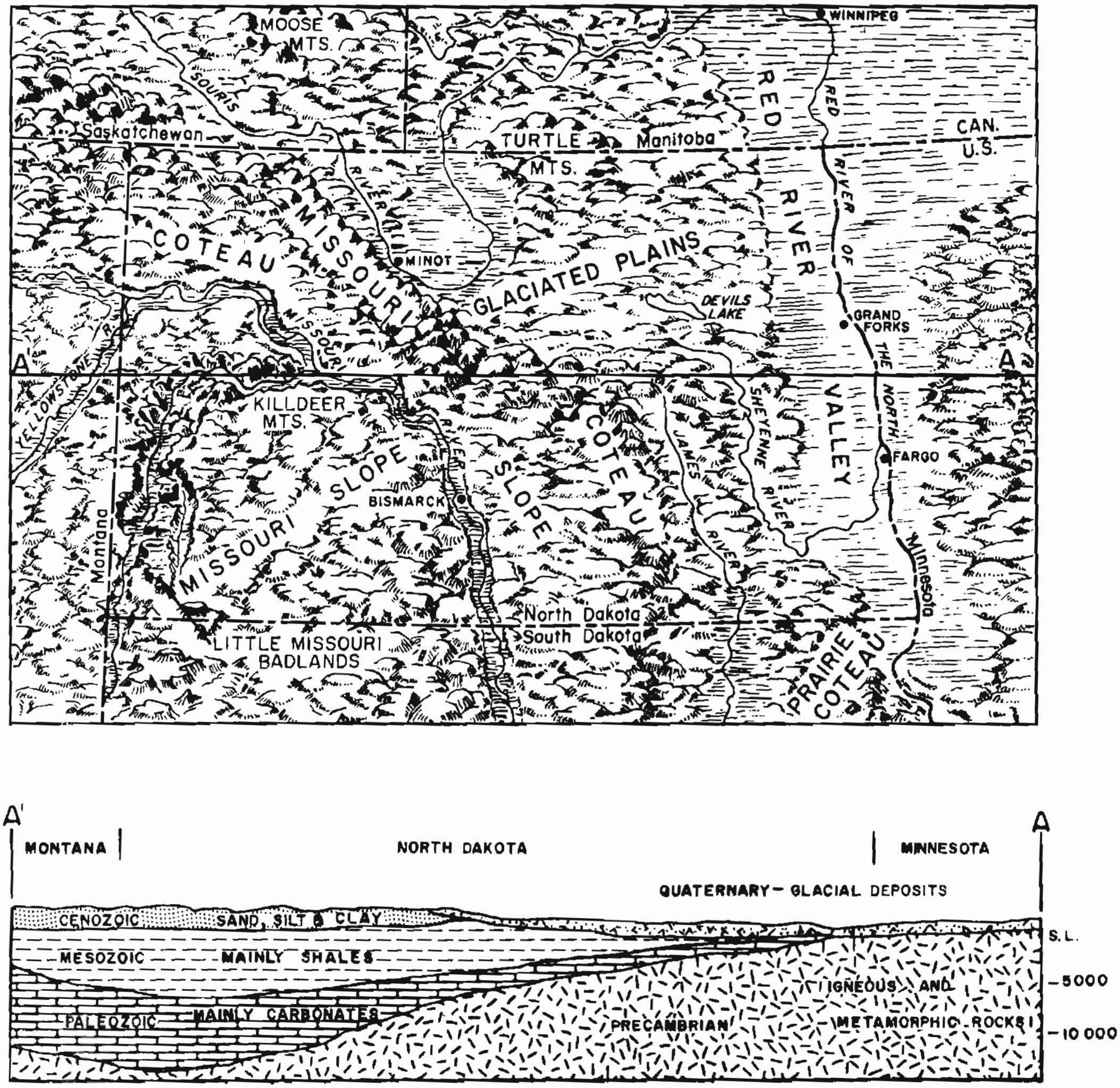

Figure 1. Physiographic map and cross section of North Dakota. The cross section A-A' shows how the sedimentary rocks are thicker in the Williston Basin in the western part of the state.

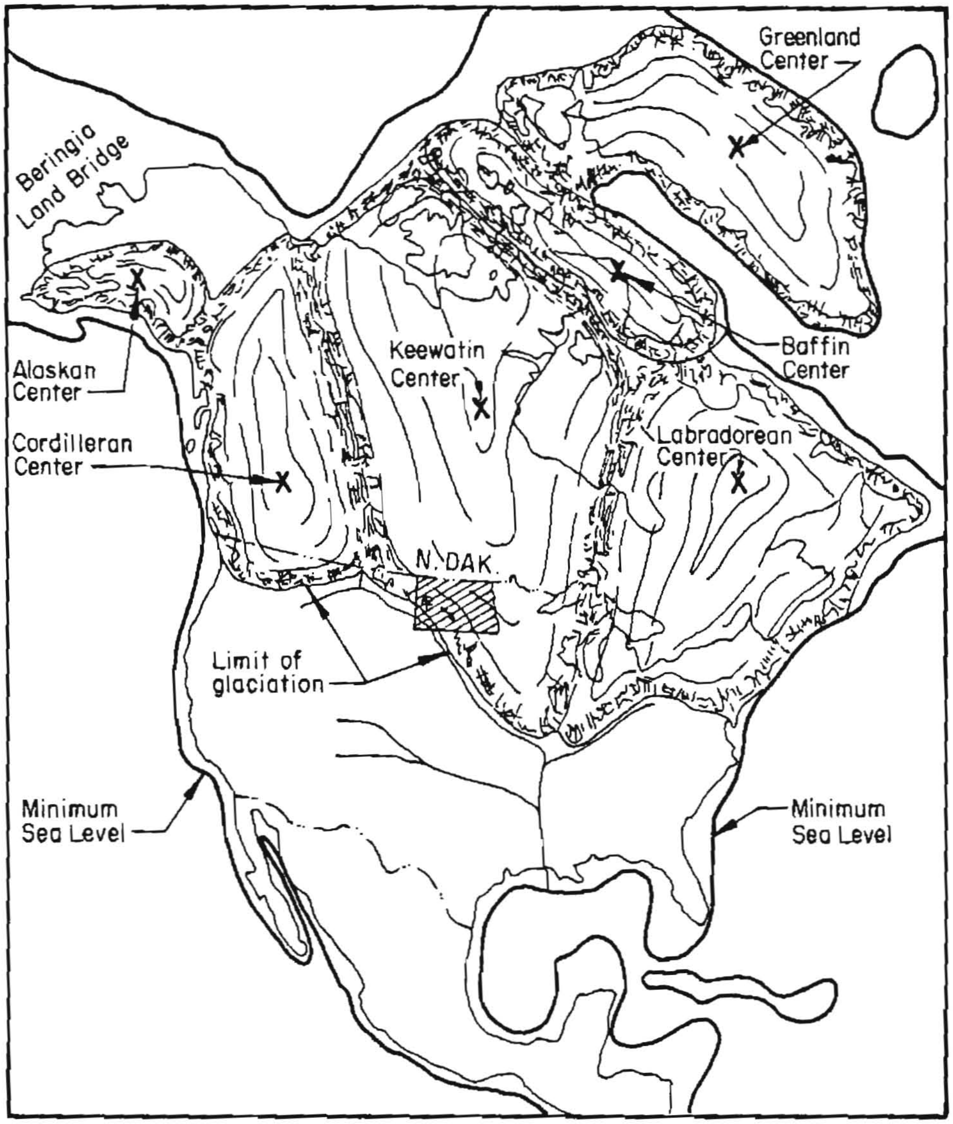

Figure 2. Map of North America showing the limit of continental glaciation. Ice that covered North Dakota originated in the Keewatin center west of Hudson Bay.

weathering at the surface are constantly disintegrating the glacial drift and changing it to soil.

THE ICE AGE IN NORTH-CENTRAL NORTH DAKOTA

Before the Ice Age, bedrock formed the landscape in north-central North Dakota. The land was gently rolling with a few buttes in the area that is now the Turtle Mountains. The larger streams flowed northward toward Hudson Bay, as the Missouri River drainage system did not yet exist.

During the Ice Age, glaciers formed west of Hudson Bay due to the accumulation and compaction of yearly snows that didn't completely melt in the summers. This same process occurs today in glaciated mountainous areas and on the Greenland and Antarctic ice caps. As snow piles up and turns to ice, its accumulated weight builds up high pressures at the base of the ice. Under sufficient pressure, ice acts as a fluid and flows, much like water. The Hudson Bay glaciers flowed into North Dakota overriding even the highest hills as they flowed southward. Large rocks, as well as other surface materials, were ground up by the ice, which was in constant movement. The shifting weight of the flowing ice caused continual slippage along fracture planes within the glacier. Materials from beneath the glacier were carried upward through the ice so that it was heavily loaded with debris. This debris was deposited on the ground when the ice melted.

When the ice first advanced over north-central North Dakota several hundred thousand years ago, the north-flowing streams became blocked and lakes formed in the valleys in front of the ice. Silt and clay accumulated in these lakes. As the ice continued to move southward, it overrode the lakes and deposited glacial sediment on top of the silt and clay. At the same time, the ice diverted the north-trending drainage to a southerly direction around the glacier margin.

The Missouri Escarpment in Wells and Sheridan Counties and the Turtle Mountains in Bottineau and Rolette Counties are steep topographic rises that the glaciers had to override as they flowed southward. When the glaciers overrode these uplands, internal shearing was initiated in the ice with the result that large amounts of material were picked up by the glacier. This material, known as glacial drift, was carried up onto the Missouri Coteau and Turtle Mountains. These areas approximately coincide with unit 7 on the geologic map. Most of the drift was dropped on the two areas when the ice melted.

Most of the glaciers had finally melted out of north-central North Dakota by about 12,000 years ago. However, ice persisted longer on the Missouri Coteau and in the Turtle Mountains (unit 7) where a blanket of glacial drift that covered the ice insulated it and caused it to melt more slowly. A nearly continuous sheet of such drift-covered ice covered these areas. Some of the ice persisted for at least 3,000 years, until about 9,000 years ago.

When the glaciers in the Turtle Mountains and on the Missouri Coteau became covered by glacial deposits, conditions were highly dynamic with the materials on top of the ice sliding to lower areas as the ice itself melted. However, as the ice continued to melt, the glacial deposits gradually became thicker because materials contained within the ice became concentrated at the surface and the ice melted more slowly. As conditions gradually stabilized, the water that collected in lakes on the surface of the ice became more temperate. Surrounding the lakes and streams were forests of spruce, tamarack, birch, poplar, aquatic mosses, and associated vegetation, all growing on the debris-covered ice. Fish were able to migrate up the streams from the Missouri River tributaries. Most of the water in the lakes was provided by local precipitation rather than melting ice. The mean annual precipitation 10,000 years ago was probably several inches higher than it is today and the mean annual temperature was a few degrees cooler.

Eventually, all the ice melted, and all the material that had been on top of the ice dropped down, resulting in the hilly topography that is typical of the Turtle Mountains and Missouri Coteau today. Modern rainfall is slightly higher over the Turtle Mountains than on the Missouri Coteau, and this results in woodlands in the Turtle Mountains (fig. 3).

The climate slowly moderated and became drier after the end of the Ice Age. In fact, between about 7,000 years ago and 2,500 years ago, it was both warmer and drier than it is

Figure 3. Wooded area of dead-ice moraine in the Turtle Mountains, Bottineau County.

today. As the climate changed, forests that covered the area gave way to prairies with tall grasses. Bison, migrating northward at this time, became plentiful. Sometime near the end of the Ice Age, nomadic tribes of primitive men apparently moved into the area. About 2,500 years ago, the climate of north-central North Dakota became somewhat cooler and wetter again, and it has remained so, with short-term variations, to the present day.

LANDFORMS OF NORTH-CENTRAL NORTH DAKOTA

Glacial Sediment

All of north-central North Dakota is covered by glacier sediment, that is, material that was moved and redeposited by the glaciers. Preglacial bedrock is exposed in some of the deeper valleys and at the edges of some hills, but the cover of glacier sediment, known also as "drift," is continuous in most places. The drift ranges from a few feet thick to over 600 feet thick in a few places; and, in fact, the eleven counties of north-central North Dakota are covered by about 350 cubic miles of it. Most of this material was deposited by glacial ice, while the remainder was deposited as sand and gravel by streams flowing from the glacier and as sand, silt, and clay in glacial lakes.

Material deposited directly from glacial ice is called "till," which is a catch-all term applied to glacier sediment. The Europeans refer to such glacial sediment as "raisin cake," indicating that it is made up of all sizes of unsorted materials in contrast, for example, to beach deposits, which are composed of materials that were sorted into layers by water. Thicker deposits of drift commonly have constructional relief, due entirely to the accumulation itself, whereas the thinner accumulations of glacier sediment do not appreciably alter the underlying bedrock topography.

Moraine

In contrast to a smooth lake plain, such as the Souris lake plain in Bottineau and McHenry Counties, areas of moraine are hilly. *Ground moraine* is shown on the geologic map in light green and is designated by the number 5. Ground moraine consists of till that was deposited at the base of the moving glacier along with till that was let down on the surface when the ice melted.

Dead-ice moraine is shown in brown on the geologic map and designated by the number 7. Dead-ice moraine resulted when large amounts of glacier sediment were deposited on top of stagnant glacial ice, that is, on glaciers that had stopped moving but had not yet melted. When the stagnant ice eventually did melt, the overlying glacier sediment collapsed, resulting in a rather rugged landscape. The largest and most spectacular area of dead-ice moraine in North Dakota is on the Missouri Coteau, which extends from South Dakota northwestward to Montana and Canada (pl. 1). The Turtle Mountains of Bottineau and Rolette Counties are also dominated by dead-ice moraine (fig. 3). Relief in areas of dead-ice moraine reaches as much as 200 feet locally. The dead-ice moraine is poorly drained and streams are absent from the area, but sloughs are abundant. Because of the large number of ponds and sloughs, the Missouri Coteau and Turtle Mountains provide an important waterfowl-breeding habitat.

A third kind of moraine is *end moraine*, which consists of relatively narrow ridges of till that were deposited at the edge of the glacier during a time when the ice margin was melting back at about the same rate that the ice was moving forward so that the margin remained stationary. All the end moraines of north-central North Dakota are designated by the number 6 and shown in dark green on the geologic map. Relief in areas of end moraine ranges from moderately rolling to hilly, up to about 150 feet locally. Although it is difficult for the casual observer to distinguish end moraine and dead-ice moraine, the differences are apparent on air photographs. From the air, the strongly linear trends of the end moraines (aligned ridges, lakes, and sloughs) are apparent, particularly in contrast to the random arrangement of such features on dead-ice moraine.

Large Ice-Shoved Blocks

Blocks of material that were transported short distances by the glacier are common in several places in north-central North Dakota. They result in prominent hills that may be composed of either bedrock or glacial sediment. In many instances, depressions, which commonly contain lakes or sloughs, are located adjacent to the blocks. In some places, areas of rugged topography are made up mainly of such ice-shoved blocks. An example of such an area is south of Fort Totten in Benson County. Perhaps the most prominent ice-shoved block in north-central North Dakota is Sully's Hill and its associated depression, which is occupied by Devils Lake. Other block-depression features are the Prophets Mountains near McClusky (fig. 4), and

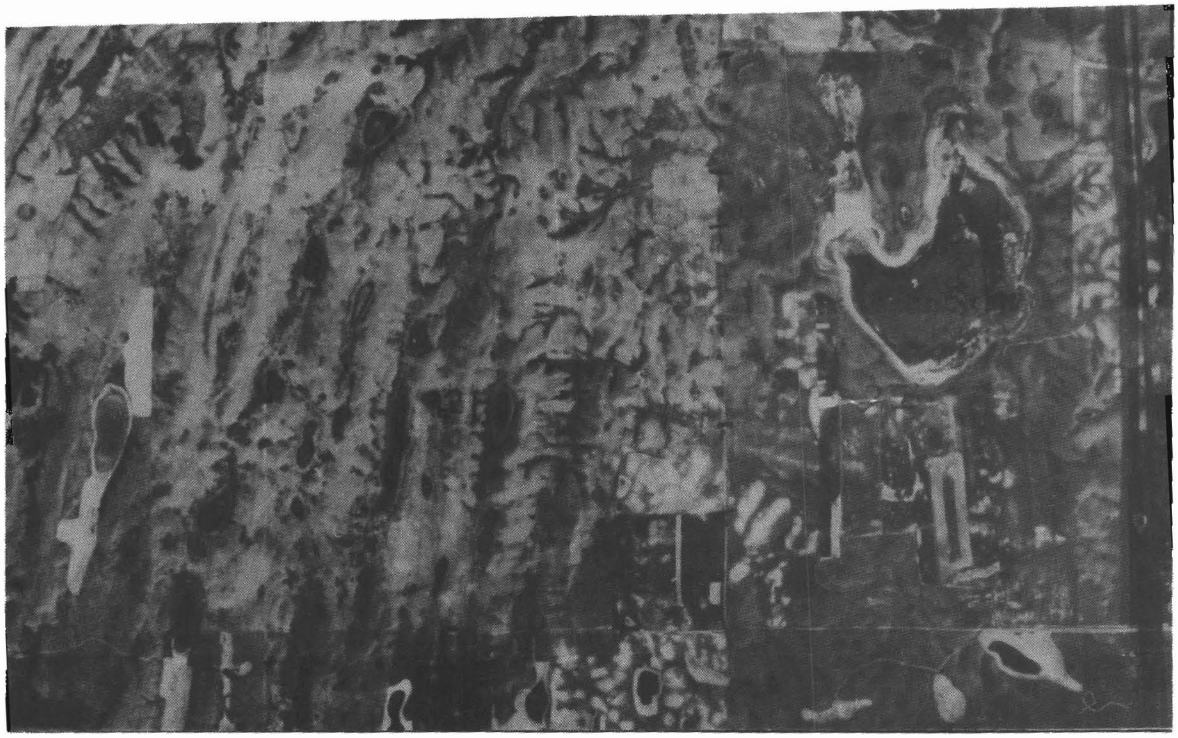

Figure 4. Vertical air view of a part of the Prophets Mountains, northwest of McClusky in Sheridan County. The glacier, advancing from right to left, caused large-scale thrusting, and stacked up layers of material (the ridges) of the Prophets Mountains. North is to the top of the photo.

numerous ones in southern Pierce, northern Sheridan, and northwestern Wells Counties.

Eskers and Kames

Eskers show the form of the glacial rivers that deposited them. In glacial times, meltwater rivers flowed on or beneath the ice, depositing sand and gravel on their beds just as modern streams deposit material on their beds. Typically, esker gravels are coarse and poorly sorted with large amounts of silt and clay, and esker surfaces may be bouldery (fig. 5). When the glacier melted, the sand and gravel remained as ridges standing above the surrounding till plain. Prominent eskers occur south of Carrington (see the roadlog for Foster County), and in north-central Eddy County (Eddy County roadlog). Kames are similar to eskers, also composed of gravel that was deposited by water flowing in or on the glacier. When the glacier melted, the gravel slumped into cone-shaped hills (fig. 6).

Drumlins

Exceptionally straight ridges that may be as much as several miles long and a few feet to a few tens of feet high are present in the Velva-Verendrye area of southern McHenry County (pl. 1). These ridges, known as drumlins, are not obvious on the ground, but they are conspicuous on air photographs. They are parallel to the direction of glacier movement and they were shaped by the move-

Figure 5. Esker ridges in Eddy County. One ridge is extremely bouldery while the other has a relatively boulder-free surface.

Figure 6. Group of prominent kames in eastern Eddy County.

ment of the glacier over the land surface.

Outwash Plains

Gravel that was washed out of the ice by water flowing from the melting glacier is known as glacial outwash and extensive areas of such material are known as outwash plains (fig. 7). Several outwash plains are shown on the geologic map in yellow and designated by the number 3. Wherever the outwash was deposited on the ground, it formed a relatively flat surface. Particularly good examples occur east of New Rockford and in the Harvey area. In some places, however, the sand and gravel were deposited on top of stagnant glacial ice, particularly on the Missouri Coteau and in the Turtle Mountains. In such areas, the original flat surface collapsed when the stagnant ice melted, resulting in a rolling surface.

The gravel of outwash plains is commonly poor in quality due to the presence of large amounts of shale. Its main value lies in its looseness, which allows large amounts of water to be stored between the grains. Such water-bearing materials are known as aquifers. The outwash deposits of north-central North Dakota are excellent aquifers that provide considerable ground water to the farmers of the area.

Lake Plains

Areas that were covered by lakes during and near the end of the Ice Age are now characterized by flat topography such as that in northern McHenry County, southeastern Bottineau County, and in the Cando and Minnewaukan areas. These areas are shown in blue on the geologic map and are designated by the number 2. The lake deposits are mainly horizontally-bedded silt and clay that were deposited in still water. In places, the horizontal bedding was disturbed by such things as mudflows in the loose, wet lake sediment, by squeezing of the lake sediments between cakes of lake-surface ice that sank as the lakes drained, by pushing

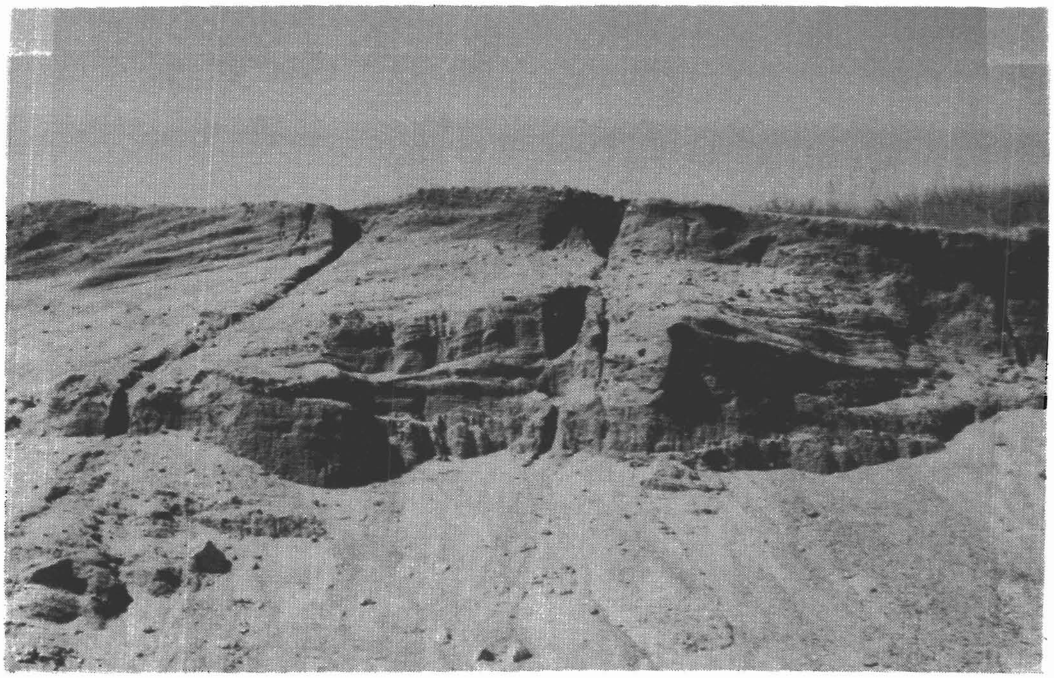

Figure 7. Cross bedded gravel in a pit in Wells County.

of lake sediments that were deposited on top of stagnant ice that later melted, or by overriding by a glacier (fig. 8).

Numerous small lakes were present on the Missouri Coteau before the stagnant ice had melted. Many of these lakes were located on top of the ice and many more were surrounded by ice. The lakes were insulated from the ice by a layer of till so that, commonly, they were actually temperate lakeswith abundant animal and plant life. Figure 9 shows the conditions that resulted in the "elevated" lake plain at Lehr in southern Logan County, but many good examples occur in the Turtle Mountains and on the Missouri Coteau in parts of Wells and Sheridan Counties.

Meltwater Trenches

The Souris, Sheyenne, and James Rivers are small streams that flow in rather large valleys that were cut by large volumes of meltwater flowing from the melting glaciers (fig. 10). During the Ice Age, the meltwater trenches carried rivers much larger than the streams that now flow in them. The Sheyenne meltwater trench and its tributaries carried large amounts of water from Lake Souris to Lake Agassiz.

Dunes

The sandy soil of glacial Lake Souris has been blown into extensive dunes in parts of McHenry County (pl. 1). The dunes are particularly large in the Denbigh area where heights of 50 feet are common. Most North Dakota dunes are covered by vegetation, and they are relatively stabilized, although some local shifting of sand occurs in dry years. Dunes are also common in northeast Eddy County and in a few scattered places where the surface material is outwash or alluvium.

Figure 8. Lake sediment that was deposited in contact with stagnant glacial ice. When the ice melted, the bedding, which was originally flat-lying, slumped into its present configuration. Southwestern Foster County.

NATURAL RESOURCES

Soils formed from glacially deposited sediments tend to be fertile. This is true in north-central North Dakota where the soil is probably the most important resource. Soils throughout the area are developed on glacial deposits. The best farmland is generally on the ground moraine, which is fairly smooth. Soils developed on the ground moraine retain moisture better than those on the sandy outwash plains.

Adequate supplies of sand and gravel are necessary for the economic growth of any area. North-central North Dakota has deposits of well-sorted gravel on terraces of the Sheyenne and James Rivers as well as abundant supplies of gravel in glacial outwash deposits.

Much of the surface water in the area is in numerous undrained depressions, intermittent streams, and a few permanent lakes, the largest of which is Devils Lake. Ground water is abundant in north-central North Dakota. Aquifers are found in the glacial gravel deposits such as those in meltwater trenches like the James and Sheyenne River valleys, and in outwash deposits such as the large one in Eddy County. Other types of water-bearing sand and gravel deposits are also found in the glacial drift. Many of these are buried within the drift and have little or no surface expression. Their location and extent are determined from subsurface data obtained from test drilling, by study of the records of existing wells, and by study of quality-of-water data. The buried drift aquifers range from narrow, linear bodies to extensive sheetlike bodies, similar to the surficial outwash deposits. Among the major buried drift aquifers are those in preglacial stream valleys such as those located in central Towner

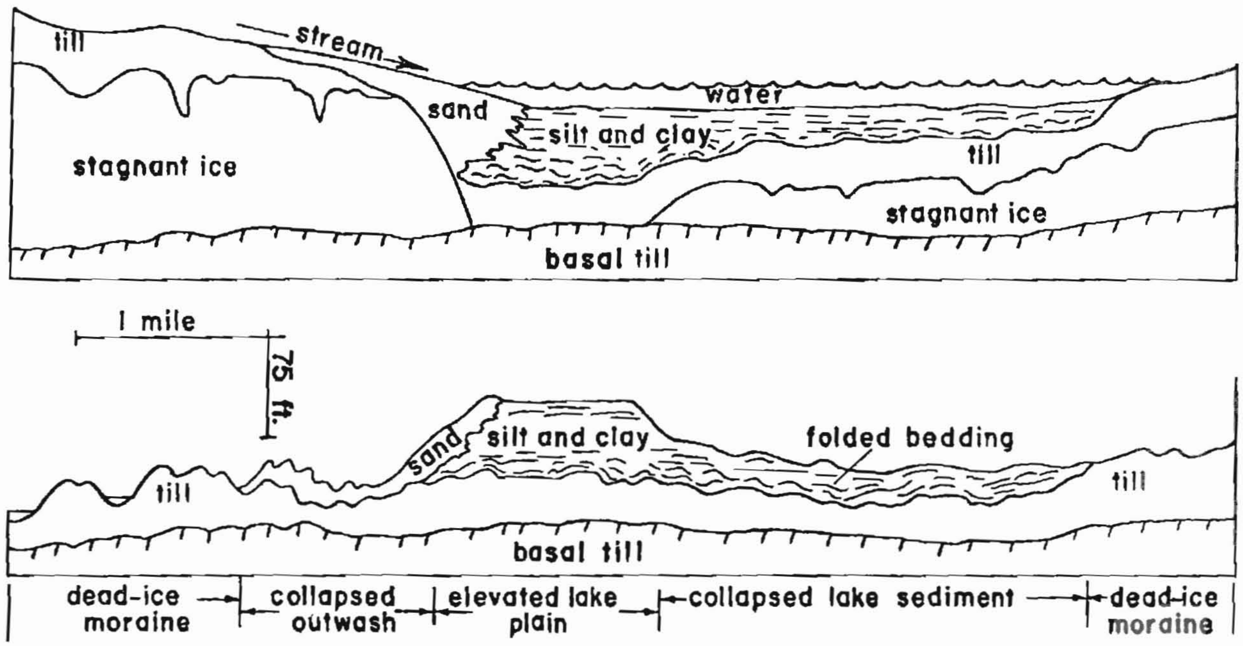

Figure 9. Schematic diagram showing the conditions that led to the development of the elevated lake plain at Lehr, in south-central North Dakota. As shown on the upper diagram, silt and clay were deposited in the lake, which was situated over an area that was partially covered by stagnant glacial ice. The lake was insulated from the ice by a layer of till so that it contained abundant life such as snails and clams. Numerous fossil shells have been found in the silt and clay deposits at Lehr.

When the stagnant ice melted, the materials on top of it were lowered. The result was an area of dead-ice moraine and a collapsed lake plain in the area where stagnant ice had been present. In the area where stagnant ice had been absent, the lake sediments did not collapse so they stand today as an elevated lake plain.

Illustration from Clayton and Freers, fig. R-13, 1967.

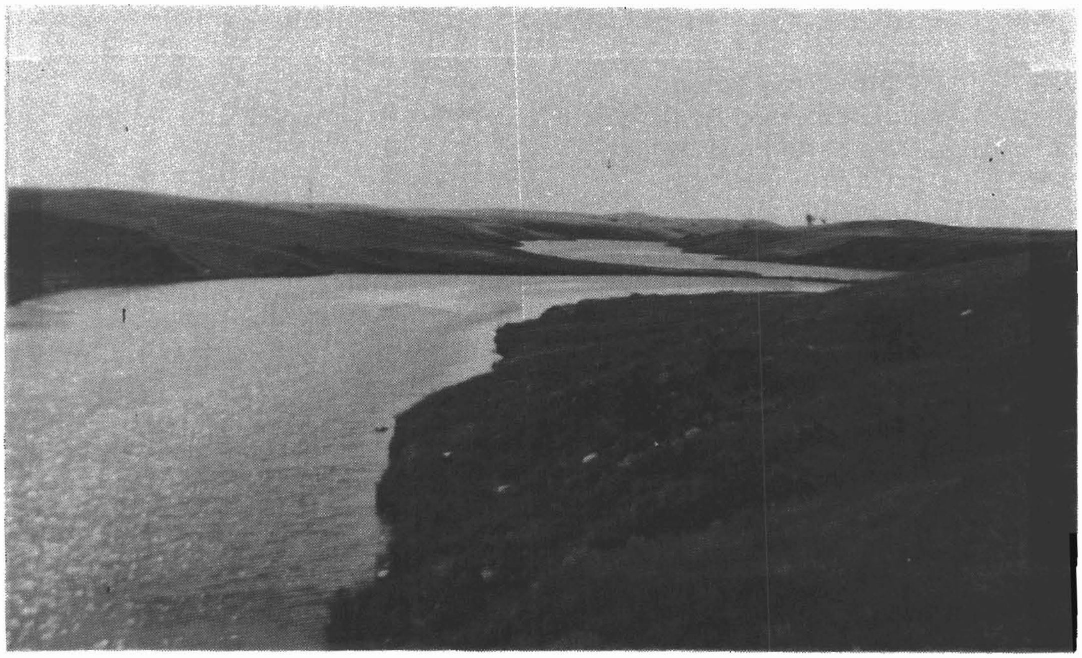

Figure 10. Meltwater trench in southwest Foster County. Small reservoir formed by Pipestem Creek.

County, eastern Ramsey County, and central Eddy County. None of these valleys are apparent on the ground and all our knowledge of them has been obtained from test drilling.

Petroleum is produced in Bottineau and McHenry Counties from about 50 oil fields. Most of the production is from rocks of the Madison Formation of Mississippian age, but some of the oil fields in Bottineau County produce from the Spearfish Formation of Triassic age. Exploratory oil wells have been drilled in the other counties in the area, but no oil has yet been found.

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GEOLOGIC ROADLOG FOR BOTTINEAU AND ROLETTE COUNTIES

(total distance about 61 miles)

Distance Between Points (miles)

Begin trip at Dunseith at junction of U.S. Highway 281 and State Highways 3 and 5. Drive north through Dunseith on Routes 281 and 3. Dunseith is built on gravel, stream sediment that was deposited by streams flowing from the Turtle Mountains at the end of the Ice Age. At that time the Turtle Mountains were covered by a more or less continuous layer of stagnant glacial ice that was itself covered and thereby insulated by a layer of glacial drift. As we drive into the Turtle Mountains, we will see landforms that resulted from this stagnant ice.

0.1

As you drive north, notice how flat the land is just south of the Peace Lutheran Church. This surface is underlain by stream sediment and if you dig anywhere in this area you will find gravel. No boulders are found on the surface in this area; the streams could not carry them. Farther north, boulders are abundant; they were deposited by the ice.

1.0

Mile marker 255. Road curves to the right.

0.1

Sharp break in slope ahead. The sharp rise marks the edge of the gravel plain and the beginning of glacial sediment (till). The gravel was deposited by water that flowed from the northwest at this point.

0.1

Notice the abundant boulders to the left as you climb the escarpment that marks the edge of the Turtle Mountains. Boulders at the surface generally indicate till. Till can be seen exposed in the roadcut by the dump to the northwest. Boulders are particularly abundant in this area because of the steep slopes; water flowing from higher areas has washed away the finer materials, allowing the boulders to remain.

0.3

Road curves to the left.

0.2

Road to San Haven. Continue northward.

0.3

Mile marker 256. You are driving into dead-ice moraine, which is typified by rugged, undrained topography. Potholes, such as the one here, are abundant. Their presence makes dead-ice moraine our main nesting area for wild ducks. The potholes represent areas where the stagnant ice was slightly thicker than surrounding areas. When the ice melted, a depression resulted. Conversely, where the ice was thin, the overlying material remained in a relatively high position when the ice melted and hills and ridges developed in these places. You will be driving through typical high relief dead-ice moraine for the next five miles or so.

3.0

Mile marker 259. Road curves to the left. You have been climbing for the past several miles, but you are now on top of the plateau that is the Turtle Mountains. The Turtle Mountains are an outlier, an erosional remnant, of Paleocene bedrock that is covered by glacial drift. The bedrock, Cannonball Formation, is everywhere buried beneath 200 to 300 feet of glacial drift and is known only from test drilling. The presence of the bedrock hills caused the glacier to "stall" as it flowed over the area, thus resulting in stagnation. Continued movement of the ice to the north, east, and west of the Turtle Mountains resulted in large amounts of glacial debris (sand, silt, clay, and boulders) being deposited on top of the stagnant ice. Later, when the stagnant ice melted, dead-ice moraine resulted.

1.7

Road curves to the left.

0.3

Mile marker 261.

0.2

Climb onto a relatively flat area.

0.4

This cultivated, flat area, which continues for about a mile, is a glacial lake plain. At the time the lake existed, stagnant ice that occurred in the area surrounded the lake and kept it from draining. Look south, and notice the ridge that marks the edge of the lake plain. This ridge consists of materials that slid into the lake off the edge of the melting ice; this indicates that the ice, and its drift cover, stood at least 50 feet higher than the lake. If you dug a hole in the lake plain, you would find black, highly organic clay. Notice the absence of boulders on the lake plain.

0.6

Road rises off the lake plain and curves to the left.

0.3

Back on dead-ice moraine.

1.3

Road to Lake Metigoshe. Turn west. This area is still dead-ice moraine. Another lake plain begins on the western horizon, about a mile away. Notice the change in topography and vegetation as you drive from the dead-ice moraine onto the lake plain.

0.3

STOP 1. Till exposures along the road. Stop to look at the till. Notice that the till is unsorted, consisting of a mixture of everything from clay-sized particles to boulders. The buff color is the oxidized color; at greater depths, below about 20 feet, the till is dark gray. Only where it is exposed to the atmosphere, and air penetrates as deep as the area that is not permanently saturated by ground water, does the till have the buff color.

0.5

STOP 2. Lake sediment exposed on the south side of the road. A good place to stop is opposite the field access road at the edge of the woods. This dark colored clay is relatively free of stones; it was deposited in an ice-walled lake in still water.

0.7

Little Prairie Cemetery. Still on lake plain. This lake plain is rolling, indicating that the lake existed on top of stagnant ice. When the ice melted, the flat-lying lake sediments collapsed, resulting in the rolling topography.

0.6

Contact between lake sediment and till. Area west of here is dead-ice moraine again.

0.6

Till exposures on both sides of the road.

2.3

Turn south. Area is dead-ice moraine.

0.6

Road curves to the right.

0.5

Willow Lake to the left.

0.9

STOP 3. Gravel pit on west side of road. Drive in and look at the sand and gravel, which was deposited by floods of water flowing southward from the ice. This was the same water that flowed out of the Turtle Mountains and deposited gravel in the Dunseith area. The gravel here is much coarser than near Dunseith because the water was flowing rapidly here; whereas, by the time it reached the Dunseith area, it had flowed and dropped much of its bedload (material it was carrying). Examine the stones and try to determine their origin. You can find such things as granite and metamorphic rocks from Ontario, limestone from Manitoba, and sandstone and shale from North Dakota and Manitoba. Return to the road and head south.

0.4

Turn west at dead end.

0.1

Gravel and sand exposed in ditch on the right.

1.4

Good exposures of till in this area.

2.5

Turn north at dead end. Area here is dead-ice moraine.

0.9

Road curves to the east.

1.0

Turn north. Dead-ice moraine.

1.0

Turn west.

1.0

Good till exposures.

0.2

Gravel pit. The gravel here is about 35 feet thick and continues for about ¼ mile to the north. It is used as road metal, but its shale content is too high for cement.

0.4

Long Lake.

0.5

STOP 4. Roadcut just west of intersection on the north side of the road. Till is exposed at the east end of the cut; sand and lake sediment at the west end. The till here is unusually hard and compact. With luck you may find a striated cobble; the scratches are the result of abrasion by the glacier as it moved over the stone or carried the stone over the area, rubbing it against other rocks.

0.9 Turn north at dead end.

1.0 Stop sign. Turn west.

1.1 North Dakota Forest Service fire tower.

1.5 Lake Metigoshe area. Continue westward on paved road.

1.5 Turn south.

0.1 Bridge over small stream. This stream, Oak Creek, drains out of Lake Metigoshe into Duck Lake and on into Bottineau. Through-flowing streams are rare in areas of dead-ice moraine where the drainage is largely unintegrated.

0.4 Second bridge over Oak Creek.

0.9 Third bridge over Oak Creek.

1.4 Lake Harman.

0.2 Climb onto the upland out of the kettle chain onto a perched lake plain.

0.6 Drive off perched lake plain onto dead-ice moraine.

1.5 Radio tower.

1.6 Drive down escarpment onto the Drift Prairie.

0.3 Bottineau County Club.

0.7 Gravel pit. This gravel is associated with the ancestral Oak Creek which washed large amounts of sand and gravel out of the area between here and Lake Metigoshe.

1.5 Paved road turns west toward Bottineau. Continue southward.

0.1 Airport. This flat area for a couple of miles south of the Turtle Mountain escarpment is largely sand and gravel that was washed out of the upland by streams. It is largely free of boulders.

0.9 Junction with State Highway 5. Turn east. Till at the surface for several miles.

0.5 Good view of the escarpment at the southern edge of the Turtle Mountains. The area you are on is underlain by Hell Creek Formation bedrock of Cretaceous age beneath the glacial drift. The Hell Creek Formation is overlain by the Cannonball Formation of Paleocene age.

The Cannonball Formation forms the escarpment, although it is covered by glacial deposits. The Cannonball Formation lies beneath the glacial deposits over the Turtle Mountains upland.

1.9

The white crust on the surface is alkali: salts that accumulate due to the upward movement of ground water in this area. This upward water movement is caused by the presence of the Turtle Mountains; water that enters the ground there moves southward beneath the ground, coming to the surface in lower areas. As it evaporates, salts that it carried became concentrated at the ground surface. The reddish plants found in such areas grow only in salty soil.

GEOLOGIC ROADLOG FOR EDDY COUNTY

(total distance about 76 miles)

Distance Between Points (miles)

Begin trip at junction of State Highway 15 and U.S. Highway 281 north of New Rockford. Drive north on U.S. 281. The first geologic feature to take note of is the valley of the James River in which the trip begins. This valley was cut by water that flowed from the melting ice to the west.

0.1

Drive out of the James River meltwater trench onto a flat sand and gravel plain that was formed by water flowing away from the glacier.

4.1

Area of end moraine. Notice the change in topography from flat to moderately rugged. The hills of the end moraine formed when the ice front stood in this area for some time. The hills are composed mainly of till that piled up at the edge of the ice.

1.3

Continental Divide. Precipitation that falls north of this point eventually makes its way to Hudson Bay; precipitation that falls south of here flows to the Gulf of Mexico.

2.3

Turn right (east) onto gravel road. This area is still part of the Heimdal end moraine. Continue eastward on the gravel road.

1.3

Drive off the end moraine onto a sand and gravel plain. Continue eastward.

0.7

The bouldery ridge along the south side of the road is an esker that formed when a stream flowing through a crack in the ice deposited sand and gravel. Boulders also slid into the crack. When the ice melted, the sand and gravel remained as a ridge. This esker is over a mile long.

1.3

Esker ends at the road. Stop here to look at the cut along the right side of the road where coarse gravel of the esker core is exposed.

2.5

Turn left (north). Continue driving over sand and gravel plain. In places the sand and gravel are thin in this area and some till at the surface results in a slightly more rolling topography.

3.0

Turn right (east).

0.5

Sheyenne River valley. This is a large meltwater trench that was cut mainly by water flowing from Lake Souris in north-central North Dakota at about the time the Ice Age was ending.

1.4

Turn right (south) at east edge of valley.

0.1

All along the east side of this road are exposures of shale, the material that underlies the glacial drift everywhere in Eddy County. This shale, the Cretaceous Pierre Formation shale, was deposited at the bottom of a sea that covered this area about 75 million years ago. This is in marked contrast to the glacial deposits that were deposited by the ice only 10,000 years ago. The best place to see the shale is at one of the cuts; dig a few inches into the brittle rock. Return to the main road.

0.1

Turn corner and stop to examine the deep cut at the north side of the road. It is in glacial deposits, till. This is typical of the materials deposited at the base of a moving glacier. The lowermost 10 feet or so is reworked shale (the darker zone). The upper, lighter colored material is glacial till.
Drive east out of the valley back onto a sand and gravel plain. In this area, particularly north of here, are a lot of potholes that formed because the sand and gravel was deposited on stagnant ice that later melted causing the overlying deposits to slump into the resulting holes.

2.0

Abandoned school on the right. As you drive east, notice the more rugged terrain. This is an end moraine.

3.6

Turn right (south) at end of shelterbelt. Continue over the end moraine, which is quite rugged and contains a lot of gravel that was deposited at the edge of the ice. It was deposited on stagnant ice, which has resulted in numerous potholes, many of which contain lakes.

1.5

Kames. These hills of sand and gravel were deposited in a hole in the ice into which debris-carrying streams flowed. When the ice melted, the sand and gravel slumped down to form the hills we see today. Several small cuts along the road expose the highly varied materials of the kame.

0.7

Turn left (east). Continue eastward over the sandy hills of the end moraine.

1.1

Turn left (north).

0.2

Turn right (east).

0.5

The small gravel pit along the left side of the road is in a small kame. Notice the bedding in the sand and how it lays at all angles. It was originally deposited as horizontal layers against the ice and slumped into the present configurations when the ice melted.

0.3

Turn left (north).

0.2

Turn right (east).

0.3

Turn left (north).

1.6

Drive off the end moraine onto a flat sand and gravel plain. This shaly sand and gravel was deposited by water flowing from ice in Benson and Ramsey Counties.

0.2

Turn right (east). Continue over the sand and gravel plain.

2.0

Road to Warwick; transformers at corner. Continue eastward. The hill ahead is cored by shale that is exposed in roadcuts along the highway.

0.1

Turn right (east) onto State Highway 20. Continue eastward.

1.4

Stop at any convenient spot for the next 5 miles or so and examine the materials of the sand and gravel plain. Notice the reddish sand mixed with chunks of shale and coarser gravel. This material was deposited by water flowing from the edge of the melting glacier to the north.

3.9

Notice the sand dunes, particularly north of the road.

0.2

Begin curve to the south and continue over the sand and gravel plain. Many sand dunes occur in this area.

2.4

Junction of State Highways 15 and 20. Continue southward.

0.3

Drive into the Sheyenne River meltwater trench.

0.3

Sheyenne River.

0.3

Drive out of Sheyenne River meltwater trench.

0.1

Exposures of the Pierre Formation shale at the edge of the valley along the right side of the road.

0.2

The gravel pits on the right produced from terraces of the Sheyenne meltwater trench.

0.2

Small meltwater trench.

0.2

Ground moraine begins.

0.8

Small meltwater trench.

2.2

Drive into large meltwater trench. Water flowed south through this trench. Notice the end moraine on the southwest horizon.

3.6

Turn right (west). About 0.2 mile to the west of the corner is a meltwater trench.

0.8

Drive onto end moraine.

2.5

Broad sag in the end moraine. In this area, the till was deposited on a large body of stagnant ice that later melted causing the overlying materials to collapse. Sand is at the surface in much of this low area.

1.0

Drive out of sag back onto uncollapsed part of end moraine.

0.9

Lake Coe on the right.

3.6

Drive onto the flat sand and gravel plain that covers much of central Eddy County (Tiffany Flats). Except for one small area of ground moraine about 4 miles to the west, you will be on this plain all the way back to New Rockford.

14.2

Enter the James River meltwater trench.

2.5

End of trip. Junction of State Highway 15 and U.S. Highway 281.

GEOLOGIC ROADLOG FOR FOSTER COUNTY

(total distance about 72 miles)

Distance Between Points (miles)

Start trip at the west side of Carrington at the site of the old Rainbow Gardens Motel. Check mileage and drive west on U.S. Highway 52 and State Highway 200. The area west of Carrington is gently rolling ground moraine that is composed mainly of sandy and gravelly clay (till). It was deposited beneath the moving glacial ice.

4.8

Turn left (south). Continue southward over the ground moraine.

3.9

Pipestem Creek meltwater trench. This trench was cut by water flowing from melting ice in Wells County to the west.

0.1

Turn right (west). Cross Pipestem Creek and turn left (south). Drive south over the ground moraine.

1.1

Sand and gravel plain formed by water that flowed from melting ice in Wells County.

1.3

Drive off the sand and gravel plain back onto ground moraine.

0.9

Turn right (west) at abandoned church building. After about a mile notice that the terrain becomes rougher. This is dead-ice moraine.

2.0

Turn left (south).

1.0

This is typical dead-ice moraine. Stop at any of the roadcuts that expose bouldery clay deposits (till) that are typical of the materials deposited at the base of a glacier. These deposits, however, were deposited on top of stagnant ice and slumped into their present positions. Potholes occur where the stagnant ice was thickest, hills where it was thin. Hawk's Nest, to the west, owes much of its height to a core of Pierre Formation shale bedrock. Return to the church building from here.

3.0

Abandoned church. Continue eastward.

0.5

Esker. This bouldery ridge formed when debris from higher areas to the southwest slid into a crack in the ice. When the ice melted, the debris (gravel, boulders, and clay) slumped into the shape of the ridge we see today.

1.6

Schoolhouse.

0.9

Pipestem Creek.

1.6

Esker. This ridge lies in the center of a valley so it is not so conspicuous from a distance. It is, however, the longest esker in Foster County. It consists of a gravel core with a cover of sandy to gravelly clay. The ridge formed when sand and gravel was deposited by a stream flowing in a valley in the ice. Debris that slid off the nearby ice resulted in a cover on the stream deposits. When the ice melted, the whole system slumped down to form the ridge we see now.

3.7

Junction with U.S. Highways 52 and 281. Turn right (south).

1.7

Melville.

0.6

Turn left (east) onto State Highway 9. Continue east over the ground moraine.

3.0

Bordulac road. Continue east.

4.0

Small esker. This esker can be seen best as a series of low knobs north of the road.

0.1

Turn left (north).

2.0

Turn right (east).

1.1

Turn left (north). The high hills to the east of here are part of an end moraine, which formed when the ice margin stood there for a prolonged period of time.

1.0

Turn right (east). This area, which is part of the end moraine, is covered mainly by bouldery clay. Boulders are also much more abundant on the surface of the end moraine than they are on the nearby ground moraine.

1.0

Turn right (south).

0.5

Turn left (east). Continue to cross the end moraine.

0.6

Meltwater trench. This trench was cut by water that flowed from melting ice to the west and north. It formed slightly earlier than the trench in which the James River now flows. While it was being formed, the glacier front stood along its eastern edge.

0.3

Drive out of the meltwater trench.

0.4

Another, smaller, meltwater trench.

0.5

James River valley. The James River flows through this third trench.

0.3

Drive out of the James River valley onto an end moraine. The end moraine here generally has a bouldery surface that is not so rugged as that west of the James River and it was deposited by a glacier that covered the area east of here. The end moraine west of the James River was deposited by a glacier that covered an area in western Foster County. It is composed mainly of sandy, gravelly to bouldery clay.

0.5

Turn right (south).

0.5

Turn left (east) at abandoned school building. Continue over the end moraine.

0.5

Turn left (north). Drive north over the end moraine. Notice the large numbers of boulders in many places. Nearly all of these were carried here by the glacial ice from several hundred miles to the north in Canada.

3.0

Turn left (west).

0.6

Drive down into the James River valley meltwater trench.

0.2

Roadcuts along the right side of the road expose weathered bouldery clay typical of that deposited beneath a moving glacier.

0.2

James River

0.1

Roadcut on the left side of the road just above the valley. The sand here was deposited by the meltwater stream when it was flowing along the west edge of the glacier. Notice also the many boulders of all different compositions. They were all carried to the area from Canada by the glacier and then retransported short distances by meltwater to their present locations.

0.6

Turn right (north) at the gate, and proceed to the high hill, a kame. In the gravel pit you can see how the bedded sand and gravel beds lie at all angles. The gravel was originally deposited in horizontal layers against the ice. When the ice melted, the sand and gravel slumped into its present configurations.
Turn around and retrace route for 1.7 miles.

1.7

Turn left (north).

4.0

Turn left (west) at the junction with State Highway 200.

0.5

Drive off the end moraine onto a small terrace of the James River.

0.2

James River meltwater trench.

0.5

James River.

0.1

Drive out of the meltwater trench onto end moraine again.

0.8

Grace City corner. Continue west.

1.6

Gradually drive off the end moraine onto ground moraine. Notice how the land levels off.

1.2

Shallow meltwater trench.

9.5

Cross a series of small disintegration ridges that trend from northwest to southeast.

1.9

Junction with U.S. Highway 281. End of trip.

GEOLOGIC ROADLOG FOR McHENRY AND SHERIDAN COUNTIES

(total distance about 22 miles)

Distance Between Points (miles)

Begin roadlog at junction of U.S. Highway 52 and gravel road heading south from Drake toward golf coarse.

0.3

Roadcuts on hills just south of Drake expose till. The area is mainly collapsed glacial sediment. It is dead-ice moraine, which is somewhat more rolling than ground moraine.

0.7

Drake Golf Club on the west.

0.7

Road crosses valley which contains a small esker that trends southeastward.

0.9

Climb out of valley. The esker can be seen to the east where it forms the eastern edge for the lake.

0.8

This area is generally gravel that was deposited by water flowing from melting ice to the northwest.

0.7

Enter valley with Lake Richard just ahead.

0.1

Exposure of lake sediment in roadcut on the east side of the road.

0.3

Lake Richard. The valley in which Lake Richard is located existed before the last glaciation. The valley was then filled with ice and, later, when the glacier melted from the area, the ice in the valley became covered by sand and gravel deposited by water flowing from the melting glacier northwest of here. The gravel collected in several cracks in the ice in the valley resulting in eskers which we will be seeing in a few miles.

2.9

This area is mainly thin gravel over glacial sediment.

0.8

Turn east on gravel road.

0.5

Begin descent into valley. This broad valley is part of the same one mentioned earlier. The valley was filled with glacial ice which, in turn, became covered by both till and gravel. When all the ice eventually melted, the original valley was obscured by the mixture of glacial drift materials that partially filled it.

0.9

Small gravel pit on the north. The ridge in which the pit is located is a part of an esker. Notice the exposures of sand as you cross the area, parallel to the esker.

0.7

Turn north.

0.4

Turn east. Looking west from this corner you can see part of the system of eskers that fills the valley you have been crossing.

0.9

Turn south.

1.0

Turn east.

0.5

The lake to the southeast is in a depression left when the glacier excavated a large mass of material from that location and deposited it just to the southeast of the lake. It is the hill you see beyond the lake. This area of Sheridan County, along with parts of McHenry, Pierce, and Wells Counties, is unique in that it is characterized by large numbers of glacially-thrust masses and associated depressions.

Some of the glacially-thrust masses cover several square miles and, although it is often difficult to determine, they are commonly several hundred feet thick.

2.6

Turn north on State Route 14 toward Anamoose.

1.3

The hill you are now on is a glacially-thrust mass that was removed from the area now occupied by the lake just north of here.

0.8

Sheridan-McHenry County line.

1.4

The large hill to the right is a glacially-thrust mass; the lake just south of the town of Anamoose is the location from which the glacier removed it. Individual ridges may be seen on this glacially-thrust mass. They probably represent separate shear zones in the glacier.

0.7

Junction U.S. Highway 52 and State Route 14 at Anamoose. End of roadlog.

GEOLOGIC ROADLOG FOR PIERCE COUNTY

(total distance about 45 miles)

Distance Between Points (miles)

Begin trip at junction of First Street West and Fourth Avenue NW at the Farmers Union Station in Rugby. Drive east out of Rugby. This area is covered by thin gravel that overlies lake sediments. The gravel was deposited by water flowing from melting ice that was located about 10 miles northeast of here.

1.0

Turn south and cross the railroad track.

0.1

Cemetery. Stop here and visit the pit just west of the road. Level bedded lake sediments are well exposed in this pit. Lake silts lie on top of fine- to medium-grained sand showing that, before it was flooded by the lake, running water flowed over the area. Continue south.

0.9

Junction with U.S. Highway 2. Turn east. You are driving over thin gravel on lake silts, the same materials you saw in the pit.

0.5

Leave the gravel and drive onto lake plain. This rather flat area was covered by the waters of Lake Souris. The level-bedded silt, which covers this flat area, was deposited at the bottom of the lake. Lake Souris was a large lake of glacial meltwater located mainly west of here in McHenry and Bottineau Counties.

1.6

The hill ahead is composed of gravel that was not covered by the waters of Lake Souris as it was too high and therefore became an island.

0.4

Top of gravel hill. Drive off the hill back onto the lake plain.

3.4

Benson-Pierce County line. Continue driving over the lake plain.

0.6

Turn northeast on gravel road toward the town of Pleasant Lake.

0.4

Road curves eastward. This is the eastern edge of the Souris lake plain.

1.1

Turn north, cross the railroad tracks, turn east and continue northward along the east edge of the town of Pleasant Lake.

0.7

Road curves northeastward at the county line (Benson-Pierce). This curve in the road is a correction line that results from the convergence of the meridians toward the north pole. The area is glacial outwash gravel. As you drive northward, notice the hills to the east. These are part of an end moraine that was deposited at the edge of the glacier.

2.5

Road curves eastward around lake. This area is gravel-covered. The gravel was deposited by meltwater flowing from the ice while the end moraine was being deposited.

0.5

Turn east. Road curves slightly northward. This area is slightly collapsed outwash that was deposited on top of blocks of stagnant glacial ice.

0.2

Good exposure of gravel in roadcut, south side of the road. This outwash was deposited by water flowing from ice about a mile east of here.

0.4

Gravel exposed on both sides of the road.

0.2

End moraine. Notice the hilly topography and numerous boulders.

0.3

Gravel pit north of road. This gravel was deposited by a stream flowing either in the glacier or near its margin, westward to the outwash area you have just crossed. Turn around and drive west.

1.1

Junction with gravel road. Continue westward over collapsed outwash gravel.

0.9

Road curves northwestward. The flat area southwest of here is typical of outwash that was not deposited on stagnant ice. Only where outwash is deposited on stagnant ice does it acquire the hilly topography you have been observing.

0.8

Road turns west.

0.2

Notice the small exposures of lake sediments on the south side of the road just west of the pond.

0.6

Small area of ground moraine with till at the surface. In the lower areas ahead occurs more gravel.

1.2

Turn north. This area is largely glacial outwash that was deposited on top of stagnant ice by meltwater flowing from the east. When the stagnant ice melted, the gravel became collapsed, resulting in the irregular topography you see today.

0.7

Drive north off the collapsed outwash onto ground moraine.

2.0

This flat area is ground moraine covered by till that was deposited at the base of the moving glacier.

0.5

Low gravel ridge. This ridge is apparently an esker, deposited largely by water flowing through a crack in the glacier. The water was flowing from northeast to southwest.

0.2

Roadcut exposes till on the west side of the road.

0.2

This valley carried meltwater from east and northeast of here into Lake Souris to the west. Gravel lies beneath the valley floor.

0.6

Road curves around lake.

0.4

Road turns north again.

0.6

Turn west. This end moraine was deposited at the edge of the glacier at a time when the glacier had become stabilized for awhile (ice was moving forward at the same rate as its margin melted back). While in this position, the ice carried much debris to its margin and dumped it. Meltwater flowing from the ice deposited the gravel you have just driven over.
Notice the hilly topography, numerous cuts in till, and bouldery surface in places. All are typical of end moraine. The glacier margin extended for several tens of miles to the southeast from here and to the northwest.

1.0

Small valley. This valley carried meltwater from about a half mile north of here to about a half mile south of here.

1.4

Roadcuts in till. This is a good place to stop and look at a fairly typical till deposit. Notice the mixture of all sizes of pebbles and cobbles in the clay to silt groundmass.

1.3

Drive down off the end moraine onto an area of outwash. The area was flooded by glacial lakes at times.

1.1

Lake sediment is exposed at the curve south of the lake. As you continue westward, the gravel gives way to sandy till. Apparently this sandy till was deposited when the glacier advanced over an area of gravel.

2.3

Turn south on gravel road.

0.4

Small valley. This valley carried meltwater from the glacier about 4 miles east of here to Lake Souris, the eastern edge of which was located about a mile west of here.

0.7

Another valley, similar to the one described above.

1.8

Stop at the gravel pit at the edge of the large hill. In this pit you can see numerous exposures of bedded, water-lain gravel as well as large chunks of till. These chunks of till slid from the ice as mudflows into the stream gravels. Notice the numerous small faults in the gravel (offsets in the bedding). These faults formed when stagnant ice beneath the gravel melted, allowing the gravels to drop. Although its origin is uncertain, it appears that this and other nearby hills were deposited by gravel-laden meltwater flowing through cracks in the glacier.

1.1

Turn west.

1.0

Turn south on State Highway 3. The steep hills just northwest of here are made of gravel. The flat area you are on is also underlain by gravel and probably was deposited the same time as the hills when meltwater from the cracks in the ice flowed onto bare ground.

1.5

Drive off the gravel area onto the Souris Lake plain.

2.0

Road curves to the southeast. Notice the lake sediments exposed in the ditch on the corner.

1.7

Drive onto glacial outwash. This gravel was deposited by meltwater flowing from melting ice about 10 miles northeast of here.

0.5

Rugby. End of log.

GEOLOGIC ROADLOG FOR RAMSEY AND BENSON COUNTIES

(total distance about 35 miles)

Distance Between Points (miles)

Begin trip at the junction of U.S. Highway 2 and Highways 20 and 57 south of the town of Devils Lake. Drive south on 20 and 57. This area is a lake plain that was once covered by Devils Lake. It is rather flat, typical of lake plains and covered by lake silts. Sand and gravel occur in areas of former beaches and some sand dunes are present.

1.9

At the curve, notice the rise ahead in the road. This is a beach ridge that has been modified by wind action. A few sand dunes are present in the area.

0.9

Beach ridge at the curve.

1.9

Another beach ridge. Notice the gravel pit on the west side of the road.

0.2

Scenic view of Devils Lake.

0.1

Junction of State Highways 20 and 57. Highway 20 goes east from here. Continue southward on Highway 57.

0.8

Devils Lake Sioux Indian Reservation. Ramsey-Benson County line.

1.5

Road to St. Michael. Continue on Highway 57. The gravel pits to the northwest are in beach deposits. Notice the beach to the southwest, to the left, trending across the field.

0.8

The road follows the lake around the north edge of Sully's Hill. It coincides in part with the former shoreline of the lake. The high relief to the south is part of Sully's Hill, which appears to be composed mainly of glacial till. Sully's Hill appears to be a huge block of material that was moved southward by the glacier from the depression now occupied by Devils Lake. Similar features are present elsewhere in North Dakota. In every case, a large block of material has been moved a short distance, usually less than a mile, by the glacier, resulting in a depression on the side of the hill from which the glacier came.

0.6

Good exposure of glacial till on the south side of the highway. Stop to look at the till. Notice the mixture of large and small pebbles and cobbles in a groundmass of silt and clay. Till was deposited at the base of the moving glacier and at its margin. It consists of materials that were carried in the ice and ground up within the moving glacier.

0.8

Good exposure of glacial till.

0.7

Good exposure of glacial till.

0.7

Good exposure of till overlying poorly exposed Pierre Formation shale. The shale is highly weathered and covered in most places by slump from above.

0.2

Road crosses part of the lake. Notice the boulders that have been piled along the road to keep the waves from eroding the road. These are glacial erratics, mainly chunks of igneous rock that were transported here from Canada by the ice.

0.5

Turn south toward Fort Totten.

0.8

Turn west.

0.1

Turn south on gravel road.

0.3

Ascend onto end moraine. This end moraine apparently marks the margin of the glacier while it extended generally southwestward from here and northeastward to Sully's Hill. From Sully's Hill it extended southeastward. The end moraine consists of a combination of many blocks of material transported short distances by the glacier, such as Sully's Hill, and debris that was carried to the area from greater distances. Till is exposed in numerous roadcuts through the end moraine.

1.2

Notice the hummocky topography, typical of end moraine areas.

0.3

First of several curves in the road.

2.1

Drive off the till of the end moraine onto an area of gravel. The ridge just to the west of the road is an esker that was deposited by a south-flowing stream in a crack in the glacier.

0.3

Dead end. Turn west.

0.1

Stop at the small gravel pit in the esker to look at the shaly gravel. Notice the bedding in the gravel and the many flakes of shale. The flat area to the southwest is also covered by gravel. It was deposited by streams that flowed from the glacier; probably the same water that deposited this esker deposited the gravel southwest of here after it had left the ice. The gravel area southwest of here is an outwash plain.
Continue west as far as the gravel pit just west of here.

0.3

Gravel pit in outwash deposits. Notice the bedding. The iron-stained coloration, reddish brown, is due to the presence of iron in the shale. Turn around and drive east.

0.5

Road to Fort Totten. Continue eastward over the gravel outwash plain.

0.4

You are driving back onto end moraine. Notice the cuts in till and the occasional boulders on the surface. Boulders are generally absent from the areas of glacial outwash gravels.

0.5

Glacial outwash. Notice the gravel in the roadcuts. This is partly collapsed outwash that was deposited on top of blocks of stagnant ice that later melted. When the ice melted, the overlying gravel, which probably originally had a fairly level surface, slumped down resulting in the irregular topography you see here today. The numerous ridges suggest that streams flowed through cracks in the ice in this area.

0.3

Road to Bouret Dam. Continue eastward.

1.2

Descend into Seven Mile Coulee. This wide valley is a meltwater trench that carried water from the ice in the vicinity of Sully's Hill, southward to the Sheyenne River. The striking vegetation of Seven Mile Coulee is supported by a high water table.

0.8

Drive up out of Seven Mile Coulee onto a gravel outwash plain. The surface in this area is slightly rolling, indicating that the gravel was deposited on stagnant ice in places.

1.1

Small gravel pit, north side of road. Notice the shaly gravel.

1.1

Drive up onto end moraine. Notice the many cuts in till. The glacier was mainly east of here when this end moraine was deposited.

0.9

Lake on the south side of the road.

0.2

Notice the good exposures of till along the road. Considerable gravel is mixed in in places, indicating that considerable running water was present while this till was deposited.

0.6

Road to Wood Lake to the south. Turn north.

1.0

The large hill to the west is Devil's Heart. It is composed of gravel that was deposited at the northwest end of a large crack in the glacier. The crack widened southeastward, allowing the water to spread over a wider area and deposit an outwash plain that becomes very extensive in the Warwick area.

1.1

Junction with east-west road. Turn east and cross the railroad tracks. Cuts in lake sediment can be seen at the railroad crossing.

0.1

Turn north, continuing over end moraine.

1.5

Road curves to the west around the lake.

0.5

Dead end road. Turn east.

0.2

Turn north.

0.6

Mission Bay to the west.

0.7

This rather flat area is ground moraine that is covered by till. It was deposited at the base of the moving glacier.

1.7

Junction with State Highway 20. Turn west. This area is part of the lake plain that was once covered by Devils Lake. The hill to the west marks the edge of the lake plain. Although this area was flooded, till is most common at the surface because the lake didn't cover this area for very long.

0.7

Drive back onto ground moraine.

0.5

Road curves northwestward.

0.4

Drive off the ground moraine onto lake plain. Notice the abundant boulders that mark the former shoreline of Devils Lake.

0.1

Benson-Ramsey county line.

0.8

Railroad crossing.

0.2

Junction with State Highway 57. End of log.

GEOLOGIC ROADLOG FOR SHERIDAN COUNTY

(total distance about 57 miles)

Distance Between Points (miles)

Begin trip at the junction of State Highway 14 and the gravel road 4 miles south of the Sheridan-McHenry County line. Drive west on the gravel road over ground moraine composed mainly of till.

1.0

Notice the large hills to the north and south. These hills consist of materials that were shoved up by the edge of the glacier moving southeastward.

0.8

As you continue driving westward, notice the large, broad depressions to the northwest of each hill. The materials of which the hills are composed were excavated from the depressions by the glacier.

0.2

This rough area is at the edge of one of the large hills. Most of this hill is located to the northwest of here.

0.6

To the south is a typical lake and hill relationship. The hill (directly south of the farm buildings) is formed of material that was lifted from the depression by a glacier. The lake later filled the depression.

0.4

Turn north.

0.3

This high area is one of the large ice-moved hills. Straight west is a lake marking the depression from which the hill came.

0.7

Turn west on dry-weather road. This area is covered by gravel. Water from the melting ice deposited gravel in this broad depression, which was partly filled by stagnant ice. When the stagnant ice melted, the gravel slumped down to form the irregular topography you will be travelling over.

0.9

Road curves to the south. The ridges to the west are eskers that were deposited by streams flowing through cracks in the stagnant ice. The depressions that contain lakes are areas that were occupied by blocks of stagnant ice.

0.4

Road curves to the west.

0.4

Notice the gravel exposed along the north side of the road.

0.2

This ridge is an esker. If you walk on top of the esker you can see how it curves around the lake.

0.2

Small gravel pit on the north side of the road. Stop and look at this gravel, which is very shaly with particles of all sizes. Such gravel is of poor quality except for road surface. Notice the bedding in the gravel, typical of water-lain deposits. This gravel deposit is in an esker ridge.

1.0

This high area is ground moraine composed mainly of till.

0.4

This low area is in a meltwater trench. Water flowed from northwest to southeast through this valley.

2.8

Turn south. Cross the old Fort Totten-Fort Stevenson Trail. As you drive south you are climbing onto a large (several square miles) hill that is composed of material, mainly till, that was moved southeastward by the ice from the depression now occupied by Kandt Lake. Notice the rough topography for the next two miles. Such topography characterizes these ice-thrust features.

2.0

Drive south off the ice-thrust hill onto dead-ice moraine. Dead-ice moraine formed when extensive areas of stagnant ice became covered by glacial drift, mainly till, and later melted resulting in rugged topography. Notice the very hilly topography, numerous lakes and sloughs, and patches of boulders. You will be driving over dead-ice moraine for the next several miles.

5.0

Meltwater trench. This valley, which contains the Sheyenne River, is near the headwaters of the river. The valley carried meltwater from the northwest when the glaciers were melting.

0.9

The broad, low area to the east probably marks a preglacial valley which carried a stream that flowed northwestward. This broad low area is known as the Lincoln Valley sag.

4.0

Ahead of you is part of the sag mentioned above. Elevations here are about 100 feet lower than to the north and south and, as you can see, the area is less hilly than that over which you have been driving. The preglacial stream through the area apparently came from the southwest.

3.1

As you drive south, you come out of the sag and the topography is once again more rugged and typical of dead-ice moraine.

2.0

Notice the gravel in the roadcuts. This gravel was deposited by a stream flowing on top of the stagnant ice.

2.6

Town of McClusky.

0.2

Railroad tracks.

0.1

Junction with State Highway 200. Turn east, proceeding over dead-ice moraine.

1.7

Notice the range of hills on the far southeast horizon. These are part of the Denhoff Hills, which were deposited at the margins of two lobes of the glacier, one moving east and the other west, although not necessarily at the same time.

3.6

Railroad crossing.

1.7

Collapsed outwash gravels. This is a good place to stop and observe the bedding in the gravels.

1.1

Town of Denhoff to the south. This area is part of the Denhoff Hills.

0.8

Junction of State Highways 14 and 200. Turn north on 14. The relatively flat area here at the corner is a perched lake plain, formed in a lake that existed on top of the stagnant ice. Bedded silts occur at the surface here.

0.1

Stop and look at the bedded lake silts in the road cuts.

0.2

Drive back onto till of dead-ice moraine.

0.8

These hills were deposited at the edge of a glacier that moved from the east-southeast.

3.6

Notice the broad, low area ahead. This probably marks a buried, preglacial valley, the Lincoln Valley sag.

2.5

The hills here are part of a small segment of end moraine that lies in the middle of the Lincoln Valley sag. Continue across the Lincoln Valley sag.

2.3

Road curves northeastward.

1.9

Sheyenne River valley.

0.2

Sheyenne River. Notice the gravel in the roadcuts. This gravel was deposited by meltwater flowing from the northwest prior to the time the Sheyenne River was formed.

0.2

The hills to the northwest are ice-thrust materials that cover about six square miles. They were moved from a low area immediately to the northwest of them.

4.6

Ground moraine covered by glacial till.

1.2

End of road log.

GEOLOGIC ROADLOG FOR WELLS COUNTY

(total distance about 59 miles)

Distance Between Points (miles)	
	Begin trip at the junction of U.S. Highway 52 and State Highway 3 south of Harvey. Drive south over ground moraine composed of glacier sediment (till). The gently rolling ground moraine was deposited directly from glacial ice as it moved southeastward over this area.
2.0	
	Turn right (west) on gravel road. Continue over ground moraine.
1.2	
	The hills about ¼ mile south of here are part of an esker that was deposited by streams flowing through cracks in the ice.
0.3	
	Sheyenne River meltwater trench. Stop to look at the exposures of Cretaceous bedrock, Fox Hills Formation sandstone, which can be seen where the road descends into the valley. The bedrock is harder than the glacial sediment, and pieces of hard, reddish-brown sandstone can be seen littering the surface. The reddish-brown stains are iron oxide, known also as limonite. Fox Hills sandstone underlies the glacial drift in most of western Wells County. Pierre Formation shale is the bedrock beneath the glacial drift in eastern Wells County. Numerous boulders, especially north of the road, are glacial erratics. They are abundant here because running water, the water that carved the Sheyenne River meltwater trench, left them behind as it carried the finer materials away.
0.2	
	Bridge over the Sheyenne River. The Sheyenne River meltwater trench carried water from glacial Lake Souris in north-central North Dakota (see pl. 1) to glacial Lake Agassiz in eastern North Dakota.
0.3	
	Notice the flat area of land above the valley floor just east of the farm. This is a stream terrace, a former floor of the valley, that was cut before the present valley floor was formed. Stream gravel covers the terrace.
0.4	
	Gravel outwash plain. This gravel, which covers the surface everywhere in this area, was deposited by streams flowing from the melting glacier, the edge of which was about 6 miles northwest of here.
0.7	
	Turn left (south), continuing over outwash. The relief in the area is due mainly to erosion working back from the Sheyenne River valley. Notice the sandy surface.
0.9	
	Climb slightly onto ground moraine.
0.1	
	Turn east on gravel road.
0.4	
	Drive off ground moraine back onto gravel of the outwash plain.

0.4

Small esker ridge to the north.

0.3

The hills to the south of here are part of a small end moraine. The glacier stood to the west of the hills and piled up materials at its margin.

0.3

Road descends into the Sheyenne River valley. Fox Hills sandstone is exposed on the south side of the road at the west edge of the valley.

0.2

Bridge over the Sheyenne River. Gaging station.

0.4

Turn south on gravel road. Continue southward over outwash gravel area.

1.9

Corner. Turn west and drive to the top of the end moraine.

0.5

End moraine. Notice the bouldery surface in places and the rough topography. Numerous roadcuts on top of the end moraine expose glacial till. Stop to look at some of this till. It is a mixture of clay-sized to boulder-sized particles that the ice carried with it.

0.2

Top of end moraine and continental divide. This divide separates drainage to Hudson Bay (west of here via the Sheyenne River) from drainage to the Gulf of Mexico (east of here via the James River). Turn around and drive east to the highway.

0.8

Junction with State Highway 3. Turn south, driving over till of the ground moraine surface.

1.5

Continental divide again. The hills on the southern horizon are part of the Missouri Coteau; the area southwest of the rise is known as the Great Plains; the area to the northeast is known as the Central Lowland.

1.2

Drive off the ground moraine surface onto a gravel outwash plain; notice the gravelly surface here. This gravel was deposited by water flowing from melting ice several miles northwest of here.

2.5

The area between this point and the rise ahead was a lake when the area north and southeast of here was still covered by ice. Lake sediments, mainly silts, cover the surface in this area.

1.7

Begin climbing the Missouri Escarpment. The landscape north of here, over which you have been driving, was formed as glaciers receded from the area, their margin melting back a little every year. In contrast, the landscape south of the Missouri escarpment, the Missouri Coteau, was formed when large areas of the glacier became covered by glacial drift (gravel, till, lake sediments) and stagnated in place. As these areas of stagnant ice melted, the overlying glacial drift slumped and slid, resulting in a rough landscape of relatively high relief in places.

2.0

Notice the view to the north. Notice the numerous potholes, bouldery areas, and high relief of this, the Missouri Coteau. This type of land is typical of areas over which glacial stagnation has occurred.

2.5

Notice the gravelly surface. This gravel was deposited by an eastward-flowing stream that flowed on top of stagnant glacial ice. When the ice melted, stream gravels were let down irregularly, resulting in the hilly topography you see here today.

0.5

Back on till of dead-ice moraine.

4.0

Hurdsfield.

0.1

Burlington Northern Railroad crossing.

0.4

Junction with State Highway 200. Turn east, continuing over dead-ice moraine.

5.0

Turn north toward Chasely. Notice the till exposed in the cuts at the corner.

0.6

Burlington Northern Railroad crossing.

3.0

Numerous roadcuts in glacial till.

1.6

East of here a quarter mile is an outwash plain. The Missouri Coteau lies to the west.

0.8

Drive onto the gravel outwash plain. Notice the flat topography.

1.3

Notice the level-bedded lake sediments in the road cuts at the curve. If you stop to look at these, you'll see that they are mainly free of pebbles, and fairly uniform in composition. These materials settled out of still waters of the lake.

0.6

More lake sediments near the abandoned schoolhouse.

0.5

Drive onto ground moraine. Notice the boulders in the fields in this area of till.

5.3

Junction with paved road. Continue north on gravel road over ground moraine. Notice the numerous boulders in the fields. This area was washed by running water. The same water that deposited gravel northwest of here flowed over this area after dropping its load of sand and gravel in the Harvey area. Boulders are particularly abundant in this area because the silts and clays, a normal constituent of till, have been washed away, leaving the boulders behind.

1.9

Dead end. Turn west.

0.7

James River.

0.2

Esker ridge. Notice the sandpit on the south side of the road. This gravel was deposited by a stream flowing in a crack in the ice. Stop to look at the gravel deposit. The flat area east of here is highly washed ground moraine with a thin layer of gravel at the surface. Turn around on the esker and head east again.

0.2

James River again.

0.3

Drive back onto ground moraine again

0.6

Road curves northeastward.

0.2

Road curves to the north.

2.9

Junction with U.S. Highway 52. Turn northwestward and cross the James River.

0.1

Northwest of the James River you are driving over a gravel outwash plain.

1.0

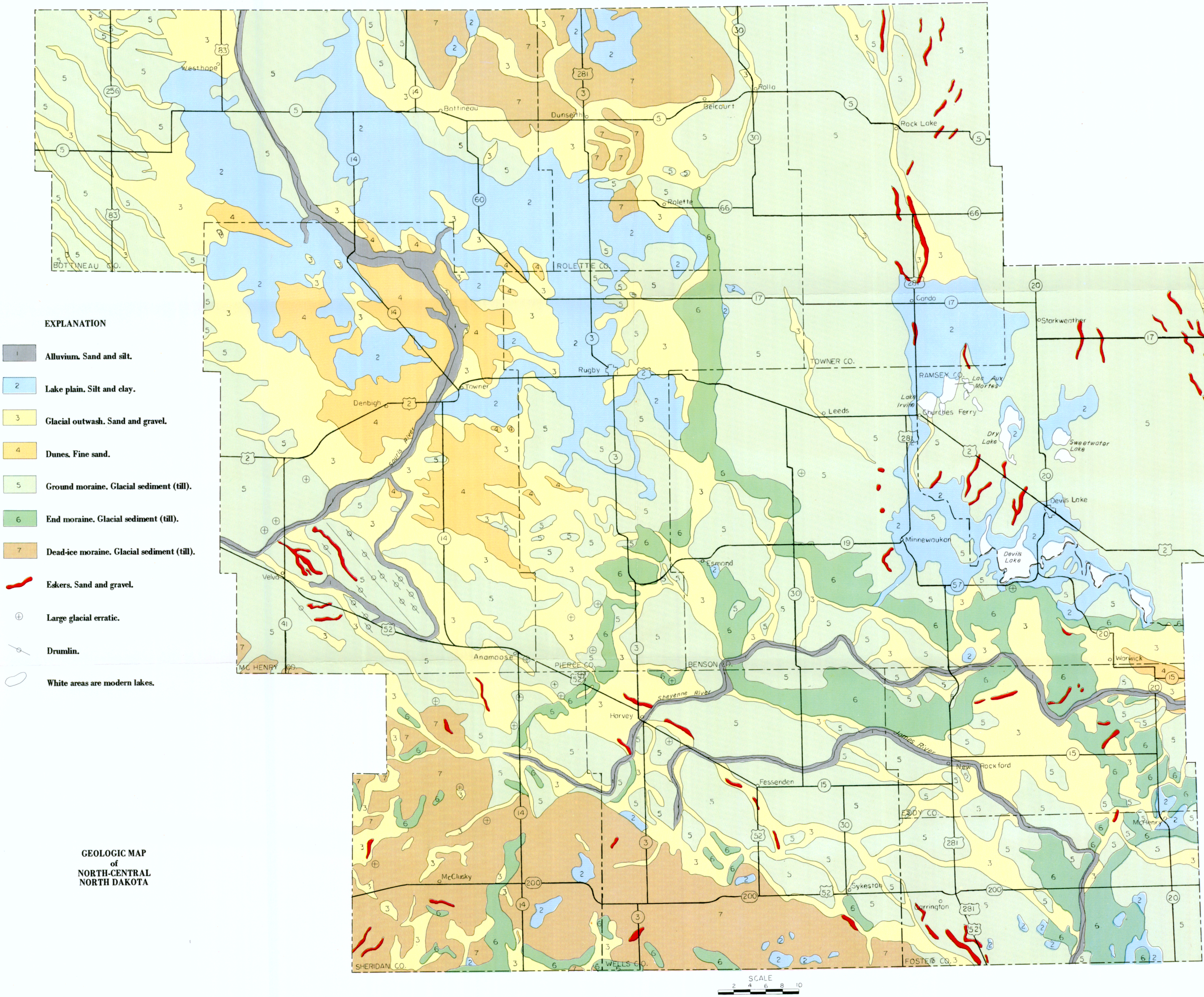
Notice the hill to the west. Immediately to the northwest of this hill is a large depression that contains Egg Lake. This depression is about the same size as the hill. The hill is a large block of material (see text of this report) that was moved from the depression to its present location. The hill was lifted about a hundred feet by the glacier.

2.4

Approximate location of the continental divide. Drainage northwest of here is to Hudson Bay, southeast of here it is to the Gulf of Mexico.

2.0

Junction of U.S. Highway 52 and State Highway 3. End of log.


GEOLOGIC MAP
of
NORTH-CENTRAL
NORTH DAKOTA
EXPLANATION
1 Alluvium. Sand and silt.
2 Lake plain. Silt and clay.
3 Glacial outwash. Sand and gravel.
4 Dunes. Fine sand.
5 Ground moraine. Glacial sediment (till).
6 End moraine. Glacial sediment (till).
7 Dead-ice moraine. Glacial sediment (till).
Eskers. Sand and gravel.
Large glacial erratic.
Drumlin.
White areas are modern lakes.
BOTTINEAU CO.
ROLETTE CO.
TOWNER CO.
RAMSEY CO.
MC HENRY CO.
PIERCE CO.
BENSON CO.
SHERIDAN CO.
WELLS CO.
FOSTER CO.
EDDY CO.
Westhope
Bottineau
Dunseith
Belcourt
Rolla
Rock Lake
Rolette
Rugby
Towner
Denbigh
Cando
Starkweather
Leeds
Lac Aux Mortes
Lake Irvine
Churches Ferry
Dry Lake
Sweetwater Lake
Devils Lake
Minnewaukan
Esmond
Velva
Anamoose
Harvey
Sheyenne River
Souris River
James River
Fessenden
New Rockford
Warwick
McHenry
McClusky
Sykeston
Carrington
SCALE
2 4 6 8 10