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N. D. Geological Survey
E. A. Noble,
State Geologist

GUIDE To The GEOLOGY Of Northeast NORTH DAKOTA

BY Mary E. Bluemle

revised edition 1975

GUIDE TO THE GEOLOGY OF

NORTHEASTERN

NORTH DAKOTA

Cavalier, Grand Forks, Nelson,
Pembina, and Walsh Counties

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Educational Series 2

North Dakota Geological Survey

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INTRODUCTION

This publication is designed to present the geology of northeast North Dakota in a nontechnical manner for nongeologists. It should be useful to the general public as a source of geologic information that can be used to explain the variation in rocks, soils, and landforms observable from cars, buses, trains, or planes. All valleys, hills, and plains are the result of geological processes, and they take on new meaning when viewed with some understanding of their origin and history. The geologic map in the pocket at the end of this publication shows the distribution and age of the surface rocks of northeast North Dakota*. Several roadlogs are included to enable you to 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.

GENERAL GEOLOGY

The part of the earth we live on is only a thin skin, known as the crust, that 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 great amount of matter, some of it extremely hard and dense. 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. Since the temperatures at the earth's core are extremely hot, the rocks are mobile, probably somewhat like very dense plastic.

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.

Geologic Time

Geology necessitates our thinking in terms of millions of years, not in days, months, or years as we are accustomed. Time is a fundamental consideration in all geological research, but it is sometimes difficult to comprehend the immensity of geologic time. The earth is about five billion years old. If all of those five 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 arrived on earth about 10:20 p.m. in the

*Cavalier, Grand Forks, Nelson, Pembina, and Walsh Counties.

midst of the ice age. At twenty seconds before midnight, Christ was born, and at ten 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; but, to the geologist, they are only an instant in the history of the earth.

Minerals and Rocks

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 very pure silica sand, quartz. The fact that glass cannot be scratched by a knife blade indicates that it is harder than steel, which is 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 can 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), but these need not concern us now.

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 rocks 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 that part of North Dakota that was glaciated. These boulders were transported to their present locations from Canada, mainly Ontario and Manitoba, by the glaciers.

Sedimentary rocks (from the Latin, *sedimentum*, "settling") have been derived from pre-existing 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. Such sedimentary rocks are as much as 15,000 feet thick in parts of western North Dakota.

All 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 by glaciers.

GEOLOGIC HISTORY

Rock and sediment deposited by glaciers and their melt waters cover most of northeast North Dakota, concealing the rocks and landscape over which the glaciers moved. Nevertheless, it is possible to reconstruct the geologic history of the area for more than a billion years before the glaciers came by studying the rocks exposed in adjacent areas never reached by the glaciers, and by studying rock fragments and drill cores brought up in the thousands of oil, gas, and water wells that have been drilled throughout the State.

The oldest rocks beneath northeast North Dakota began as thick sediments—layers of clay, sand, and mud—that built up on the floors of seas for millions, perhaps billions, of years. These sediments gradually hardened into shale, sandstone, and limestone. Then, about a billion years ago, they were transformed by pressure and heat into hard, crystalline metamorphic rocks—granite, schist, gneiss, and marble. These ancient rocks, which we refer to as the "Precambrian basement," were then raised above the sea and eroded by streams, wind, and ocean waves, until they were worn down to a smooth surface.

About 620 million years ago, northeast North Dakota again sank beneath the sea and remained submerged for much of the next 550 million years. During that time, thousands of feet of sediment that accumulated in the western part of the State hardened into limestone, sandstone, and shale. The sea floor sank as the sediment accumulated. The water, which was probably never more than a few hundred feet deep, was alive with a tremendous variety of marine plants and animals, some of whose remains decayed to form oil that became trapped within the rocks. The sea floor did not sink at the same rate everywhere; sinking was greatest below what is now the Killdeer Mountains in west-central North Dakota, where more than three miles of rock eventually accumulated. This accumulation of sediment is known as the Williston basin, and it underlies 200,000 square miles of western North Dakota, eastern Montana, northwestern South Dakota, and southern Saskatchewan. Figure 1 shows the Williston basin and related structural features in North Dakota. Only a small part of northeastern North Dakota is affected by the Williston basin.

Throughout most of the past 500 million years, North Dakota's climate has been warmer than it is now, more like Florida or the Bahamas than present-day North Dakota. During the Pleistocene Epoch or "ice age" from which we are now emerging, North Dakota has had a continental climate, with cold winters and hot summers. The Pleistocene Epoch, which began about two or three million years ago, was the beginning of a markedly colder climate. 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 (fig. 2). 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, the 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 northeast 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 motion. The shifting weight of the flowing ice caused continual slippage along fracture planes within the ice so that it was heavily loaded with debris. The debris was deposited on the ground when the ice melted.

When the ice first advanced over northeast North Dakota, all the north-flowing streams were blocked and lakes formed in the valleys in front of the glacier. Silt and clay accumulated in these lakes. As the glacier 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.

In the eastern part of the five-county area of this report, the water that was dammed in front of the glacier formed glacial Lake Agassiz, which extended from near Hudson Bay to south of Wahpeton (fig. 3). From an airplane one can clearly see the shape of the ancient lake reflected in the vegetation and landforms. Lakes Manitoba, Winnipeg, and Winnipegosis are existing remnants of Lake Agassiz.

Most of the glaciers had finally melted out of northeast North Dakota by about 12,000 years ago. By about 11,000 years ago, there was no longer any glacial ice in the five-county area, but Lake Agassiz didn't drain for the last time until 9,500 years ago. As the glacier continued to melt, its margin receded back into Canada and the level of the lake fell. The lake level dropped in a series of steps and at each step a beach formed, marking a new, lower lake shore.

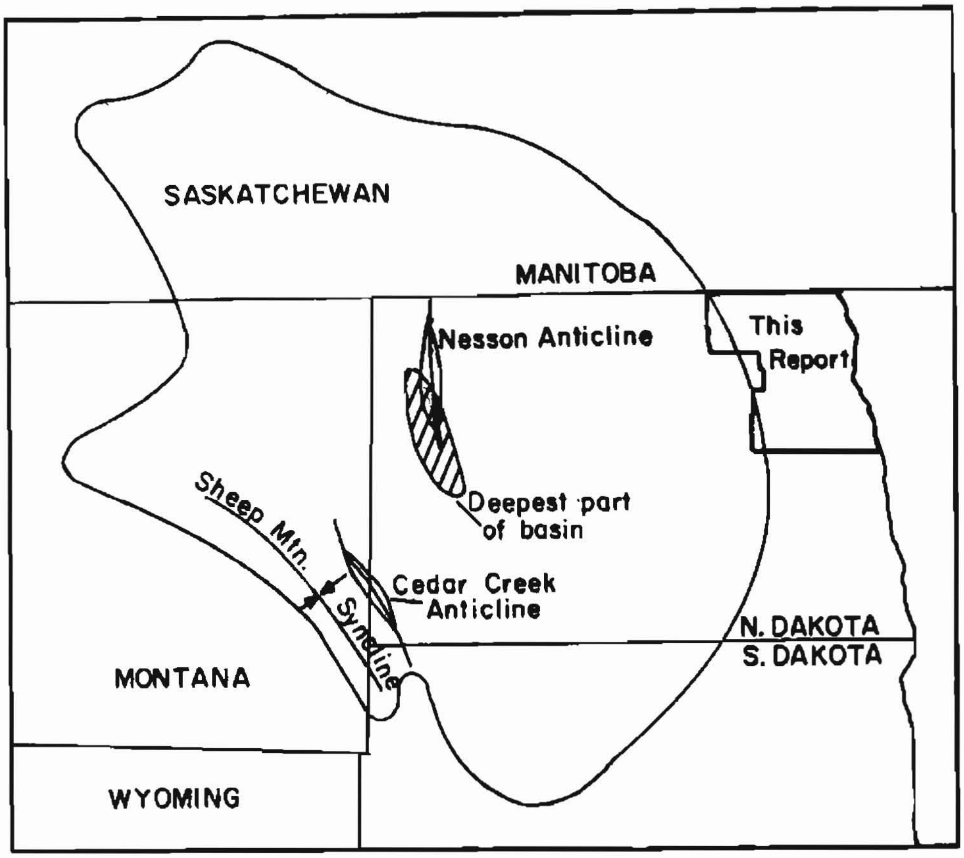

Figure 1. Map of the Williston basin showing major related structural features.

The lowering of the lake was not a steady process. There is evidence that at times the lake drained completely and then refilled. During the periods that it was drained, soils had time to form on the exposed lake sediments and spruce and tamarack forests grew there. Caribou bones that have been found in Traill County date to this time. Elephant-like woolly mammoths and elk also roamed the area.

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 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 northeast North Dakota became somewhat cooler and wetter again, and it has remained so, with short-term variations, to the present day.

LANDFORMS OF NORTHEAST NORTH DAKOTA

Nearly all the landforms of northeast North Dakota consist of materials that were deposited by the glaciers. 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 the landscape was somewhat like that along the Missouri River where buttes and large-scale, wind- and water-sculptured scenery of non-glacial origin predominate. When the glaciers overrode northeast North Dakota, they planed off the more rugged features and filled in the

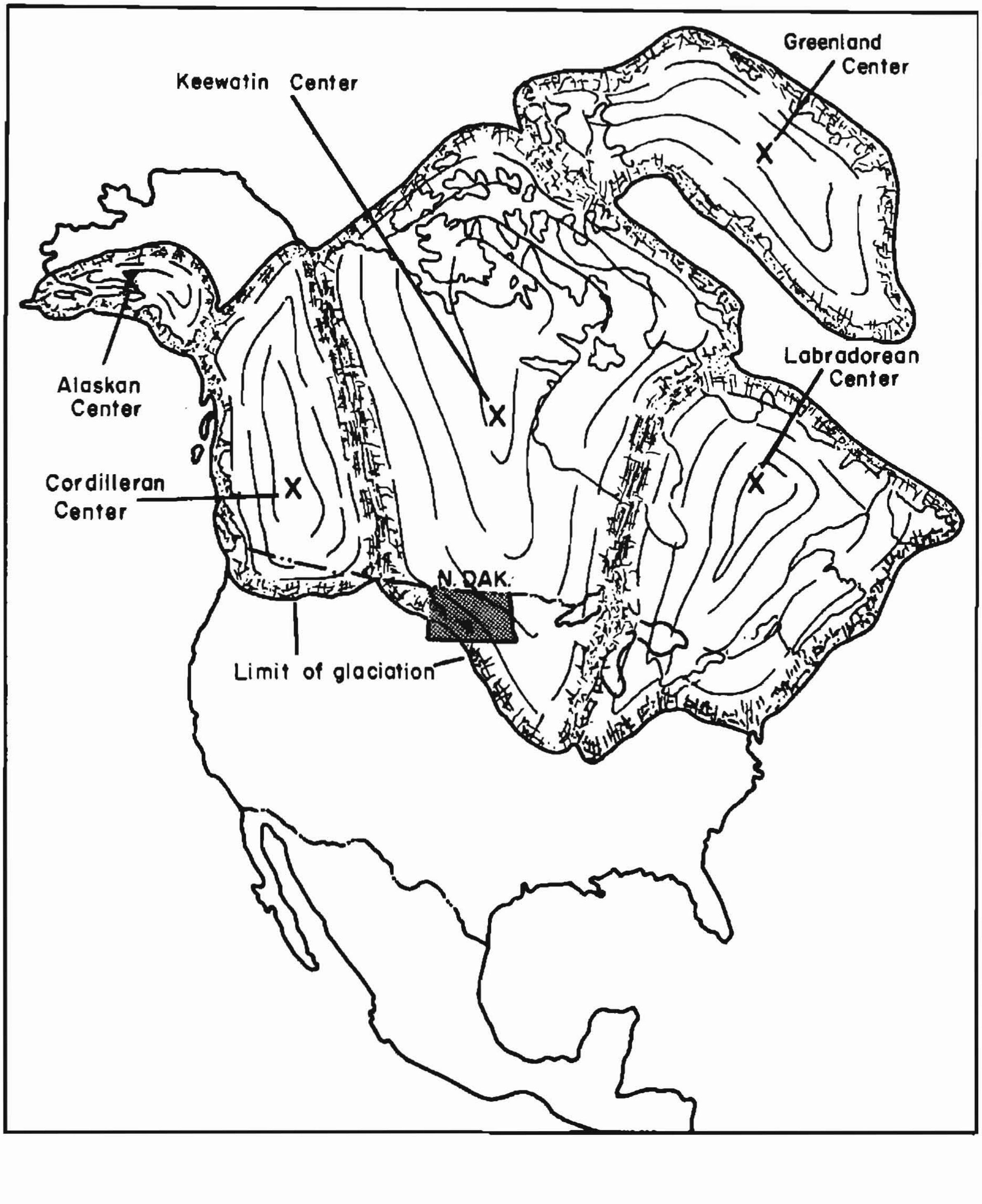

Figure 2. The above map of North America shows the limits of continental glaciation during the ice age. The main centers of snow accumulation from which the ice moved are shown. North Dakota was glaciated by ice that moved from the Keewatin center west of Hudson Bay.

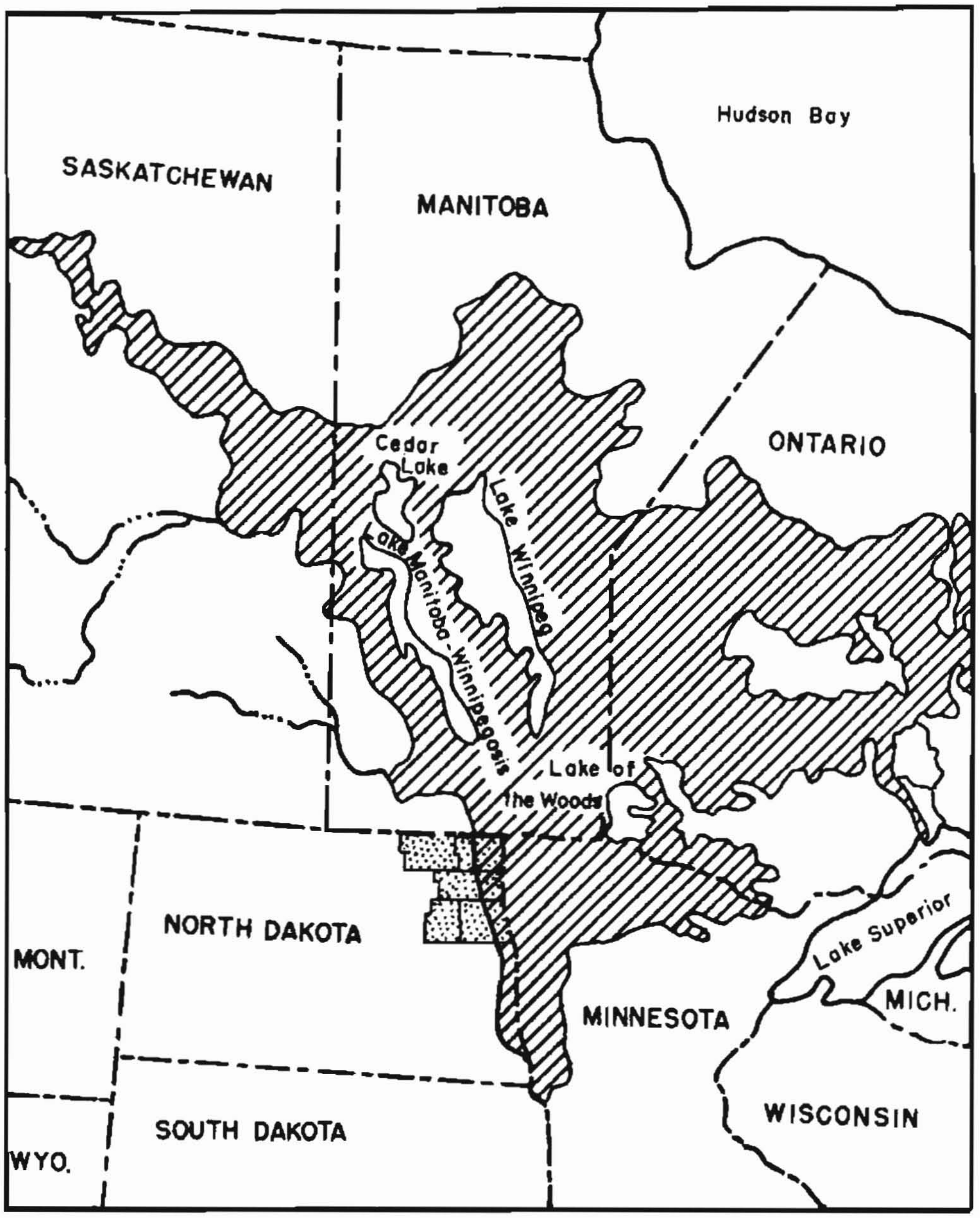

Figure 3. Map showing the area covered by Lake Agassiz, about 200,000 square miles (the combined area of the Great Lakes is about 288,000 square miles). A few of the larger existing remnants of Lake Agassiz, the largest of which is Lake Winnipeg (9,500 sq. mi.) are shown on the map. The darkened area in North Dakota is the area covered in this publication. (Illustration modified from Elson, Geology of Glacial Lake Agassiz *in* Life, Land and Water, University of Manitoba Press).

Figure 4. Boulder pavement separating two tills in Walsh County (arrow shows boulder zone). The boulder pavement separates hard, sandy glacial sediment at the base from equally hard, clayey glacial sediment above.

valleys with loose, ground-up deposits that had been carried southward in the ice. The landscape in glaciated areas is *constructed* (deposited by the ice), but the landscape of unglaciated areas such as the badlands of southwestern North Dakota is *eroded* and was worn down by running water and wind action.

Most of the sediment associated with glaciation was deposited directly by the ice. Sand and gravel was deposited by streams flowing from the glaciers, and layers of sand, silt, and clay were deposited in glacial lakes. All of these materials–glacial sediment, stream sediment, and lake sediment–are collectively known as "drift." The drift is as much as 300 feet thick in some buried valleys in northeast North Dakota. The five counties of northeastern North Dakota are covered by over 160 cubic miles of glacial deposits. Of this, about 100 cubic miles were deposited by glacial ice, 30 cubic miles were deposited as water-lain material in Lake Agassiz, and 30 cubic miles were deposited as gravel and sand by streams flowing from the glacier.

Glacial sediment is sometimes referred to as "till." The Europeans refer to the 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 the water. Figure 4 shows an exposure of glacial sediment in an excavation in Walsh County. Thicker deposits of the drift commonly have constructional relief, due entirely to the accumulation itself, whereas the thinner accumulations of drift do not alter the underlying bedrock topography appreciably. One of the few places in northeast North Dakota where preglacial topography can be seen is along the Pembina Escarpment, particularly in the northern part of the area.

Glacial Landforms

The various glacial landforms of northeast North Dakota are represented by different colors on the geologic map (pl. 1) in the pocket at the back of this guidebook. Areas shown in shades of green on the map represent glacial sediment that was deposited directly by

Figure 5. Air photo showing washboard moraines in northern Nelson County. This area of about three square miles occurs northwest of Lakota. North is to the top of the photo.

glacial ice. The manner in which the glacial sediment was deposited, and the amount that was available to be deposited, determined the type of landform that resulted. Moderate amounts of glacial sediment that were deposited at the base of the moving glacier, and from within the ice when it eventually melted, formed ground moraine, a gently rolling landscape with a few potholes and hills. This type of deposition was common; and large areas of North Dakota, shown in light green on the map, are covered by glacial sediment that was deposited in this way.

Low, irregularly-shaped and spaced ridges, known as washboards, formed parallel to the edge of the glacier in many places. They probably are the result of material beneath the glacier being carried to the surface of the ice along shear planes in the ice, although it has been suggested that some of the ridges may have been formed as annual accumulations of material at the edge of the glacier while its margin was stationary. Washboards are common on the ground moraine of northern Nelson County (fig. 5).

Large-scale shearing by the glacier moved huge blocks of material short distances in some places. If the glacier continued to advance over such a block of material, the block was effectively masked by subsequent erosion and deposition of glacial sediment. However, if the glacier stopped advancing soon after it moved a large block, the result was commonly a hill and an adjoining depression, the hill consisting of material that was transported from the depression by the ice. Blue Mountain in western Nelson County and the hill just west of Rugh Lake in southeastern Nelson County are good examples of large blocks of material that were moved as units by the glacier. Just north of Blue Mountain is a depression containing a lake marking the spot from which the ice excavated the material that now forms Blue Mountain. Similarly, the material in the hill west of Rugh Lake was taken from the depression that is now occupied by the lake.

At times, glacial sediment was deposited at the edge of the glacier while the ice margin was melting back at about the same rate at which the ice was moving forward, so that the margin remained stationary. This resulted in an end moraine, a hilly accumulation of glacial sediment that is commonly a few miles wide and several tens of miles long. Relief of twenty feet and more is common in areas of end moraine such as the North Viking and McHenry end moraines of Nelson County and the Edinburg end moraine of western Grand Forks and central Walsh Counties (pl. 1).

Glacial Melt Water Landforms

During the ice age, rivers of melt water flowed on or beneath the glacial ice, depositing sand and gravel on their beds just as modern streams deposit material on their beds. When the glacier melted, the sand and gravel remained as ridges standing above the surrounding area. These ridges are known as eskers. Typically, esker deposits are coarse and poorly sorted with large amounts of silt and clay, and esker surfaces may be bouldery. Numerous small eskers occur in northeastern North Dakota, but only a few of the larger ones are shown on plate 1. The largest esker in the five-county area is the Dahlen esker in Grand Forks and Walsh Counties.

Kames are conical hills composed of gravel that was deposited by melt water within the glacier. When the glacier melted, the sand and gravel slumped into cone-shaped hills. Kames rise a few tens of feet above the surrounding land and are about 500 feet in diameter, too small to show on plate 1. Examples of the type of bedding found in the interior of a kame are shown on figure 6.

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. Several outwash plains are shown in light yellow on plate 1. Wherever the outwash was deposited on the ground, it formed a relatively flat surface. A large outwash plain extends north to south across the western part of Grand Forks and central Walsh Counties, and another occurs in the McVille-Tolna area of southwestern Nelson County. The sands and gravels of these outwash plains form good aquifers that yield good supplies of groundwater to the farmers of the area.

In central Pembina County, an area of sand extends eastward from the Pembina Escarpment into the Agassiz lake plain. This sandy area is a delta that was deposited by the Pembina River as it flowed into the lake, much as the Mississippi River today is building a delta in the Gulf of Mexico. The Pembina River was a much larger river when it flowed into Lake Agassiz than it is today. Extensive areas of sand dunes have developed on the Pembina delta. Although most of these are stable today, a few active blowouts can be seen in places.

Just as modern lakes have beaches, so did Lake Agassiz (see plate 1). The westernmost beaches mark the edge of the lake when it covered its greatest area. Beaches are also present on what was the east side of the lake in Minnesota. These are larger than are the beaches in northeastern North Dakota because prevailing winds in glacial times were from the west just as they are today. For this reason, the heaviest wave action was directed toward the east shore of the lake. (Turkeys thrive on well-drained sandy soil. The "turkey belt" of Minnesota follows the larger beaches of Lake Agassiz.) Near the cities of Grafton and Grand Forks, small beach remnants mark the edge of the shrinking Lake Agassiz, shortly before it drained.

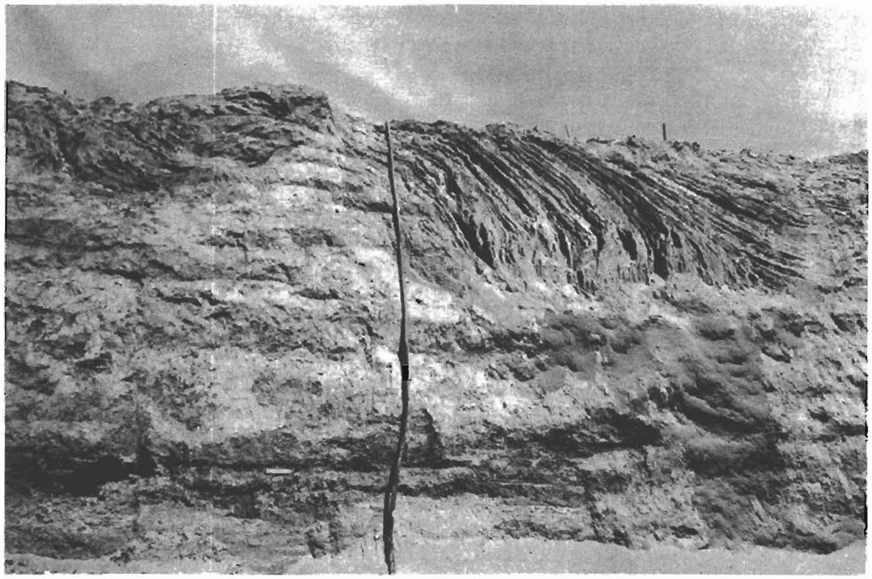

Figure 6. Two examples of slumped bedding typically found in kames, in which the sand and gravel were originally deposited in contact with glacial ice. These examples of slumped bedding are from Nelson County.

The beaches trend generally northwestward in Grand Forks County and become nearly north-south in Walsh and Pembina Counties. They rise five to twenty feet above the surrounding landscape. Like modern beaches, they are made of layers of sand and gravel. Wave action at the edge of the lake tended to sort the materials, removing the silt and clays and leaving sand and gravel. This sand and gravel is commonly layered. Many commercial gravel pits are located in fossil beaches of old glacial Lake Agassiz.

The present Red River Valley, which coincides with the lake plain formed by glacial Lake Agassiz, has the same bowl-shaped profile as most lake beds. Its floor rises a total of 300 feet between the Red River and the highest of the beaches about 50 miles to the west. Whereas the earth's curvature causes most horizons to sink, the lake plain's bowl-shaped profile results in a horizon that rises westward from the Red River Valley to the edge of the old glacial Lake Agassiz.

The Lake Agassiz plain has grooves that are cut five to ten feet deep into the surface in the area five to ten miles from the present Red River in Pembina, Walsh, and Grand Forks Counties. These were cut by floating lake ice at the time when Lake Agassiz was very shallow, perhaps during spring breakup the last year the lake was in existence. The lake became very shallow and finally drained when the glacial ice dam on the north melted sufficiently to allow the water to enter Hudson Bay. You, the ground observer, can see the effects of the grooves on the floor of the lake plain, but the grooves themselves are difficult to see. They are reflected in the "beaded windbreaks" visible from Fargo to Gimle, Manitoba. The highest trees in the windbreaks stand in the grooves because the land is more fertile there.

The lake deposits are mainly horizontally-bedded silts and clays that were deposited in still water (fig. 7). In places, the horizontal bedding was disturbed (fig. 8) by such things as mudflows and turbidity currents in the loose, wet lake sediment, by squeezing of the sediments between cakes of lake-surface ice that sank as the lake drained, by pushing of lake sediments by icebergs that scraped along the floor of the lake, or by collapse of lake sediments that were deposited on top of stagnant ice that later melted. With the help of weathering processes and bacterial decay, the lake deposits developed into rich, heavy soils. These soils contain numerous trace elements that were introduced by the glaciers and they are very fertile.

Low ridges that trend generally southwest-northeast, parallel to modern drainage, can be found in a few places on the lake plain. These are "differential compaction ridges," and they were formed when streams flowed over the lake plain while it was drained for awhile. These streams deposited sand and gravel in their beds. Later, the lake again flooded the area and laid down a covering of silt and clay over the stream deposits. When the lake finally drained for the last time, the water-saturated sediments slowly dried out, settling several feet (fig. 9). The gravel and sand settled less than the surrounding lake sediment, and ridges resulted. Examples of differential compaction ridges are the Horgan Ridge in northern Pembina County, and the Forest River Ridge just west of the town of Forest River.

Numerous artesian salt water wells and salty sloughs occur in the eastern part of the lake plain area. These wells and sloughs mark the edge of the Dakota Sandstone, a bedrock aquifer (water-bearing rock) buried beneath that part of the lake plain. The salty water leaves the Dakota Sandstone under artesian pressure and percolates upward. Where the salty water reaches the surface, halophytes such as *Salicornia rubra,* a small, red, salt-loving, salt-flavored plant, are common. In these areas, "white dirt" may be seen after a summer dry spell. This is salt-encrusted soil from which the salt water evaporated. Kelly Slough in Grand Forks County, and Lake Ardoch and Salt Lake in Walsh County, are salty marshes that are fed by water from the Dakota Sandstone. Streams, such as the Turtle, Forest, and Park Rivers, which flow eastward over the places where salty Dakota Sandstone waters are coming to the surface, become very salty in these areas. Clams are abundant in the upper parts of such streams, but they are virtually absent downstream from where the salty water appears.

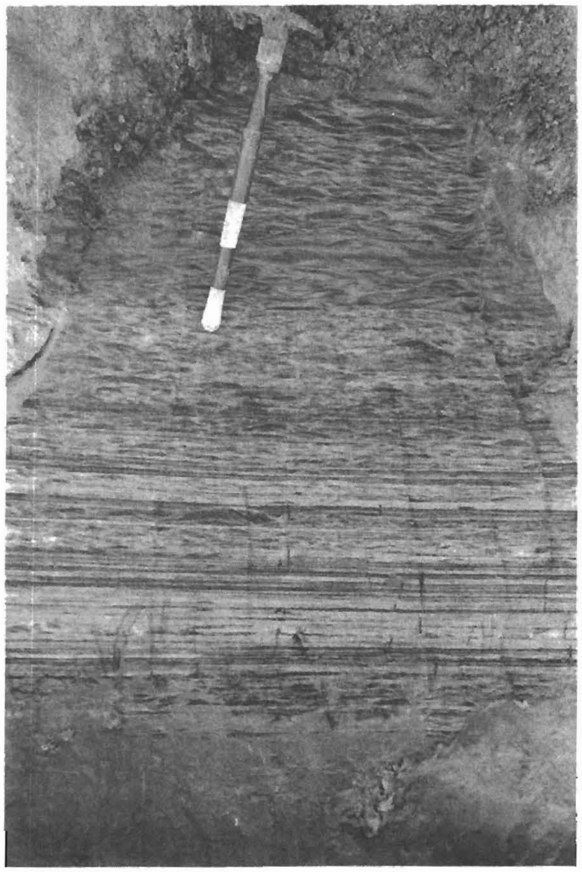

Figure 7. Plane and ripple-bedded sand at the west edge of Lake Agassiz in Walsh County.

Non-glacial Landforms

The most prominent feature in the northern part of the area is the Pembina Escarpment, an east-facing scarp that marks the western edge of Lake Agassiz and the Red River Valley (fig. 10). Surface elevations rise 300 to 400 feet in a distance of a few miles; most of the rise occurs in about a half mile. The scarp becomes less pronounced southward, although it is still apparent in western Grand Forks County.

The Pembina Escarpment is held up by a hard zone in the shale. This resistant bed, the Odonah Member of the Pierre Formation, is harder than the shale that lies beneath it due to the presence of hard, siliceous material. Some geologists have also suggested that the Pembina Escarpment is caused by a fault, but no evidence for such a fault has been found. It seems more likely that the scarp was initiated by differential erosion of the shales in preglacial time and that glaciers moving southward through the Red River Valley eroded its face, tending to accentuate it. Finally, the waters of Lake Agassiz further modified it, steepening it through wave action at the lake shore.

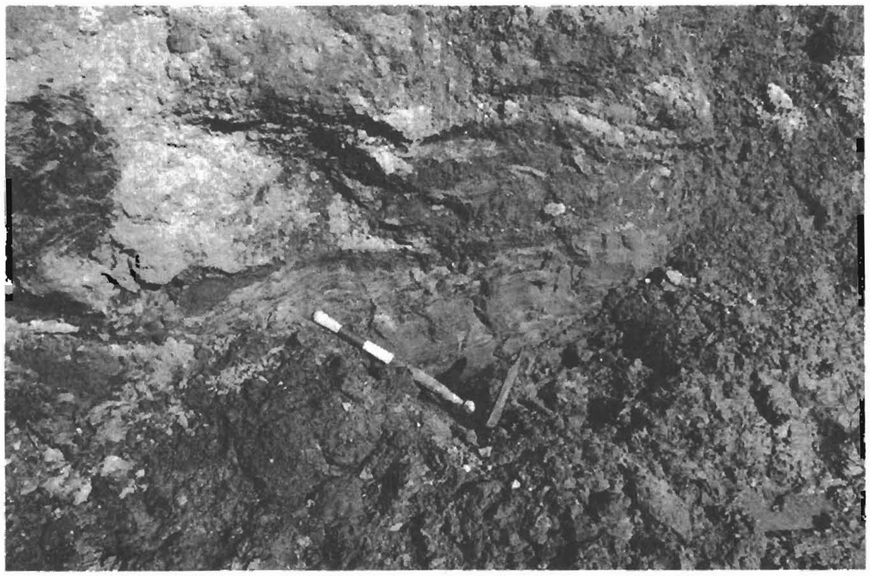

Figure 8. Contorted sand beds in till beneath the Agassiz lake plain in Walsh County. This appears to be lake sediment that was over-ridden by glacial ice.

NATURAL RESOURCES

Soils formed from glacially deposited sediments tend to be fertile. This is true in northeastern North Dakota where the soil is probably the most important resource. Soils in the eastern part of the area are developed on lake sediments deposited directly by Lake Agassiz. In the western part of the area, soils are formed on till.

Adequate supplies of sand and gravel are necessary for the economic growth of any area. Northeastern North Dakota has some deposits of good quality sand and gravel in the beaches that mark the former shorelines of Lake Agassiz. Buried deposits of sand and gravel may contain groundwater, which, if it is potable, is an important resource.

Other possible natural resources include Fuller's earth, petroleum, and cement rock. Several exploratory oil wells have been drilled in the area, but as yet no oil has been found. Fuller's earth, a natural bleaching powder, is the name applied to the bentonitic clay in western Grand Forks, Walsh, and Pembina Counties, and eastern Cavalier County. It is used in the manufacture of iron and in the bleaching of some vegetable and animal oils. Fuller's earth is now mined in Morden, Manitoba. A similar mining operation might be possible in northeastern North Dakota. A lime-rich shale that could be used as cement is present beneath the Shawnee and McCanna areas. It is, however, inferior to Portland grade cement and it has not been used. Brick can be made from the silt and clay of the Lake Agassiz deposits and, in fact, the city of Grand Forks at one time early in the century had four brick plants.

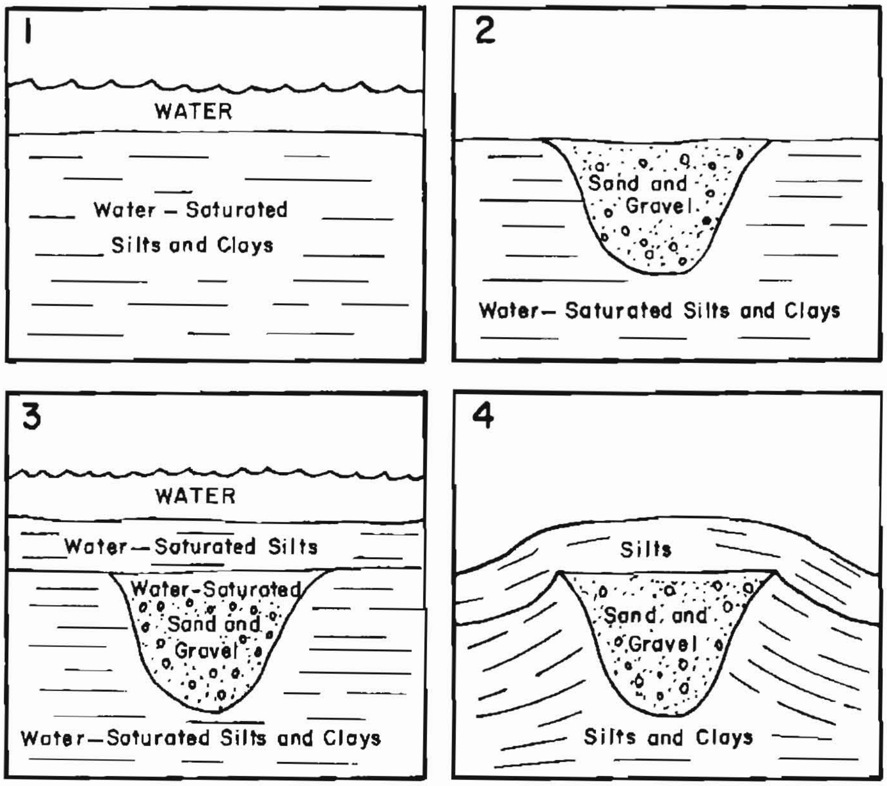

Figure 9. Steps in the formation of a compaction ridge such as the Horgan or Forest River ridges. 1. Silts and clays were deposited in the lake. 2. A valley was cut during the time the lake was drained. Sand and gravel were deposited in the valley. 3. Silts were deposited when the lake again flooded the area. 4. The area was drained for the last time. The sand and gravel in the valley did not settle as much as the surrounding silts and clays when they dried.

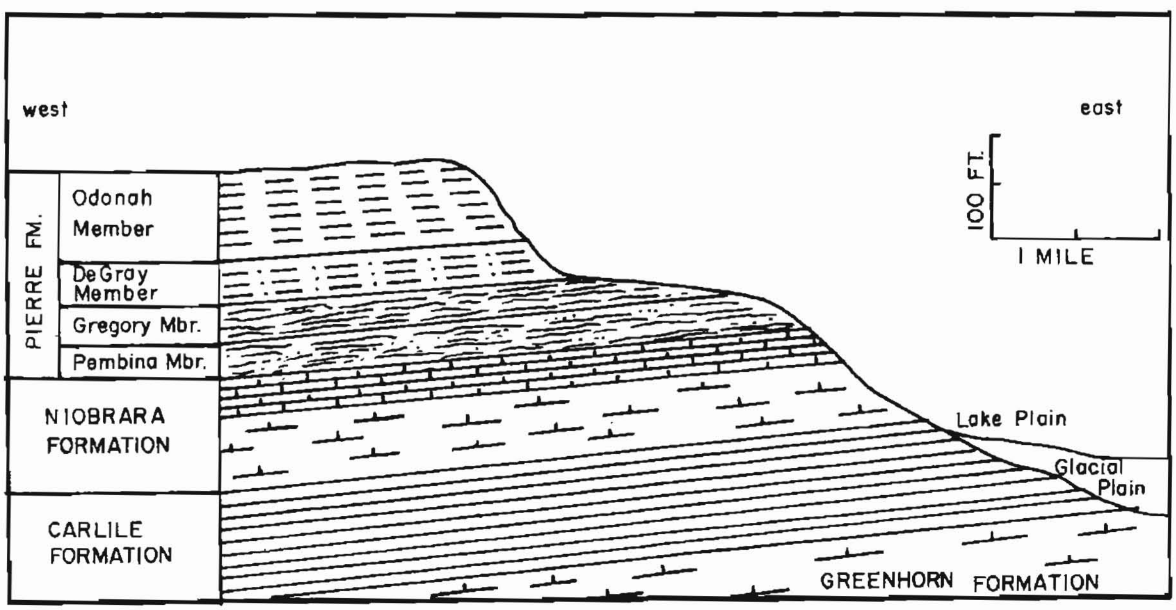

Figure 10. West to east profile of the Pembina Escarpment showing the gently westerly-dipping bedrock formations. The hard, resistant Odonah Member of the Pierre Formation keeps the escarpment from being eroded to a more gentle feature.

REFERENCES

Arndt, B. M., 1975, Geology and groundwater resources of Cavalier and Pembina Counties; Part I, Geology: North Dakota Geol. Survey Bull. 62, 68 p.

Bluemle, J. P., 1971, Geology and ground water resources of Nelson and Walsh Counties; Part I, Geology: North Dakota Geol. Survey Bull. 57, 70 p.

Clayton, Lee, Laird, W. M., Klassen, R. W., and Kupsch, W. O., 1965, Intersecting minor lineations on Lake Agassiz plain: Jour. Geology, v. 73, p. 652.

Hansen, D. E., and Kume, Jack, 1968, Geology and groundwater resources of Grand Forks County; Part I, Geology: North Dakota Geol. Survey Bull. 53, 76 p.

Kume, Jack, 1967, The Dahlen esker of Grand Forks and Walsh Counties, North Dakota: North Dakota Geol. Survey Miscellaneous Series 32, 6 p.

Laird, W. M., 1943, The geology of the Turtle River State Park: North Dakota Geol. Survey Bull. 16, 16 p.

Mayer Oakes, W. J. (ed.), 1967, Life, Land and Water: University of Manitoba Press, Winnipeg, Manitoba, 416 p.

Wills, B. L., 1963, North Dakota; the northern prairie state: Ann Arbor, Edwards Brothers, 318 p.

GEOLOGIC ROADLOG FOR CAVALIER AND PEMBINA COUNTIES

(total distance about 65 miles)

Distance Between Points (miles)

Begin trip in Walhalla in southwest part of town at junction between State Highway 32 and County Route 55. Drive west on 55. Notice the marked rise just outside of town. This scarp marks the boundary between the Agassiz lake plain (lower area) and the Pembina Delta (higher level). Northeast of and below the scarp, the main lithologies are silts and clays; above it, sand is predominant.

3.2

Turn north on gravel road. Gravel pit on right after ½ mile.

3.0

Turn west on unimproved road.

1.0

Stop. Walk north about ¼ mile to trees. The gully on the left (west) side of the section line exposes Carlile Formation shale, the oldest bedrock exposed in North Dakota. Notice the abundant large concretions and selenite (gypsum) crystals. The yellow mineral on the surface in places is sulphur and the odor of sulphur is apparent in the gully at times. Retrace route to highway.

4.0

Turn west on highway (County Route 55). Drive west over the Pembina Delta.

2.0

Turn north on gravel road.

1.0

Turn west. Follow the winding, hilly road toward the valley of the Little Pembina River. This gorge, and the gorge of the Pembina River to the south, resulted when meltwater from glacial Lake Souris in north-central North Dakota and southern Manitoba overflowed through the present Pembina valley. The large quantities of sediments, consisting chiefly of granites and Pierre shale, were carried along by the stream and deposited at the river's mouth in Lake Agassiz as a delta because of the checking of the stream current by the standing lake water.

1.8

Cross bridge over the Little North Pembina River.

0.2

Notice cut in the Niobrara shale to northeast across river.

0.5

Fresh cut in shale. The road was rebuilt here after it slid into the valley. The buff-colored shale is part of the Niobrara Formation, which has been studied as a potential cement rock. The Niobrara is overlain by the relatively more gray Pierre Formation shale near the north end of the cut. Notice the several beds of creamy, smooth, bentonitic clay (Fuller's earth) in the Pierre shale. The bentonite beds are altered layers of volcanic ash that were deposited in the Cretaceous seas when volcanoes in the Rocky Mountains erupted, and the wind-blown ash settled in the North Dakota seas. Bentonite is used as a binder for foundry sands; as a decolorizing and clarifying agent for oils; as an oil-well drilling mud; and for various other purposes, such as water softening and as fillers.

Return to junction with County Route 55 near Country Club.

3.5

Turn west-southwest on County Route 55 and descend into Pembina River valley.

1.0

Bridge over the Pembina River. Turn left at fork in road. Follow south-southwest trending road, gradually climbing from the valley.

2.3

Turn straight south. Drive southward over ground moraine. The glacial drift cover is thin here, generally less than 20 feet thick.

2.0

Turn east.

2.0

Begin descent of Pembina Escarpment.

0.9

Notice the gravel on the south side of the road. This is alluvial material that was washed down the Pembina Escarpment.

0.5

Bridge over the South Pembina River.

0.7

Turn south. Notice the river cut to the west. Gradually ascend the Pembina Escarpment again.

3.0

Near the top of the Pembina Escarpment is a good cut on the west side of the road that exposes shale. This light gray shale is the Odonah Member of the Pierre Formation. It is rather hard, with fine, indurated sand; and it forms the cap rock on the Pembina Escarpment so it is at least partially responsible for holding the escarpment up, making it more resistant to erosion.

0.5

Turn west. Driving over relatively level ground moraine.

1.1

Turn south toward Olga.

1.5

Town of Olga to the west.

2.5

Junction with North Dakota Highway 5. Turn east.

3.1

Begin descent down the Pembina Escarpment. Notice the excellent cuts in the Pierre Formation shale along the road.

2.0

Turn south on paved road at the Oak Lawn Cemetery toward Concrete.

0.5

Road crosses a small reservoir behind Herzog Dam.

0.5

Town of Concrete, the site of an old cement plant. In the Fifth Biennial Report of the North Dakota Geological Survey, 1908, the following accounts of the cement plant and the workings are given:

> The cement rock of the Pembina Mountains was discovered some years ago by Professor E. J. Babcock, who subsequently became interested with several others in the establishment of a cement mill on the Tongue

River. The product manufactured is a natural hydraulic cement which has found a ready market. The products include bricklayer's cement, hydraulic cement, Northern cement plaster, Northern fiber and Northern stucco. With improvements recently made the plant has a capacity of 500 barrels per day.
The workings of the cement company reveal the character of the cement rock at this place. One tunnel extends nearly 900 feet into the face of the bluff and discloses two small faults or slips.

The cement was produced from the Cretaceous Niobrara Formation.

1.0

Turn east. Drive past the Safeguard radar installation, south side of road.

3.0

Junction with North Dakota Highway 32. Turn north.

0.8

Tongue River.

0.4

Edge of Pembina Delta. Notice the fine sand. Much of the topography here and to the north is due to the wind blowing the sand into dunes. This rather sharp edge of the delta on the east is often called "First Mountain." The Pembina Escarpment containing the Cretaceous shales is called "Second Mountain."

0.8

Junction State Highways 5 and 32. Continue northward on gravel road through sand dunes. Notice the character of the woods, typical of vegetation in areas of dunes. Stop to look at one of the numerous cuts in the uniformly graded sands. Continue northward for a mile or so, turn around and return to Highways 5 and 32. Turn west.

3.0

Junction of State Highways 5 and 32. Turn north.

2.4

Good view of the Pembina Escarpment to the west.

3.8

Good outcrop of sand in roadcut to east.

2.5

Gravel pit on east. Notice the large number of Pierre Formation shale cobbles and pebbles.

0.9

Sand and gravel bank on east side of road demonstrates ice contact features. This outcrop shows interesting phenomena associated with the front of a melting ice sheet. During the glacial period, the ice front must have been very near this locality at the time these deposits were laid down. The ice was depositing the glacial till directly while the water caused by the melting of the ice was carrying away the coarser material which was deposited as outwash. The finer materials were apparently deposited in an ice-front lake and are rather evenly bedded, a fact that indicates deposition in standing water.

0.5

Terrace along the Pembina River.

0.2

Masonic Hill to west (left). Good view of Pembina River gorge. Notice the buff colored lake silts in the river cut across the Pembina River below the Masonic marker.

0.5

Pembina River.

0.1

City of Walhalla. End of trip.

GEOLOGIC ROADLOG FOR GRAND FORKS COUNTY

(total distance about 100 miles)

Distance Between Points (miles)

Begin trip at the junction of U.S. Highway 2 and Interstate Highway 29, at the west edge of Grand Forks (elevation 833). You are slowly ascending from the basin of glacial Lake Agassiz. As you drive west over the lake plain, notice that the horizon to the west seems to ascend, rather than to sink. This is due to the gradual rise in elevation toward the edge of the lake plain on the western edge of Grand Forks County.

0.4

Weighing station to left. To the right side of the road, watch for areas covered with white salts. Note the small, red-stemmed plant that is growing there. It is a halophyte, the only plant that will grow in some of these areas. It grows in areas where-salty ground water comes to the surface. The salt seems to disappear after a rain because the water washes it down into the subsoil. Through capillary action, water in the subsoil percolates upward, carrying the dissolved salt with it, and with evaporation, the salt is left on the surface until the next rain.

1.4

Notice the silty soil in the roadcuts. The lake sediments are of three main types; sand, silt, or clay, depending on the relation of the area to streams that emptied into glacial Lake Agassiz and the sorting of material by currents within the lake. Most of the soil in the Grand Forks area is silty with small amounts of sand. Notice the lack of boulders in the fields. Along the beach ridges several miles to the west, boulders are more common due to concentration near the shore of the lake. Scattered boulders can be seen in fields; these may have been rafted into place by icebergs on the glacial lake.

1.9

Road to Grand Forks International Airport.

2.7

Bridge over Freshwater Coulee. Notice the beaded windbreaks throughout eastern Grand Forks County. This is a region of salty groundwater discharge from the Dakota Sandstone. Depending on the concentration of salt, the saline groundwater that is escaping at the land surface stunts or kills most plants. One of the more interesting examples of the stunting effect is reflected by the beaded windbreaks, which are located on areas of micro-relief (relief ranging from three to six feet) on the lake plain. This micro-relief formed when large ice blocks were blown over the shallow lake, scraping and grooving the lake floor (Clayton and others, 1965). See the discussion of the Dakota Aquifer in the text.

1.1

Bridge over Saltwater Coulee. The only noticeable depressions in the lake plain are these coulees.

2.6

Edge of a large depression that is characterized by saline water, soils, and vegetation. This depression extends northward for several miles and terminates in Kelly Slough, a national wildlife preserve. The depression may have been eroded by saline water moving upward from the Dakota Formation and washing out the surface materials. An alternative hypothesis (Joe Downey, U.S. Geological Survey, personal communication) suggests that during glaciation of the area, water flowing beneath the ice was forced into the permeable Dakota Sandstone because of the great hydrostatic and geostatic pressure of the overlying water and ice. On deglaciation, large quantities of water were released from the contact between the Dakota Sandstone and the underlying Paleozoic rock. The rapid upward movement of this water resulted in the erosion of the overlying lake sediment. The discharging water was at a maximum immediately after deglaciation and has since decreased to its present rate.

0.6

End of salt springs.

1.7

Grand Forks Air Base entrance to right. Town of Emerado to left.

1.1

Burlington Northern Railroad tracks. Notice the gravel sieving plant to right (north) where material from the Emerado beach is processed.

0.4

End of divided highway. You are now on a broad diffuse beach that extends for several miles.

2.1

Descend down west edge of beach.

1.1

Upper Blanchard strandline (elevation 960). Notice the boulder piles. This area is till that was eroded by waves at the edge of the lake. Only small patches of lake sediment remain. Notice that the eroded till plain is less smooth than was the lake plain.

0.7

McCauleyville-Campbell beach complex (elevation 980-1000). The McCauleyville ridge is the lowest that formed while glacial Lake Agassiz drained southward through the Minnesota River valley. When the glacier in Ontario and northern Minnesota receded somewhat, the waters of Lake Agassiz were able to drain northeastward into Lake Superior and the Minnesota River valley was abandoned. Strandlines lower than the McCauleyville formed while the lake drained northeastward along the ice front.

0.7

Campbell beach terrace with gravel pit.

0.4

Entrance to Turtle River State Park. The geology of the park has been described in a North Dakota Geological Survey bulletin (Laird, 1943).

0.4

Turtle River.

2.4

Tintah strandline (elevation 1045).

0.8

Norcross strandline (elevation 1080).

0.1

Here begins the sandy soil of an outwash plain. Notice the many windbreaks. They are even more necessary in this sandy region than in the lake silt of the lake plain. This outwash plain consists of sand that was deposited by a glacial meltwater system that discharged into Lake Agassiz. Further north, the outwash deposits are coarser.

0.2

Turtle River.

1.8

Junction of Highways 18 and 2.

2.9

Cut through outwash sands and gravels on the south side of the highway.

0.2

Burlington Northern Railroad tracks.

1.9

Herman strandline (elevation 1170). The Herman strandline represents the highest level reached by Lake Agassiz. Notice how the topography on the Drift Prairie west of the Herman strandline is more rolling than it is to the east. On the western horizon is the Pembina Escarpment, which is the eroded edge of the relatively hard, siliceous Odonah Member of the Pierre Formation. It forms the western edge of glacial Lake Agassiz and was also the western edge of the preglacial Red River valley.

8.1

Junction of Highways 32 and 2. Turn right (north). The town of Niagara is south of the road.

0.6

Pierre Formation shale outcrops in road cut on west side of road across gully and on the sides of the creek flowing through the fields on either side of the road. The Pierre shale was deposited during Cretaceous time about 60 million years ago so it is much older than are the glacial deposits that overlie it. As you ride imagine a big lake in the lowland to the east. Glacial Lake Agassiz was about ninety miles wide in this region.

0.2

You are driving over ground moraine, till that was deposited by the glacier ice. Numerous exposures of till can be seen along the road. Notice the bouldery areas in many places. The landscape of rolling hills hasn't changed much since it was formed by the ice 12,000 years ago.

4.0

Minuteman missile site, east side of road.

5.6

Forest River. Notice roadcuts in till.

1.3

Notice the hills on the northwest horizon. These hills are part of the Dahlen Esker, which formed when a river flowing through the ice deposited large amounts of gravel. When the ice melted, the gravel was left as the hills you see today.

1.6

Dahlen Esker to left.

0.1

Soo Line railroad crossing.

0.8

Middle Branch Forest River.

0.2

Turn east (right) on the Fordville road.

0.3

Cut through shaly gravel in a small esker.

2.0

Drop down into the Forest River valley, an old meander scar.

0.2

Forest River.

0.1

Driving over glacial outwash gravel.

0.5

Turn south (right) in town of Fordville. Gravel pits to east. Two roads enter the pits. This coarse gravel was deposited mainly as outwash by water flowing from the glacier to the east. Some of the gravel was deposited by water flowing from the northwest in a large river. The red stains on the gravel are due to oxidized iron that was derived from the Pierre shale.

0.2

Turn around. Return to Fordville.

0.2

Highway. Continue east on paved road. You are driving over glacial outwash that was deposited by the ice when the Edinburg end moraine was deposited. The Edinburg end moraine is on the east horizon.

0.9

Continue straight onto gravel road.

0.2

Turn south (right) on gravel road and drive in a southeasterly direction.

1.2

Turn south at curve in road.

0.3

Notice the Indian mound on the horizon straight east. It is about six feet high. The material east of the pond here on which the mound is located is gravel that was deposited as a spit in Lake Agassiz. At the time this road log was written, there was a beaver dam and lodge in the pond here.

0.3

Bridge over the Forest River.

0.6

Grand Forks County line.

0.1

Good gravel cuts to west (right).

0.3

Turn east (left). Road follows rim of Forest River valley.

0.5

Forest River.

0.1

Turn south (right) in Forest River valley.

0.2

Climb from valley. Notice the river-deposited sand and gravel.

0.3

Turn east (left). You are driving over generally sandy land. Thin shore deposits lie on top of glacial till. Several strandlines of Lake Agassiz occur in the area.

1.3

Gravel pit to left.

0.1

Road to Forest River Colony to the left.

0.2

Enter the Forest River valley.

0.1

Forest River.

0.3

Roadcut at the edge of the Forest River valley here is till overlain by beach deposits.

0.3

Notice the rivercut ½ mile south of the road. The black band about a third of the way down on the cut is a buried soil zone overlain by loess (windblown silt and sand).

1.1

Road turns north (left).

0.2

Turn east (right).

1.1

Turn south (right).

0.1

Forest River. Continue south into Inkster.

2.0

Junction with County Highway B-1 in Inkster. Turn east.

0.2

East of Inkster, drive off the Campbell escarpment and onto the Lake Agassiz plain.

0.8

Junction with State Highway 18. Continue eastward on County Highway B-1.

4.8

Midway High School to left.

2.1

Junction County Highways B-1 and B-2. Turn south (right). Johnstown is to the left. Driving over lake plain.

4.9

Turn left on highway at Gilby.

13.1

Manvel. Continue southward to Grand Forks. End of trip.

GEOLOGIC ROADLOG FOR NELSON COUNTY

(total distance about 70 miles)

Distance Between Points (miles)

Begin trip at the intersection of State Highway 1 and U.S. Highway 2, south of Lakota. Travel south on 1 over a rolling area of ground moraine consisting mainly of till that was deposited at the base of the melting glacier. Notice the abundance of potholes, many of which are filled with water in wet years and serve as nesting areas for waterfowl.

5.0

Turn west on gravel road. Small exposure at corner is a clayey silt that is part of an esker ridge that trends northwest-southeast at this location.

2.2

Esker ridge just west of abandoned farm. Gravel is exposed in the cut on the north side of the road near the pole. See the text for a discussion of eskers.

0.2

Slough in a north-south trending meltwater trench just west of the above-mentioned esker. This meltwater trench carried water southward into Stump Lake from melting ice to the north.

0.6

Intersection of road to south. The view from this corner includes Stump Lake to the southwest and a low, flat basin to the west that was once flooded by the lake when it stood at a higher level. Stump Lake received its name when numerous tree stumps were found around the lake when the level dropped. They grew along the shore of the lake several hundred years ago when its level was low, as it is today. The large hill to the west-southwest is known as Blue Mountain.

0.4

Valley, part of the Stump Lake basin. Notice the lake sediments, mainly silts, exposed in the cuts on either side of the road. Lake sediments are exposed in several places along the road for about the next mile.

3.6

Turn south on gravel road. Glacial till is exposed at the corner on the west side of the road.

0.7

Notice Blue Mountain about 1 mile to the south-southwest. Immediately to the northwest of Blue Mountain is a large depression that contains a slough. This depression, which is about the same size as Blue Mountain, is barely visible from the road. Blue Mountain is a large glacial erratic (see text of this report) that was moved by the glacier from the depression to its present location. The hill was lifted at least 250 feet by the glacier.

2.3

Road intersection. View to the east is over a flat, westward extension of Stump Lake, which once flooded the area to about a tenth of a mile east of the road. Notice the straight, level lines along the south side of the basin. These beach ridges mark former shorelines of Stump Lake.

0.3

Esker ridge. Roadcuts on either side of road. Cut on the east exposes lake sediments lying on gravel. Apparently the water in the esker became ponded for a time, resulting in deposition of the lake silts. On the south side of the esker is a gravel pit (west side of road) in which is exposed cross-bedded sand that ranges from very fine to very coarse texture and contains a large amount of shale. Notice how some of the larger shale cobbles disintegrate easily. This characteristic makes gravel with a high shale content unsuitable for such uses as concrete aggregate.

0.5

Back on the flat, former bed of Stump Lake.

1.4

Climbing the north (inner) edge of the North Viking end moraine. The ice that deposited this end moraine was moving southward at this point. From the top of the end moraine, notice the relatively more hilly land and the abundant boulders on the surface. You can see the broad, flat area of glacial outwash to the south of the end moraine. This outwash was deposited by meltwater flowing from the glacier at the same time it deposited the end moraine.

0.8

Turn east on gravel road. Drive east, climbing gently along the contour of the end moraine.

2.0

Intersection. Turn south on gravel road toward Tolna. Drive south over a gravel outwash plain.

0.8

Begin descent down onto stream terrace.

0.5

Good exposure of Pierre Formation shale (see text) in roadcut, along the east side of Tolna Coulee. Notice the many large boulders west of the road. In the ditch by the roadcut is a large, pinkish boulder composed mainly of feldspar. This rock contains large crystals of orthoclase and microcline and is an example of a pegmatite rock, one that cooled from liquid magma to a solid, very slowly. It was carried to the area from Ontario by the ice.

0.4

Bottom of Tolna Coulee.

0.3

Town of Tolna.

0.5

Cross the Burlington Northern Railroad tracks. Continue southward over the outwash plain.

1.5

Junction with State Highway 15. Continue south on outwash surface.

1.0

Gully. A tributary to the Sheyenne River. Outwash gravel is exposed in roadcuts south of the gully.

0.6

Bridge over the Sheyenne River. The Sheyenne River carried excess water from Lake Souris in northwestern North Dakota to Lake Agassiz in the east.

0.3

Back on top of outwash plain.

1.1

Intersection. Turn west.

0.9

Bridge over a small coulee.

1.1

Intersection. Turn south. Driving over ground moraine.

4.0

Fork in road. Gravel pit in esker which trends generally northwest-southeast. Notice the buff-colored material in the pit. This is till that probably got into its present position as a mudflow that slid off the ice into the gravels of the glacial stream. Continue southward from the pit.

1.0

Turn east on unsurfaced, dry-weather road. Notice the excellent shelter belt along the south side of the road. Such shelter belts are important in controlling soil erosion and in conserving moisture. They also provide cover for birds and small game.

0.9

Road curves southeastward. Notice the pond to the east and the esker just beyond the pond. This is the same esker we saw a couple of miles back. Continue southward.

1.0

Turn east on gravel road. Notice the McHenry end moraine ahead and to the southeast. The ice that deposited the McHenry end moraine was moving eastward at this point.

1.0

Turn north on gravel road.

0.6

Notice the gravel pit in the southwest slope of the esker (same esker as before) east of the road.

0.2

Top of esker. Notice the gravel in the roadcuts and the gravel pit near the abandoned farm.

1.2

Turn east on gravel road and drive 2 miles. The first 3/4 mile to the east is over relatively flat lake plain, and the remainder is till that contains a large amount of lake silts because the ice that deposited it had just advanced over a lake.

2.0

Turn south on gravel road. Notice the McHenry end moraine to the east.

1.0

Roadcut on east side of road near corner. This cut exposes glacial till over bedded lake sediment. The lake sediment was overridden by the glacier and its bedding, which was originally horizontal, was highly contorted in places as till was deposited on top of it. Turn east at corner.

1.4

Notice the lake sediments exposed by roadcuts through this ridge.

2.6

Junction with North Dakota State Highway 1. Turn north.

1.4

Notice the McHenry end moraine on the west horizon.

2.0

Exposures of Pierre shale in roadcuts.

1.0

Descend into the Sheyenne River valley. Notice the shale exposures in the valley walls.

0.8

Bridge over the Sheyenne River.

0.5	
	Back on top of gravel of the outwash plain north of the Sheyenne River.
1.0	
	Cross the Burlington Northern Railroad tracks.
0.2	
	Junction of North Dakota State Highways 1 and 15. Continue northward over ground moraine.
6.0	
	Entrance to Stump Lake park area. Continue northward.
10.5	
	Junction of North Dakota State Highway 1 and U.S. Highway 2. End of trip.

GEOLOGIC ROADLOG FOR WALSH COUNTY

(total distance about 90 miles)

Distance Between Points (miles)	Begin trip at the intersection of State Highway 17 and U.S. Highway 81 in Grafton. Travel south on 81.
0.3	
	Burlington Northern Railroad tracks.
1.4	
	Notice the many shelter belts along the highway. Shelter belts are important in controlling soil erosion and in conserving moisture.
3.5	
	Notice the "beaded" shape of the shelter belts on the west side of the highway (see text). The highest trees in these shelter belts grow in the grooves, which, however, are difficult to see.
3.3	
	Town of Minto. Minto was established in 1878 on the south side of the Forest River about a mile from the present site. A corduroy bridge was built across the stream at that time. Minto obtains its water from a buried course of the Forest River.
0.8	
	Bridge over the Forest River.
1.0	
	Be on the lookout for small red plants in the ditches. These are halophytes that grow in salty soil. This is an area where salt water is coming to the surface. Lake Ardoch, about a mile east of here, is a rather salty lake.
4.2	
	Junction of Highway 81 with Walsh County Road 19. Turn west. The town of Ardoch is to the east. Ardoch was established in 1882.
0.3	
	Bridge over a small stream that meanders northeastward into Lake Ardoch. An exposure of Lake Agassiz sediments can be seen on the west side of the bridge.
1.1	
	Cross the Soo Line Railroad tracks. In this area, you are driving on the flat Agassiz lake plain.

2.6

Notice a small rise in the road at the corner by the farm. This is a minor scarp, a former shoreline of Lake Agassiz.

1.1

Cross the Burlington Northern Railroad tracks. Junction of Walsh Co. Roads 19 and 6. Continue west on 19. The town of Forest River is to the north. It was platted in 1887.

0.7

Notice the scarp, another former shoreline. The Forest River is to the north. The trees in this valley are mainly ash.

0.5

Bridge over the Forest River.

0.5

Gravel pits and rubbish dump. These gravel pits are in a differential compaction ridge (see text), a former route of the Forest River.

2.2

Road turns north. This is an area of thin lake sediments lying on a till surface that was washed by wave action at the edge of Lake Agassiz. Watch for boulders in the fields.

1.0

Turn west again. Drive over a sandy area of many low beaches. Erosion since the beaches were deposited has tended to spread the sand over the surface.

1.8

Ops grain elevator to the north. Notice the boulder piles in the fields.

1.2

Junction of Walsh Co. Road 19 and North Dakota State Highway 18. Continue west.

0.2

Pile of boulders in the field just south of the road. These boulders are glacial erratics (transported boulders) that were carried to the area from Canada.

2.3

Burlington Northern Railroad Tracks. The railroad coincides with a beach ridge. The town of Conway, which came into existence with the building of this railroad to Park River, is to the north. Continue to the west.

0.5

Campbell wave-cut scarp and beach. This is generally the most prominent shoreline of Lake Agassiz throughout the Red River valley. The hills on the western horizon are part of the Edinburg end moraine.

2.2

Soo Line Railroad tracks.

0.4

East edge of the Edinburg end moraine.

0.4

Crest of the Edinburg end moraine. From here you can see the towns of Fordville (to the west), and Lankin (to the northwest). To the south is the Forest River valley. Roadcuts in the end moraine at this point expose till.

0.3

West edge of the Edinburg end moraine.

0.9

Turn south. Pavement begins. The hills to the east are part of the Edinburg end moraine.

0.5

Turn west toward Fordville.

0.5

Fordville. Fordville was founded in 1905 when the Soo Line built its Wheat Line from Thief River Falls, Minnesota, to Kenmare, North Dakota.

0.5

Turn south on paved road and visit the gravel pit along the south edge of town. The gravel in this pit was deposited by running water from the melting ice and the ancient Forest River, which flowed southward into early Lake Agassiz. Return to the main highway (Walsh Co. 19). Cross the railroad tracks.

0.5

Bridge over the Forest River. You are driving through the Forest River valley. Notice the boulder-strewn bed of the valley.

2.2

Overpass over the Soo Line Railroad mainline.

0.3

Junction of Walsh Co. 19 and State Highway 32. Turn south on 32.

0.4

Bridge over the Forest River. Notice the gravel in the roadcuts at the river crossing. The hills on the southwestern horizon are part of the Dahlen esker (see text).

0.7

Soo Line Railroad crossing. The Dahlen esker is to the west.

0.4

Grand Forks County line. You can drive west to the crest of the esker if the roads are dry. Return to the Fordville corner.

1.5

Junction of State Highway 32 and Walsh Co. 19. Continue northward.

0.3

Notice the esker ridge on the east side of the highway. It parallels the highway at this point.

1.3

Soo Line Railroad crossing. The highway crosses the bouldery esker ridge at this point. The esker contains considerable till, and apparently much of the glacial drift that was contained in the ice slid into the same crack through which the stream flowed.

0.9

Notice the esker ridge on the west side of the highway.

2.3

Northeast-facing wave-cut scarp. This very bouldery scarp coincides with an esker. It was cut by wave-action at the lake shore when the lake stood at the Herman level, which is generally considered to be the highest level the lake reached in this area. North of the scarp is a flat lake plain.

1.7

Junction of State Highway 32 and Walsh Co. Highway 15. Turn west toward Lankin.

1.0

Crest of an esker.

0.4

Bridge over a small creek. Notice the abundance of boulders. This is an area that was washed by running water. The water, which flowed southward, carried away the fine particles of the till and left the boulders behind.

0.7

Bridge and refuse dump.

0.8

Town of Lankin, founded in 1905. Turn north.

0.5

Leave paved road. This area is a wave-washed till surface and is rather bouldery.

1.6

Bridge over the Forest River.

4.0

Junction with State Highway 17. Turn east. This area is a wave-washed till surface.

1.5

Golden Valley Lutheran Church.

1.4

Junction of State Highways 17 and 32. Turn north on 32. The hills to the east are part of the Edinburg end moraine.

1.1

Bridge over the Park River. The Park River was named by Captain Alexander Henry when he found the Indians had made corrals (parks) near the stream. The Indians drove buffalo into these corrals for slaughter. The Park River flows northward between the highway and the Lutheran Bible Camp for a few hundred yards at this point.

0.4

Bridge over a tributary to the Park River. Stream cuts along the valley of this stream east of the highway reveal layered lake sediments on top of till of the Edinburg end moraine. Return to the junction of Highways 17 and 32. Turn east on 17.

0.3

Climbing the west side of the Edinburg end moraine.

0.7

Crest of the end moraine. Notice the rolling hills that are characteristic of end moraines.

1.0

Gravel pits on north side of road in small esker that trends northwest-southeast.

0.1

Entrance to recreation area along Homme Reservoir.

1.0

Entrance to Homme Dam. Drive to the dam. Notice the wave-cut shorelines along the lake. Return to the highway.

1.8

West edge of the town of Park River. Park River was founded in 1884.

0.2

Top of the Campbell beach and east-facing scarp. Notice the height of this beach above the part of the town that lies to the east.

0.8

East edge of the town of Park River. Continue east on Highway 17. Driving over the flat Agassiz lake plain.

14.8

Grafton. Grafton was founded in 1878 and is the county seat of Walsh County. End of trip.

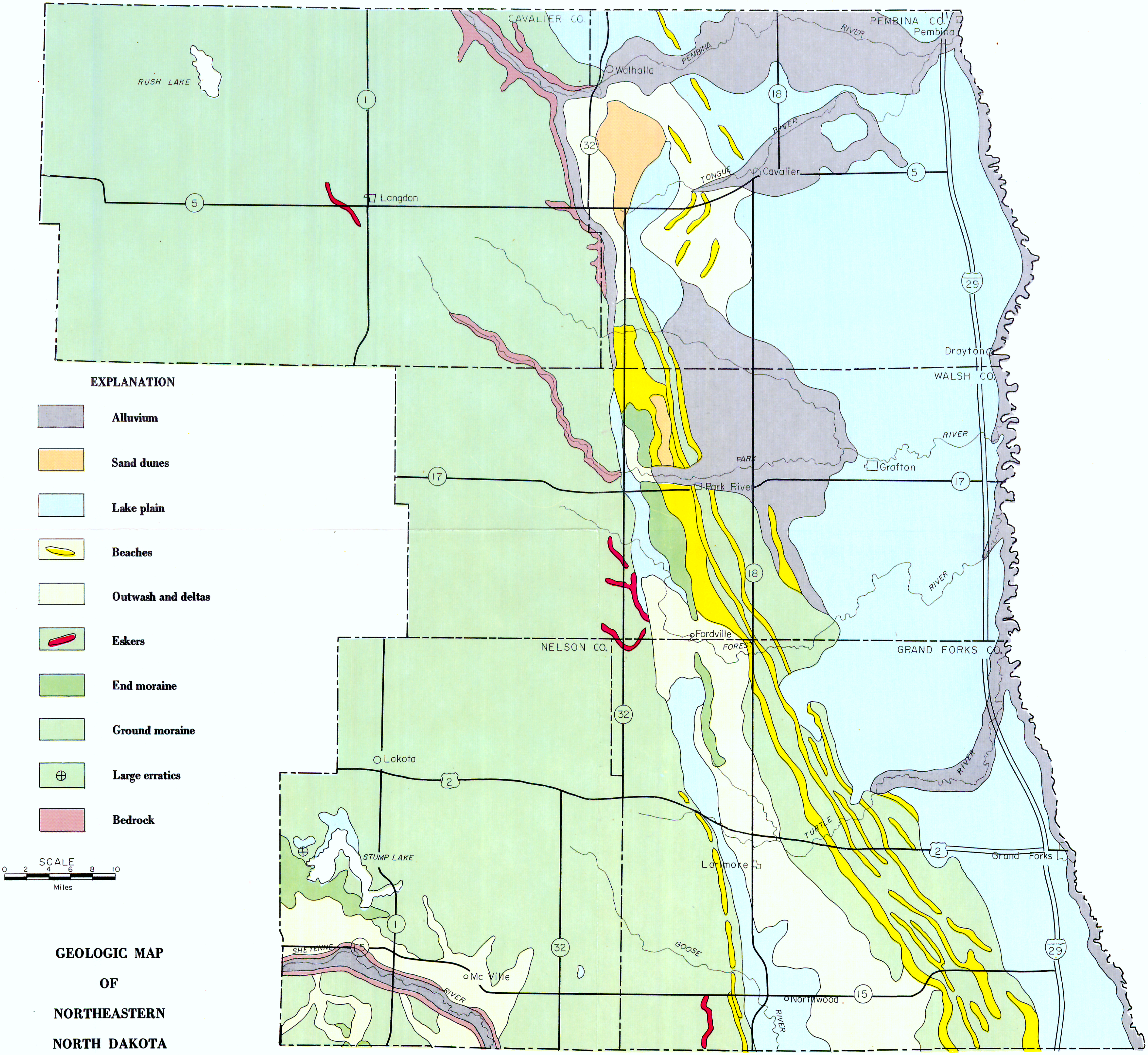
CAVALIER CO.
PEMBINA CO.
Pembina
PEMBINA
RIVER
Walhalla
RUSH LAKE
1
18
32
TONGUE
RIVER
Cavalier
5
Langdon
29
Drayton
WALSH CO.
RIVER
PARK
Grafton
17
Park River
18
RIVER
Fordville
FOREST
NELSON CO.
GRAND FORKS CO.
32
Lakota
2
RIVER
TURTLE
STUMP LAKE
Larimore
Grand Forks
GOOSE
SHEYENNE
15
Mc Ville
RIVER
Northwood
RIVER
EXPLANATION
Alluvium
Sand dunes
Lake plain
Beaches
Outwash and deltas
Eskers
End moraine
Ground moraine
Large erratics
Bedrock
SCALE
0 2 4 6 8 10
Miles
GEOLOGIC MAP
OF
NORTHEASTERN
NORTH DAKOTA

FIGURE 12