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

GUIDE To The GEOLOGY Of South - Central NORTH DAKOTA

BY John P. Bluemle

revised edition 1975

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GUIDE TO THE GEOLOGY OF SOUTH-CENTRAL NORTH DAKOTA

Burleigh, Dickey, Emmons, Kidder, LaMoure,
Logan, McIntosh, and Stutsman Counties

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Educational Series 6

North Dakota Geological Survey

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GUIDE TO THE GEOLOGY OF SOUTH-CENTRAL NORTH DAKOTA

Introduction

Have you noticed the change in the landscape as you travel west along North Dakota Interstate Highway 94 west of Jamestown? Have you ever wondered why so many more sloughs are found in western Stutsman County than in the east? What caused the deep valley through which the James River flows? Why does the valley become so much less spectacular near Oakes? How old is the Missouri River Valley and how did it form? Geologists are concerned with the above questions. Their science, geology, is the study of the earth, the science that attempts to learn how and when rocks have formed, when the earth began, how it has evolved, and what is going on within it today. This may seem to be an impossible undertaking, but we do have some of the answers to many of these questions, and solutions to other questions are being found every day.

Geologists with the North Dakota Geological Survey study the mineral resources of the state and make their findings available to the public. The Survey also administers the oil and gas conservation laws for the State Industrial Commission. North Dakota is considered a leader in the conservation of natural resources and mineral pollution control.

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

Further information may be obtained from the North Dakota Geological Survey, University Station, Grand Forks, North Dakota 58201.

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 5 billion years old. If all of those 5 billion years were compressed into a single imaginary year, the earliest life would have appeared in late April of that year. Dinosaurs would have come on the scene in mid-December and lasted only six of our imaginary days. The ice age would have begun in North Dakota at 8:40 p.m. on December 31 and ended

* *Burleigh, Dickey, Emmons, Kidder, LaMoure, Logan, McIntosh, and Stutsman Counties.*

only two minutes before midnight. Primitive man arrived on earth about 10:20 p.m. in the midst of the ice age. At 20 seconds before midnight, Christ was born, and at 10 seconds, Leif Ericson discovered America. So, as you can see, the two thousand years since the birth of Christ may seem like a long time; but, to the geologist, they are only an instant in the history of the earth.

General Geology

Introduction

The part of the earth we live on is only a thin skin, known as the crust, that encases a huge volume of denser materials known as the mantle and core. The crust is built from solid materials, known as rocks, the density, chemical composition, color, hardness, and origin of which vary widely. 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 dense and hard. Tremendous pressures bear down on much of the interior; and, for this reason, some of the mantle and core materials behave more like liquids than solids. Certainly, at the earth's core, the rocks are mobile, probably something like very dense plastic. The temperatures within the earth are also great.

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

Minerals

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

Perhaps the most common mineral is quartz, a colorless silicate with a complex crystal structure. Glass is made from 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, is used to cut glass. Because minerals differ in hardness, this physical property may be used to distinguish between minerals that are otherwise similar. Color, luster, and specific gravity are other properties of importance to the mineralogist (one who works with minerals), but these need not concern us now. Suffice it to realize that minerals can be distinguished by their particular properties.

Rocks

Rocks are made of combinations of minerals. The three varieties of rocks are *igneous, sedimentary*, and *metamorphic*. The igneous rocks (from the Latin, *ignis*, "fire") were once hot, molten rock matter known as *magma*, which subsequently cooled to a firm, hard material, much as water freezes to ice. Some of the deepest crustal rocks in North Dakota are igneous granites. The granites are buried under 300 to 15,000 feet of younger 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, 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, or from the North Dakota badlands, and deposited in the Gulf of Mexico. Such sedimentary rocks are as much as 15,000 feet thick in parts of western North Dakota. Figure 1 is a cross-section showing how the sedimentary rocks thicken westward toward the deeper parts of the Williston Basin. The Williston Basin of western North Dakota was once a sea in which thick sediments were deposited, much as sediments are being deposited today in the Gulf of Mexico.

All 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.

Rocks in South-Central North Dakota

In general, two kinds of sedimentary rocks are found in south-central 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 (Figure 2). Where glacial deposits are absent, bedrock can be seen (Figures 3, 4, 5, 6, and 7). In south-central North Dakota, the oldest bedrock that is exposed is shale of Cretaceous age about 70 to 80 million years old in the James River Valley north of Jamestown. Further west in western Emmons and parts of Burleigh County, the bedrock consists of sandstone, shale, and lignite that ranges in age from late Cretaceous to Tertiary, about 50 million years old. The shale accumulated as streams deposited mud in shallow seas and on their floodplains. When the mud hardened, it became shale. Sandstone resulted when sand deposits, such as beach, dune, or river sediments, became cemented into solid rock.

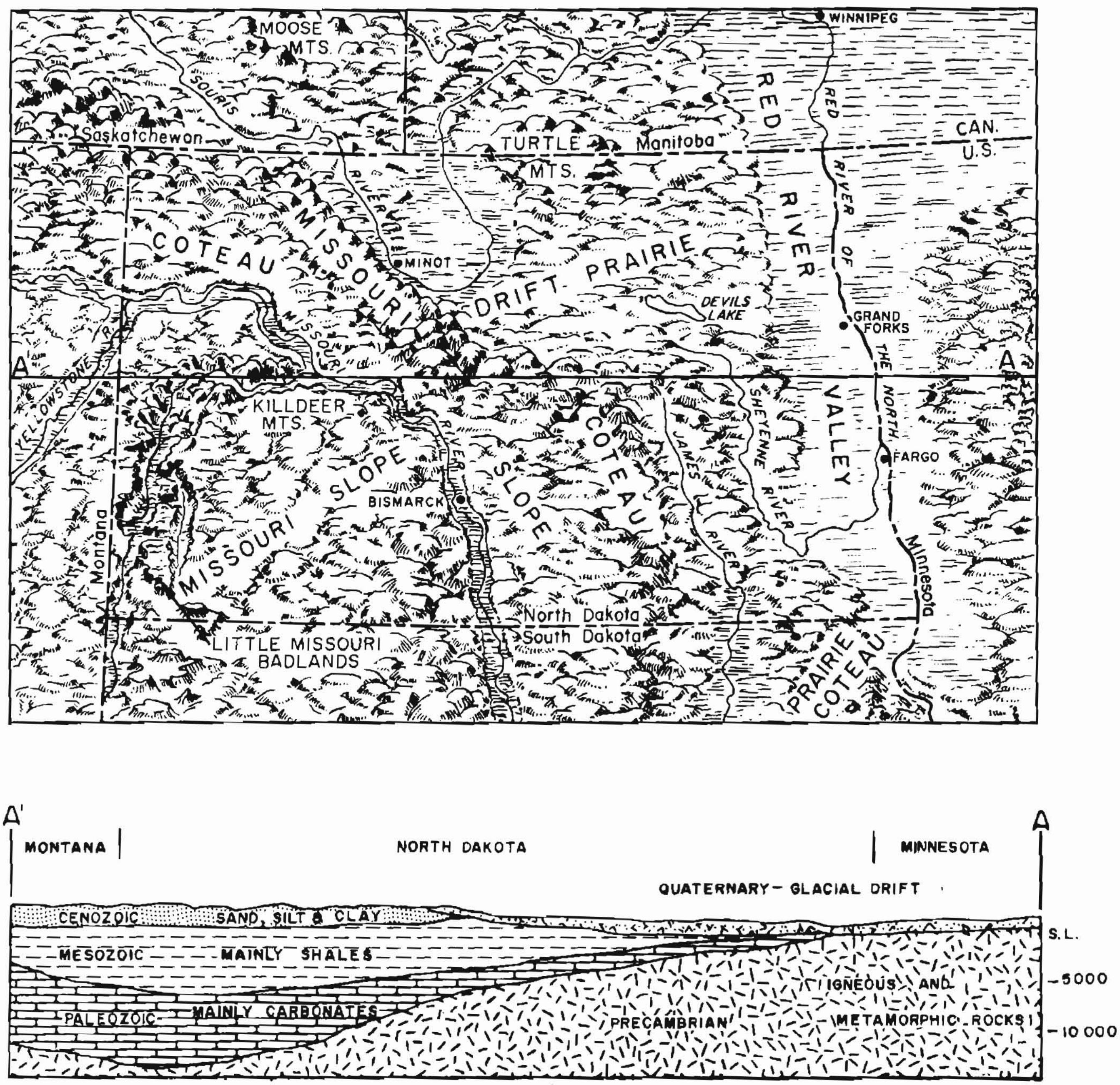

Figure 1. Physiographic map of North Dakota. The cross-section A-A' shows how the sedimentary rocks are thicker in the Williston Basin in the western part of the state.

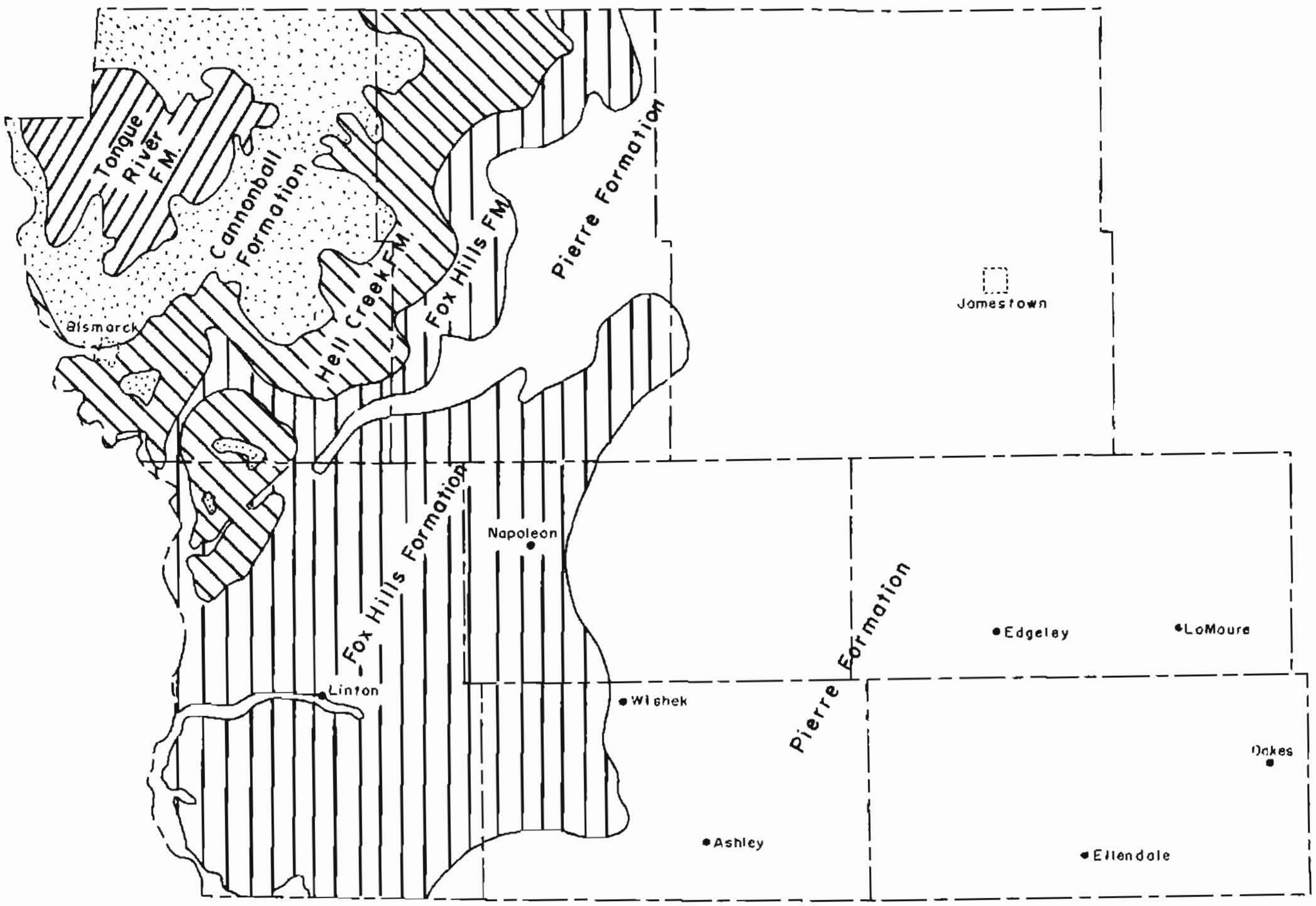

Figure 2. This map of south-central North Dakota shows the formations that would be exposed if all the glacial drift was removed. Successively younger sedimentary rocks occur from southeast to northwest; the Pierre Formation shale is the oldest and the Tongue River Formation sandstone is the youngest.

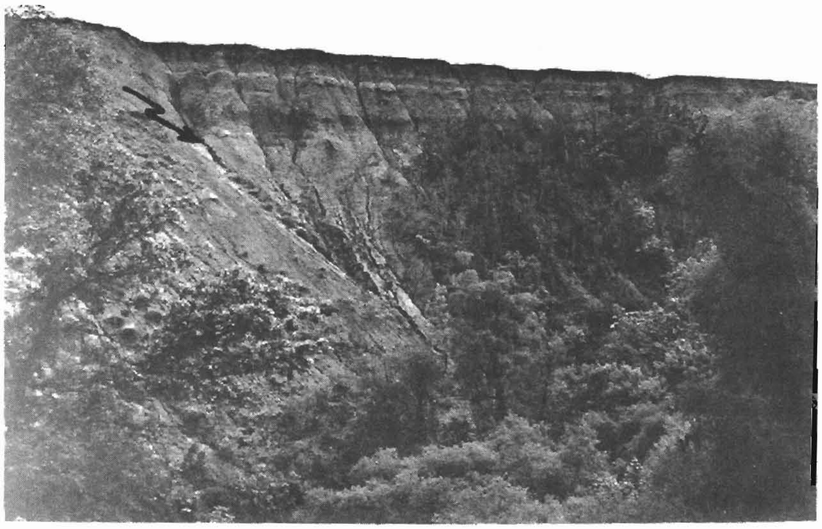

Figure 3. Photo of Pierre-Fox Hills formational contact exposed on a north-facing bank of Beaver Creek in Seeman Park southeast of Linton, Emmons County. Photo by Rodney Feldmann.

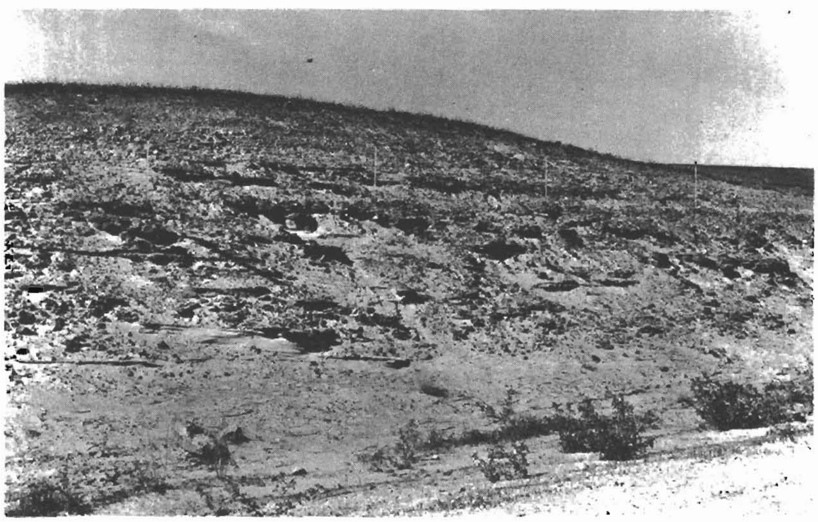

Figure 4. Fox Hills Formation with discontinuous ledges and lentils of reddish-brown sandstone cemented by a combination of limonite and calcium carbonate. Photo by Rodney Feldmann.

Figure 5. Cannonball and Tongue River Formations exposed north of Bismarck. Photo by Jack Kume.

Figure 6. Cross-bedded sand and sandstone at the base of the Tongue River Formation in northern Burleigh County. Photo by Jack Kume.

Figure 7. Hell Creek and Cannonball Formations exposed along Apple Creek southwest of the Annunciation Priory in Burleigh County. The darker material at the top of the bluff is the Cannonball Formation. Photo by Jack Kume.

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

During the past million years, several glaciers overrode south-central North Dakota. The last of these glaciers melted about ten thousand years ago. There were times between glaciations when the area was as free of glacial ice as it is today, but the entire period (a million to ten thousand years ago) is known as the ice age or "Pleistocene Epoch." Figure 8 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. Boulder piles and "stony" fields report "the glacier was here!" Before the ice age, all of North Dakota had buttes and large-scale, wind- and water-sculptured scenery similar to the area west of Mandan today. When the glaciers overrode south-central North Dakota, they planed off the more rugged features and filled in the valleys with loose, ground-up deposits that were carried southward in the ice. The landscape in the glaciated part of North Dakota is *constructed* (deposited by the ice) but the landscape of the unglaciated part of the state is *eroded* and was worn down by running water and wind action. Included in the glacial deposits are boulders of all sizes that were broken from the Canadian Shield area northeast of Winnipeg. 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 soil.

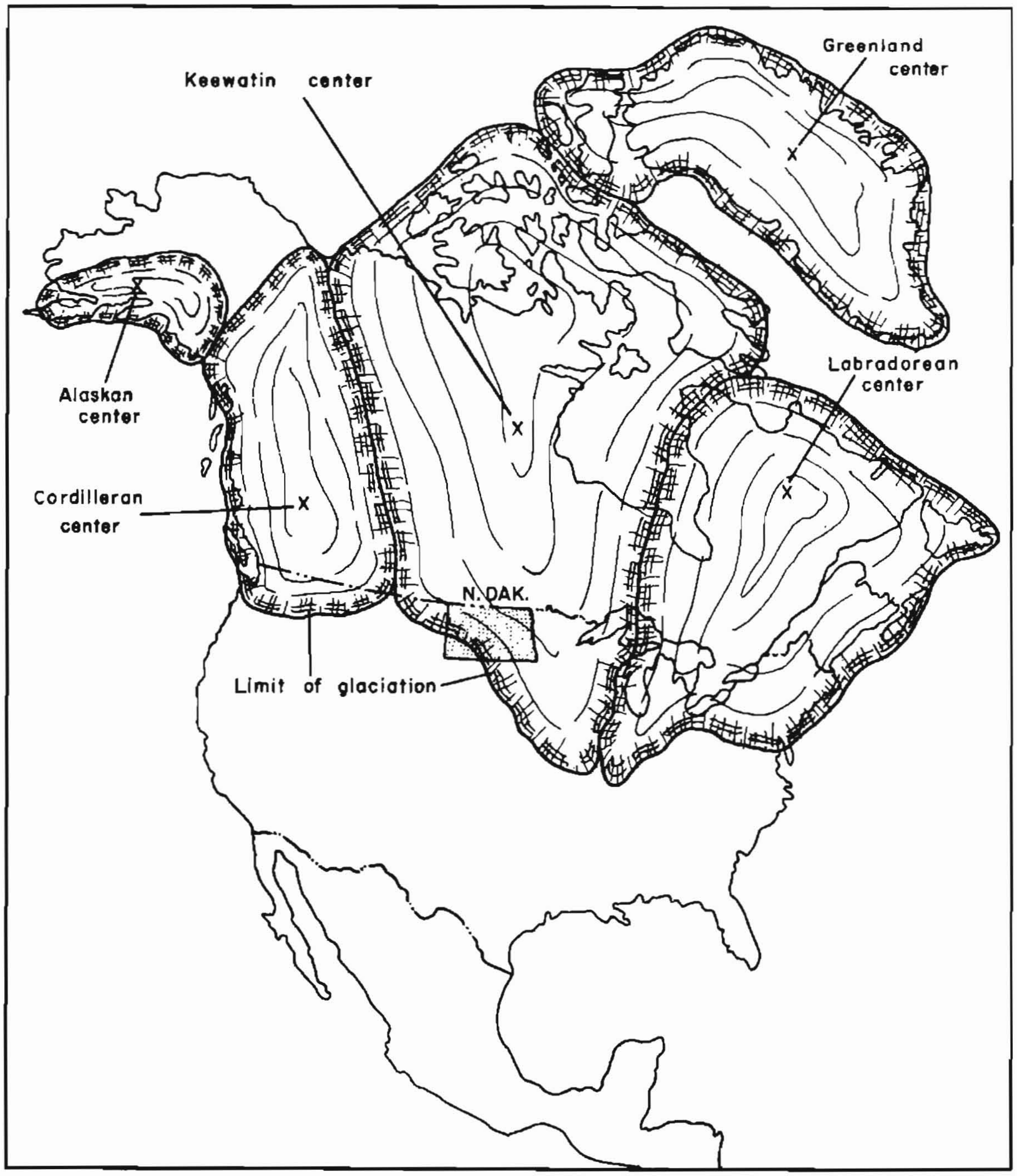

Figure 8. The above map of North America shows the limits of continental glaciation during the ice age. The main centers of snow accumulation from which the ice moved are shown. North Dakota was glaciated by ice that moved from the Keewatin center west of Hudson Bay.

The Ice Age in South-Central North Dakota

Before the ice age, bedrock formed the landscape in south-central North Dakota (Figure 2). The land was gently rolling with a few buttes in Burleigh County in the area covered by the Tongue River Formation. The larger streams flowed northeastward toward Hudson Bay as the Missouri River drainage system did not yet exist.

During the ice age, glaciers formed west of Hudson Bay due to the accumulation and compaction of yearly snows that didn't completely melt in the summers. This same process occurs today in glaciated mountainous areas and on the Greenland and Antarctic ice caps. As snow piles up and turns to ice, 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 glacier. Materials from beneath the glacier were carried upward through the ice so that it was heavily loaded with debris. This debris was deposited from inside the glacier when the ice melted.

When the ice first advanced over south-central North Dakota several hundred thousand years ago, the northeastward-flowing streams became blocked and lakes formed in the valleys in front of the ice. Silt and clay accumulated in these lakes. As the ice continued to move southward, it overrode the lakes and deposited glacial sediment on top of the lake sediment. At the same time, it diverted the northeast-trending drainage to a southerly direction around the glacier margin. The Missouri River Valley, which forms the western boundary of the area discussed in this publication, is the largest such diversion trench in North Dakota.

Although the entire south-central part of North Dakota has been glaciated, the amount of glacial sediment in the east is much greater than it is in the west, near the Missouri River. Only the earlier glaciers advanced across the western part of the area, and much of the sediment they deposited has since been eroded away. The eastern half of the area was glaciated more often and by the most recent glaciers, so the glacial drift cover there is thicker and fresher with a landscape much as it was when the glaciers melted about 12,000 years ago. Land elevations in south-central North Dakota were important in determining which areas were glaciated by the more recent glaciers and which areas were not. Higher elevations in the west (elevations were about 500 feet higher in western Burleigh and Emmons Counties than they were in eastern Stutsman, Dickey, and LaMoure Counties) made it impossible for the later, thinner glaciers to advance much beyond the area shown as unit 7 on Plate 1 (in the pocket at the back of this booklet). Another reason for the thicker glacial drift in the east is the presence of the Missouri Escarpment, which coincides with the eastern edge of unit 7 on Plate 1. The Missouri Escarpment is a steep topographic rise that the glaciers had to override as they flowed southwestward. When the glaciers overrode the escarpment, internal shearing was initiated in the ice with the result that large amounts of material were picked up by the glacier. This material was carried over the escarpment, onto the Missouri Coteau, which approximately coincides with unit 7 on Plate 1. As pointed out above, the glaciers did not advance much farther after they encountered higher elevations, so most of this material was dropped on the Missouri Coteau when the ice melted.

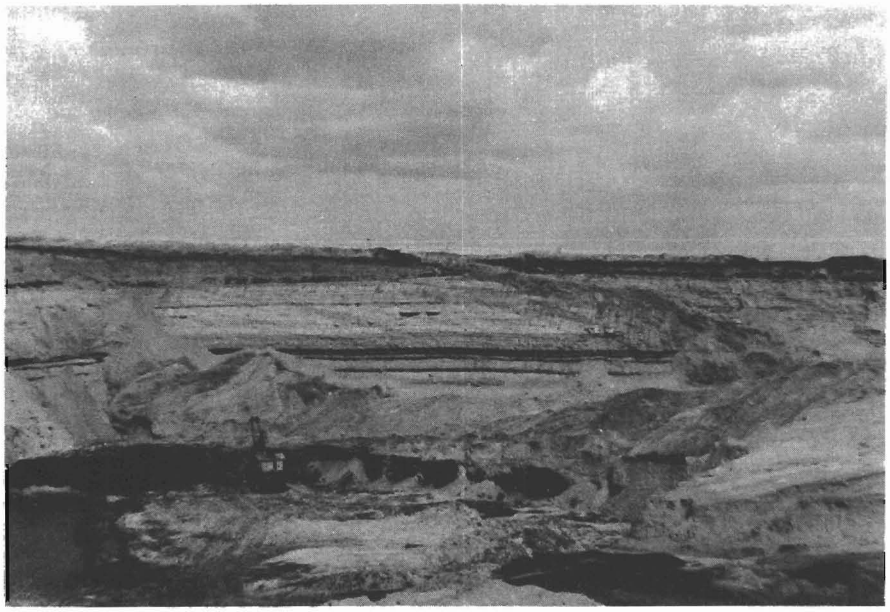

Figure 9. Lignite strip mine near Wilton, North Dakota in Burleigh County. The lignite is being taken from the Tongue River Formation. State law now requires the operators of strip mines to reclaim the spoil piles to a rolling topography. Photo by Jack Kume.

Figure 10. Circular depressions caused by tunnel collapse of an abandoned coal mine in the Wilton, North Dakota area. Photo by Jack Kume.

Most of the glaciers finally melted out of south-central North Dakota by about 12,000 years ago. However, ice persisted longer on the Missouri Coteau (unit 7 on Plate 1) where a blanket of glacial drift that covered the ice insulated it and caused it to melt more slowly. A nearly continuous sheet of such drift-covered ice covered much of the Missouri Coteau. Some of the ice persisted for at least 3,000 years, until about 9,000 years ago.

Conditions on the Missouri Coteau shortly after the glaciers there became covered by drift were highly dynamic with the materials on top of the ice sliding to lower areas as the ice rapidly melted. However, as the ice continued to melt, the drift gradually became thicker (because materials contained within the ice became concentrated at the surface) and the ice melted more slowly. Conditions gradually stabilized and the water in lakes that formed on the surface of the drift-covered ice became more temperate; most of the water on the surface was from local precipitation rather than from melting ice. Fish were able to migrate up the streams from the Missouri River tributaries. Surrounding the lakes and streams, the drift-covered ice was itself covered by spruce, tamarack, birch, poplar, aquatic mosses, and associated vegetation. The mean annual precipitation 10,000 years ago was probably several inches higher than it is today, and the mean annual temperature was a few degrees cooler.

Eventually, all the ice melted, and all the material that had been on top of the ice was let down, resulting in the hilly topography that is typical of the Missouri Coteau today.

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

Landforms of South-Central North Dakota

Bedrock Topography

The western part of south-central North Dakota, including parts of Burleigh, Emmons, Logan, and McIntosh Counties, has relief that is developed on the bedrock surface (units 8, 9, 10, 11, and 12 on Plate 1). Buttes and large hills with intervening wide, gentle valleys characterize the area, which is covered by a discontinuous veneer of glacial deposits. This is mainly an eroded landscape that is much like the preglacial landscape in the area. The most rugged relief occurs in areas where the Tongue River Formation is present. (Figures 9 and 10). Most of the larger buttes have a caprock of Tongue River Formation sandstone overlying Cannonball Formation shale (Figure 11).

Moraine

The eight counties of south-central North Dakota are covered by about 300 cubic miles of glacial deposits; that is, materials that were moved and redeposited by the glaciers. Probably 80 to 90 percent of this material was deposited by glacial ice, and the remainder was deposited as sand and gravel in streams flowing from the glacier, mainly in Kidder County, and as silt and clay in glacial lakes Dakota and McKenzie in Dickey and Burleigh Counties, respectively.

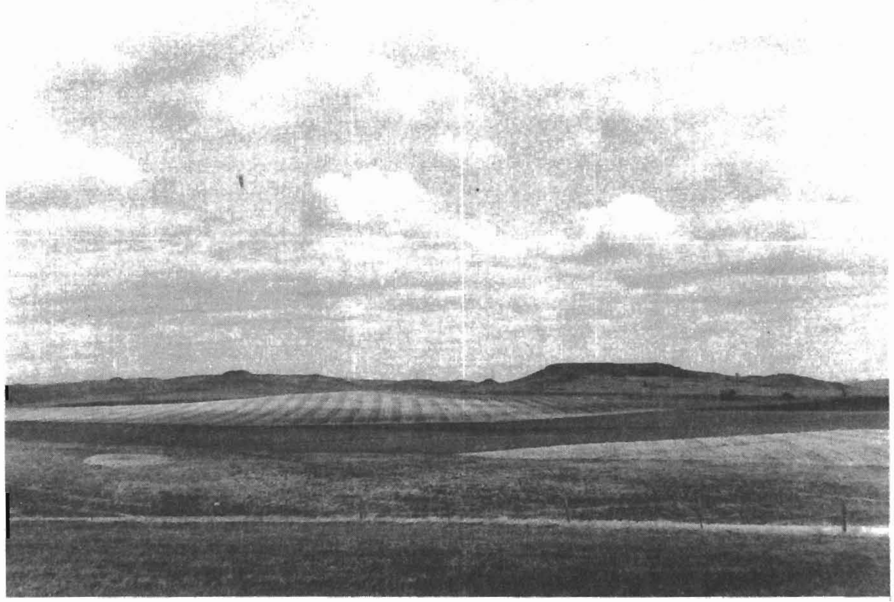

Figure 11. Buttes in Burleigh County. Tongue River Formation sandstone that forms the caprock on these buttes helps to keep them from eroding away. Photo by Jack Kume.

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 a smooth lake plain, such as the Agassiz lake plain of the Red River Valley, the moraines are hilly areas. The *ground moraine* is shown on Plate 1 in light green and designated by the numbers 5a and 5b. Thicker deposits of ground moraine (5a) have constructional relief that commonly ranges from about ten to twenty feet. The thinner accumulations of glacial sediment (5b) do not alter the underlying bedrock topography appreciably. Such areas commonly have relief of over a hundred feet locally. Ground moraine consists of till that was deposited at the base of the moving glacier along with till that was let down on the surface when the glacier melted.

Dead-ice moraine is shown in brown on Plate 1 and designated by the number 7. Dead-ice moraine 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 North Dakota lies on the Missouri Coteau, which extends from the South Dakota boundary northwestward to the Montana and Canadian boundaries (Figure 1). Relief in areas of dead-ice moraine on the Missouri Coteau of south-central North Dakota reaches as much as 200 feet locally. The dead-ice moraine is poorly drained and streams are absent from the area, but sloughs are abundant. Because of the large number of ponds and sloughs, the Missouri Coteau of North Dakota provides one of the most important waterfowl- breeding habitats in North America.

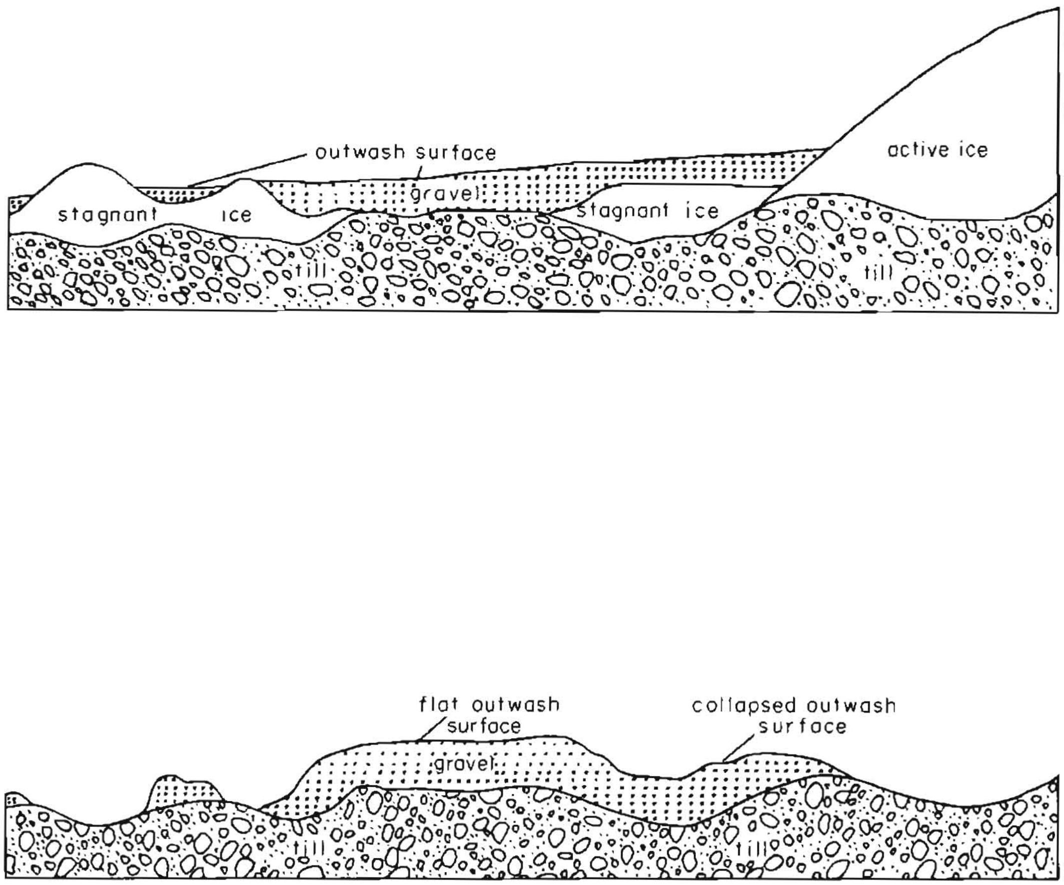

Figure 12. Steps in the formation of a collapsed or pitted outwash plain such as the one in central Kidder County. On the upper diagram, sand and gravel are deposited on the surface in front of the glacier. In places, this sand and gravel is deposited on stagnant ice, in other places on top of till, 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.

A third kind of moraine is *end moraine*, which consists of relatively narrow ridges of till that were deposited at the edge of the glacier during a time when the ice margin was melting back at about the same rate as the ice was moving forward so that the margin remained stationary. All the end moraines of south-central North Dakota are designated by the number 6 and shown in dark green on Plate 1. Relief over the end moraines ranges from moderately rolling to hilly, up to about 150 feet locally. Some of the end moraines on the Missouri Coteau in Kidder, Logan, and McIntosh Counties are particularly steep. Both end moraine and dead-ice moraine commonly have large numbers of surface boulders. Although it is difficult for the casual observer to distinguish end moraine and dead-ice moraine, the differences are apparent on air photographs. From the air, the strongly linear trends of the end moraines (aligned ridges, lakes, and sloughs) are apparent, particularly in contrast to the random arrangement of such features on dead-ice moraine.

Outwash Plains

Areas of sand and gravel that were washed out of the ice by water flowing from the melting glacier are known as outwash plains. Several outwash plains are shown on Plate 1 in yellow and designated by the number 3. Wherever the outwash was deposited on the ground, it formed a relatively flat surface. In some places, however, the sand and gravel was deposited on top of stagnant glacial ice, particularly on the Missouri Coteau. In such areas, the original flat surface collapsed when the stagnant ice melted and the surface is rolling (Figure 12). The large area of outwash in central Kidder County is an example of such a collapsed area.

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

Lake Plains

Areas that were covered by lakes during and near the end of the ice age are now characterized by flat topography such as that in south-central Burleigh County and southeastern Dickey County. These areas are shown in blue on Plate 1 and designated by the number 2. The lake deposits are mainly horizontally-bedded silt and clay that were deposited in still water. In places, the horizontal bedding was disturbed by such things as mudflows in the loose, wet lake sediment, by squeezing of the lake sediments between cakes of lake-surface ice that sank as the lakes drained, by pushing of lake sediments that were deposited on top of stagnant ice that later melted, or by overriding by a glacier.

Numerous smaller lakes were present on the Missouri Coteau while stagnant ice was still present. Many of these lakes were located on top of the ice and many more were surrounded by ice. These lakes were insulated from the ice by a layer of till so that, commonly, they were actually temperate lakes with abundant animal and plant life. Figure 13 shows the conditions that resulted in the "elevated" lake plain at Lehr in southern Logan County. Such elevated or perched lake plains are common on the Missouri Coteau.

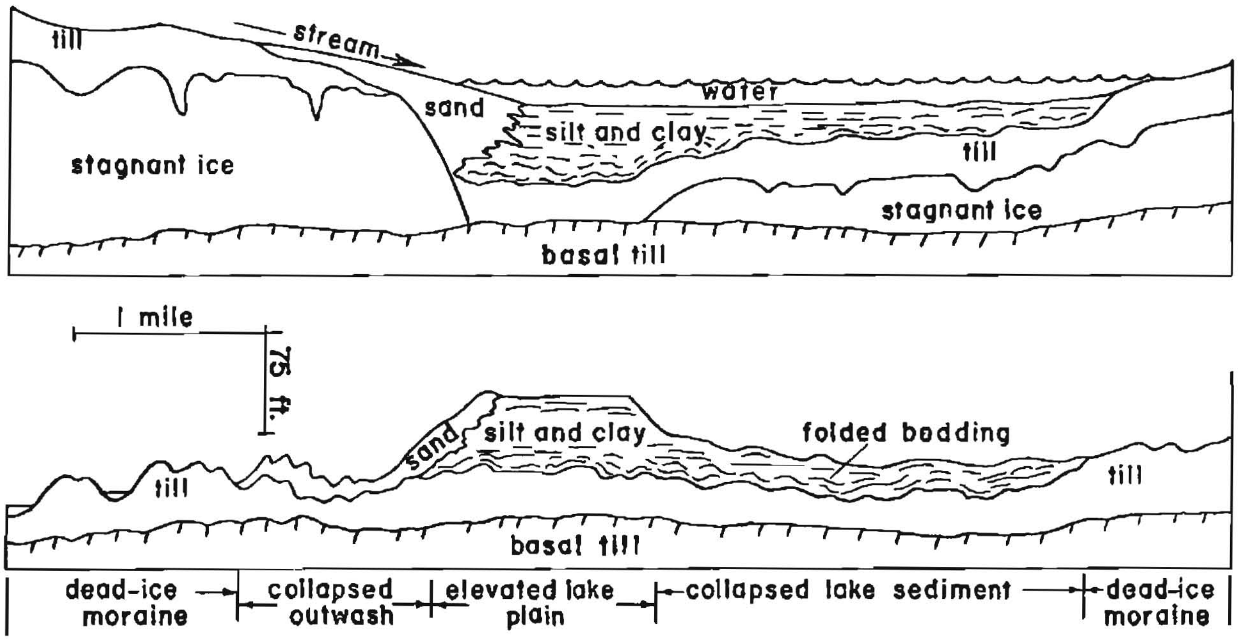

Figure 13. Schematic diagram showing the conditions that led to the development of the elevated lake plain at Lehr, North Dakota. As shown on the upper diagram, silt and clay were deposited in the lake, which was situated over an area that was partially covered by stagnant glacial ice. The lake was insulated from the ice by a layer of till so that it contained abundant life such as snails and clams. Numerous fossil shells have been found in the silt and clay deposits at Lehr.

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

Illustration from Clayton and Freers.

Meltwater Trenches

The James River and Pipestem Creek are small streams that flow in rather large valleys that were cut by large volumes of meltwater flowing from the melting glaciers. The glacial river that flowed in the James River Valley entered Lake Dakota near Oakes; and for this reason the meltwater trench ends there, although the modern James River flows southward across the lake plain. During the ice age, the meltwater trenches carried rivers much larger than the streams that now flow in them. The largest meltwater trench in North Dakota is the Missouri River Valley, which marks the western boundaries of Burleigh and Emmons Counties. The Missouri River Valley has a complex history because, although it did carry meltwater during the ice age, it is not entirely the product of erosion by that meltwater. Certain segments of the valley carried streams long before glaciers advanced over the state and other segments of the valley were cut as the ice age ended. Generally, the narrower parts of the Missouri River Valley trend southward. These parts of the valley are younger than are the wider parts, most of which trend eastward or northeastward.

Fossils

Fossils are simply the preserved remains of animals or plants that once lived. They are commonly encased in rock, but in some instances, the parts of the organism itself have dissolved away and left only their impression in the enclosing rocks. Those left as fossil *casts* represent the imprint of the interior of a fossil animal, while *molds* are external impressions of shells or other skeletons which have long since been dissolved away.

In a broad sense, fossils are rocks themselves, most commonly sedimentary rocks. Some limestones, for example, are composed entirely of millions of tiny fossil shells. Many different types of fossils have been found in south-central North Dakota. Oysters and associated organisms occur in great profusion in Fox Hills Formation sandstone in parts of Emmons County (Figure 14). Fossil crabs have been found in the Cannonball Formation of Burleigh County along with shark's teeth. The Tongue River Formation sandstone contains abundant fossils including snails, clams, and ostracods (Figure 15). Petrified wood is common in the Tongue River Formation.

Fossils have also been found in the glacial deposits. Clam and snail shells are commonly found in lake deposits in areas of dead-ice moraine. Fossil clam and snail shells have been found in several dozen locations in lake deposits associated with areas of dead-ice moraine. Fish also occurred in these ice-supported lakes because the parasitic glochidial stage of the clams and snails require established fish populations.

One of the more important fossil locations in south-central North Dakota is a slough in northwest Stutsman County. At this location, known as the Seibold Site, about 160 species of plants and animals of late Pleistocene age were found. Beaver and muskrat, frogs, and several species of fish, insects, ostracods, and mollusks were found at the Seibold Site.

Figure 14. Abundant oysters and associated organisms in the Fox Hills Formation in Emmons County. Photo by Rodney Feldmann.

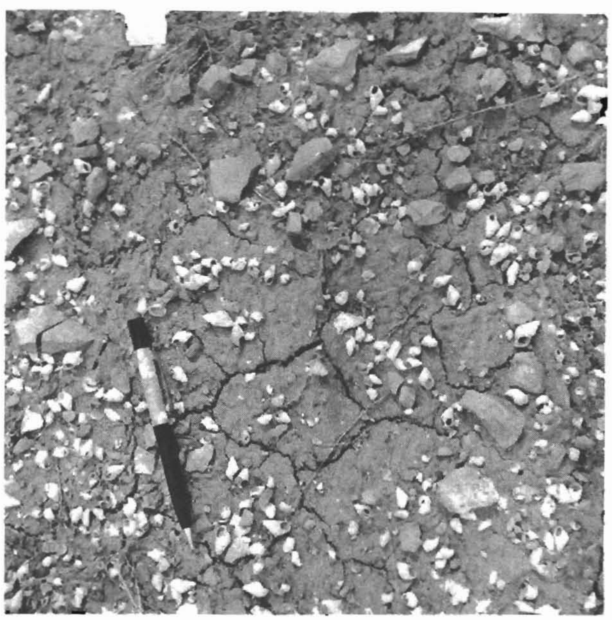

Figure 15. Fossil snail shells in the Tongue River Formation near Wilton, Burleigh County. Photo by Jack Kume.

Natural Resources

Soils formed from glacially deposited sediments tend to be fertile. This is true in south-central North Dakota where the soil is probably the most important resource. Soils throughout the area are developed on glacial deposits. The best farmland is in Dickey and LaMoure Counties and eastern Stutsman County where the land is mostly gently rolling. Throughout much of the rest of the area, the land is strongly rolling.

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

Much of the surface water in the area is in numerous undrained depressions, intermittent streams, and a few permanent lakes, the largest of which is Lake Oahe along the western edge of Emmons and part of Burleigh Counties. The Missouri River supplies the municipal water supply for Bismarck and is also used for irrigation. Ground water is abundant in south-central North Dakota. Aquifers are found in sandstone of the Fox Hills, Hell Creek, Cannonball, and Tongue River Formations and in the glacial gravel deposits. Aquifers are common in meltwater deposits, both in trenches such as the James River and Pipestem Creek, and in outwash deposits such as the large one in Kidder County. Other types of water-bearing sand and gravel deposits are also found in the glacial drift. Many of these are buried within the drift and have little or no surface expression. Their location and extent are determined from subsurface data obtained from test drilling, by study of the records of existing wells, and by study of quality-of-water data. The buried drift aquifers range from narrow, linear bodies to extensive sheetlike bodies, similar to the surficial outwash deposits. Among the major buried drift aquifers are those in preglacial stream valleys. Such a buried valley is located in the Spiritwood area of eastern Stutsman County.

Other possible natural resources include Fuller's earth, clay, riprap and building stone, petroleum, and volcanic ash. Several exploratory oil wells have been drilled in the area but no oil has yet been found. Lignite has been mined near Wilton in Burleigh County but currently none is being produced. Volcanic ash, also known as pumicite, occurs in a bed about 26 feet thick near Linton in Emmons County. It was deposited in water in Cretaceous time by winds blowing from the west. The source was probably about 500 miles to the west in the Livingston, Montana, area. Volcanic ash is used in road construction, concrete admixtures and aggregates, railroad ballast, and as an abrasive.

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* *Publication is available from the North Dakota Geological Survey, Grand Forks, North Dakota 58201.*

GEOLOGIC ROADLOG FOR SOUTHWESTERN BURLEIGH COUNTY

(total distance about 38 miles)

Distance Between Points

Begin trip at the corner of Main and Airport Road in Bismarck. Travel south on Airport Road, which is built on a terrace of the Missouri River. This terrace, the highest in the Missouri River trench of southwest Burleigh County, is covered by as much as 170 feet of gravel. From Broadway northward, the city of Bismarck is built mainly on sandstone, siltstone, and shale of the Cannonball Formation, bedrock of Tertiary age. South of Broadway, the city is built on the above-mentioned terrace.

1.2

Another, slightly lower terrace. This terrace, at an elevation of 1,660 feet, is the second highest and second thickest (150 feet) gravel terrace deposit.

0.3

Turn right (west). Municipal airport is to the east. Notice the gravel pits in the terrace gravels for the next half mile.

0.5

Turn left (south). Low terrace is to the west, upper terrace to the east. Notice the steep terrace escarpment (edge).

0.4

Stop. Observe the composition and appearance of the terrace gravel deposits. The Missouri River trench is 7 miles wide at this point.

0.6

Terrace escarpment. Travel on the lower terrace.

0.2

Turn left (west).

0.4

Terrace escarpment. Travel by Fort Lincoln Nursery and Military Reservation.

0.7

Turn right (south). This is a ground-water irrigation area. Two wells can be seen, one on each side of the road. The water is taken from the terrace gravels.

1.6

River floodplain. Apple Creek has cut through the terrace and has eroded the steep walls of sedimentary bedrock. These walls contain excellent exposures of sedimentary rocks.

0.4

Sedimentary rock bluff. Stop and observe the Hell Creek, Ludlow, and Cannonball Formations. The base to the middle of the hill is Hell Creek Formation, the upper part of the hill is Cannonball Formation with a thin layer of Ludlow Formation in between them. Notice the slope erosion and the formation bedding, composition, and color. Leave the stop and continue south up the bluff slope.

1.0

Turn left (east). Annunciation Priory is on the hill crest to the right. Follow the main road, which curves south in a mile.

1.7

Turn left (east). Follow the main road, curves south in a mile.

2.0

Turn left (east). Notice the two isolated small pinnacles of Hell Creek Formation. Notice the gray color, which suggests the local name "Somber beds."

0.5

Upland valley. This was probably a preglacial valley that later served as a meltwater trench. It is now covered by windblown sand.

1.5

Dune sand. Notice the low rounded mounds of sand. Notice also the few exposures of Hell Creek Formation bedrock.

2.4

Turn left (north).

0.2

Stop to look at the sand dune and blowout. Notice the shape of the dune, the sand size and color, deflation basin, and vegetation. Leave the dune, continuing north.

1.8

Turn left (west). The sedimentary rock hill is made of the Cannonball Formation bedrock.

1.0

Turn right (north). Sand dunes and blowouts.

1.0

Cannonball Formation bedrock. Notice numerous roadcut exposures for the next mile.

1.0

Glacial till lying on older sedimentary rocks.

1.2

Dune sand.

0.9

Hell Creek Formation. Notice the narrow, abandoned valley ahead.

0.3

Spillway. This is one of three major water outlets for glacial Lake McKenzie. The other two are Glencoe Trench and Badger Creek Trench.

0.4

Trench drainage divide. This area is composed of glacial till and outwash gravel.

0.2

Turn left (west). Travel on former U. S. Highway 10.

0.3

Apple Creek floodplain.

0.7

Turn right (north).

1.0

Turn right (east). Travel on U. S. Highways 10 and 83.

1.2

Stop to observe the deep road cut into Cannonball Formation shale and glacial outwash gravel. This is the Apple Creek meltwater trench. Most of the shells here are Pleistocene (ice age), but a few are much older reworked Paleocene shells. The shells are most abundant in the sand on the north side of the road. Apple Creek trench was a major meltwater route. A thick valley fill (150 feet) of glacial outwash gravel and alluvium occurs in this partly filled trench. Leave the fossil site and continue east. For the next 2.8 miles the route is along and within Apple Creek valley.

2.8

McKenzie proglacial lake plain. Travel on this lake plain as far as McKenzie.

2.1

Pothole or kettle in the lake plain. This hole formed when an isolated, buried chunk of ice melted, allowing the overlying materials to collapse.

0.6

Menoken.

4.0

McKenzie Slough.

1.5

Town of McKenzie. The town is built on the lake plain.

GEOLOGIC ROADLOG FOR WESTERN BURLEIGH COUNTY

(total distance about 26 miles)

Distance Between Points

Begin trip at Bismarck Junior College which is built on the stream-dissected rocks of the Cannonball Formation (sandstone, siltstone, and shale). Notice the surface boulders. Leave the college and travel north (0.5 mile) and northwest (0.9 mile) toward Pioneer Park.

1.4

Pioneer Park. Stop to observe the Cannonball Formation. Roadcuts provide excellent exposures along this winding road as it descends toward the river. Notice the color, bedding, and composition of the rocks. Fossil seaweed (Halymenites), a branching, tubelike, rusty form can be seen in places. Leave the park and travel north on River Road. Terraces, flat, step-like areas, can be seen on the west side of the valley. The Mandan Refinery is across the river.

4.6

Burnt Creek bridge. This valley was a glacial meltwater trench.

1.3

Turn north (right) off the River Road. This gravel road makes three bends before the next junction (0.3 mile north, 1 mile east, 0.5 mile north, 1 mile east). Notice the Cannonball Formation exposures along the road.

2.8

Turn north (left). This road makes two bends before the next stop (1 mile north, 0.5 mile west, 0.5 mile north).

2.0

Stop to look at the contact between the Cannonball Formation and the overlying Tongue River Formation. Notice the thin-bedded shales and siltstones overlain by a cross-bedded friable sandstone that is easily eroded by the wind. This is the basal sandstone of the Tongue River Formation. The

two formations display the change from a marine sea to a continental shallow waterway that was swampy at times (hence the lignite).
Leave the exposure and travel north. Notice the excellent exposures of Tongue River Formation along the road, especially 0.3 mile north.

0.5

Riverview School No. 1.

1.0

Turn west (left). Ball Butte is north of the road junction.

0.3

Coal Butte. Notice the coal seam exposed on the west slope of the butte. Fossil mollusks occur in the roadcut at the crest of the butte. Clams can be found in the north roadcut.

1.0

Basal sandstone of the Tongue River Formation. Notice the blowouts along the curve in the road. Excellent cross-bedding in the sands can be seen in the blowouts. Several bends occur in the road; travel west to River Road.

1.5

River Road. Turn north (right). Gently sloping alluvial-covered sedimentary rock terraces occur on the west side of the road.

1.5

Road curves to the east. Notice the width of the Missouri River trench. Here it is 2.1 miles wide, whereas upstream 4 miles it narrows to 1 mile wide. South of Bismarck it is 7 miles wide.

0.2

Road junction. Leave the River Road, which continues north, and travel east toward the buttes ahead.

0.8

Stop to look at the Tongue River Formation. Exposed here is the resistant butte-capping unit containing a cross-bedded sandstone and conglomerate, the basal sandstone unit, and the formation contact. Climb butte on north side of the road to observe the resistant unit. Leave the butte and travel east up the steep, dissected, trench wall.

1.7

Edge of the Missouri River trench. Notice the difference in dissection (erosion) of the trench. Till-covered upland.

1.6

U. S. Highway 83. Turn north (left) and travel on the highway.

1.0

Road junction. Tongue River Formation. Fossils can be collected in roadcuts 0.2 miles north or 0.5 miles east. Reworked or detrital fossils can be collected in gravel piles 1.6 miles east.

1.0

Turn east (right) off the highway and travel to Baldwin. Notice the lignite beds in the roadcuts.

2.0

Baldwin. Baldwin is located within the Burnt Creek meltwater trench. The basal sandstone of the Tongue River Formation occurs here.

GEOLOGIC ROADLOG FOR DICKEY COUNTY

(total distance about 65 miles)

Distance Between Points

Begin trip at the west edge of Ellendale at the railroad crossing. Drive west on State Highway 11. You are driving over a ground moraine surface covered mainly by glacial till that is about 100 feet thick.

4.2

Notice the hills on the western horizon. These are part of the Missouri Escarpment, which marks the eastern boundary of the Missouri Coteau.

0.9

The hills on either side of the road are remnants of an esker. Eskers formed when rivers flowing through the ice deposited gravel. When the ice melted, the gravel was left as the hills you see today.

0.2

Road crosses the esker. Notice the gravel exposed in the roadcuts.

1.3

Pheasant Lake. This lake occurs in the Elm River valley, a meltwater trench that carried water from melting ice on the Missouri Coteau as well as from the melting glacier to the northeast.

0.6

After you cross the Elm River valley, notice the slightly hillier topography. The glacial drift is thin here, generally less than 5 feet thick, and you are driving over preglacial shale topography. Cretaceous age Pierre Formation shale is exposed in many places along the roads where the ditches have cut through the drift cover.

1.2

Highway turns northward. Continue westward on gravel road.

0.2

Stop where the road curves to the south and look at the shale that is exposed at the corner. The shale is highly weathered here but if you dig back a ways into the cut, you can find intact pieces of shale.

0.2

Shale is exposed on the west side of the road.

0.3

Road curves to the west.

0.5

Shale is exposed along the south side of the road.

1.8

The glacial drift cover becomes slightly thicker in this area. Notice that the topography is slightly smoother.

0.7

Stop sign. Cross the highway and continue westward on the gravel road over ground moraine.

3.0

Turn south. The Missouri Escarpment is one mile to the west.

1.0

Turn west.

1.0

Turn north. This area is mainly coarse gravel that was deposited by streams flowing off the Missouri Escarpment at the end of the ice age.

0.7

Turn west and begin climbing the Missouri Escarpment. Notice the marked change in topography as you drive westward and the first appearance of large numbers of boulders. Till is the most common material in this area of dead-ice moraine, but gravel or sand may occur in places. Dead-ice moraine formed when large areas of the glacier became covered by glacial drift (gravel, till, lake sediments) and stagnated in place. As these areas of stagnant ice melted, the overlying glacial drift slumped and slid, resulting in a rough landscape of relatively high relief such as you see here. Notice the numerous potholes and small lakes.

0.5

Stop to examine the glacial till in one of the cuts along the road. Till is glacial sediment that consists of a ground-up mixture of unsorted clay, silt, sand, and cobbles that was transported by the glacier and dropped when the ice melted.

0.2

Stop to look at the lake sediments in the ditch cuts on the north side of the road at the curve. These silts were deposited in a lake which was bounded on the west by dead-ice moraine and on the east by the glacier. When the glacier melted back, the lake drained.

2.6

Turn north, continuing to drive over dead-ice moraine.

2.1

Junction with State Highway 11. Stop to look at the large boulder at the corner. This boulder is a glacial erratic that was carried here from Ontario by the ice. It is a metamorphic boulder, perhaps best called "gneiss" (pronounced "nice"). Although the rock originally crystallized from a molten magma, it later underwent considerable alteration. Try to determine which parts of the rock cooled first and which parts were later injected into it as a fluid.
Turn and drive west on Highway 11.

0.7

Junction with State Highway 56. Continue west around the lake.

1.2

Gravel pit. Stop here to look at the gravel in this area of collapsed outwash. Water from the melting ice and from local precipitation flowed over stagnant glacial ice, depositing gravel in this area. When the stagnant ice melted, the gravel slumped down to form the irregular topography you see here today. Return to the junction with State Highway 56.

1.2

Turn north on Highway 56. This area is still collapsed outwash.

2.4

This flat area is an elevated lake plain. A lake surrounded by stagnant ice formed here. When the ice melted, the silts and clays that were deposited in the lake were left as an isolated flat area that stands above the surrounding countryside. Notice the lack of boulders on the lake plain.

4.5

Drive off the dead-ice moraine onto collapsed outwash gravel.

1.2

Turn east on gravel road toward Whitestone Hill. Travel over gravel of collapsed outwash.

0.6 Small pond. Exposures of glacial till are common along the road in this area.

1.6 Gravel pits ¼ mile south of the road are in collapsed outwash.

0.4 Gravel pit at the top of the hill. Large slough to the north. Depressions such as this slough mark places where large blocks of stagnant ice occurred. When the ice melted, the slough-filled depressions remained.

1.1 Leave the collapsed outwash and drive onto dead-ice moraine. Notice that till and boulders have replaced the gravel we have been driving over.

2.5 Road to Whitestone Hill Battlefield. Continue east over dead-ice moraine.

1.9 This is the approximate eastern edge of the Missouri Coteau. The slope from the Coteau to the lowland to the east is known as the Missouri Escarpment. At this point, notice the silt exposures on either side of the road. Stop here to observe the light buff-colored lake silts and clays. These sediments were deposited while a glacier stood to the east and water was dammed between the ice and the higher land to the west. The lake drained when the glacier retreated.

0.8 This sloping, fairly level area is composed of material that was washed down the Missouri Escarpment by streams. It is covered by coarse gravel.

0.8 This gently rolling area is ground moraine again. Till covers the surface in most places.

0.4 Junction with paved Dickey County Road 2. Turn south.

4.0 Turn east on gravel road, Dickey County 5. This area is ground moraine, covered by glacial drift about 100 feet thick.

3.0 The glacial drift becomes considerably thinner in this area and shale bedrock is exposed in places where the drift cover is absent. The shale can be recognized as the dark gray material in the ditches.

0.4 Small shale exposure. Notice the low hills in this area as contrasted to the area a couple of miles back, which was flatter. These hills are composed of bedrock.

0.1 Bridge.

2.5 Bridge over the Elm River. East of here the drift is thicker again.

0.1 Till exposure just east of road intersection.

4.8 Railroad crossing. Junction with U. S. Highway 281. Turn south, continuing to drive over ground moraine.

5.2 Junction with State Highway 11. Town of Ellendale. End of log.

GEOLOGIC ROADLOG FOR EMMONS COUNTY

(total distance about 40 miles)

Distance Between Points

Begin trip in Linton, at junction of U. S. Highway 83 and Beaver Creek road (just north of the bridge). Drive west on Beaver Creek road. Western Emmons County is mainly bedrock with a veneer of glacial deposits. Boulders are the most common glacial deposit although till can be seen in places.

0.3

Road curves to north.

0.2

Cemetery. Buttes east of cemetery are composed of Fox Hills Formation sandstone with scattered deposits of glacial boulders on top.

0.5

Road curves to the west.

0.2

Bridge over a small coulee. Notice how the tree growth is restricted to the valley. Alluvium in the valley, that is material that has been washed in from the nearby hill slopes, retains more water than do the bedrock slopes and as a result, trees can grow there.

0.8

Beaver Creek valley to the south. This valley carried large volumes of water away from the melting glacier, which stood a few miles to the east, in Logan and McIntosh Counties, about 13,000 years ago. The glacial deposits of this part of Emmons County are about 50,000 to 75,000 years old and related to an earlier glacial advance.

1.5

Flat-topped buttes to the north are composed of Fox Hills sandstone of Cretaceous age. The buttes are capped by a resistant bed of sandstone.

0.6

STOP 1. This area is a terrace (former valley floor) of Beaver Creek. Water that flowed over this terrace deposited gravel and sand. Stop to dig and look at the gravel along the north side of the road in the ditch. This gravel and sand was carried by the water from melting ice east of here.

1.9

Climb off the terrace level on which you have been driving to a higher level.

0.4

This slightly higher area is another, slightly older terrace than the one you can see below you to the south. The stream flowed on this level before it cut down and formed the lower level.

0.5

Bridge over Sand Creek. Notice the flat, gravel and sand-covered valley floor of Sand Creek.

0.1

Climb out of Sand Creek valley. As you climb, you are driving through sand dunes. Notice the roadcuts in the fine, uniform sand. The sand was blown here from the adjacent terraces, which are themselves covered largely by sand and gravel.

0.1

STOP 2. As you look at the sand, note that it contains no gravel; the wind has sorted it, removing the finer material from the gravel. Note the complete absence of boulders and cobbles on the surface of the ground.

0.2

Back on the upper terrace of Beaver Creek; gravel at the surface. To the south you can see sand dunes for about ¼ mile, then the lower terrace level.

0.9

Road curves to the north.

0.5

Road curves to the west again. You are still driving on the relatively flat, gravel-covered, upper terrace of Beaver Creek valley.

1.4

Climb off terrace onto bedrock upland topography. The hilly land ahead is typical of eroded bedrock topography. Although this topography has been glaciated, the glaciers didn't change the relief much; only a thin layer of glacial deposits, mainly scattered boulders, resulted in most places.

0.3

STOP 3. Outcrop of Fox Hills Formation sandstone. Notice the reddish-brown layers of cross-bedded sand. Iron-rich minerals in the sand give it the reddish color. If you break up some of the red sand ledges, you will note that some are harder than others. When the sand was first deposited, it was all soft, much like the gray sand here. With time, minerals in water that moved through the sand cemented it to hard rock in places. Particularly hard layers account for the existence of many of the buttes in the area. They are resistant to erosion and they remain, while surrounding areas are eroded away.

2.9

Road to Beaver Creek Public Use Area. Turn north on main road.

1.1

Notice the increasing numbers of boulders at the surface. These are glacial erratics, most of which were transported here from Canada by the ice. The Missouri River valley is a short distance to the west. When the glacier advanced to this area, it diverted drainage along its margin. The ice marginal stream carved the Missouri River valley in this area. Water flowing from the ice and along its margin extensively washed the surface, resulting in removal of the finer materials. Surface lags of abundant boulders resulted in places.

0.8

As you drive north, notice that the road crosses many more valleys than did the west-heading road we were just on. All the small tributaries of the Missouri River trend westward toward the river and the road crosses several of them. No large tributaries to the Missouri River occur on its east side because, as was already pointed out, the Missouri River valley itself is a glacial diversion trench. The largest tributary valleys are those of Beaver, Badger, Cat, Horsehead, and Little Beaver Creeks; none of these has a really large valley, certainly not nearly so large as are the tributary valleys west of the river. This is because the pre-glacial drainage, prior to the development of the Missouri River valley, was generally eastward and northeastward across North Dakota; such streams as the Cannonball, Knife, and Heart are examples of streams that existed prior to glaciation. East of the Missouri River, the continuations of these valleys are buried beneath glacial deposits; and only small valleys, such as the ones you are driving over, have developed since then.

2.6

Roadcut exposes Fox Hills sandstone on the left.

1.3

Road curves to the west. Hills to the north are made of Fox Hills formation sandstone.

0.4

Road curves to the northwest. Valley of Horsehead Creek is to the right.

0.7

Road curves to the north.

0.6

Road curves around hill.

1.0

Road curves around hill. Abundant boulders on the surface.

0.2

Road curves to the west. STOP 4. Exposure of Fox Hills Formation sandstone with a cover of glacial deposits, mainly boulders. Notice the banded bedrock. The banding suggests that it was deposited in a lake environment. Near the top of the exposure you can obtain abundant oyster shells (mostly *Tancredia americana*), which should also tell you something about the environment that existed when the Fox Hills Formation was deposited. At the top of the exposure are abundant cobbles and boulders of glacial origin; most were transported great distances from Ontario and Manitoba although locally-derived rocks are also present. A few large boulders of "pseudoquartzite" occur on top of the exposure. These are gray, smooth, and very hard. Pseudoquartzite apparently formed in Miocene or Pliocene time when fine silt, mainly quartz, possibly windblown, accumulated on the surface, mainly in lower, swampy areas, and hardened into the material you see today. It is very hard, partly because quartz is highly resistant to erosion, and partly because the material is monomineralic.

0.3

Road to right. Continue ahead.

0.9

Road curves to left.

0.1

STOP 5. Examine the large boulders on the right. These are typical glacial erratics, although larger than average. The light-colored ones are mainly granite, with abundant quartz. The pinkish ones, also granite, contain more feldspar. The darker ones are gabbros. Of particular interest is the banded black and white boulder a few yards from the fence. This is a metamorphic rock, one that was changed by heat and pressure. By careful study, you can determine which bands are older than the others (the younger bands, or dikes, cross the older ones). Turn around, retrace your route for 5.0 miles.

5.0

Turn east.

2.9

Road curves to the north. Numerous exposures of Fox Hills sandstone occur in the roadcuts ahead.

1.0

Road curves to the east.

0.1

Exposure of Fox Hills Formation sandstone.

3.8

Exposure of Fox Hills Formation sandstone with gravel of glacial origin on top.

0.5

Gravel pit on right.

0.2

The abundant boulders found in this area may mark the position the edge of the glacier occupied for an extended period of time. As the glacier stood in this position (glacier to the east, its edge trending north-south), it dumped debris, much like a conveyor belt. Melting water washed the finer materials away, leaving the boulders behind.

1.1

Exposures of Fox Hills Formation sandstone.

0.3

Bedrock exposures with gravel at the top.

2.1

Junction with U. S. Highway 83. End of roadlog.

GEOLOGIC ROADLOG FOR LaMOURE COUNTY

(total distance about 49 miles)

Distance Between Points

Begin trip in Edgeley at the junction of U. S. Highway 281 and State Highway 13 at the southeast corner of Edgeley. Drive south on 281 over ground moraine. The till in this area is rather thin and Cretaceous Pierre Formation shale bedrock is exposed in many places. Most of Edgeley is located on gravel that was deposited by meltwater flowing southward ahead of the glacier while its margin was located a few miles northeast of here.

1.3

Drive from till of the ground moraine onto gravel.

0.7

Road crosses a small meltwater trench that carried water from the west.

0.5

Drive back onto ground moraine.

0.6

Small meltwater trench that carried water from the west.

0.2

Turn west on gravel road and cross the railroad tracks.

0.3

Shale is exposed in the stream cut about 50 yards north of the road. The surface of the exposure is covered by gray chips of rock and by digging in a ways you can see relatively intact shale.

0.7

Shale exposures along the south side of the road.

0.1

Small bridge. As you drive west, the glacial drift becomes considerably thicker.

0.4

Small bridge. This valley is an extension of the same meltwater trench you just crossed.

2.9

This area of gravel is mainly material that was washed off the Missouri Coteau by east-flowing streams. The hills on the west horizon are part of the Missouri Coteau, which you will be driving onto shortly.

2.1

Notice the change from smooth to more rolling topography as you drive onto the Missouri Coteau. The boundary between dead-ice moraine and the smoother ground moraine to the east is poorly defined in this area; in some areas it is sharply defined. Till is the most common material in this area of dead-ice moraine, but gravel or sand may occur in places. Dead-ice moraine formed when large areas of the glacier became covered by glacial drift (gravel, till, lake sediments) and stagnated in place. As these areas of stagnant ice melted, the overlying glacial drift slumped and slid, resulting in a rough landscape of relatively high relief such as you see here. Notice the numerous potholes and small lakes.

0.9

Small meltwater trench.

1.9

Turn south, continuing to drive over typical dead-ice moraine of rather low relief. Till is the most common lithology in this area.

0.5

Abandoned school house on the west. Soo Line Railroad crossing.

0.5

Turn west on the road, LaMoure County Road 33.

1.1

Notice the gravel exposed in the roadcuts. This is collapsed outwash that was deposited by streams on top of stagnant glacial ice. When the ice melted, the gravel slumped and slid into its present hilly configuration.

0.2

Slough.

1.2

This rather flat area on which the town of Kulm is located is a perched, or elevated, lake plain that consists of silts and clays that were deposited in the lake and remained when the lake drained as the ice that surrounded it melted. Although coarse sand and gravel is the most common material on this lake plain, many such lake plains are covered by silt and clay. Notice that boulders are absent from the lake plain.

0.9

Kulm.

0.5

Junction with State Highway 56. Turn northward, continuing over the lake plain.

0.5

Soo Line Railroad crossing.

0.6

Junction with State Highway 13. Continue northward.

0.9

Drive off the lake plain onto dead-ice moraine.

1.5

Large slough. Numerous sloughs occur in this area. Some are almost dry, some still contain marsh. Notice the rings of vegetation surrounding the sloughs. As the center of the slough is approached, each type of plant has a greater water demand. With time, all lakes die and are replaced by swampland, or slough, and finally, by dry land as succeeding years of vegetation form swamp and finally dry soil. The highly humic soil that replaces a former lake forms some of the richest farmland in any region of dead-ice moraine.

0.3

Highway curves to the east. Continue northward on the gravel road.

1.6

Ray's Park.

0.7

Watch for numerous till exposures along the road.

3.8

Turn east on LaMoure County Road 34, continuing over dead-ice moraine.

0.2

Stop to look at the till, which is well exposed north of the road. This till is typical of this area, consisting mainly of silt with pebbles and cobbles mixed in. Notice the soil that has developed at the top of the till and how it grades downward into unaltered till. Till is glacial sediment that consists of a ground-up mixture of unsorted clay, silt, sand, and cobbles that was transported by the glacier and dropped when the ice melted.

1.3

Good till exposures in this area. This higher, more hilly area is part of an end moraine that formed when the glacier margin extended through this area, the glacier to the east.

1.2

Good exposures of till.

3.2

Deisem.

0.1

Burlington Northern Railroad crossing.

1.5

Drive off the dead-ice moraine onto gravel of a meltwater trench.

1.0

Drive out of the meltwater trench onto ground moraine.

1.3

Junction with U. S. Highway 281. Turn south, continuing to drive over ground moraine.

1.9

This flat area is an outwash plain over which water flowed southward. Little gravel is present in this area.

2.3

Burlington Northern Railroad crossing.

0.1

Gravel pit on the west. This gravel is located in the same outwash plain spoken of above.

0.2

Railroad crossing.

1.4

Edgeley. End of roadlog.

GEOLOGIC ROADLOG FOR LOGAN COUNTY

(total distance about 37 miles)

Distance Between Points

Begin trip in Lehr at junction of State Highways 13 and 30. Travel north on State Route 30. Lehr is situated on the Lake Lehr plain which is a good example of one of the most characteristic features of large-scale glacial stagnation: ice- walled-lake plains. These features are flat glacial-lake plains underlain by horizontally-laminated silt and clay deposits that are perched above the surrounding moraine, like buttes or small mesas. The silt and clay were deposited in lakes that were surrounded by stagnant ice. When the ice melted, the lakes drained and the silt and clay were left as elevated deposits.

0.4

Railroad crossing. Descend the ice-contact face at the north edge of the Lake Lehr plain. Drive onto collapsed superglacial alluvium.

0.8

Dead-ice moraine (till) for 4½ miles. Notice abundant boulders on the surface in places.

4.9

Collapsed alluvium. Notice the flat-topped, boulder-free hills, which are uncollapsed remnants of original alluvial plain (where it was deposited on solid ground in holes in the stagnant ice sheet). Notice the Streeter end moraine to the northeast. Much of this river sediment came from behind (east of) the moraine, through the gap (meltwater trench) in the middle of the moraine loop. The gap is 100 feet above and 5 miles northeast of the uncollapsed remnants of alluvial plain in this area.

2.2

Road to Beaver Lake. Turn *east*.

0.4

Observation stop. Collapsed stream sediment gravel with uncollapsed remnants (flat hilltops). Get out to examine the gravel deposit.

1.6

Turn north.

0.4

Esker ridge, best seen to the east. Notice the abundant boulders on the surface.

0.7

Turn east. Alternating gravel and till. Streeter end moraine is conspicuous 2 miles north.

2.0

Turn north.

1.6

Start to climb up the Streeter end moraine. Notice the abundant surface boulders in places. Many small end moraine ridges are superimposed on the larger ridge. They can be seen here.

0.7

Crest of the Streeter end moraine. Observation stop. This is one of the more striking end moraines in the state. It consists of a discontinuous series of loops formed by small ice lobes flowing out from the main ice mass. These lobes were 4 to 8 miles across. Each loop consists of a curved ridge, about 2 miles wide and 200 to 300 feet high. Superimposed on this ridge are small ridges 10 to 50 feet high and a few hundred feet apart.
The entire loop can be seen from here. The north limb (4 miles north of here) joins the south limb of the next loop to the north, forming an interlobe area that is as much as 575 feet above adjacent depressions immediately behind the moraine.
Examine the till exposed at the crest of the end moraine.
Continue northward after completing the stop.

0.1

Gravel deposit on left.

0.7

Till exposures along the road.

3.3

Exposures of superglacial alluvium, sand and gravel.

0.8

Streeter end moraine again.

1.4

Junction with State Route 34. Turn west. This area is dead-ice moraine.

4.3

Streeter end moraine.

0.7

Junction State Routes 34 and 30. Turn south. This area is collapsed superglacial alluvium.

0.9

Junction State Routes 34 and 30. Continue southward on 30.

0.9

Meltwater trench here carried water from southeast to northwest.

1.4

The lakes ahead on either side of the road occur in a kettle chain, which formed when large blocks of buried ice melted allowing the overlying materials to drop down. This area is mainly till.

2.4

Mainly gravel (collapsed superglacial alluvium) for the next 7 miles.

3.5

Road to Beaver Lake. End of roadlog.

GEOLOGIC ROADLOG FOR STUTSMAN COUNTY

(total distance about 65 miles)

Distance Between Points

Begin trip at the corner of 12th Ave. NE and 13th Street NE, at the northeast edge of Jamestown. Drive north on State Highway 20 over an area of relatively flat ground moraine. This area is covered by glacial till that was deposited at the base of the moving glacier. The ice that deposited the till in this area advanced from the northwest. The covering of glacial drift is thin in this area, probably less than 50 feet thick in most places.

3.9

Road curves northeastward.

0.8

Road curves northward again. This area of ground moraine becomes slightly more rolling now as we approach the end moraine.

4.0

Road to Fried. Continue northward.

0.4

The hills to the northwest are part of the Buchanan end moraine. The flat area we are now driving over just south of the hills is glacial outwash consisting of sand and gravel that was deposited by water flowing away from the ice while the end moraine was being deposited.

1.0

Buchanan end moraine. Notice the hilly topography and relatively greater relief than the area over which we have been driving. The end moraine was formed at a time when the glacier had become stabilized for awhile (ice was moving forward at a rate sufficient to offset the melting back of the margin and allow the margin to remain in the same position). While it was in this position, the ice carried much debris (mainly till) to its margin and dumped it.

1.6

Turn west on Stutsman County Highway 42.

0.2

Notice the numerous roadcuts that expose glacial till.

1.8

Stop here at the section line corner as you begin your descent into the valley. Look at the exposure at the corner on the north side of the road where glacial till overlies Pierre Formation shale (the shale is dark gray and the overlying till is buff colored). Notice the platy character of the rather uniform shale and how it fractures horizontally. This characteristic is known as fissility. The purple irridescent stains on the fracture faces are iron and manganese oxides that were deposited by ground water. Look for small fossils in the shale. These are mainly shellfish that lived in the warm seas in which the shale was deposited. The contact between the shale and overlying glacial drift is unusally distinct here. Commonly, the contact between bedrock and glacial drift is more gradational. Look at the glacial till and notice how much more varied it is in texture and composition than is the shale. Notice the numerous pebbles of granite, limestone and shale which the glacier has picked up and incorporated in the till. The shale was probably picked up nearby; the other constituents were carried here from Canada. As you continue into the valley, notice the cuts which are entirely in shale. Before the area was glaciated, this shale covered the surface everywhere.

0.3

This valley is a meltwater trench that was cut by water flowing from ice a few miles northeast of here. At the time the valley carried meltwater, the James River valley, about a mile west of here, had not yet been cut.

0.2

Cuts in glacial till along the road. The reason the shale was exposed in the valley is that it lies beneath the till in all places and the valley is deep enough to cut through the till into the shale.

0.5

Begin descent into the James River valley. Notice the excellent cut in glacial till along the road.

0.1

Stop and look at the roadcuts on the south side of the road. Beginning at the east end of the cuts, notice the pebble-free silt lying directly on top of the shale. This is lake sediment that was probably deposited in small ponds immediately ahead of the glacier as it advanced over the area. As the ice continued to advance, it deposited till on top of the lake sediment. About 30 yards to the west, lake silts are absent and till lies on top of the shale, but the shale here has been crushed by the weight of the overriding ice. However, as you go downward in the shale, the bedding becomes more distinct again as it was at the last stop. About a tenth of a mile nearer the center of the valley, you can see hard, undisturbed shale exposed in the dark gray cuts.

0.5

Bridge over the James River. Water has backed up here from the Jamestown Dam. The Jamestown Dam was constructed by the Bureau of Reclamation in 1952. It is a part of the Missouri River Basin Project authorized by the Flood Control Act of 1944. The dam is an earth-filled structure 86 feet high with a crest length of 1,420 feet. The reservoir has a storage capacity of 230,000 acre-feet and is for flood control. Its long-range purpose is as regulator and irrigation control for flow to the LaMoure and Oakes Sections of the Garrison Diversion Unit. Notice the dead trees, the roots of which have been smothered by the encroaching water. The James River valley is a large meltwater trench. It is relatively narrow here compared to its greater width in Jamestown where the Pipestem Creek flows into it. As you climb out of the valley, notice the till cuts on the west side of the valley.

1.2

You are now back on ground moraine.

1.2

This shallow valley carried meltwater from the northwest into the James River valley about 3 miles southeast of here. Gravel covers the valley floor.

1.1

Turn south at Buchanan and continue southward on the gravel road from Buchanan.

1.4

You are now on the Buchanan end moraine again. Notice the slightly hillier topography here than in the area over which we have been driving. The glacier was located north of here while its margin stood in this area so that materials were carried southward to this area and dropped at the edge of the ice.

2.6

Turn west. You are now driving over ground moraine. Notice that the relief is slightly less here than it was over the end moraine.

1.5

Begin the descent into the Pipestem Creek valley. Stop and look at the till cuts on the east side of the valley, especially on the south side of the road. Notice how the till is of a different consistency and hardness as you descend into the valley, generally becoming harder downward.

0.2

On the valley floor notice the dark gray alluvium along the stream. This alluvium, which was carried here by the stream, is probably not more than a few hundred years old.

0.1

As you begin your ascent out of the valley, notice the slight, steplike rise onto the gravel terrace. This terrace was formed when the Pipestem Creek flowed at a higher level than it does today (before it had cut its valley as deep as it is today). The terrace gravels were deposited by the stream when it flowed at the higher level. Notice the gravel pit south of the road.

0.3

Back on the upland, west of the valley, you are driving over glacial outwash. Notice the exposures of sand and gravel along the road. The relatively flat terrane in this area is typical of glacial outwash plains.

2.3

Stop at the gravel exposure on the south side of the road just east of the valley. Look at the sand and gravel that was deposited by meltwater flowing away from the glacier. Notice the looseness of the gravel in contrast to the almost cemented character of the gravel at the last stop. The reddish color of the gravel is due to staining by iron oxide (the mineral iron oxide); the iron came from particles of shale that are included in the sand.

1.1

Gravel exposures along the road. The gravel in this area was deposited by meltwater flowing from the ice while the Buchanan end moraine was being deposited. The glacier covered most of northern Stutsman County and its edge was located about two miles north of here.

1.3

Notice the till cuts along the road. We are now driving over end moraine again. This, the Eldridge end moraine, was deposited by ice moving southwestward. While the Eldridge end moraine was being deposited, the glacier covered the eastern two-thirds of Stutsman County. Notice the numerous boulders in places. Boulders are particularly abundant in areas of end moraine because such areas are commonly highly washed and the fine materials have been removed and deposited in the outwash plains, leaving the larger, heavier boulders behind.

2.2

Turn north, continuing to drive over the Eldridge end moraine.

0.7

Small meltwater trench. Notice the till cuts as you drive northward.

2.2

This area was covered by a lake that was surrounded by glacial ice. When the ice melted, the lake drained leaving this upland area veneered with lake sediments.

1.1

Turn west, continuing over lake sediments. The lake sediments in this area consist mainly of bedded silts and fine sands.

0.3

Drive off the lake plain onto dead-ice moraine. Notice the rugged topography and large boulders, both typical of dead-ice moraine. Till is the most common material in this area of dead-ice moraine, but gravel or sand may occur in places. Dead-ice moraine formed when large areas of the glacier became covered by glacial drift (gravel, till, lake sediments) and stagnated in place. As these areas of stagnant ice melted, the overlying glacial drift slumped and slid, resulting in a rough landscape of relatively high relief such as you see here. Notice the numerous potholes and small lakes.

1.9

This area, in which gravel occurs on the surface, is collapsed outwash that formed when meltwater deposited sand and gravel on top of stagnant glacial ice. When the stagnant ice melted, the gravel slumped down, resulting in the irregular topography you see here today.

2.8

Turn south on Stutsman County Road 67. Drive southward over an area of relatively low relief dead-ice moraine. Notice the numerous sloughs, some almost dry, some still containing marsh. Notice the rings of vegetation surrounding the sloughs. As the center of the slough is approached, each type of plant has a greater water demand. With time, all lakes die and are replaced by swampland, or slough, and finally, by dry land as succeeding years of vegetation form swamp and finally dry soil. The highly humic soil that replaces a former lake forms some of the richest farmland in any region of dead-ice moraine.

5.9

Road curves southeastward. This curve in the road is a correction line that results from the convergence of the meridians toward the north pole.

0.5

Road curves southward again.

0.7

Slightly hillier topography in this area may mark an area in which an end moraine was deposited on top of stagnant ice.

1.6

Elevated lake plain. This small flat area with the radio towers was covered by a lake that was surrounded on all sides by stagnant ice. When the ice melted, the materials that had been deposited in the lake were left as a small plateau.

3.7

Road curves to the west.

0.4

Town of Cleveland. Continue through Cleveland to I-94.

0.6

Turn east on I-94 toward Jamestown. We are on the dead-ice moraine of the Missouri Coteau and we will be driving off the coteau near Windsor onto ground moraine of the Drift Prairie. The boundary between the Drift Prairie and the Missouri Coteau is marked by the Missouri escarpment which in some places is a pronounced, east-facing scarp. In this area, the Missouri escarpment is rather subdued.

3.2

Approximate location of the Missouri escarpment.

3.4

Drive off the ground moraine onto a slightly lower area of glacial outwash. This is a part of the Minneapolis Flats meltwater trench. Gravel covers the surface in this area.

1.7

Minneapolis Flats Creek.

0.2

The hills on either side of the road are part of the Eldridge end moraine.

0.7

Standard Oil storage tanks. Continue driving over ground moraine to Jamestown. End of roadlog.

GEOLOGIC ROADLOG FROM ASHLEY TO LEHR

(total distance about 18 miles)

Distance Between Points

Begin trip at junction of McIntosh County road 23 and State Routes 3 and 11. Drive north on McIntosh County Route 23. As you drive north, you are passing over elevated lake plain. This is an example of one of the most characteristic features of large-scale glacial stagnation: ice-walled-lake plains. These features are flat glacial-lake plains underlain by horizontally-laminated silt and clay deposits that are perched above the surrounding moraine, like buttes or small mesas. The silt and clay were deposited in lakes that were surrounded by stagnant ice. When the ice melted, the lakes drained and the silt and clay were left as elevated deposits.

0.2

Railroad crossing.

0.7

Lake sediment exposed in ditch.

0.8

Drive off lake plain onto glacial till and then onto collapsed superglacial alluvium.

0.6

Gravel pit in collapsed superglacial alluvium. Alternating gravel areas and till areas for the next six miles to the north. Areas of till can often be recognized by the presence of surface boulders; such boulders are not common on areas of gravel.

3.0

Collapsed superglacial alluvium north of here. Dead-ice moraine to the south. Notice the lack of boulders north of here and the presence of abundant boulders to the south.

2.7

Gravel. This is collapsed superglacial stream sediment gravel ahead of the Burnstad end moraine. The glacier stood north of here as it deposited the end moraine and water flowing from the ice deposited the gravel in this area.

1.3

Burnstad end moraine. Notice the hilly topography.

1.9

Collapsed superglacial alluvium. This area of gravel is part of the Burnstad end moraine and the gravel is part of a stream deposit. The stream flowed to the west, depositing gravel on top of stagnant ice.

1.0

Cross esker. The esker is best seen west of the highway, paralleling the road. Notice the bouldery surface on the ridge.

0.5

Cross esker again.

1.4

Good exposure of till on the east side of the road. Stop to examine the till. Notice the chunks of black material; this is carbon formed from bits of wood that were incorporated in the material as the glacier moved over trees, etc. Notice that the till consists of materials of all sizes, from cobbles to clay.

1.5

The hills about two miles to the west are part of the Burnstad end moraine.

1.0

Collapsed lake sediment to the north, dead-ice moraine to the south.

0.7

Exposure of lake sediment.

0.3

Collapsed lake plain.

0.2

Junction with State Route 13. End of roadlog.

GEOLOGIC ROADLOG BETWEEN GACKLE AND LEHR

(total distance about 35 miles)

Distance Between Points

Junction of State Highways 46 and 56 in Gackle. Drive south on Route 56. This area of dead-ice moraine is part of the Missouri Coteau. It is the largest wild-duck producing area in the United States. The ducks nest in thousands of "prairie potholes" or sloughs, which characterized dead-ice moraine topography.

0.1

Railroad crossing.

0.9

Collapsed superglacial alluvium: a half-mile-wide band of collapsed alluvium with hilly topography nearly identical to that of collapsed superglacial till. The alluvium is sand and gravel that was deposited on top of the stagnant ice sheet. Melting caused the sand and gravel to collapse, producing the irregular topography.

Most of the alluvium on the Missouri Coteau is nonglacial. The stagnant ice was approximately 300 feet thick and took about 3,000 years to melt, producing about 1 inch of meltwater per year. Precipitation was probably at least 25 inches a year because spruce and associated vegetation typical of a slightly moister and cooler climate than at present lived in the area (the present annual precipitation is about 17 inches). For these reasons, only a very small fraction of the water in the rivers on the ice was meltwater, especially after the superglacial drift thickened and its insulating effect increased.

0.6

Back onto collapsed till for about 4 miles.

2.3

The roadcuts in this area expose till. This is typical dead-ice moraine topography.

1.9

Contact of till and gravel. Notice the gravel pit 0.3 mile south of the farm. For the next 2 miles, you will be driving over alternating areas of collapsed river sediment (gravel) and collapsed glacial sediment (till). The two lithologies can frequently be distinguished from the car window by the presence of boulders on the till and the absence of boulders on the collapsed alluvium.

1.2

Junction of State Routes 56 and 34. Continue south on 56.

2.4

This relatively flat area is a partially collapsed lake deposit. The lake existed on top of stagnant ice.

1.7

STOP 1. Typical till deposit. Examine the till at any of the several cuts along the highway in this area. Notice the chunks of black material; this is carbon formed from bits of wood that were incorporated in the material as the glacier moved over trees, etc. Notice the presence of all sized particles, from clay to cobble size.

2.0

Road curves to the south again.

3.8

Notice the change in the topography from highly rolling to gently rolling. The flatter area from here to Fredonia is also collapsed superglacial till, but less stagnant ice and less till was involved so the resulting topography is flatter than it was to the north.

4.7

Town of Fredonia.

0.2

Railroad crossing.

0.6

High-relief dead-ice moraine again.

0.6

Junction of State Routes 56 and 13. Turn west on 13. Alternating collapsed till and gravel. Notice the occasional gravel pits.

6.9

Notice the flat skyline 1½ miles south. This is a perched (but slightly collapsed) alluvial plain on the same level as the perched Lake Lehr plain (see below).

4.0

The flat skyline a mile to the southwest is the perched plain of ice-walled Lake Lehr. The area you are on now is gravel, an apron of collapsed stream sediment that surrounds the Lake Lehr plain.

0.7

Climb up ice-contact face onto the Lake Lehr plain. The Lake Lehr plain is a good example of one of the most characteristic features of large-scale glacial stagnation: ice-walled-lake plains. These features are flat glacial-lake plains underlain by horizontally-laminated silt and clay deposits that are perched above the surrounding moraine, like buttes or small mesas. The silt and clay were deposited in lakes that were surrounded by stagnant ice. When the ice melted, the lakes drained and the silt and clay were left as elevated deposits.

GEOLOGIC ROADLOG BETWEEN LaMOURE AND EDGELEY

(total distance about 19 miles)

Distance Between Points

Begin trip at the west city limits of the town of LaMoure. Drive west on State Highway 13.

0.4

James River. The wide valley through which the James River flows is a large glacial meltwater trench that carried water from melting ice throughout a large area of central North Dakota.

1.6

Omega Tower to the north.

1.0

Climb out of the James River valley onto ground moraine that is composed mainly of glacial till. Till is glacial sediment that consists of a ground-up mixture of unsorted clay, silt, sand, and cobbles that was transported by the glacier and dropped when the ice melted.

0.4

Road to Grand Rapids. Continue westward on Highway 13.

1.4

Bridge over Cottonwood Creek. This valley is another meltwater trench that carried water from the northwest.

4.5

Road to Berlin. Continue westward over ground moraine.

5.9

Road to Medberry.

0.4

Drive down into the Maple Creek valley. This valley is a meltwater trench that carried water mainly from the Missouri Coteau to the west.

0.4

Bridge over the Elm River. Continue over ground moraine west of the Elm River valley.

2.3

Meltwater trench.

0.7

End of roadlog in Edgeley at the corner of U. S. Highway 281 and State Highway 13. Ground moraine.

GEOLOGIC ROADLOG BETWEEN OAKES AND ELLENDALE

(total distance about 30 miles)

Distance Between Points

Begin trip at the corner of Main Avenue and 7th Street (State Highway 1) in Oakes. Drive south on State Highway 1. This flat area is the lake plain that was once covered by Glacial Lake Dakota. To the north of Oakes, gravel covers the surface. This gravel was deposited at the mouth of the James River where it entered the lake near its north end. The lake plain in this area is rather sandy and wind action has modified the surface somewhat although large dunes have not developed.

0.5

Soo Line Railroad crossing.

0.5

Stop here to examine the long excavation to the west of the road. This excavation exposes sand that was deposited near the mouth of the James River where it entered Lake Dakota. Further south, further from the river mouth, the sand becomes finer because, as the stream current was checked by the still lake waters, the coarser sand was the first to be deposited.

1.0

Junction with State Highway 11 to Forman. Continue southward on State Highways 1 and 11.

0.1

Rest area.

3.5

Notice the hills on the eastern horizon about 6 miles away. These hills are part of the Oakes end moraine that formed when the glacier margin was located in that area. While the glacier was depositing the end moraine, water flowing from the melting ice, as well as from the James River, collected to form Lake Dakota, the former floor of which we are now driving on.

1.9

Burlington Northern Railroad crossing.

1.3

Highway curves to the west.

1.6

Town of Ludden. The sediments of the lake plain are slightly less sandy in this area.

0.2

Railroad crossing.

0.3

Drop down into a slough. This slough is a former route of the James River, which meandered over the lake plain after the lake drained before the present river route was established. The lower area ahead is covered mainly by river alluvium (sands and silts) that have been deposited by the river in postglacial time.

0.8

Junction of State Highways 1 and 11. Continue west on Highway 11.

0.1

Bridge over the James River. From Oakes southward, the James River valley is very shallow and poorly defined in contrast to northwest of Oakes where it is about 75 feet deep and very distinct. The deeper part of the valley was cut mainly during the glacial epoch when large volumes of meltwater flowed through the valley. The shallow valley in this area, in addition to being much younger than the valley northwest of Oakes, never carried large volumes of water.

0.1

Drive out of the James River valley onto ground moraine. From here to Ellendale you will be driving over glacial sediment, mainly till. Notice the contrast from the flat lake plain you just left with the slightly rolling topography of the ground moraine in this area. Notice the first appearance of boulders in the fields.

2.4

This slightly hillier area may mark a position in which the glacier margin stabilized for awhile as it receded from the area.

1.2

Road to Guelph.

0.1

This small valley is a meltwater trench that carried water southward from melting ice to the north. Gravel can be found on the valley floor.

0.8

Stop here to observe the composition of the material in the roadcut. This is glacial till, typical of areas of ground moraine. Till is glacial sediment that consists of a ground-up mixture of unsorted clay, silt, sand, and cobbles that was transported by the glacier and dropped when the ice melted.

7.4

Bridge over the Maple River. The Maple River is another meltwater trench that carried water southward.

0.2

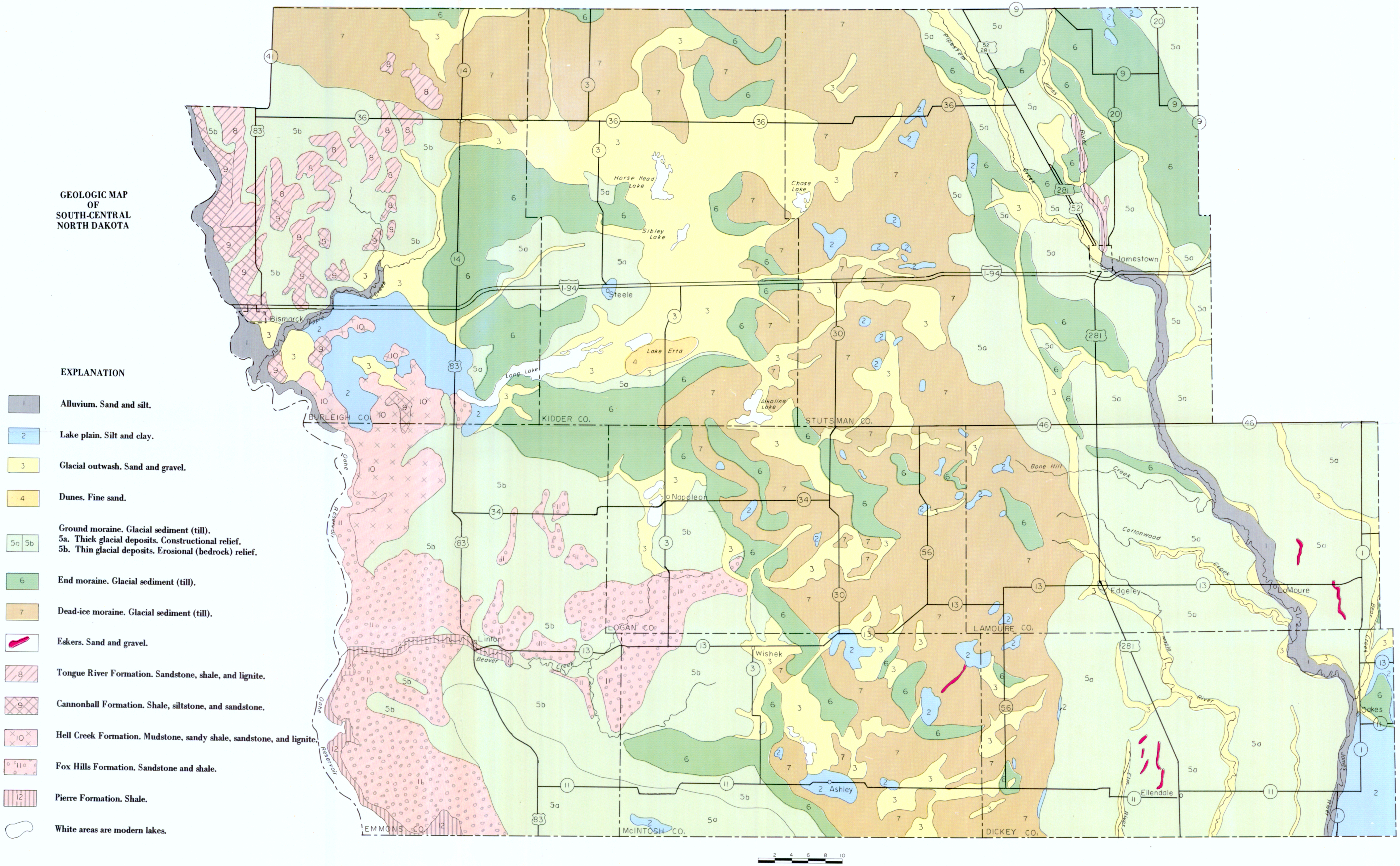
Burlington Northern Railroad crossing.

3.8

Meltwater trench. Notice the gravel north of the highway. This valley is somewhat older than is the Maple River valley.

1.5

Junction of State Highway 11 and U. S. Highway 281 at the north edge of Ellendale. End of roadlog.


GEOLOGIC MAP
OF
SOUTH-CENTRAL
NORTH DAKOTA
EXPLANATION
1 Alluvium. Sand and silt.
2 Lake plain. Silt and clay.
3 Glacial outwash. Sand and gravel.
4 Dunes. Fine sand.
5a 5b Ground moraine. Glacial sediment (till).
5a. Thick glacial deposits. Constructional relief.
5b. Thin glacial deposits. Erosional (bedrock) relief.
6 End moraine. Glacial sediment (till).
7 Dead-ice moraine. Glacial sediment (till).
Eskers. Sand and gravel.
8 Tongue River Formation. Sandstone, shale, and lignite.
9 Cannonball Formation. Shale, siltstone, and sandstone.
10 Hell Creek Formation. Mudstone, sandy shale, sandstone, and lignite.
11 Fox Hills Formation. Sandstone and shale.
12 Pierre Formation. Shale.
White areas are modern lakes.
BURLEIGH CO.
KIDDER CO.
STUTSMAN CO.
LOGAN CO.
LAMOURE CO.
EMMONS CO.
McINTOSH CO.
DICKEY CO.
Bismarck
Steele
Jamestown
Napoleon
Linton
Wishek
Ashley
Edgeley
LaMoure
Ellendale
Oakes
Horse Head Lake
Chase Lake
Sibley Lake
Lake Etta
Long Lake
Pipestem Creek
James River
Apple Creek
Beaver Creek
Oahe Reservoir
Bone Hill Creek
Cottonwood Creek
Maple River
Elm River
Bear Creek
miles