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

GUIDE To The GEOLOGY Of Southeast NORTH DAKOTA

BY John P. Bluemle
revised edition 1975

GUIDE TO THE GEOLOGY OF SOUTHEASTERN NORTH DAKOTA

Barnes, Cass, Griggs, Ransom, Richland,
Sargent, Steele, and Traill Counties

by

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Educational Series 3

North Dakota Geological Survey

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INTRODUCTION

This publication is designed to present the geology of southeast 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 southeast 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 earth is made up of three zones: crust, mantle, and core. The crust is the earth's thin skin on which we live. Some of the deepest crustal rocks in southeastern North Dakota are igneous granites. These igneous rocks (from the Latin, *ignis*, "fire") were once hot, molten, liquid-like material known as *magma*, which subsequently cooled into firm, hard rock. The granites are buried under 300 to 2,500 feet of younger rocks so they cannot be seen any place in the area. In much of the area, limestone, sandstone, and shale that was deposited in water lies above the granite. These sedimentary rocks (from the Latin, *sedimentum*, "settling") are composed of particles derived from the breakdown of pre-existing rocks. They formed when sediments washed into the seas that covered North Dakota during much of the past 600 million years. In the same way, topsoil today is washed from southeastern North Dakota and deposited in Hudson Bay. Such sedimentary rocks are as much as 15,000 feet thick in parts of western North Dakota. Figure 1 is a cross-section of the outer portion of the earth's crust in North Dakota showing how the sedimentary rocks thicken westward toward the deeper portions 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.

In general, there are two kinds of sedimentary rocks in southeastern North Dakota: bedrock and glacial drift. The bedrock, which is much older than the drift, forms the basement on which the glacial drift was deposited throughout the area. In a few places, where the glacial deposits are absent, such as along the Sheyenne River in Griggs, Barnes, and Ransom Counties, bedrock can be seen. In southeastern North Dakota, all the bedrock that is exposed is shale of Cretaceous age that is about 70 to 80 million years old. This shale accumulated as streams deposited mud in shallow seas and on their floodplains, much as the modern Mississippi River is depositing mud today on its delta and in the Gulf of Mexico. When the mud hardened, it became shale.

During the past two to three million years several glaciers overrode southeastern 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

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*Barnes, Cass, Griggs, Ransom, Richland, Sargent, Steele, and Traill Counties.

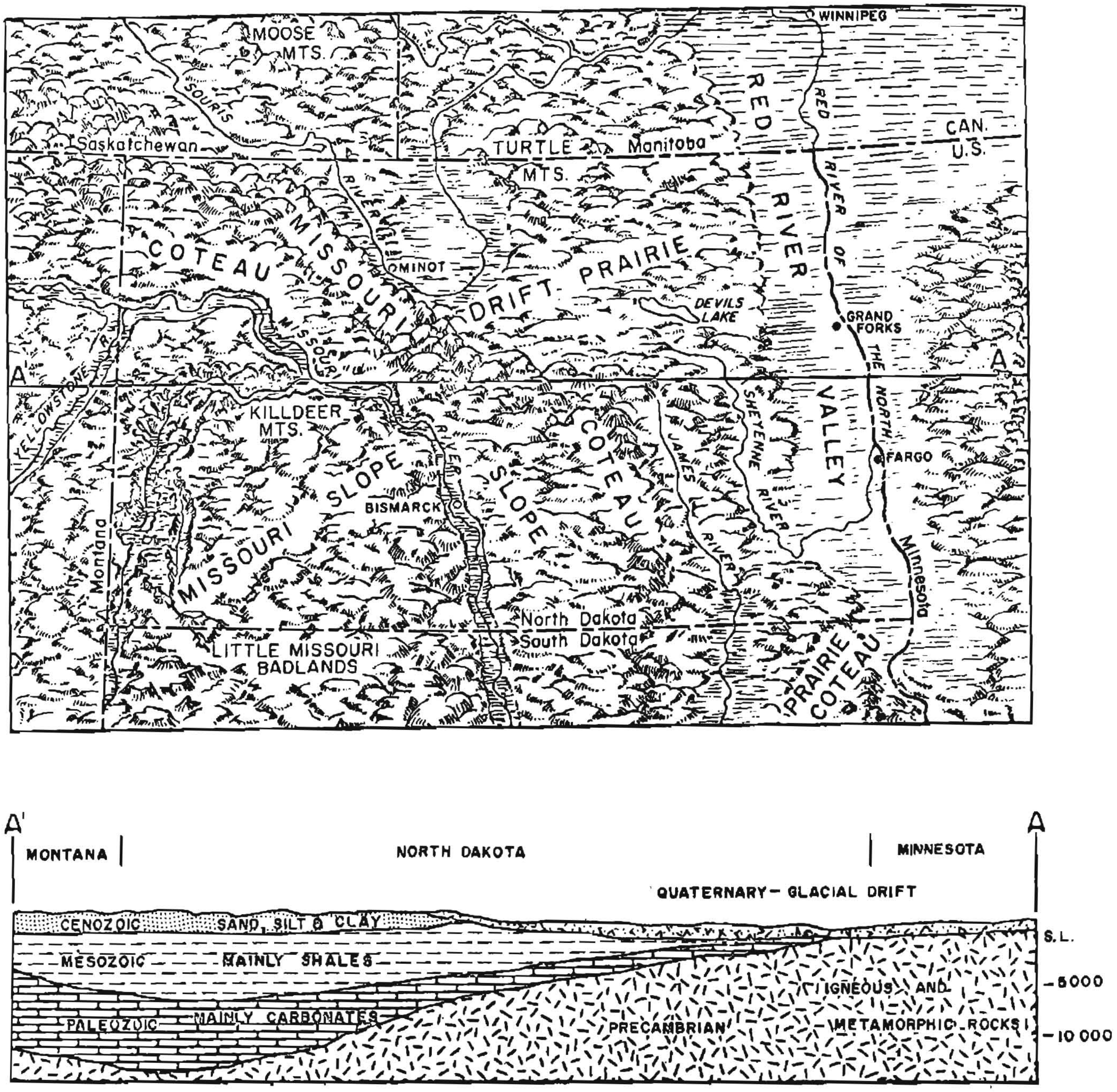

Figure 1. Physiographic map of North Dakota. The cross-section A-A' shows how the sedimentary rocks are thicker in the Williston basin in the western part of the state.

period (one million to ten thousand years ago) is known as the ice age or "Pleistocene Epoch." Figure 2 shows the glaciated area of North America. Only the southwestern part of North Dakota escaped glaciation.

Sand, silt, gravel, and clay are among the materials deposited by glaciers. 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 southeastern North Dakota, they planed off the more rugged features and filled in the valleys with loose, ground-up deposits 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 carved 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. Mineral-rich North Dakota soils derived these minerals from rocks ground up by the glaciers. Bacterial action and weathering at the surface are constantly disintegrating the glacial drift and changing it to soils.

THE ICE AGE IN SOUTHEASTERN NORTH DAKOTA

Before the ice age, granite, limestone, and sandstone were exposed in the eastern part of the area. These rocks were very similar to those found at the surface today in eastern Manitoba and southwestern Ontario. Shale covered the surface west of the Red River Valley. The land was rolling, with a few hills and deep valleys. Elevations above sea level ranged from about 500 feet in the eastern part of the area to about 1,500 feet in parts of Griggs County, and streams flowed generally north and northeastward. Drainage throughout North Dakota was directed generally northward toward Hudson Bay.

During the ice age, glaciers formed west of Hudson Bay due to the accumulation and compaction of yearly snows that did not completely melt in the summers. This same process occurs today in areas where there are mountain glaciers 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 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 ice. Materials from beneath the glacier were carried upward through the ice so that the ice was heavily loaded with debris. This glacial debris was deposited from inside the glacier when the ice melted.

When the ice first advanced over the area several hundred thousand years ago, the northward-flowing streams became blocked and lakes formed in the valleys in front of the ice. Silt and clay was deposited in these lakes. As the ice continued to move southward, it overrode the lakes and deposited glacial sediment on top of the lake sediment. Lakes again formed in front of the ice when it receded, and more sand and silt was deposited. Glaciers advanced across the area several times during the past several million years and each time a similar sequence of deposits resulted: lake sediment, glacial sediment, and lake sediment. In this way, a thick accumulation of alternating lake sediment and glacial sediment was deposited in what is now the Red River Valley. Sometimes when the glaciers advanced, they picked up and carried away some of the earlier deposits. Erosion that occurred between glaciations removed some of the deposits. For these reasons, the stratigraphic column (rock record of geologic history) is incomplete.

The last glacier advanced over the area about twenty thousand years ago. When it receded from the area, Lake Agassiz formed to the south of it. From an airplane one can clearly see the shape of the ancient lake reflected in the vegetation and landforms. The lake extended from near Hudson Bay to northeastern South Dakota (fig. 3). Lakes Manitoba, Winnipeg, and Winnipegosis are existing remnants of Lake Agassiz. By about eleven thousand years ago, all the glacial ice had melted from the area, but Lake Agassiz did not

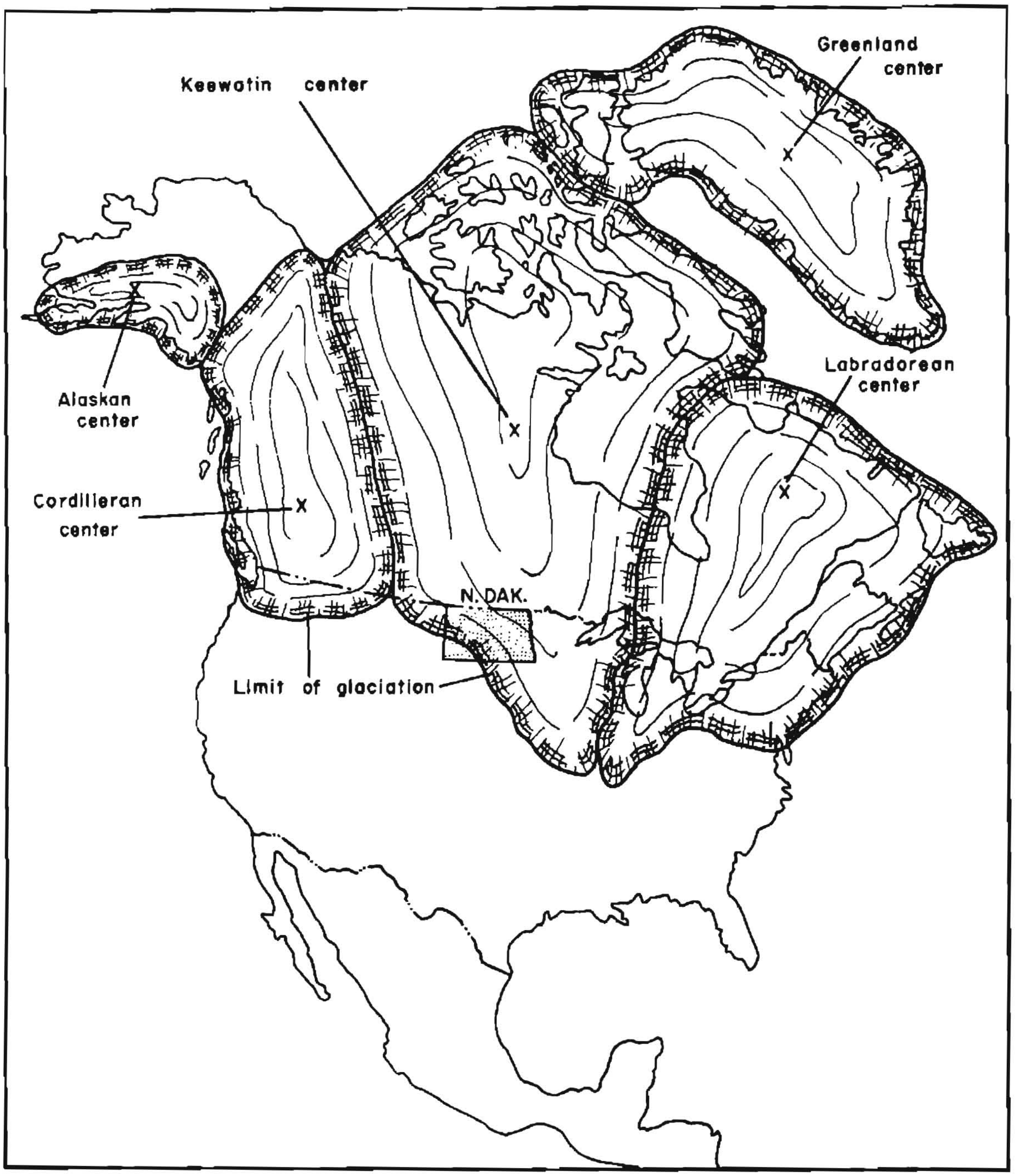

Figure 2. The above map of North America shows the limits of continental glaciation during the ice age. The main centers of snow accumulation from which the ice moved are shown. North Dakota was glaciated by ice that moved from the Keewatin center west of Hudson Bay.

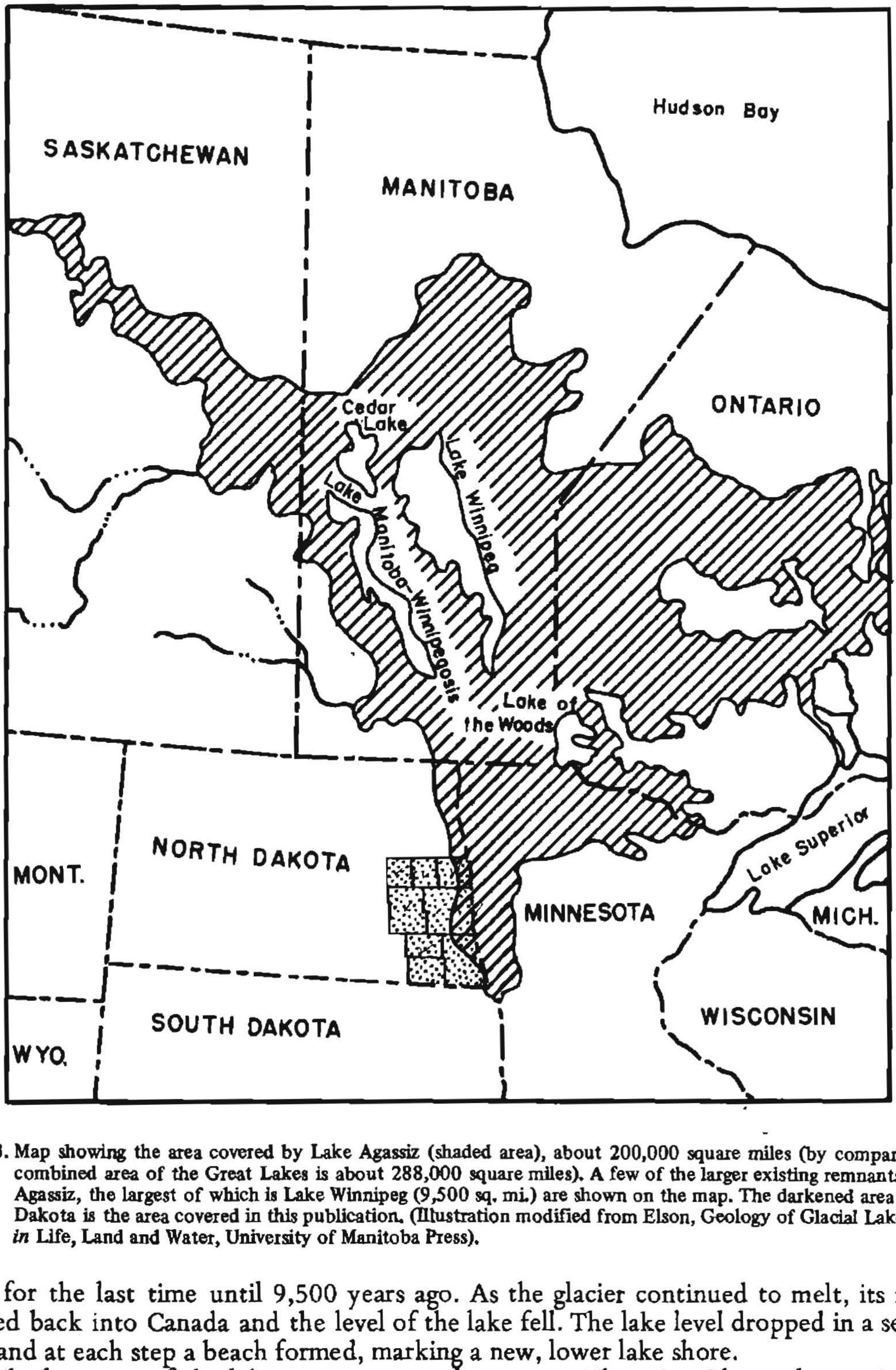

Figure 3. Map showing the area covered by Lake Agassiz (shaded area), about 200,000 square miles (by comparison, the combined area of the Great Lakes is about 288,000 square miles). A few of the larger existing remnants of Lake Agassiz, the largest of which is Lake Winnipeg (9,500 sq. mi.) are shown 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).

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.

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.

Primitive man probably lived on the shores of the lake. Cool, damp winds blew from the north off the ice in Canada during the short summer season and rainfall was heavy. The winters were probably no colder than our present North Dakota winters but there was much more snow. In general, the climate was probably similar to that today in parts of northern Manitoba.

At the end of the ice age about eleven thousand years ago, nomadic tribes of primitive men apparently moved into the area. As the climate continued to moderate and become drier, forests gave way to prairies with tall grasses. Bison, migrating northward at this time, became plentiful.

Southeastern North Dakota has not changed a great deal since the ice age. The climate has become drier and somewhat warmer, although there have been times since the ice age when the climate was considerably drier and warmer than it is today. As a result of the climate change, the area is mainly grassland; at the end of the ice age the area was forested, much like northern Minnesota today.

LANDFORMS OF SOUTHEASTERN NORTH DAKOTA

Lake Plain

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 three hundred feet between the Red River and the highest of the beaches about forty 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 Agassiz lake 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 from the Fargo area northward. 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 lower areas because the soil is more fertile there (fig. 4).

The lake deposits are mainly horizontally-bedded silt and clay that was deposited in still water (figs. 5 and 6). Areas of lake plain are shown in blue on figure 13 in the pocket at the back of this guidebook. They are identified by the number 2. In places, the horizontal bedding was disturbed by such things as mudflows and turbidity currents in the loose, wet lake sediments, by squeezing of the sediments between cakes of lake-surface ice that sank as the lake drained, by pushing of lake sediments that were deposited on top of the stagnant ice that later melted, or by overriding by a glacier (fig. 7). During its earliest stages, Lake Agassiz covered parts of eastern Barnes and northwestern Ransom Counties. This part of the lake flooded a part of the glacier that had stagnated. Lake sediment was deposited on top of this stagnant ice. When the ice eventually melted, the lake sediment slumped down and became mixed with till and shore sand which had also been deposited on the ice. The complex mixture of lithologies that resulted when the stagnant ice later melted, thereby destroying the original bedding, is represented on figure 13 by light brown areas with the number designation 3. Similar areas of collapsed lake sediment can be found in Sargent and Richland Counties (fig. 13).

Salt water wells and salty sloughs are common over much of the lake plain area. This area is underlain by the Dakota Formation sandstone, an aquifer (water-bearing rock). 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. Such areas of salty soil are common in the Sheldon area of Ransom County.

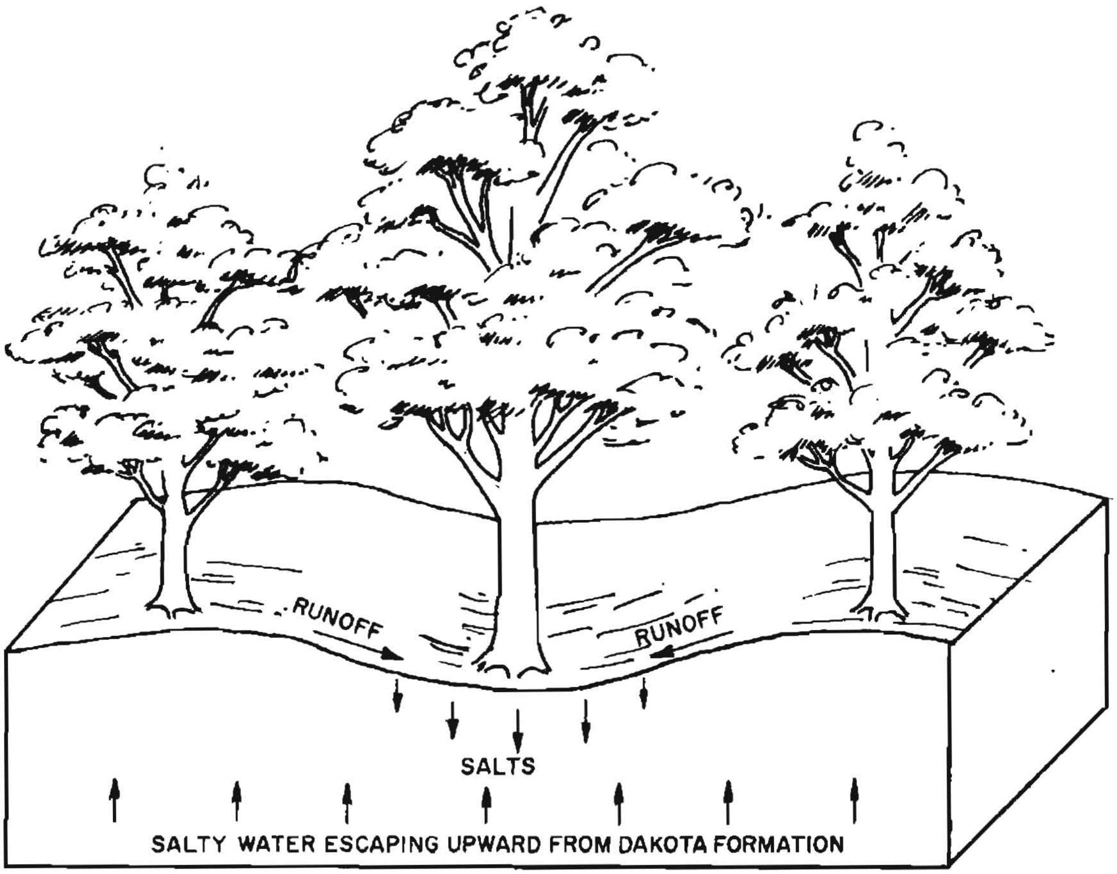

Figure 4. Magnesium and sodium sulphate salts, which are left as residues from water rising from the Dakota Formation sandstone, build up to higher concentrations in ridges than in the adjacent depressions. This is because the salts are flushed downward from the lower areas by runoff water percolating downward, whereas the higher areas retain their higher salt concentrations. As a result, trees tend to grow better in the lower, more fertile, areas.

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 sediment slowly dried out, settling several feet. The gravel and sand settled less than the surrounding lake sediment, and ridges resulted (fig. 8). Examples of differential compaction ridges are the Maple and Sheyenne Ridges in the Fargo area and the Kelso Ridge in southern Traill County (see figure 13).

Lake Dakota covered part of western Sargent County. The Dakota lake plain is similar in most respects to the Agassiz lake plain although it is much smaller. Beaches around the lake plain are smaller than those around the Agassiz lake plain. The north end of the lake plain, where the James River flowed into the lake, is rather sandy. Lake Dakota drained southward by way of the James River into the Missouri River in South Dakota.

Beaches

Just as modern lakes have beaches, so did Lake Agassiz. These are shown in yellow on figure 13, and identified by the number 4. The westernmost beaches mark the edge of the

Figure 5. Plane and ripple-bedded sand at the west edge of Lake Agassiz. This type of bedding is typical of near-shore Lake Agassiz sediment in areas where streams entered the lake.

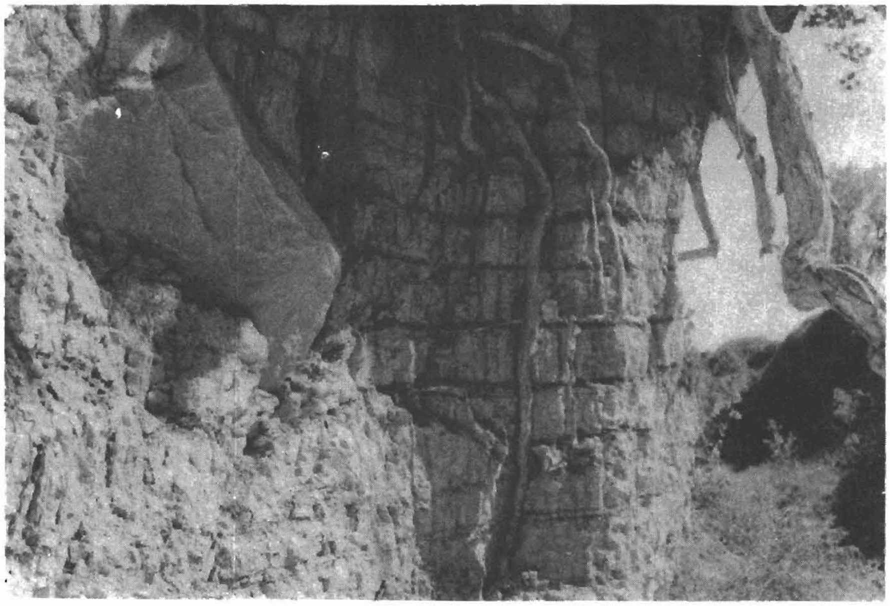

Figure 6. Banded lake sediment south of Mayville, North Dakota. Light-colored beds represent summer accumulation in Lake Agassiz, the material in the dark bands was deposited during the winters. The boulder was probably rafted by an iceberg and dropped into the lake at this point.

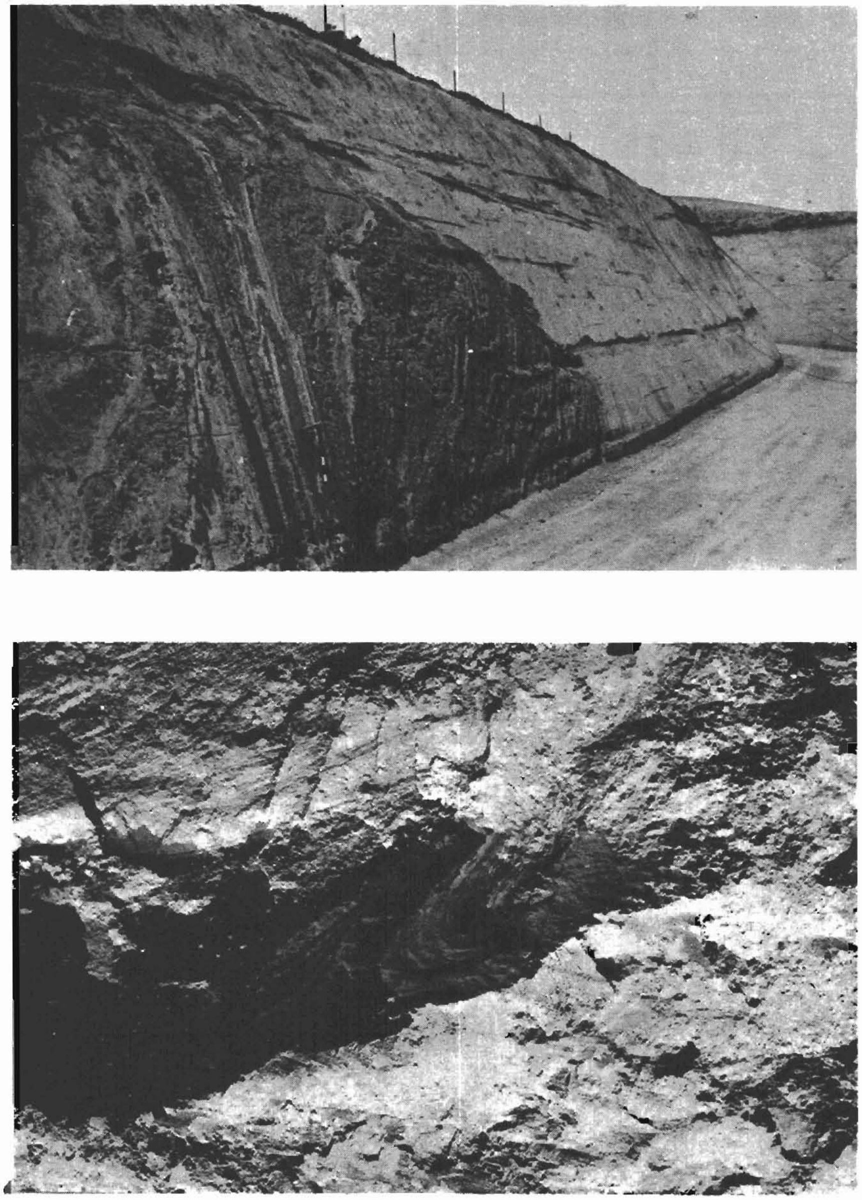

Figure 7. Two examples of contorted lake sediments in western Steele County. In each case, glacial ice overrode flat-lying lake sediments and folded them into the positions shown here. In the upper photo, ice movement was from the right; on the lower photo, it was from the left.

lake when it covered its greatest area. These beaches, which are located in eastern Barnes County, are poorly-developed and difficult to see. The larger beaches are found in Traill and Cass Counties where the shoreline of the lake stood for an extended period of time. Beaches are also present on what was the east side of the lake in Minnesota. These are larger than are the beaches in southeastern 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.)

The beaches trend generally north-south in Traill and Cass Counties, but in Richland County, near the southern end of the lake, they trend northwest-southeast. The larger beaches rise five to twenty feet above the surrounding landscape, but some of the lower beaches, near the center of the lake plain, have less than five feet of relief. Many of the

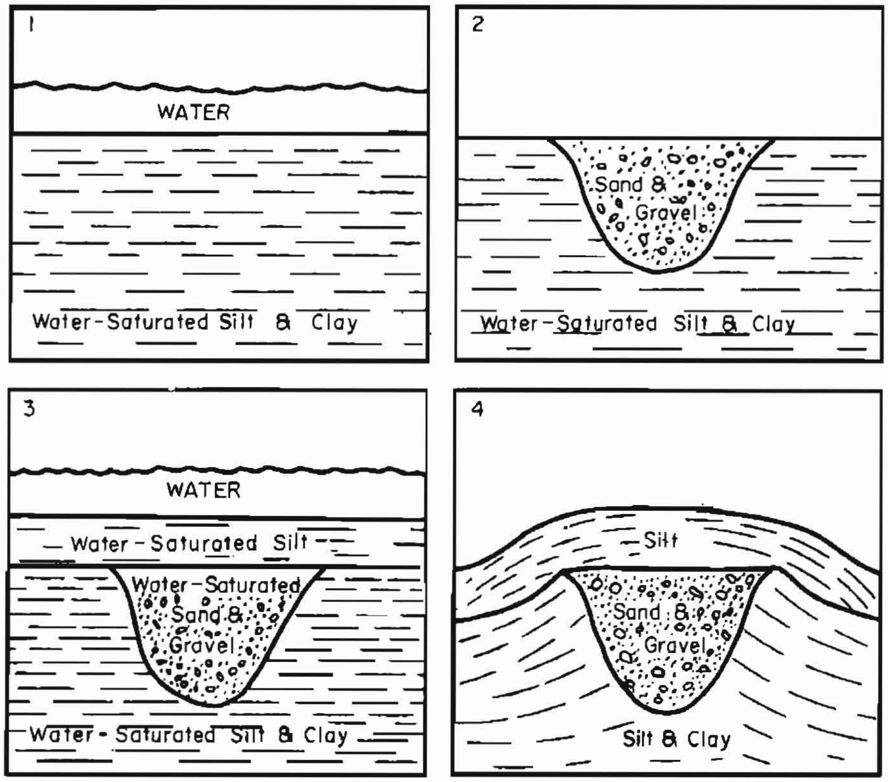

Figure 8. Steps in the formation of a differential compaction ridge such as those near Fargo and Kelso: (1) Silt and clay were deposited in the lake; (2) A valley was cut during the time the lake was drained. Sand and gravel were deposited in the valley; (3) Silt was deposited when the lake again flooded 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 silt and clay when everything dried.

ridges are probably bars and spits. Like modern beaches, the Lake Agassiz beaches 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 clay leaving sand and gravel. This sand and gravel became bedded into layers. Many commercial gravel pits are located in fossil beaches of old Lake Agassiz.

In places, the beach sediments were deposited on top of blocks of stagnant glacial ice. In such areas (designated 4a on figure 13), the stagnant ice eventually melted causing the overlying sand and gravel to slump down and lose its typical beach bedding.

Deltas

In areas where large rivers flowed into Lake Agassiz and Lake Dakota, deltas were built up at the river mouths. Such areas are shown in yellow and designated by the number 7 on figure 13. The largest such delta is the one that was built by the Sheyenne River in Ransom and Richland Counties. The surface of the Sheyenne Delta has been modified by wind action, and rather large dunes can be found in places. These areas, shown in orange, are designated by the number 5 on figure 13. In general, the sediment of the Sheyenne Delta becomes finer eastward as it interfingers with lake sediment. Most of the sediment of the western part of the delta (except for the windblown deposits) is gravel and sand that was deposited by running water.

Other delta areas in southeastern North Dakota occur in Steele and Traill Counties. The southern end of the Elk Valley Delta covers northwestern Traill County. It consists mainly of fine sand and silt. The Park, Forest, and Turtle Rivers, which formed it, were some distance to the north in Walsh and Grand Forks Counties. The Galesburg Delta in eastern Steele and western Traill Counties was apparently formed where the Goose River flowed into Lake Agassiz.

The Maple River flowed into Lake Agassiz in western Cass County while that part of the lake covered stagnant glacial ice. As a result, the deltaic sand that was deposited eventually collapsed when the ice melted.

Moraine

The eight counties of southeastern North Dakota are coverd by about 340 cubic miles of glacial deposits. Of this, probably two-thirds was deposited by glacial ice, and the remainder was deposited as silt and clay in Lake Agassiz and as sand and gravel by streams flowing from the glacier.

Material deposited directly from glacial ice is called "till," which is a catch-all term applied to glacial sediment. The Europeans call such glacial sediment "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.

In contrast to the smooth lake plain, the moraines are hilly areas. *Ground moraine*, deposited beneath the moving glacier, has local relief of about ten to twenty feet. It is shown in light green on figure 13 and designated by the number 8. More striking than the ground moraine is the relief of twenty feet and more found in the hills and ridges of *end moraine* such as the McHenry and Cooperstown End Moraines of Griggs County, the Kensal End Moraine of Barnes County, and the Oakes End Moraine of Ransom County. These end moraines are 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 as the ice was moving forward so that the margin remained stationary. All the end moraines are dark green on figure 13. They are unit 9.

A third kind of moraine is *dead-ice moraine*, which results when large amounts of glacial sediment are deposited on top of stagnant glacial ice, that is, a glacier that has stopped moving but has not yet melted. When the stagnant ice eventually does melt, the overlying glacial sediment, which is mainly till, but which may include gravel, sand, and lake silt and clay, collapses, resulting in a rather rugged landscape. The largest and most spectacular area of dead-ice moraine in southeastern North Dakota is in Sargent County and southwestern Richland County. This area, the Prairie Coteau, is an upland (a plateau), with many lakes, and a generally hilly landscape. The dead-ice moraine is unit 10 on figure 13, and it is shown in dark brown.

Melt Water Trenches

The Goose, Maple, Sheyenne, and Wild Rice Rivers all are small streams that flow in rather deep valleys upstream from where they enter the Agassiz lake plain. After they reach the lake plain, the valleys are much more subdued. These melt water trenches were cut by great rivers of melt water flowing from the glacier. The rivers all flowed into Lake Agassiz. Not much erosion has taken place since the lake drained, so the river valleys on the lake plain are rather small, more suited to the size of the rivers that flow in them today. Modern alluvium that is deposited on the river floodplains consists mainly of sand and silt. Such areas of alluvium are designated by the number 1 on figure 13 and generally coincide with the melt water trenches.

The largest melt water trench in eastern North Dakota is the valley of the Sheyenne River. This trench was cut in a relatively short period of time when it carried overflow from glacial Lake Souris in north-central North Dakota into glacial Lake Agassiz. At the same time the deep trench was being cut, the Sheyenne Delta was built into Lake Agassiz. At the height of its flow, the Sheyenne River was huge and filled the trench from rim to rim.

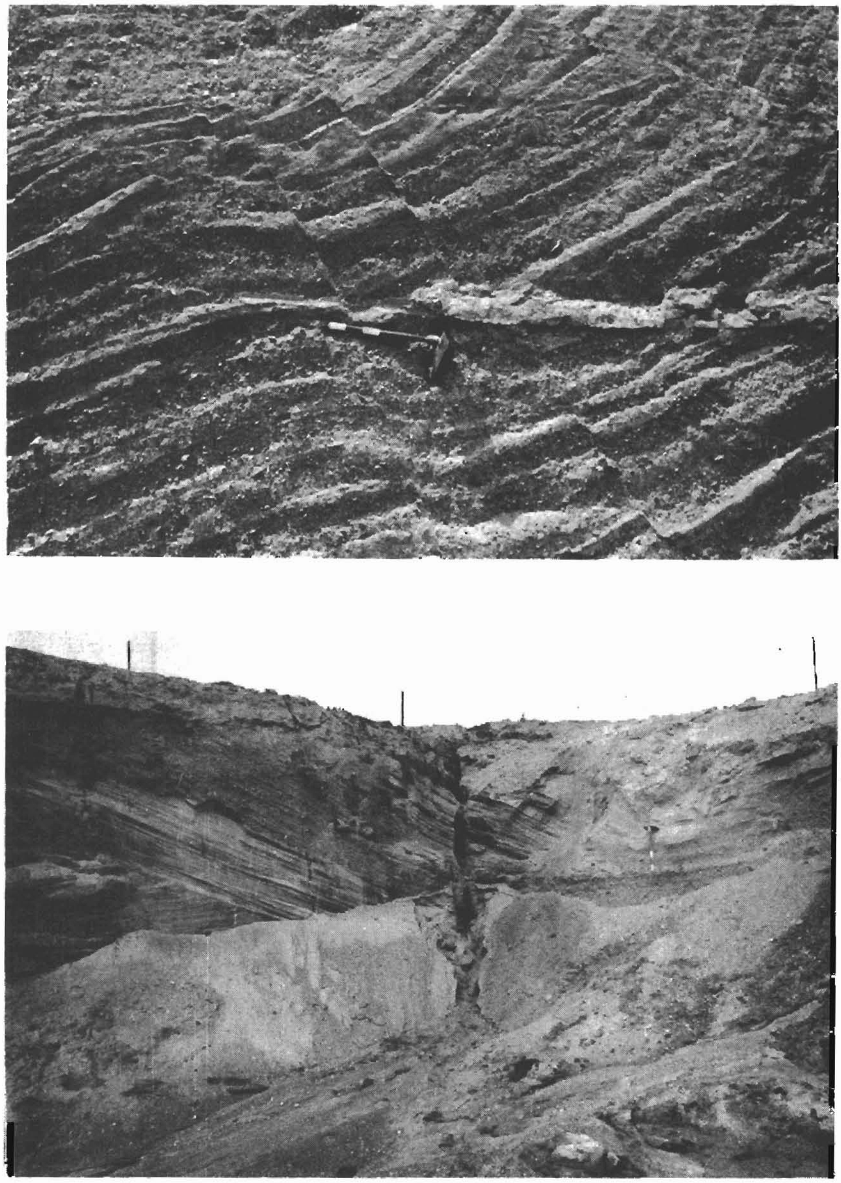

Figure 9. Two photos of glacial outwash. The upper photo shows faulting in sand in southeastern Steele County. Small structures such as those shown here are common where fluvial and lake sediments were deposited on top of stagnant glacial ice. Shovel is about 2½ feet long. The upper 2 to 3 feet of material on the lower photo is till that was deposited when the glacier advanced over slumped sand and gravel that was originally deposited in flat layers on top of stagnant glacial ice. When the stagnant ice melted, it allowed the sand to slump down. This sequence, till over slumped sand, is common in northern Griggs and southern Nelson Counties.

Glacial Outwash

Glacial outwash is composed of sand and gravel that was washed out of the ice by glacial streams (fig. 9). Examples of glacial outwash are found in western Griggs County and in western Ransom County. The sand and gravel is a good aquifer that can provide considerable groundwater to the farmers of the area.

Although most glacial outwash is found as broad, flat plains, in some places the gravel was deposited on top of the stagnant glacial ice. In these areas, the surface is rolling because the original flat surface collapsed when the stagnant ice melted. The outwash area near

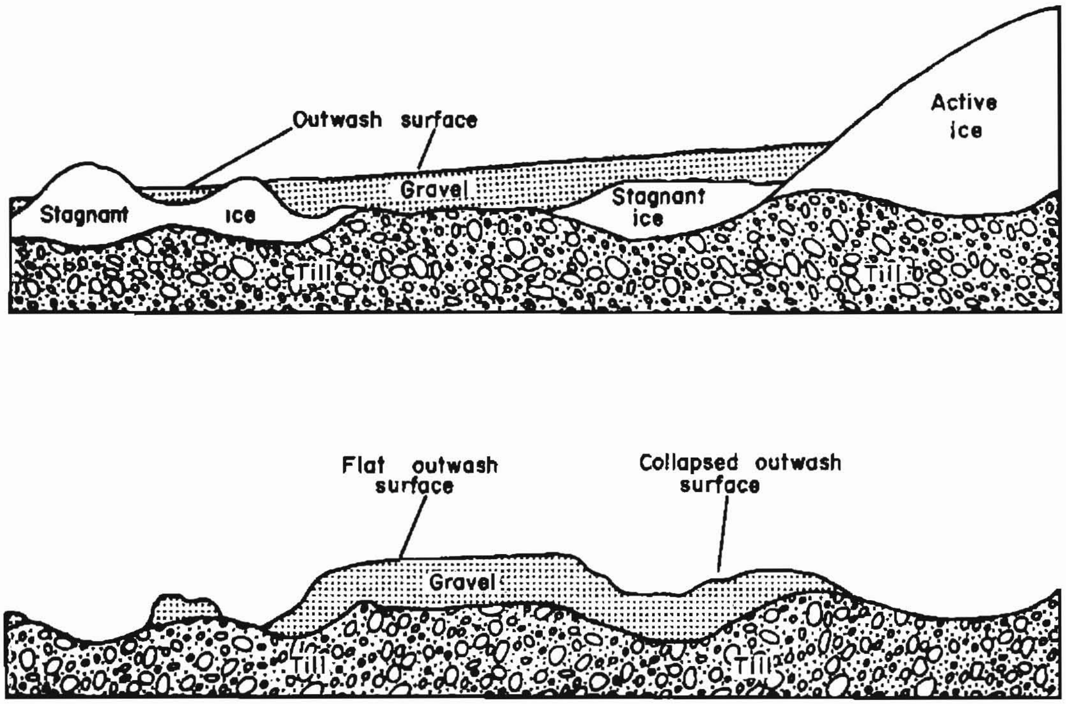

Figure 10. Steps in the formation of a collapsed or pitted area of outwash gravel such as the one near Binford in Griggs County. On the upper diagram, sand and gravel are deposited on the surface in front of the glacier. In places, this sand and gravel is deposited on stagnant ice, in other places on top of till, and in still other places it is not deposited because the stagnant ice is too thick. On the lower diagram, the ice has all melted and only the gravel and the till remain. In places where stagnant ice had been absent, a flat outwash surface remains. Where there was once stagnant ice, an irregular outwash surface has formed. In areas where no gravel was deposited, till covers the surface.

Binford in Griggs County is slightly pitted because chunks of stagnant ice were present on the surface when the gravel was deposited (fig. 10).

Eskers

Eskers show the form of the glacial rivers that deposited them. In glacial times, melt water rivers flowed on or beneath the ice, depositing sand and gravel on their beds just as modern streams deposit material on their beds. Typically, the esker gravels are coarse and poorly sorted with large amounts of silt and clay (fig. 11). When the glacier melted, the sand and gravel remained as ridges standing above the surrounding till plain. The heaviest concentration of eskers are in areas of dead-ice moraine. Several hundred small eskers occur in the area of dead-ice moraine west of Cooperstown. Eskers are common also in areas of ground moraine. The largest eskers in southeastern North Dakota are found near Hannaford in southern Griggs County and between Wimbledon and Dazey in northwestern Barnes County. These are shown in red on figure 13. The Hannaford esker is an example of an esker that was deposited on top of stagnant ice. It rises about 40 feet above the surrounding countryside.

Large Glacial Erratics

Standing Rock Hill in northwestern Ransom County, about a mile and a half east of the Little Yellowstone Park, is a good example of a large glacial erratic that was moved as a unit by the glacier. It is a block of shale that was moved about 3 miles southwestward and

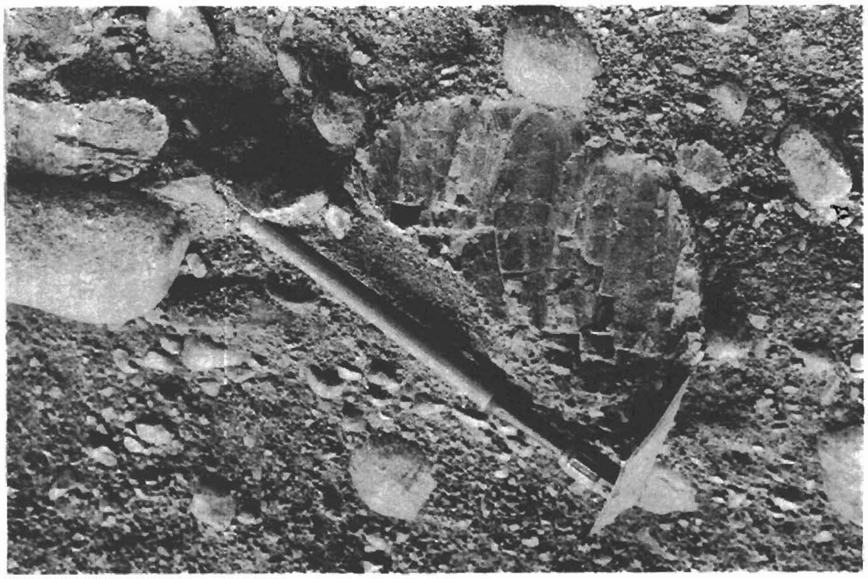

Figure 11. Gravel from an esker with a "boulder" of glacial till. The till boulder may have been frozen so that it held together while it was washed downstream in an ice tunnel or valley. Notice the jointing that has developed in the till since it was deposited.

lifted about 200 feet. The location from which the block was taken is now marked by a cluster of sloughs. Similar large glacial erratics are common in central North Dakota where blocks of material several square miles in area and several hundred feet thick were moved short distances by the glacier.

Bedrock Along the Sheyenne River

Through much of its route, the Sheyenne River melt water trench cuts through the covering of glacial material into bedrock. Shale of the Pierre Formation can be found in the trench in Griggs and the northern two-thirds of Barnes County. Slightly older Niobrara Formation shale occurs in the trench in southern Barnes and northern Ransom Counties. The Niobrara shale is particularly well exposed in and near the Little Yellowstone Park where it weathers to a golden color and gives the park its name. The bedrock is unit 11 on figure 13.

In many places, the shale tends to split into small, thin slabs that parallel the old bedding planes. This characteristic, which is known as fissility, gives the shale a blocky appearance (see figure 12). The shale of the Niobrara Formation is limy in places and it may have a future for the production of cement.

Drainage Pattern

The modern drainage pattern in southeastern North Dakota is not much different than it was at the end of the ice age. Except for southwestern Barnes, extreme western Ransom, and western Sargent Counties, the area is drained by the Red River of the North, which flows to Hudson Bay. The areas mentioned above are drained by the James River, which flows to the Missouri River, the waters of which eventually reach the Gulf of Mexico. The line separating the two drainage areas is the Continental Divide.

The routes of many of the smaller streams are strongly affected by the beaches. Where the east-flowing streams reach beaches, they commonly flow either north or south a short distance before cutting through the beach resulting in a sort of trellis-like drainage pattern in the beach areas. The Red and other rivers that meander over the nearly level lake plain have very gentle gradients, and, as a result, they are sluggish streams with many meanders,

Figure 12. Glacial till lying on top of shale bedrock. The shovel, which is about 2½ feet long, marks the contact between till and bedrock. Notice the blockiness of the shale.

cut-offs, and ox-bow lakes along their routes. The routes of the Sheyenne and Maple Rivers are unusual. Both trend southward for some distance and then hook back to northeasterly routes across the lake plain. The southward-flowing segments of the rivers were established when glacial ice filled the Red River Valley. The water was forced to flow southward along the ice margin. When the ice melted and Lake Agassiz formed, the rivers flowed into the lake, depositing the deltas. After the lake drained, the rivers cut shallow valleys parallel to the regional, northeasterly, gradient on the lake plain.

Modern streams deposit a layer of sand and silt on their beds and, during times of flood, on the areas adjacent to their banks. This water-lain material is known as river alluvium. It consists of sediment that has been eroded from areas upstream. The Red River has deposited considerable amounts of this "overbank" alluvium along its route. One result of this deposition has been to form low, but continuous levees so that the Wild Rice River (fig. 13) flows north for a considerable distance, very close and parallel to the Red River before it is able to enter the Red River south of Fargo.

FOSSILS

Fossils, the remains of ancient animal and plant life, are exposed in a few places in the area. Fossil dinosaur bones (Mosasaur vertebra) have been found in shale exposures near Little Yellowstone Park on the Barnes-Ransom County line. Fish scales are common in the Niobrara Formation shale.

In a few places, fossils have been found in the glacial deposits, mainly in the lake sediments. Caribou bones were found near Mayville in Traill County in a 1-foot-thick layer of fossiliferous material within the Lake Agassiz sediment. They apparently date to about 10,000 years ago when Lake Agassiz was temporarily drained. Clam and snail shells are common in glacial lake sediment, and fossil wood has been found in a few places. Abundant bison bones, including numerous skulls, have been found in river alluvium along nearly all the streams in the area. Most of these are probably only a few hundred years old.

NATURAL RESOURCES

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

Adequate supplies of sand and gravel are necessary for the economic growth of any area. Southeastern North Dakota has 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. Petroleum is another possible natural resource; but, although several exploratory oil wells have been drilled in the area, no oil has yet been found.

Although gold has never been an important natural resource in North Dakota, northwestern Ransom County had a small gold mine early in the century. The gold was mined from a cemented placer deposit, gravel that was probably brought to the area by a stream flowing from the southwest or west prior to the ice age.

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GEOLOGIC ROADLOG FOR GRIGGS COUNTY

(total distance about 45 miles)

Distance
Between
Points
(miles)

Begin trip at the south edge of Cooperstown at the Champlin station on the bypass. Drive west on State Highway 200 over ground moraine composed mainly of till.

0.2

Burlington Northern Railroad tracks.

0.9

Notice the numerous isolated hills in this area. Although they look like kames, most of these hills are composed of till and were probably deposited at the edge of the ice; insignificant amounts of gravel were found in the hills.

1.4

Junction of State Highways 200 and 1. Continue westward over low relief dead-ice moraine. Many of the hills through this area are esker ridges, formed when streams flowing through the stagnant glacial ice deposited gravel in their channels. When the ice melted, the gravel remained as ridges. Other hills in the area are till.

1.5

Rest Area. Notice the gravel operation to the north. This gravel is being taken from an esker.

0.6

Esker. The central part of this esker on the north side of the highway has been removed for gravel. Notice the shaly character of the gravel. This is typical of eskers in this area. This esker is several miles long and trends from northeast to southwest.

1.0

Drive onto a gravel outwash plain. This outwash was deposited by melt water flowing from ice to the northeast and to the northwest. In this area, the relief is slightly rolling because blocks of stagnant ice were present in the area when gravel was deposited. When these blocks of ice melted, the overlying gravel collapsed, resulting in an irregular surface.

2.9

Junction of State Highways 200 and 1. Turn north on 1, continuing over the outwash plain.

4.8

Road curves to the west. The hills to the north and east are part of the Cooperstown End Moraine. You are still driving over outwash sand and gravel.

0.9

Road curves to the north. Till is exposed in the ditch here. The hill to the west is mainly till; it was apparently a high area while outwash was deposited over the surrounding area.

0.7

Camp Atchison Historic Site monument. North of here notice the slightly hillier topography. Larger amounts of stagnant ice were present in this area.

2.2

Junction of State Highways 1 and 46. Turn east on 46.

0.8

Road crosses the Cooperstown End Moraine. The ice was to the east of here when the end moraine was deposited. Notice the hills about ½ mile to the north. These are part of the Binford End Moraine, which was deposited by southward-moving ice (ice to the north of the hills). Till is exposed in the roadcuts at the top of the hill here. Notice the large chunks of pure silt. These are lake sediments that were picked up by the ice as it moved westward over a lake.

0.5

Lake Jessie to the south. Several Indian mounds are situated along the west shore of the lake, on the east face of the end moraine.

0.7

Burlington Northern Railroad crossing.

2.4

Town of Jessie.

1.5

The numerous, isolated hills in this area are Pierre shale bedrock. The area was one of buttes before the ice advanced over it, depositing a thin layer of glacial sediment on the bedrock. Melt water was dammed ahead of the ice as it advanced over the area and lakes formed in places. Lake sediments can be seen in a few exposures in the area.

3.4

Junction of State Highways 45 and 65. Continue east on 45 over ground moraine that has been washed by running water from the north. This running water deposited sand in a few places.

2.9

Begin descent into the Sheyenne River melt water trench. The Sheyenne trench carried water from glacial Lake Souris in north central North Dakota to glacial Lake Agassiz in eastern North Dakota. Till and gravel are exposed in cuts at the west edge of the valley.

0.1

Pierre shale is exposed on the north side of the road.

0.5

Notice the gravel pits in the valley.

0.3

Bridge over the Sheyenne River.

0.8

Exposure of Pierre shale on the north.

0.3

Turn south on gravel road where the highway curves to the north. Notice the level-bedded lake sediments overlying dark shale at the corner. This was deposited at sometime before the melt water trench was cut as deeply as it is now.

0.2

Good exposure of shale on the east side of the road.

0.3

Turn east. Continue driving over the valley floor alluvium.

1.9

Sand exposure on the north side of the road. This is part of the same sequence as the lake sediments at the corner 2½ miles back.

1.3

Turn south, continuing through the Sheyenne valley.

5.8

Junction with State Highway 200. Turn west.

0.2

Bridge over the Sheyenne River.

0.4

Shale exposure on the south side of the road.

0.8

Back on ground moraine that continues to Cooperstown.

2.9

Bypass. Cooperstown. End of trip.

GEOLOGIC ROADLOG BETWEEN FINLEY AND COOPERSTOWN

(total distance about 17 miles)

Distance Between Points (miles)

Begin trip at south edge of Finley at the airplane. Drive south on State Highways 200 and 32. You will be driving over ground moraine that is composed mainly of glacial till.

0.1

Burlington Northern Railroad tracks.

0.2

Slough. This is located in a tributary to the Maple River.

1.2

Small gully, a tributary to the Maple River. The Maple River was a melt water trench that carried water southward from melting ice along its eastern bank. Notice the till exposed in roadcuts on either side of the gully.

1.4

Small gully.

1.5

Road curves to the west. Continue westward on State Route 200. Cross another gully, another tributary to the Maple River.

3.1

Notice that the land in this area is a little more hilly than that a few miles to the east. This is part of the Luverne End Moraine, a range of hills that extends southward from Nelson County to southern Barnes County. The end moraine formed when the glacier margin that was receding into the Red River Valley readvanced slightly and stabilized in the position of the end moraine. Notice the numerous lakes in the area.

1.7

Notice the lower land to the west. This marks the western edge of the Luverne End Moraine. West of here, melt water flowed southward from the ice and from ice to the north of here in Nelson County. This melt water washed the till surface between here and the Sheyenne River, which was not yet in existence, depositing gravel in places.

2.2

Griggs-Steele County line.

0.4

Gully, a tributary to the Sheyenne River. The lithology in this area is mainly Pierre Formation shale. This shale bedrock is dark gray and easily distinguishable from the glacial deposits, which are less uniform in texture and lighter in color.

0.7

Good exposure of shale. The Sheyenne River valley, to the west of here, is a melt water trench that carried water from Glacial Lake Souris in north central North Dakota to Glacial Lake Agassiz in eastern North Dakota. At its largest, the Sheyenne melt water trench was full, rim to rim (about ¾ mile wide and 130 feet deep here).

0.5

Bridge over the Sheyenne River.

0.4

Shale exposure on the south side of the road.

0.8

Back on ground moraine that continues to Cooperstown.

2.9

Bypass. Cooperstown. End of trip.

GEOLOGIC ROADLOG FOR BARNES COUNTY

(total distance about 45 miles)

Distance Between Points (miles)

Begin trip at the corner of 12th Street NE and Central Avenue N at the north edge of Valley City. Drive east on the hard-surfaced road. You are driving on a river terrace, a level at which the Sheyenne River flowed in the past.

0.2

Road curves north. Notice the gravel operations on the right below. These are terrace gravels, deposited by the river.

0.3

Railroad overpass (Burlington Northern Railroad tracks).

0.1

Bridge over the Sheyenne River. North of here you are driving on the modern floodplain of the river. If, some time in the future, the Sheyenne River cuts a deeper valley, this floodplain would become a terrace level above the river.

0.4

Soo Line Railroad crossing. The road forks here; continue north. Notice the hills to the east. These river banks have slumped and slid extensively resulting in the knobby topography. Numerous glacial boulders cover the surface and till is exposed in places, but the hills are cored by Cretaceous Pierre shale.

0.2

Begin climb out of the Sheyenne River valley, which is really a melt water trench cut when glacial Lake Souris in north central North Dakota overflowed and drained, via the Sheyenne melt water trench into Lake Agassiz in southeastern North Dakota.

0.3

Notice the deep roadcuts that expose till overlying Pierre Formation shale. The till occurs at the top of the cut and appears buff in color. It is very stony. The shale is uniform and dark gray in color.

0.4

Gully, a tributary to the Sheyenne River.

0.2

Small exposure on east of lake sediments (horizontally banded fine sand and silt) over till (stony surface). Lakes were dammed ahead of the ice as it receded from the area.

0.2

You are now driving over a flat lake plain, composed of silts and clays similar to those you saw 0.2 mile back. The glacier stood to the east a few miles when this lake plain formed, prior to the cutting of the Sheyenne River valley. The lake sediments are thin and discontinuous in the area; and, in many places, where they are absent, till is found at the surface.

1.0

Curve in road. Continue north over the lake plain.

7.0

Drive up off the lake plain onto ground moraine. This area, because it is slightly higher than that to the south we have been driving over, was not covered by the lake. The topography here, a little more hilly than that to the south, is probably about the way it was to the south before that area was flooded by a lake. The lake sediments collected in the lower areas, tending to smooth the landscape.

0.5

Ashtabula Township Hall.

0.5

Drive down off the ground moraine into a gully. Notice the numerous boulders in the banks.

0.4

Pavement ends. Notice the gravel in the cuts and pits. This gravel was deposited by melt water flowing from the ice, which was about 3 miles to the east at the time. The gravel was deposited on top of stagnant glacial ice, which, when it melted, caused the gravel to collapse, resulting in the rolling topography we have here today.

0.6

Turn east on gravel road. The hills to the east are part of the Luverne End Moraine. You are driving over outwash interspersed with till.

1.8

Begin climbing the Luverne End Moraine.

0.2

Luverne End Moraine. This hilly topography resulted when the glacier margin stood here (the main ice body was to the east). Large amounts of materials carried in the glacier accumulated at the ice margin, which trended north-south. Melt water flowing from the ice deposited the gravels we have just seen to the west and became dammed in a lake, the deposits of which we drove over. Notice the cuts in till along the road and the abundance of boulders.

1.0

Turn north and drive on and parallel to the end moraine. The end moraine here is a little more subdued than to the west a mile or so. Numerous cuts in till along the road.

3.0

Turn west and cross the end moraine again. Numerous curves in road ahead.

2.1

Leave the end moraine and drive back onto gravel outwash. Notice the gravel exposures.

1.0

Stop sign. Turn north on the gravel road and drive over outwash.

0.5

Road curves to the west.

0.2

Good exposure of gravel, sand, and lake sediments.

0.3

Bridge over Lake Ashtabula.

0.2

Notice the exposures of shale in cuts along the road.

0.6

The road curves northward. This area is lake plain.

0.5

Turn west and drive over lake plain.

2.0

Turn south. The hills on the north are part of the Cooperstown End Moraine, which is slightly older than the Luverne End Moraine. You are still driving over lake plain.

1.1

Begin descent into valley. Notice the exposures of lake sediment in the roadcuts as you drive into the valley.

0.3

Bridge over Bald Hill Creek. Bald Hill Creek flows in a melt water trench that carried water from melting ice in northern Griggs County, and parts of Eddy and Foster Counties to the northwest. Wesley Acres Camp to the west. Climb out of the valley.

0.3

Road curves. This and the area to the south is ground moraine.

1.4

Turn west.

1.0

Turn south. Continue driving over ground moraine.

0.2

Small pit in esker on the west side of the road. This cross-bedded sand is typical of such ice-contact deposits. The esker trends northwest to southeast.

1.8

Small esker. Continue southward.

1.9

Small coulee. This valley once served as a melt water trench.

2.1

Begin descent into Sheyenne River valley. Bald Hill Dam to the left. The Bald Hill Dam was constructed as a multiple purpose project. It stabilizes stream flow, helps prevent floods and serves to supplement municipal water supplies and assists in pollution abatement downstream. The dam is an earth fill dam 1,650 feet long with a concrete spillway and control works. The reservoir is approximately 27 miles long and has a maximum width of ½ mile. Immediately behind the dam the lake is about 40 feet deep at normal full pool level and the depth decreases about 1 foot for every additional river mile upstream from the structure.

0.3

Pavement begins.

0.4

Bridge over the Sheyenne River. Turn right. Notice the numerous till cuts along the east side of the road. Notice the bouldery slopes of the valley walls.

6.7

U.S. Fish Hatchery.

0.3

Maryvale.

1.3

Stop sign. End of trip.

GEOLOGIC ROADLOG BETWEEN MAYVILLE AND FINLEY

(total distance about 24 miles)

Distance Between Points (miles)	
	Begin trip in Mayville at junction of State Highways 18 and 200. Drive west, descending into the Goose River valley.
0.7	Bridge over the Goose River. Notice the cuts in buff-colored lake silts to the south of the bridge.
0.1	Climb out of valley onto the lake plain. This flat area is covered by silt and clay that was deposited at the bottom of Lake Agassiz.
1.0	Town of Portland.
0.4	Burlington Northern Railroad tracks.
0.2	Rise in road. This is the Campbell beach line which, in this area, is a wave-cut scarp along which no sand was deposited. After crossing the scarp, continue westward over the lake plain.
1.4	Bridge over the South Branch of the Goose River. The area to the north of here for several miles consists mainly of fine sand that was deposited at the mouth of rivers that flowed into glacial Lake Agassiz. The resulting deltaic deposits are known as the Elk Valley Delta.
2.2	Junction of Highways 18 and 200. Continue west on 200.
1.1	Traill-Steele County line. Continue driving westward over the Agassiz lake plain.
2.3	Gully. Notice the exposures of lake sediment on either side of the gully. This is mainly silt that is mottled gray and brown. The uneven coloration is the result of intermittent wetting and drying, which did not allow oxidation to proceed uniformly.
0.8	Gully. Exposures of lake sediments in the gully walls.
1.1	Gully. Lake sediments exposed on east side.
2.7	Begin ascent of the rise that marks the western limit of Lake Agassiz in this area. The maximum limit of the lake is marked by a one-mile-wide zone of wave-washed till with numerous, small beach ridges. South of here, in Barnes and Cass Counties, the lake flooded land that was considerably higher than here, but this area was apparently still covered by ice at that time.
0.5	Small beach ridge.
0.2	Road curves southward.
1.3	This area is ground moraine composed mainly of glacial till that was deposited directly by the ice. Notice that it is rolling, compared to the very flat lake plain you just left. In a few places, between here and Finley, the

land is even more rolling. These areas were probably formed when the ice margin stabilized there for a while, allowing more debris to be deposited at the edge of the ice.

1.4

Small exposures of gravel in roadcut in till on the south. This is probably a small esker deposit.

1.2

Melt water trench. This small valley once carried water from melting ice a few miles north of here. Notice the gravel that is exposed on the uplands adjacent to either side of the valley. Apparently it was deposited by melt water shortly before the valley was cut by the water.

0.6

Road to Hope. Continue toward Finley on Highway 200. Notice the occasional road cuts in glacial till between here and Finley.

4.8

Finley. End of trip.

GEOLOGIC ROADLOG BETWEEN HANKINSON AND WYNDMERE

(total distance about 26 miles)

Distance Between Points (miles)

Begin trip at corner of Sixth Street and Main Avenue in Hankinson. Drive west on State Route 11. Drive west over shore deposits of Lake Agassiz. Just west of town, Grass Lake, Willow Lake, and Lake Elsie are all located in depressions that formed when large blocks of stagnant ice melted, lowering the overlying shore sands of Lake Agassiz. The hills to the southwest of Hankinson are composed of gravel that was deposited by melt water that flowed at the edge of the glacier before Lake Agassiz formed.

3.5

Road trends straight west from here.

0.5

Notice that the land to the north is level, the land to the south rolling to hilly. This marks the approximate northern limit of the area that was covered by stagnant glacial ice when Lake Agassiz flooded the area. The areas that were covered by stagnant ice are rough because the overlying materials collapsed when the ice melted. About two miles to the north of here the land is also hilly, but this is because the wind has blown the sand into dunes.

2.5

After about 2½ miles, notice that the land becomes more rolling. This is dead-ice moraine composed mainly of glacial sediment, till.

2.7

Back on flat shore deposits. This area of shore sediment, from here to Lidgerwood, was deposited on discontinuous stagnant ice, and ponds and sloughs are common.

1.3

Junction with State Route 18 to the south. Continue west.

1.9

Lidgerwood. Continue through Lidgerwood on Highway 18.

0.6

Turn north on Highway 18; cross the Soo Line Railroad tracks. This low area is a broad melt water valley that trends west to east here. It carried water from the northwest along the edge of the glacier.

1.2

Slightly higher land here is mainly till that was washed by water along the shore of Lake Agassiz. Numerous small, hard-to-see beach remnants occur over this area and to the north.

7.4

Slight drop from wave-washed till plain to gravel-covered shore area. This is an area of numerous low beaches.

1.6

Wild Rice River. This small river is cut into bedded silt and fine sand deposits of the Sheyenne Delta which begins about here and continues for many miles to the north. The Wild Rice River flows in a valley that was cut by glacial melt water.

0.5

Sheyenne Delta. This flat, sandy area is part of the Sheyenne Delta that formed when the Sheyenne River flowed into Lake Agassiz, depositing sand and silt at its mouth. The surface of the delta has been greatly modified in many places by wind action; numerous dunes are present.

1.8

Town of Wyndmere. End of trip.

GEOLOGIC ROADLOG FROM WESTERN RICHLAND COUNTY TO LISBON

(total distance about 38 miles)

Distance
Between
Points
(miles)

Begin trip at the junction of State Highways 27 and 18 in northeastern Richland County. Drive west. This is the Sheyenne Delta, covered mainly by sand that has been blown into low dunes by the wind.

5.5

In this area, notice the pastureland. In some places, this land is rather salty, as in the Sheldon area. In such areas, artesian water (water under pressure) is escaping to the surface from the bedrock below. This water is salty, containing large amounts of minerals it has dissolved in its movement through the bedrock. Some wells drilled to this bedrock still flow at the surface; but, in most places, pumping over the past 60 years or so has lowered the pressure sufficiently to keep the water from flowing over the ground without pumping.

1.5

Ransom-Richland County line. Notice that the land is becoming a little more hilly as the dunes are more prominent.

1.0

Road to McLeod. Dunes at the corner. Continue to the west.

2.0

Ransom County Road 53. Turn north.

1.8

Cuts in windblown sand. Dig in this sand and notice how uniform it is, with no pebbles.

2.2

Turn east on gravel road.

2.0

Road turns north. Sheyenne River valley ahead and to the west side of the road.

1.0

Road turns west and heads into the valley.

0.5

Larson Bridge. Stop and examine the river cut about 50 yards south of the bridge on the east side of the river. In general the lower 25 feet of it consists of alternating bands of sand, silt, and clay. Some of the clay beds are pebbly with nodules of dark colored clay. These beds look like mudflows that probably occurred near the mouth of the Sheyenne River when it was emptying into Lake Agassiz. The upper 30 feet of the cut is sand that was also deposited near the river mouth but in somewhat shallower water.

0.4

Climb out of the valley.

0.7

Descend into the valley again.

0.5

Road turns north and climbs out of the valley again. After leaving the valley, notice the large dunes to the right.

1.0

Road turns west, crossing several tributaries of the Sheyenne River.

2.0

This area is again the flat, Sheyenne Delta. In this area, however, and between here and Sheldon, several potholes occur. These were formed when deltaic sediments were washed over blocks of stagnant glacial ice. When the blocks of ice melted, depressions resulted.

1.0

Turn south at junction near Anselm.

0.5

Soo Line Railroad Crossing. The depression to the east of the road at the crossing is an example of the potholes that were formed when blocks of stagnant ice melted.

0.5

Bridge over the Sheyenne River. The area between here and Highway 27 is part of the Sheyenne Delta.

5.0

Junction with Highway 27. Turn west.

0.1

Bridge over the Sheyenne River. West of the Sheyenne River, and continuing all the way to Lisbon, you are on a mixture of till, collapsed shore sediment, and collapsed lake sediment. Numerous ridges of sand occur throughout the area. Many of these are remnants of beaches and others are eskers.

8.8

Bridge over the Sheyenne River in Lisbon. End of trip.

GEOLOGIC ROADLOG BETWEEN FARGO AND VALLEY CITY

(total distance about 57 miles)

Distance Between Points (miles)

Start trip at junction of Interstate Highways 29 and 94. Drive west on 94. This flat land is part of the Agassiz lake plain, which resulted when the glacial Lake Agassiz drained. Lake Agassiz was named after a Swiss zoologist, Louis Agassiz, whose research during the last century popularized the idea of the ice age. The lake plain is essentially featureless for the first 10 miles or so.

12.1

Maple River. The Maple River flows in a gentle valley in this area. The valley was cut after Lake Agassiz drained. To the west, upstream, the valley is deeper. The deeper portion of the valley was cut while the river flowed into the lake. Rest area is to the west of the river.

2.3 Maple Ridge. This ridge (just east of the valley of Swan Creek) is a differential compaction ridge that resulted when a stream that flowed over the temporarily drained lake bed deposited gravel in its channel. (See the text for a discussion of differential compaction ridges.)

3.8 Junction with State Highway 18. Continue west over the lake plain.

6.8 Beaches begin here and for about the next 6 miles you will be crossing a series of beaches. Although they are not conspicuous from the road, the beaches can be observed as step-like rises toward the west. They mark former shorelines of Lake Agassiz and extend north-south for several hundred miles. Like modern beaches they are composed of sand and gravel that is used throughout the Red River Valley.

6.4 This area is a combination of collapsed shore and lake sediment that resulted when the lake flooded an area of stagnant ice. When the ice melted, the lake and shore sediment slumped down resulting in the rolling topography you see in the area today.

3.0 Junction with State Highway 32. Continue west.

1.5 Melt water trench that carried water from the north.

4.1 Melt water trench.

1.4 Cass-Barnes County line.

2.5 Notice the low, east-facing scarp. This and a few other low, hardly noticeable scarps that occur in this area mark shorelines of Lake Agassiz when it stood at a high level, but only for short periods of time, so that extensive beaches did not form. The area is primarily ground moraine.

0.7 Rest area.

1.7 Junction with State Highway 32. Continue west.

3.4 Luverne End Moraine. The glacier covered the area east of here when the Luverne End Moraine was deposited at its margin.

1.3 Crest of end moraine. Notice the view to the east.

4.4 Start gradual descent into the Sheyenne River valley.

2.0 Sheyenne River. Notice the exposures of Pierre Formation shale in the valley wall just southwest of the bridge. End of trip.

GEOLOGIC ROADLOG FOR RANSOM COUNTY

(total distance about 43 miles)

Distance Between Points (miles)

Begin trip in Lisbon at the corner of Main Street and Fifth Avenue. Drive west, out of the Sheyenne River valley, a melt water trench that carried water from Glacial Lake Souris in north central North Dakota to Glacial Lake Agassiz in eastern North Dakota. At its largest, the Sheyenne melt water trench was full, rim to rim (about a mile wide and a hundred feet deep at Lisbon). After leaving the main valley, you are driving on gravel terraces that border the valley. These were cut during an early stage in the development of the Sheyenne valley.

1.1

Notice the gravel exposure to the north of the road.

0.4

Leave the terrace and drive up onto ground moraine. This ground moraine, which is composed mainly of till, was washed in places by water before the water established a definite course, the Sheyenne River valley. Continue on ground moraine for several miles.

4.8

Road to Elliot. Continue west over ground moraine.

3.1

Drive off the ground moraine onto outwash gravel. This gravel was deposited by melt water flowing southward from melting ice to the north. It was deposited before the Sheyenne River valley came into existence.

0.3

Road to Englevale. Continue west over outwash gravel.

1.0

Turn north toward Fort Ransom. Drive north over outwash gravel for about a mile, then over ground moraine for about 3 miles.

0.6

Good gravel exposure on the west side of the road.

2.5

Cut in till on the east side of the road.

1.6

Road curves to the west.

0.6

Road turns north toward Fort Ransom. Gravel pit at the corner is in glacial outwash material.

0.8

Site of old Fort Ransom. Directly west of the fort site is a bouldery hillside. These boulders are glacial erratics, concentrated by erosion processes. Water flowing over the area removed the finer materials, leaving the heavier boulders behind. Some of the boulders on the hillside show good glacial striations, scratches that resulted when materials in the ice rubbed over the rocks. Contrary to local legend, there is no evidence of writing on the rocks. The "Viking Mooring Stones," also present on this hillside, are simply rocks with blast holes that were drilled into them, perhaps as an exercise for the soldiers stationed at Fort Ransom.

0.1

Road curves right and drops down into the Sheyenne River valley.

0.6

Bridge over the Sheyenne River. Town of Fort Ransom. Drive through town on paved road and turn left.

0.3

Turn north on Scenic Route. The pyramid-shaped hill to the east is composed of bedrock and the result of erosion in the valley. Again, contrary to local legend, it is a natural feature and was not built by a "lost civilization."

0.6

Good exposure of Niobrara Formation shale.

0.2

Bridge over a small coulee.

3.0

Cut in till on the right side of the road. Contrast this bouldery glacial till with the excellent exposures of bedrock 0.2 mile further along on the right.

0.2

Cuts in Niobrara shale. This shale weathers to a golden color and gives the Little Yellowstone Park its name. Notice the abundant gypsum crystals along joint faces in the shale. If you dig back into the shale a ways, you will notice that it is pebble-free and grayer where it is less weathered and not exposed to oxygen. Along the top of the long cut you can see the stony till that lies on top of the shale.

5.8

Good roadcut in glacial till.

0.1

Scenic road turns left. Turn sharply left.

0.3

Preston Lutheran church.

0.1

Turn right on Scenic Road.

1.4

Small dam with lake to right.

1.8

Turn right (north).

1.9

Junction with State Highway 46. Turn east.

0.1

Exposure of Pierre Formation shale on the north side of the road. The Pierre Formation overlies the Niobrara Formation.

0.8

Road to Standing Rock Hill. Turn right (south) and drive to the top of the hill.

0.5

Top of Standing Rock Hill. This hill is actually a huge boulder of Niobrara shale that was moved about 3 miles from the northeast by the glacier. A cluster of lakes and sloughs marks the depression from which the hill was taken.
Standing Rock itself is a boulder of metamorphic gneiss, transported to this area from Ontario by the ice. Notice the monument with the sign. Most of the rocks in this monument are glacial erratics, transported to the area by the ice.
Return to the highway and continue eastward.

0.5

Turn east on State Highway 46.

4.8

Junction with State Highway 32 to the north. Continue eastward over ground moraine.

0.7

Descend to a slightly lower level as you cross the east-facing scarp. This scarp marks an early stage in the history of Lake Agassiz when the lake was still small and most of the area to the east was still covered by ice. Although the surface materials in the area immediately east of the scarp are still till, this till shows evidence of having been washed at the shore of the lake.

1.3

Small sand exposure on the north side of the road marks an early beach of the lake. The area to the east of here, although it looks similar to the ground moraine over which we have been traveling, consists of a mixture of till, shore sands, and lake sediment. The latter two of these were deposited on top of stagnant ice which was lying on top of the till. When the ice melted, the sand and lake silts slumped down on top of the till. By digging at any particular spot you could find any of these materials.

4.1

Junction of State Highways 46 and 32. Continue eastward on 46.

0.3

Drive down onto a slightly lower level, another wave-cut shoreline scarp. The land surface for the next two miles is mainly till that bears evidence of washing at the lake shore.

2.8

Descend into the Maple River valley. The Maple River flows in a melt water trench that emptied into Lake Agassiz. Town of Enderlin in the valley. End of trip.

GEOLOGIC ROADLOG FOR TRAILL COUNTY

(total distance about 43 miles)

Distance Between Points (miles)

Begin trip at the junction of State Highways 200 and 18 in Mayville. Drive south on 18, descending into the Goose River valley as you leave town.

0.7

Bridge over the Goose River.

0.3

Turn west on gravel road.

0.2

Bridge over canal cut by airport. Examine the cut to the north of the bridge. The material is silt and clay that was deposited in Lake Agassiz. It is banded, each band representing a separate phase in the process of deposition. Bands that represent annual deposition are known as varves. They are typically alternating dark and light, the darker, thinner layers representing winter deposition, the lighter, thicker layers representing summer deposition. Try to determine whether these bands are varves. Notice the boulder in the banded silts on the west side of the cut.
Return to the highway.

0.2

Turn south on Highway 18. Drive south over lake sediments, similar to those you just looked at. This is the Agassiz lake plain.

8.3

Notice the rise in elevation just north of the curve. This is the Campbell beach scarp, which marks a level of Lake Agassiz that persisted for some time. The Campbell scarp can be traced all around the lake plain. As you drive up on the Campbell scarp, the lithology changes from lake sediment to till. The till plain south of the Campbell scarp has been washed by waves at the shore of the lake.

0.3

Turn off the highway on Traill Co. Route 9 and continue southward over till.

1.0

Elm River valley. The Elm River valley is a small melt water trench that carried water from the melting ice to the southwest. It was active early in the history of Lake Agassiz; and when the lake stood at a high level, it built a delta in the lake in the Galesburg and Clifford areas.

0.2

Bridge over the Elm River.

2.0

Notice the rise in elevation about a half mile ahead and to the west. This is the wave-cut scarp of the Tintah beach, one of the upper levels of Lake Agassiz. Also notice the boulders in the fields here. This is till that was washed extensively at the lake shore, probably while the lake was dropping from the Tintah to the Campbell level.

0.5

Tintah scarp. Notice the sand and gravel in cuts just above the scarp. This is shore sediment. The area for the next two miles or so is mainly sand and gravel that was deposited at the shore of Lake Agassiz. Several beach ridges are noticeable in the area.

2.4

Junction with paved road, Traill County Route 1. Turn west toward Galesburg.

1.9

Bridge over the Elm River. West of here you will be driving over deltaic materials, deposited by the Elm River when it flowed into Lake Agassiz. These sediments consist mainly of fine sand and silt.

1.6

Bridge over a tributary to the Elm River.

0.2

Galesburg.

0.2

Turn north through Galesburg on Traill County Route 16.

0.5

Cuts on both sides of the highway near the curve. You can see the fine sands in these cuts. The uneven color of the sand is the result of weathering under alternating dry and moist conditions. This area is one of groundwater discharge, where groundwater is escaping to the surface. A little oil is sometimes present in the water, but so far no hydrocarbons have been found in the area.

0.2

Bridge over a tributary to the Elm River.

1.4

Notice the many shelterbelts in this area. They are particularly necessary in areas covered by sand, which might otherwise be subject to severe wind erosion.

0.9

Cross the Burlington Northern Railroad tracks and continue driving northward over the delta.

2.6

Clifford.

0.4

Turn west on gravel road. Notice the fine sand exposed at the corner. This sand is finely banded with dark-brown layers that appear to be fossil plant materials.

1.6

Beach scarp. Notice the beach sand exposed at the top of the scarp.

0.4

Turn north on the gravel road.

0.2

Ridge on which the abandoned farm is located is a beach ridge.

0.7

Notice the character of the vegetation in this area (Waterfowl Production Area to the east). This is typical wherever slightly saline groundwater is escaping to the surface. The upward movement of the water tends to continuously saturate the deltaic sands, making it a perpetually swampy area. The white crust you see in places is salt (alkali) that was precipitated as the water evaporated.

1.6

Beach ridge. Notice the gravel.

0.4

Turn east. You will be traveling down a series of sandy beach ridges that mark successively lower levels of Lake Agassiz.

2.0

Junction with highway. Continue east.

0.9

Road curves to the north. You will be traveling over lake sediment, silt and clay.

7.0

Junction with State Highway 200. Turn east.

0.4

Town of Portland.

0.2

Descend to a lower level. The slight drop here is the Campbell Beach which, however, does not have much sand or gravel associated with it. Here, it is simply a wave-cut scarp.

1.6

Mayville. Descend into the Goose River valley.

0.1

Bridge over the Goose River. End of trip.

GEOLOGIC MAP OF SOUTHEASTERN NORTH DAKOTA

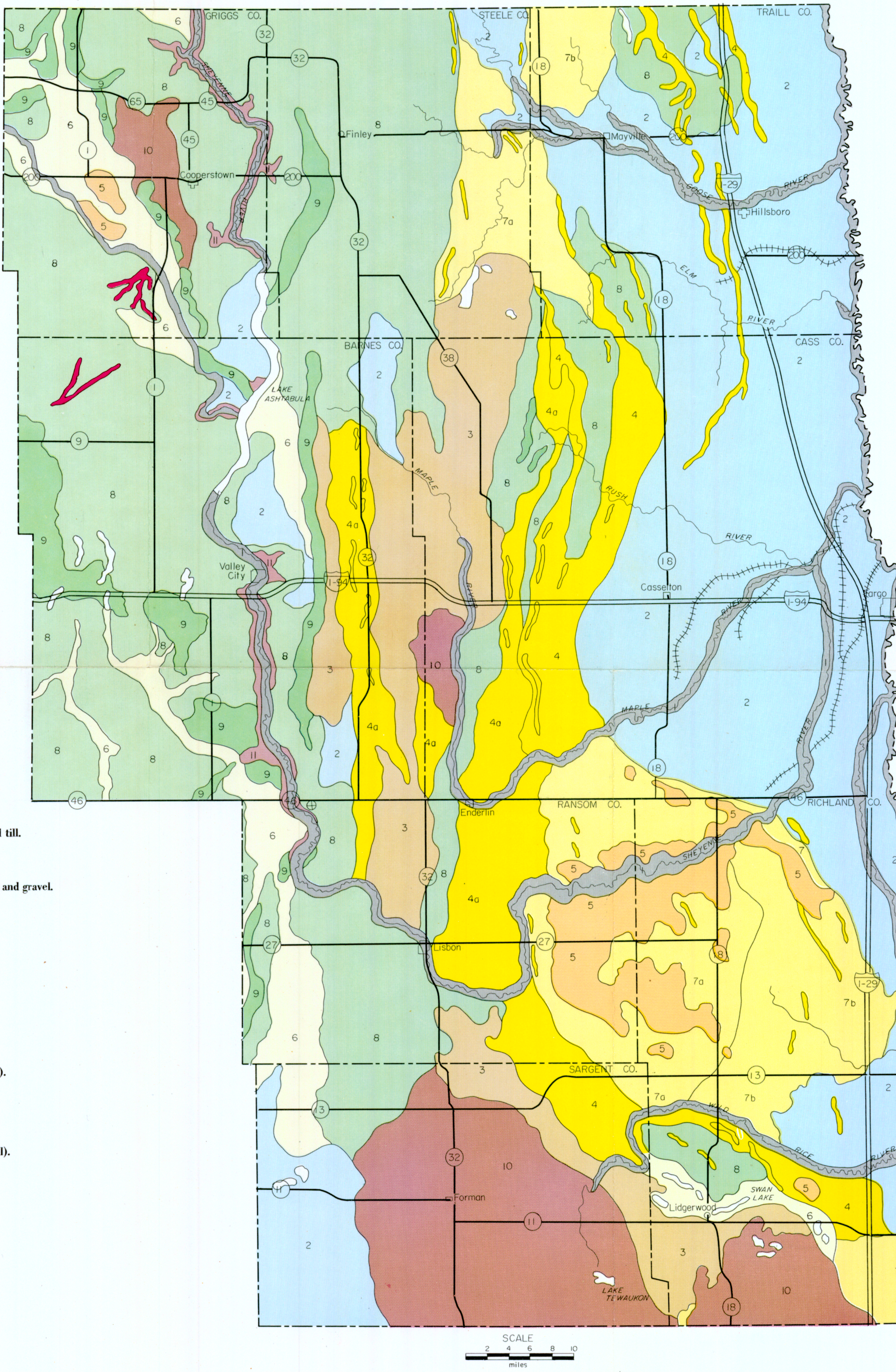

FIGURE 14

EXPLANATION

1	Aluvium. Sand and silt.
2	Lake plain. Silt and clay.
3	Mixture of collapsed lake sediment and till.
4	Shoreline deposits. Sand and gravel. 4a. Collapsed shoreline deposits. Sand and gravel.
5	Dunes. Fine sand.
6	Glacial outwash. Gravel and sand.
7	Deltaic deposits. 7a. Coarse to fine sand. 7b. Fine sand to silt.
8	Ground moraine. Glacial sediment (till).
9	End moraine. Glacial sediment (till).
10	Dead-ice moraine. Glacial sediment (till).
11	Bedrock. Shale.

Symbols

▬	Eskers. Gravel and sand.
⊕	Large glacial erratics.
┼┼┼┼	Differential compaction ridges.