N. D. Geological Survey
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State Geologist

GUIDE TO THE GEOLOGY OF Northwestern NORTH DAKOTA

by John P. Bluemle
revised edition 1980

GUIDE TO THE GEOLOGY OF NORTHWESTERN NORTH DAKOTA

Burke, Divide, McLean, Mountrail, Renville,
Ward, and Williams Counties

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Educational Series 8

North Dakota Geological Survey

Lee C. Gerhard, State Geologist

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INTRODUCTION

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

Geologic educational aids available to North Dakota schools and other organizations include taped lectures and collections of selected slides, which may be borrowed free of charge. Members of the Survey staff give illustrated lectures by arrangement. Rock and mineral collections are available to schools. Numerous technical maps and reports on North Dakota geology are also available, at nominal costs.

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

GENERAL GEOLOGY

The part of the earth we live on is only a thin skin, known as the crust, that encases a huge volume of denser materials known as the mantle and core. The crust is built from solid materials, known as rocks, 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. Since the temperatures at the earth's core are extremely hot, the rocks are mobile, probably somewhat like very dense plastic.

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

Geologic Time

Geology necessitates our thinking in terms of millions of years, not in days, months, or years as we are accustomed. Time is a fundamental consideration in all geological research, but it is sometimes difficult to comprehend the immensity of geologic time. The earth is about five billion years old. If all of those five billion years were compressed into a single imaginary year, the earliest life would have appeared in late April of that year. Dinosaurs would have come on the scene in mid-December and lasted only six of our imaginary days. The ice age would have begun in North Dakota at 8:40 p.m. on December 31 and ended only two minutes before midnight. Primitive man arrived on earth about 10:20 p.m. in the midst of the ice age. At twenty seconds before midnight, Christ was born, and at ten

*Burke, Divide, McLean, Mountrail, Renville, Ward, and Williams Counties.

seconds, Leif Ericson discovered America. So, as you can see, the two thousand years since the birth of Christ may seem like a long time; but, to the geologist, they are only an instant in the history of the earth.

Minerals and Rocks

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

Perhaps the most common mineral is quartz, a colorless silicate with a complex crystal structure. Glass is made from very pure silica sand, quartz. The fact that glass cannot be scratched by a knife blade indicates that it is harder than steel, which is why diamond, a form of carbon that is the hardest of minerals, can be used to cut glass. Because minerals differ in hardness, this physical property 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.

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

Sedimentary rocks (from the Latin, *sedimentum*, "settling") have been derived from pre-existing rocks by the processes of erosion. Rain, ice, and wind are powerful destructive forces that constantly tear down the earth's surface and reduce its topography. The particles worn from any eroded rock mass are eventually carried by rivers and streams to lakes and seas. In North Dakota, sedimentary rocks such as limestone, sandstone, and shale, all of which were deposited in water, lie above the igneous rocks. They formed when sediments washed into the seas that covered the State during much of the past 600 million years. In the same way, topsoil today is washed from the Souris 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.

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

GEOLOGIC HISTORY

Rock and sediment deposited by glaciers and their melt waters cover most of northwest North Dakota, concealing the rocks and landscape over which the glaciers moved. Nevertheless, it is possible to reconstruct the geologic history of the area for more than a billion years before the glaciers came by studying the rocks exposed in adjacent

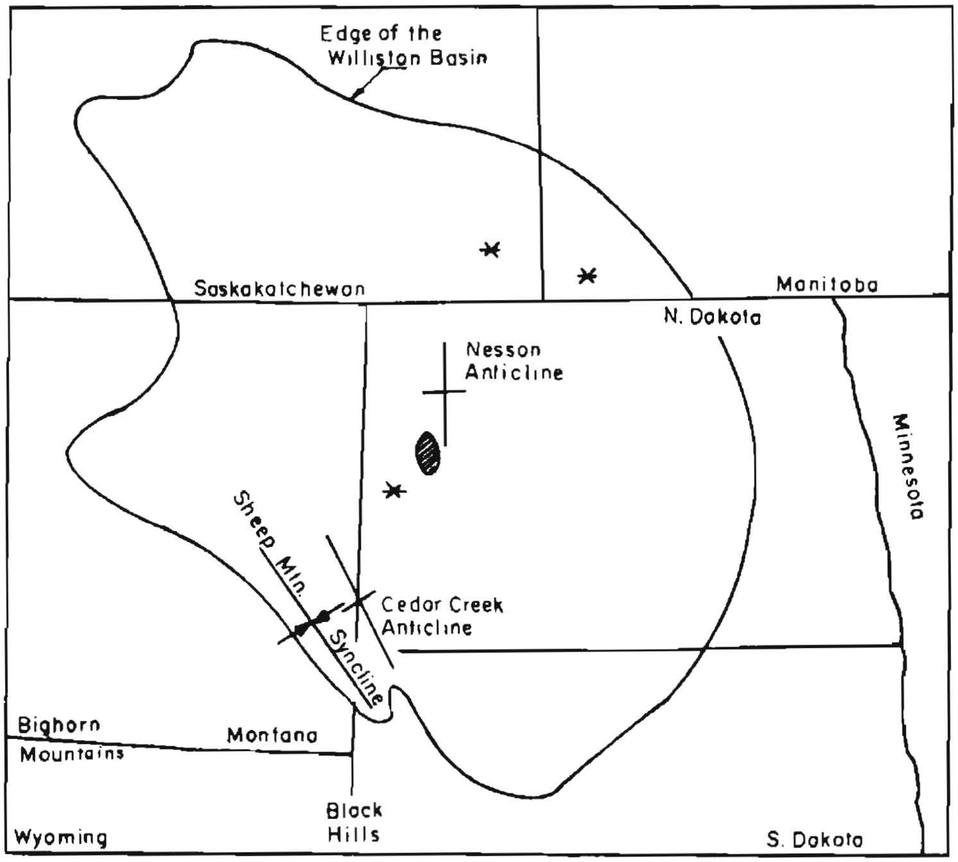


Figure 1. Map of the Williston Basin showing the main structural elements. The shaded area is the deepest part of the basin. Starred locations are astroblems, places that were disturbed when they were struck by large meteors.

southwestern North Dakota, an area never reached by the glaciers, and by studying rock fragments and drill cores brought up in the thousands of oil, gas, and water wells that have been drilled throughout the State.

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

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

Throughout most of the past 500 million years, North Dakota's climate has been warmer than it is now, more like Florida or the Bahamas than present-day North Dakota.

During the Pleistocene Epoch or "ice age" from which we are now emerging, North Dakota has had a continental climate, with cold winters and hot summers. The Pleistocene Epoch, which began about two or three million years ago, was the beginning of a markedly colder climate. During the ice age, glaciers formed west of Hudson Bay due to the accumulation and compaction of yearly snows that didn't completely melt in the summers (fig. 2). This same process occurs today in glaciated mountainous areas and on the Greenland and Antarctic ice caps. As snow piles up and turns to ice, the accumulated weight builds up high pressures at the base of the ice. Under sufficient pressure, ice acts as a fluid and flows, much like water. The Hudson Bay glaciers flowed into northwest North Dakota overriding even the highest hills as they flowed southward. Large rocks, as well as other surface materials, were ground up by the ice, which was in constant movement. The shifting weight of the flowing ice caused continual slippage along fracture planes within the ice so that it was heavily loaded with debris. The debris was deposited on the ground when the ice melted.

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

The Missouri Escarpment is a steep topographic rise that the glaciers had to override as they flowed southward onto the Missouri Coteau (fig. 3). 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, known as glacial drift, was carried up onto the Missouri Coteau. Most of the drift was dropped on the coteau when the ice melted.

Most of the glaciers had finally melted out of northwest North Dakota by about 12,000 years ago. However, ice persisted longer on the Missouri Coteau where a blanket of glacial drift that covered the ice insulated it and caused it to melt more slowly. Some of the ice persisted for at least 3,000 years, until about 9,000 years ago.

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

Eventually, all the ice melted, and the material that had been on top of the ice dropped 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 northwest North Dakota became somewhat cooler and wetter again, and it has remained so, with short-term variations, to the present day.

LANDFORMS OF NORTHWEST NORTH DAKOTA

Nearly all the landforms of northwest North Dakota consist of materials that were deposited by the glaciers. Sand, silt, gravel, and clay are among the materials deposited by glaciers. Boulder piles and "stony" fields report "the glacier was here!" Before the ice age

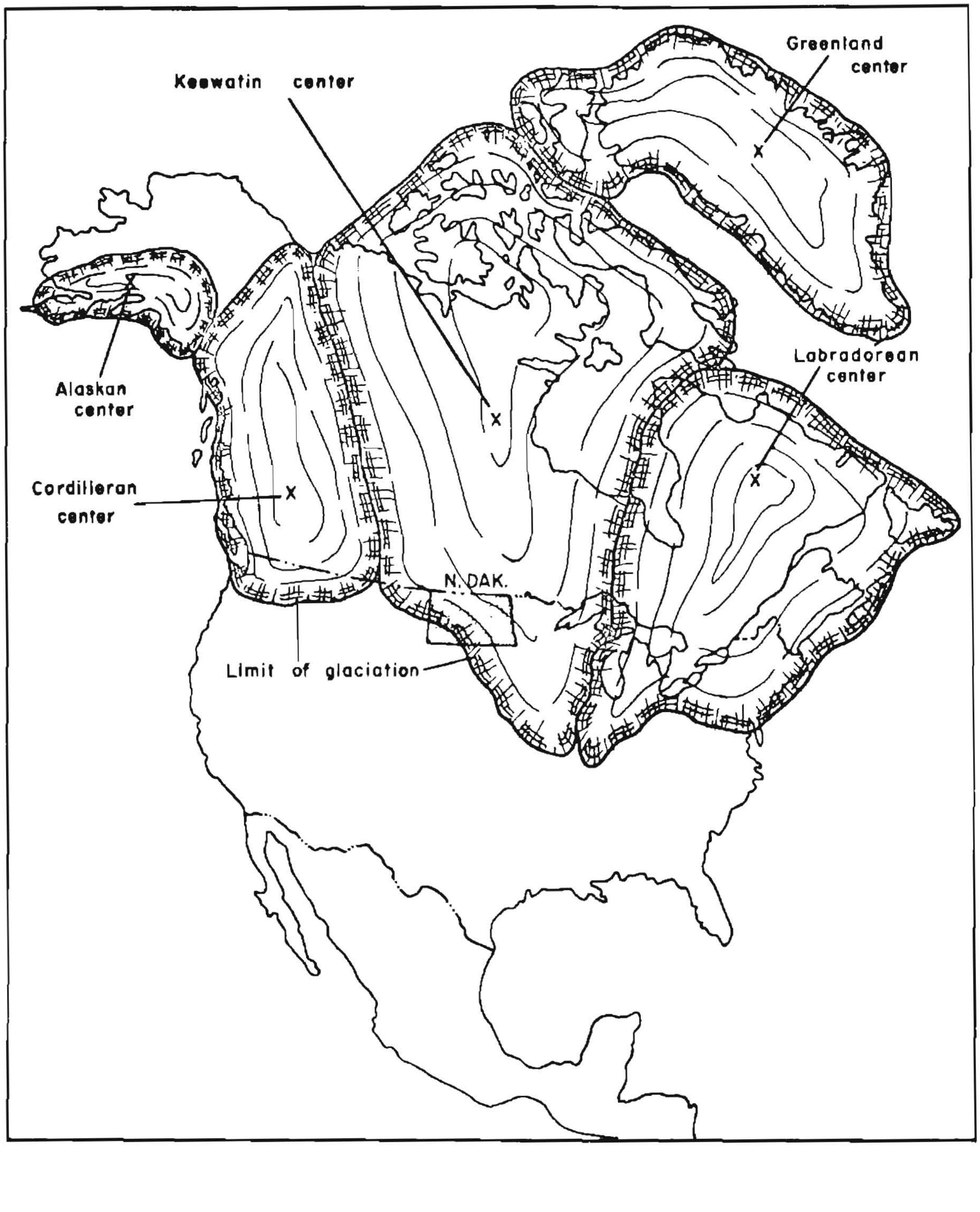


Figure 2. Map of North America showing the limits of continental glaciation during the ice age. The main centers of snow accumulation from which the ice moved are shown. North Dakota was glaciated by ice that moved from the Keewatin center west of Hudson Bay.

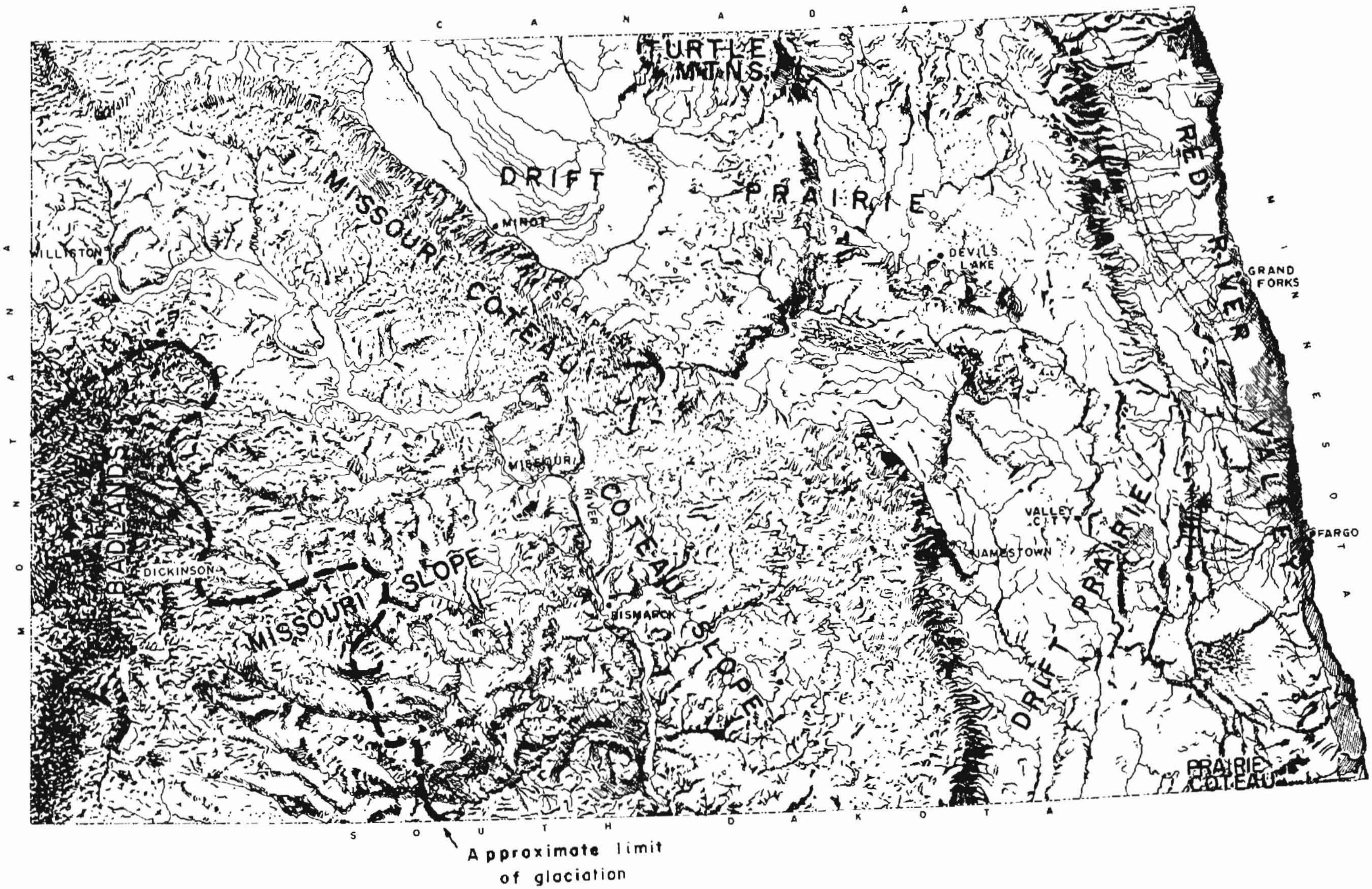


Figure 3. Physiographic map of North Dakota.

Figure 4. Glacial drift along Lake Sakakawea in McLean County (sec 22, T147N, R84W). Three layers of glacial sediment (till) are shown, separated by two layers of water-lain gravel. The glacial sediment is compact and held tightly together by the clay it contains. In contrast, the gravel is loose, and washes out easily. Each layer of till was probably deposited by a different glacier, the oldest, on the bottom, several hundred thousand years ago, the youngest, on the top, only about 15,000 years ago.

the landscape was somewhat like that along the Missouri River where buttes and large-scale, wind- and water-sculptured scenery of non-glacial origin predominate. When the glaciers overrode northwest North Dakota, they planed off the more rugged features and filled in the valleys with loose, ground-up deposits that had been carried southward in the ice. The landscape in glaciated areas is *constructed* (deposited by the ice), but the landscape of unglaciated areas is *eroded* and was worn down by running water and wind action.

Most of the sediment associated with glaciation was deposited directly by the ice; but sand and gravel was deposited by streams flowing from the glaciers, and layers of sand, silt, and clay were deposited in glacial lakes. All of these materials—glacial sediment, stream sediment, and lake sediment—are collectively known as "drift." The drift is as much as 600 feet thick in some places. The seven counties of northwest North Dakota are covered by about 315 cubic miles of drift.

Glacial sediment is sometimes referred to as "till." The Europeans refer to the glacial sediment as "raisin cake," indicating that it is made up of all sizes of unsorted materials in contrast, for example, to beach deposits, which are composed of materials that were sorted into layers by the water. Figure 4 shows an exposure of glacial sediment along Lake Sakakawea in McLean County. Thicker deposits of the drift commonly have constructional relief, due entirely to the accumulation itself, whereas the thinner accumulations of drift do not alter the underlying bedrock topography appreciably.

Nonglacial Landforms

In some places bordering the Missouri River and in certain other deep valleys, such as the White Earth valley in Mountrail County, much of the rock and sediment is of nonglacial origin. Badlands and buttes are cut from the Tongue River and Sentinel Butte Formations of Paleocene age, about 65 million years old.

The erosion that has shaped the badlands areas has been selective in its action. The harder, more resistant sandstone and limestone beds have remained as protective caps on buttes and ridges while the softer silt and clay layers have been washed away (fig. 5). Other materials that are resistant to erosion include layers of reddish scoria, a natural brick that

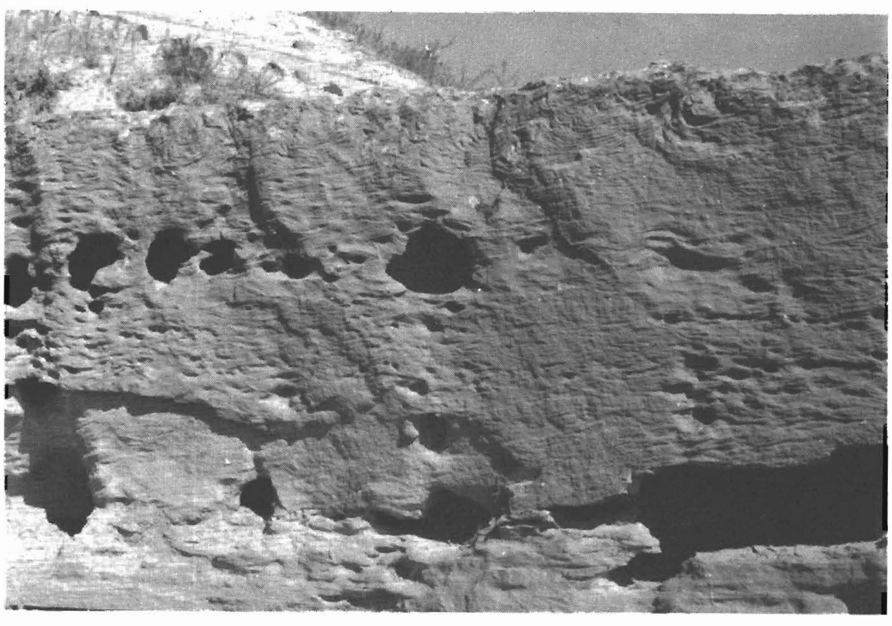


Figure 5. Two examples of hard, resistant sandstone of the Tongue River Formation, about 65 million years old. Resistant layers, such as this one, result in buttes, ridges, and badlands topography when erosion removes the softer materials. The bedding in the sand, especially noticeable on the lower photograph, resulted when sand was deposited by running water. A few miles southeast of Williston, Williams County.

formed when the heat from nearby seams of burning coal baked the adjacent sediments (fig. 6); layers of exceptionally hard pseudoquartzite, which were probably deposited in ancient swamps and later silicified; and, in some places, beds of snail and clam shells and layers of petrified wood (fig. 7).

Although the landforms near the Missouri River are composed mainly of preglacial sediments, they were eroded to their present configurations during and since the ice age. The Missouri River valley was carved during the ice age when northeast-trending drainage was diverted around the edge of the glacier.

Glacial Landforms

The various glacial landforms of northwest North Dakota are represented by different colors on the geologic map (pl. 1) in the pocket at the back of this guidebook. Areas shown in shades of green on the map represent glacial sediment that was deposited directly by glacial ice. The manner in which the glacial sediment was deposited and the amount that was available to be deposited, determined the type of landform that resulted. Moderate amounts of glacial sediment that were deposited at the base of the moving glacier and from within the ice when it eventually melted, formed ground moraine, a gently rolling landscape with a few potholes and hills. This type of deposition was common and large areas of North Dakota, shown in light green on the map, are covered by glacial sediment that was deposited in this way.

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

Large-scale shearing by the glacier moved huge blocks of material short distances in some places (fig. 8). If the glacier continued to advance over such a block of material, the block was effectively masked by subsequent erosion and deposition of glacial sediment. However, if the glacier stopped advancing soon after it moved a large block, the result was commonly a hill and an adjoining depression, the hill consisting of material that was transported from the depression by the ice. Dogden Butte in northeastern McLean County is an example of an ice-shoved block of material that is over 200 feet thick. A test hole on the top of the butte penetrated 100 feet of glacial sediment, 212 feet of preglacial sediment, and 44 feet of glacial sediment before reaching undisturbed preglacial sediment. The block of preglacial sediment that accounts for much of the butte's bulk, was apparently transported from the northeast by the ice. Later, the glacier advanced southeastward, covering the depression from which the preglacial sediment had been taken.

At times, glacial sediment was deposited at the edge of the glacier while the ice margin was melting back at about the same rate at which the ice was moving forward, so that the margin remained stationary. This resulted in an end moraine, a hilly accumulation of glacial sediment that is commonly a few miles wide and several tens of miles long. Areas of end moraine are shown in medium shades of green on plate 1.

The most rugged topography of glacial origin in northwest North Dakota is found on the Missouri Coteau, which extends from northwest to southeast through the area. The landform of the Missouri Coteau is known as dead-ice moraine and it owes its origin to the fact that the glacier had to advance over the steep Missouri Escarpment before it flowed onto the upland. Elevations rise as much as 600 feet in less than a mile along parts of the Missouri Escarpment, which marks the northeastern edge of the Missouri Coteau. When the glacier advanced over the Missouri Escarpment, the stress resulted in internal shearing in the ice. Large amounts of rock and sediment beneath the glacier were carried to the surface along shear planes in the glacier and deposited on top of the ice that had already moved onto the upland. This resulted in a thick cover of glacial sediment on top of the ice on the

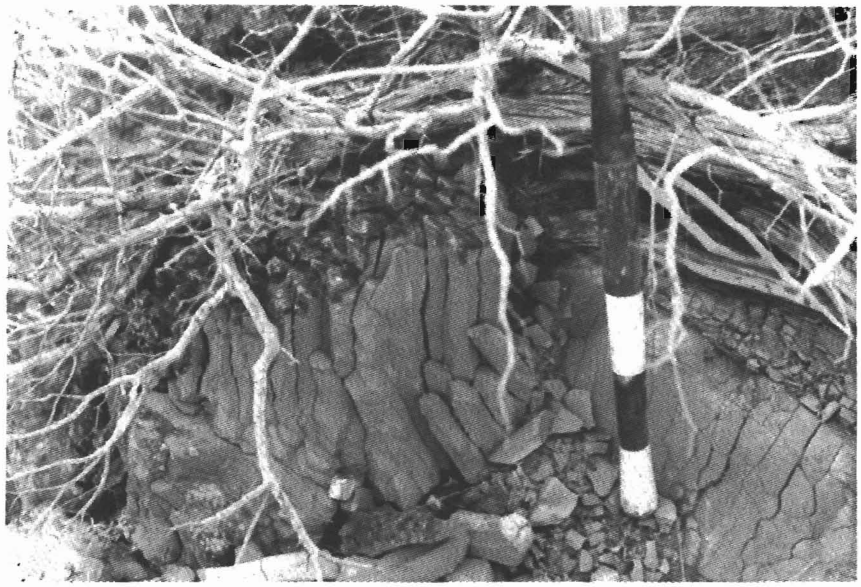


Figure 6. Photo of scoria, showing how the material has "jointed" into sections due to the baking. This scoria is hard, natural brick that is widely exposed in areas where lignite beds have burned beneath the ground. Location of photo is sec 16, T153N, R100W, southeast of Williston in Williams County.

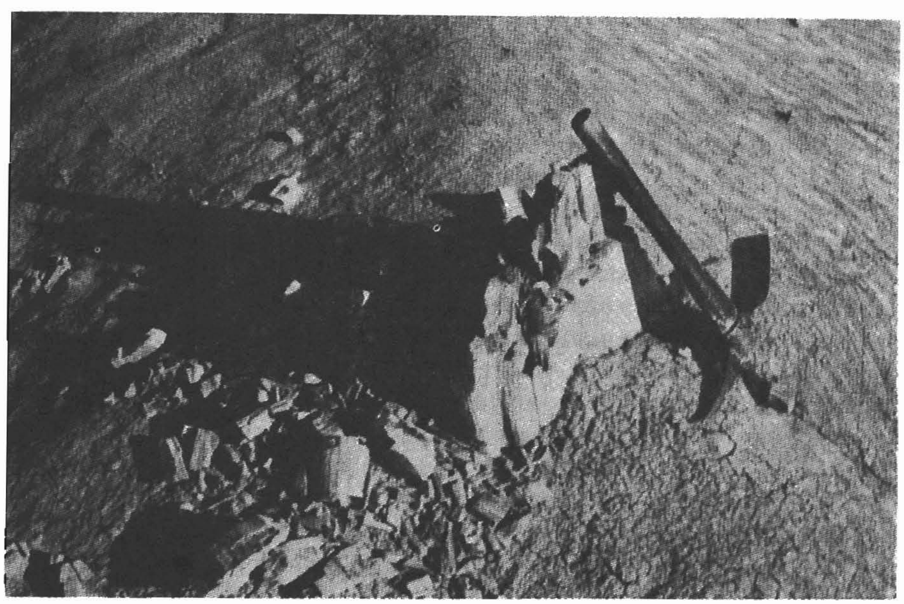


Figure 7. Petrified tree stump weathering out of softer material. This is a good example of the difference in resistance that two materials offer to erosion. A few miles southeast of Williston in Williams County.

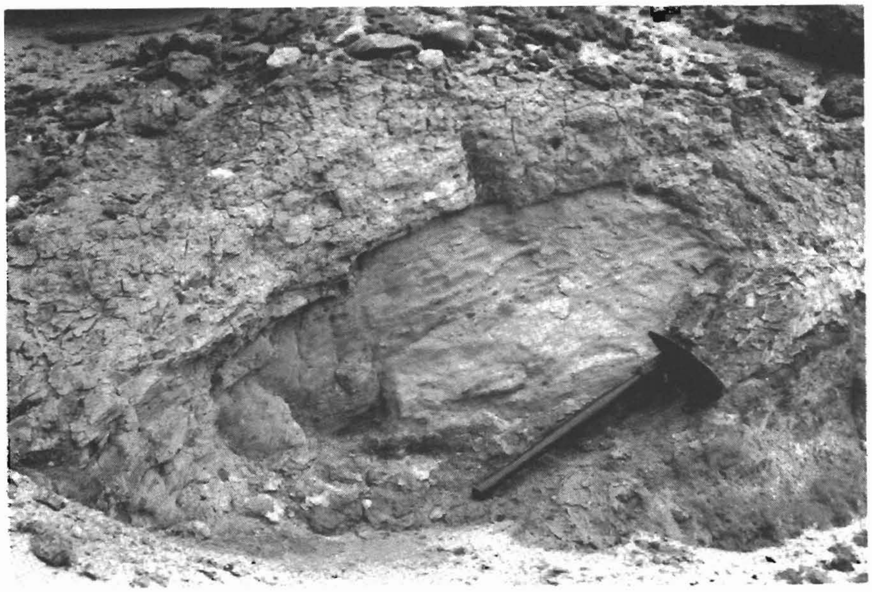


Figure 8. Two photos illustrating shearing by the glacier. The upper photo is of a 5-foot-long piece of sandstone in McLean County that has been incorporated into the glacial sediment; glacial till surrounds the sandstone block. The lower photo shows the edge of a sandstone block, perhaps 25 feet across, that has been shoved into a nearly vertical position by the glacier. This ice-shoved block is in northern Burke County, near Lignite.

Missouri Coteau. The cover of glacial sediment helped to insulate the underlying ice so that it took several thousand years longer for it to melt than it did from nearby areas on the Drift Prairie where there was no insulating cover. When the ice finally did melt, the cover of glacial sediment slumped and slid, forming the hilly landscape we see there today. In some places, lakes formed on top of the stagnant ice (fig. 9). The dead-ice moraine is shown in brown on plate 1.

Glacial Melt Water Landforms

During the ice age, rivers of melt water flowed on or beneath the glacial ice, depositing sand and gravel on their beds just as modern streams deposit material on their beds. When the glacier melted, the sand and gravel remained as ridges standing above the surrounding area. These ridges are known as eskers. Typically, esker deposits are coarse and poorly sorted with large amounts of silt and clay, and esker surfaces may be bouldery. Numerous small eskers occur in northwest North Dakota, but only a few of the larger ones are shown on plate 1. A large esker is found near Benedict in McLean County (fig. 10). Kames are similar to eskers in that they are also composed of gravel that was deposited by water flowing in or on the glacier. When the glacier melted, the gravel slumped into cone-shaped hills. Paint Hill in western McLean County is an example of a kame, but numerous other examples occur in northwest North Dakota.

Gravel that was washed out of the ice by water flowing from the melting glacier is known as glacial outwash, and extensive areas of such material are known as outwash plains. Several outwash plains are shown on plate 1 in yellow. Wherever the outwash was deposited on the ground, it formed a relatively flat surface. A good example is in the Turtle Lake area of eastern McLean County. In some places, however, the gravel was deposited on top of stagnant glacial ice, particularly on the Missouri Coteau in association with dead-ice moraine. In such areas, the original flat surface collapsed when the stagnant ice melted, resulting in a rolling surface.

The gravel of outwash plains is commonly poor in quality due to the presence of large amounts of shale. Its main value lies in its looseness, which allows large amounts of water to be stored between the grains. Such water-bearing materials are known as aquifers. Some of the outwash gravel deposits of northwest North Dakota are excellent aquifers that provide considerable groundwater to the farmers of the area. The outwash deposit near Turtle Lake in McLean County is an excellent aquifer.

MINERAL RESOURCES

Mineral production is an important source of income in northwestern North Dakota. Petroleum resources, along with natural gas and coal, account for most of the total mineral value.

Petroleum production in North Dakota dates to 1951 when oil was discovered in the Clarence Iverson number 1 well, SW¼SW¼sec 6, T155N, R95W, about 8 miles south of Tioga in Williams County. Petroleum is produced from all the counties in northwestern North Dakota except McLean, which, however, has an apparent discovery well and will soon be included in the list of producing counties. Production of oil in northwest North Dakota through January 1, 1980 was over 278 million barrels. Williams County produced more than half of the total amount.

Lignite occurs throughout northwestern North Dakota. At several locations along the Missouri River, lignite beds are found directly under the glacial deposits. The glacial deposits are generally thin along the Missouri River, and most of the lignite beds directly beneath glacial deposits have weathered to leonardite. Numerous abandoned underground mines occur throughout the area, but lignite is now mined in surface mines where the material above the coal is stripped off, the lignite removed, and the original cover material replaced. North Dakota law requires reclamation of strip-mined areas.

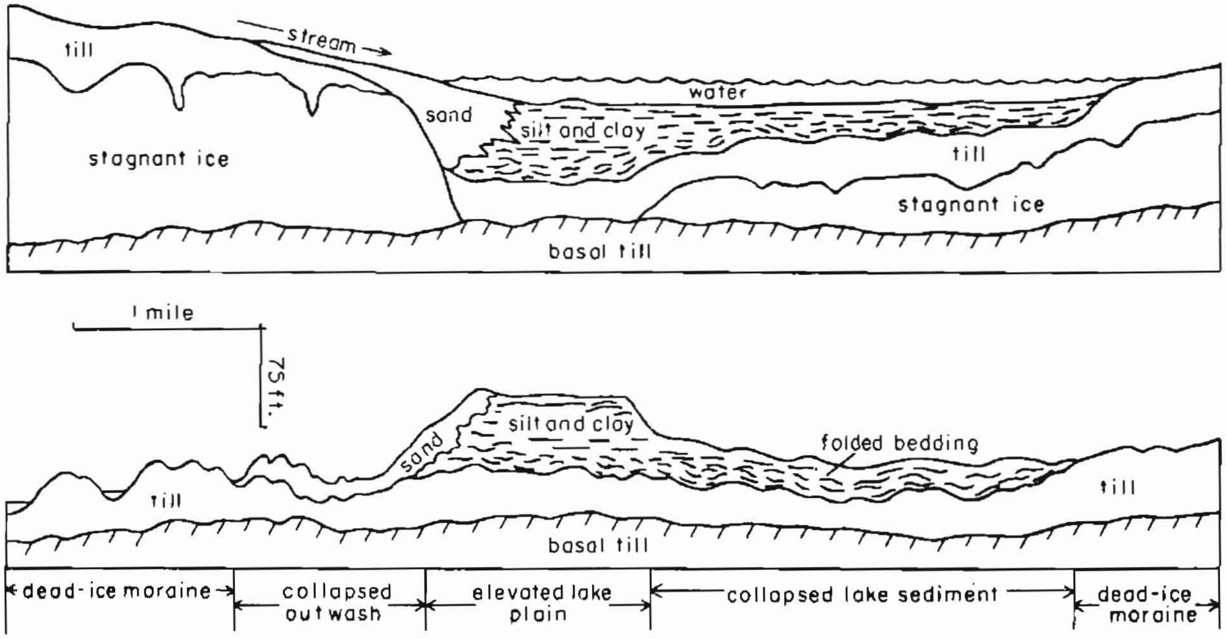


Figure 9. Schematic diagram showing the conditions that led to the development of a typical elevated lake plain in dead-ice moraine. Silt and clay were deposited in the lake, which was situated over an area that was partially covered by stagnant glacial ice. Lakes like this one were insulated from the ice by a layer of till and many of them contained abundant life such as snails and clams. When the stagnant ice melted, the materials on top of the ice 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 areas where stagnant ice had been absent, the lake sediments did not collapse so they stand today as elevated lake plains.

Figure 10. Esker near Benedict in northern McLean County (sec 21, T150N, R82W). This view is to the northwest over the crest of the ridge. The esker ridge is about 50 feet high. Numerous gravel pits in the esker expose generally coarse, poorly sorted gravel and sand.

Figure 11. Photo of a "buffalo boulder." Boulders like this one in Burke County are common in glaciated areas. They are encircled by a depression that may be several feet deep. The depressions are the result of erosion caused by the hoofs of bison and cattle. The animals use the stones for rubbing, and their hoofs loosen the soil around the boulders. Wind carries the loose material away.

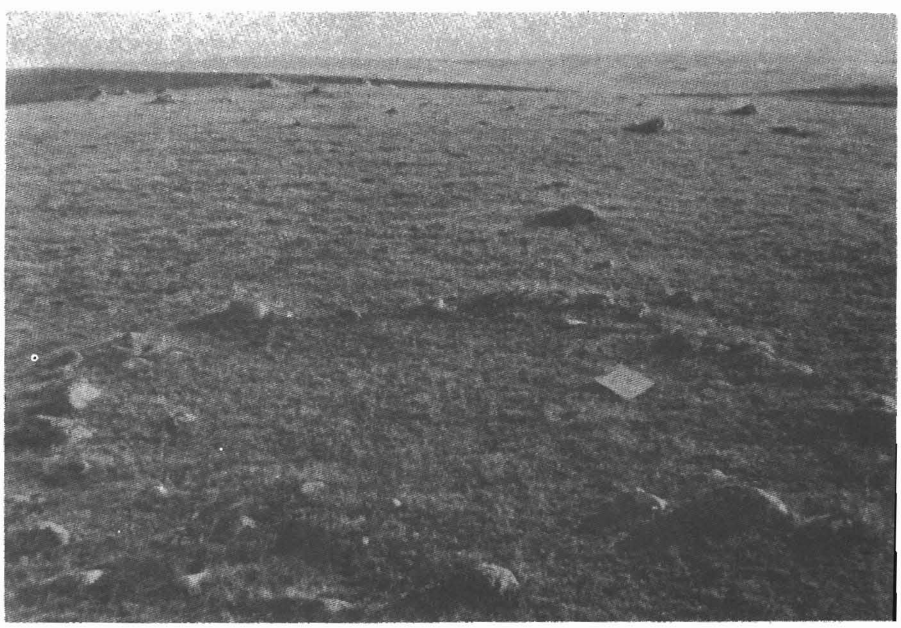


Figure 12. Photo of a tepee ring. These circles of stones date to times when Indians built tepees on the plains. The stones were used to anchor the hides, which covered the tepee. This tepee ring is near Turtle Lake in McLean County.

The seven counties included in this northwestern North Dakota Guidebook have lignite reserves estimated at 85 billion tons. Of this, approximately 3 billion tons is considered to be economically strippable. The entire state of North Dakota will produce approximately 15 million tons of lignite in 1981. If lignite conversion plants for the production of synthetic natural gas and hydrocarbon liquids become a reality, production will increase dramatically.

Vast deposits of salt, discovered during drilling for oil, lie buried beneath the northwestern North Dakota plains. The salt is recovered by injecting water into the salt bed and pumping out and processing the resulting brine. The salt is used chiefly in the chemical manufacturing industry for snow and ice removal and road base construction, for stock feed, for food preservation, as an additive in oil well drilling solutions, and in water softening. Potash occurs with salt in the Prairie Formation of Devonian age, but it is not mined at present in North Dakota. It occurs as the ore-rock sylvinite and is used primarily for agricultural purposes.

Other mineral resources include such things as peat, sulfur, sodium sulfate, uranium, and gem stones. Sand and gravel for highway construction, railroad ballast, paving and sidewalk construction, and buildings is found in association with the glacial outwash deposits and on terraces in the Missouri River valley.

REFERENCES

Bluemle, J. P., 1971, Geology of McLean County, North Dakota: North Dakota Geological Survey Bulletin 60 and North Dakota State Water Commission County Ground Water Studies, 19, 65 p.

Bluemle, J. P., 1977, The face of North Dakota–the geologic story: North Dakota Geological Survey Educational Series 11, 73 p.

Clayton, Lee, 1972, Geology of Mountrail County, North Dakota: North Dakota Geological Survey Bulletin 55–IV and North Dakota State Water Commission County Ground Water Studies 14–IV, 70 p.

Clayton, Lee, Moran, S. R., and Bluemle, J. P., 1980, Explanatory text to accompany the geologic map of North Dakota: North Dakota Geological Survey Report of Investigation 69, 93 p.

Clayton, Lee, and others, 1980, Geologic map of North Dakota: U.S. Geological Survey.

Freers, T. F., 1970, Geology and ground water resources of Williams County, North Dakota, part I-geology: North Dakota Geological Survey Bulletin 48 and North Dakota State Water Commission County Ground Water Studies 9, 55 p.

Freers, T. F., 1973, Geology of Burke County, North Dakota: North Dakota Geological Survey Bulletin 55–I and North Dakota State Water Commission County Ground Water Studies 14–I, 32 p.

Hansen, D. E., 1967, Geology and ground water resources of Divide County, North Dakota, part I-geology: North Dakota Geological Survey Bulletin 45 and North Dakota State Water Commission County Ground Water Studies 6, 90 p.

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

GEOLOGY BETWEEN WASHBURN AND THE MONTANA STATE LINE
(The Lewis and Clark Trail in Northwest North Dakota)

Travel west from Washburn. About three miles west of Washburn, on the edge of the Missouri River, the Fort Mandan Historic Site is being reconstructed (this is being written during the summer of 1973, so certain facts may be dated) by the McLean County Historical Society. The original site, which was destroyed by the shifting channel of the Missouri River, was about 14 miles west of Washburn on low land on the east bank of the river.

The Lewis and Clark expedition began cutting timber for their winter quarters November 2, 1804, and eighteen days later moved into Fort Mandan, the first military post in North Dakota. Members of the expedition visited the Mandan and Hidatsa Indians living in the area throughout the winter months and obtained some information about the lands farther west. During the winter, the explorers employed Toussaint Charbonneau, a Frenchman living with the Mandans, as interpreter. Charbonneau's captive Shoshone wife, Sakakawea ("bird woman"), later acted as a guide. Her role was significant in obtaining horses from the Shoshones with which to cross the Rocky Mountains.

Continue northward to Garrison Dam. Garrison Dam is one of the largest earth-filled dams in the world. It backs up Lake Sakakawea, which is nearly two hundred miles long. Guided tours of the powerhouse are available. A federal fish hatchery is located below the dam.

In the bluffs north of Riverdale are found some of the most outstanding exposures of glacial sediment in North America. Numerous layers of glacial till and gravel, representing successive glacial advances, are being excavated by wave action along the shore of Lake Sakakawea (fig. 4).

Continuing northward on U.S. Highway 83, cross the long causeway holding in the Snake Creek embayment. At the north end of the causeway, the pumping station, where water will be taken from Lake Sakakawea for the Garrison Diversion project, is being constructed (written in 1973). Water from Lake Sakakawea will be carried in an extensive canal system to eastern North Dakota for irrigation purposes.

Just south of the junction of U.S. Highway 83 and State Highway 37 are spoil piles of the Custer Coal Mine, abandoned in the 1940's. At the time this mine was operational, North Dakota had no laws governing the reclamation of spoiled land. Today, the State requires that spoiled land be reclaimed. The mining of lignite coal, of which North Dakota has vast reserves, is expected to drastically increase as large amounts are used to produce electricity and gas for consumers to the east.

West of Garrison the highway crosses several deep valleys. These valleys once carried large rivers of water from the melting glacier a few tens of miles to the north. This 35-mile, east-west stretch of Highways 37 and 1804 parallels a part of the Missouri River valley that coincides with a preglacial valley. The broad, preglacial valley continued eastward where the Missouri valley today turns southward near Riverdale. East of Riverdale, the preglacial valley is buried beneath thick glacial sediments, although a part of it coincides with the Snake Creek Embayment.

White Shield, the eastern segment subagency of the Fort Berthold Indian Reservation, consists of a school that serves both Indian and non-Indian children. The Fort Berthold Indian Reservation, with Mandan, Arikara, and Hidatsa Indians, covers parts of five North Dakota counties.

Highway 1804 turns north 13 miles west of White Shield. Deepwater Creek Bay, six miles north of the turn, is apparently a part of an old valley that is buried beneath glacial deposits east of the highway. The buried continuation of the valley passes beneath the White Shield area.

The effects of glaciation become gradually more apparent north of Deepwater Creek Bay so that, by the time you reach the McLean-Mountrail County line, the landscape is typical glaciated terrane. This is reflected in somewhat better farmland, small, closely-spaced hills, and numerous small sloughs and ponds.

At Parshall, the Paul Broste Rock Museum features rock and crystal displays from throughout the world, housed in a building constructed of glacial erratics.

Traveling west toward Newtown, notice the broad bay of Lake Sakakawea, known as the Van Hook arm. This bay marks the location of the Missouri River prior to the most recent glaciation. The river flowed east around the north side of Newtown and south through the Van Hook arm. The glacier blocked the river's flow here and forced it to flow south a few miles west of Newtown.

Newtown was built on high land when the villages of Sanish and Van Hook were flooded by the waters of Lake Sakakawea after Garrison Dam was constructed. Travel north on Highway 1804 out of Newtown.

A few miles north of Newtown the broad valley is partly filled with glacial deposits, rather small hills that cover the bottom of the larger preglacial valley. These glacial deposits prevent the Missouri River from flowing through the valley as it did prior to the last glaciation.

At about mile 253 (mile markers along the road), notice the bright-colored clayey and sandy layers of the Golden Valley Formation, which was deposited in lakes and rivers in latest Paleocene and early Eocene time.

At mile marker 259 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 slid and slumped, resulting in a rough landscape of relatively high relief such as you see here. Notice the numerous potholes and small lakes. The dead-ice moraine continues for about ten miles.

The White Earth valley (mile 275) carried large quantities of water southward from the melting glacier.

The oil wells in this area are in the Capa and Hofflund Oil Fields. Oil is taken from rocks of Mississippian age here. This area is known as the Nesson anticline (fig. 1).

The broad, flat area ahead is Hofflund Flats. It is a valley that existed before the State was glaciated and the Little Missouri River flowed northward through the valley into Canada before the glacier diverted the river to the east. The exposures of sediment are Tongue River Formation silt and sand layers.

The Lewis and Clark Recreation area is at about mile 301. If you follow the side road south to the recreation area, you can see several exposures of Tongue River Formation sediments, petrified wood, lignite, and scoria.

Continue west through Williston on Highway 2. Williston is located at the mouth of Little Muddy Creek, which is a small south-flowing stream. The valley that carries Little Muddy Creek was a north-trending drainage before the glaciers blocked it.

Turn south toward Fort Buford 2.5 miles past the junction of U.S. Highways 2 and 85. The Missouri and Yellowstone Rivers meet at the site of Fort Buford. Fort Buford was active from 1866 to 1963. Prior to its construction, a trading post was active on the same site; Fort William was erected in 1833 and Fort Mortimer in 1843. Fort Union was established in 1828 by Kenneth McKenzie of the American Fur Company as a trading post, and dismantled in 1867 to help expand Fort Buford. Fort Union Trading Post was the largest and most imposing trading post on the Missouri River. It was on the north bank, about 25 feet from the river and about six miles from the mouth of the Yellowstone, flowing into the Missouri from the south. Around it was prairie that gave way on the west and north to rolling hills and bluffs. Up and down river from the fort were river bottomlands having a heavy growth of cottonwood, ash, and elm—timber necessary for building and maintaining of the fort.

The extensive exposures of sediment of western North Dakota have been named the Fort Union Formation, after old Fort Union. We now refer to the Fort Union Group of formations, which includes the Cannonball, Tongue River, and Sentinel Butte Formations.

GEOLOGIC ROADLOG FOR THE WILLISTON AREA
(total distance about 55 miles)

Distance Between Points (miles)

The surface geology of the Williston area is quite complex, because it combines several preglacial features, ranging from Paleocene coal deposits to badlands and deep valleys that existed just prior to glaciation, with glacial modifications. Any field trip to observe the geology must necessarily jump from one thing to another and the student must be alert to the rapidly changing scene. Williston itself is located in the valley of Little Muddy Creek, now a bay of Lake Sakakawea. This valley, which carries the south-flowing Little Muddy Creek, is actually a preglacial valley that once carried a large north-flowing river (perhaps an ancestor of the modern Yellowstone River) into Canada. This is why the valley is much larger than a stream the size of Little Muddy Creek would normally require.

Begin the field trip driving east on State Route 1804 at the corner of Broadway and University Avenue. You are driving over a flat gravel surface that was deposited during glaciation by water flowing southward through Little Muddy Creek and Stony Creek valleys from melting ice north and northeast of here.

0.8

Cross Williston Levee of Lake Sakakawea.

0.1

Cross bridge over Little Muddy Creek bay.

0.4

Oil refinery on the right.

0.7

Hardy Salt Co. plant to the left.

0.3

Mileage marker 316. Climb out of Stony Creek valley. Note the exposures of Paleocene bedrock along the road and coal exposures a short distance farther on. The lignite here is about five feet thick.

0.9

The boulders in the fields show that a thin cover of glacial sediment lies on top of the Paleocene bedrock in this area.

1.2

Mileage marker 314.

3.0

Mileage marker 311. This rather hilly area was probably somewhat more hilly before it was glaciated. The glacial sediment seems to be draped over the hills to a fairly uniform thickness although it is somewhat thicker in lower areas. Thus, although the Missouri River did not exist before the glaciers came, there was probably a deep valley in its position here and badlands development had already begun before it was arrested by the glacier. After the glaciers melted, badlands development was renewed, probably at an accelerated rate near the Missouri River. We will see fresh badlands topography on this field trip.

2.6

Turn south at Lake Jessie corner. Glacial sediment overlying Paleocene bedrock can be seen just south of the corner. The glacial sediment is stony and relatively dark-colored compared to the bright, stone-free bedrock surface. Several exposures of glacial sediment can be seen along this road.

0.3

STOP 1. Exposures of glacial sediment. At this location, the glacial sediment is lying on top of a thin bed of coal so the contact between the coal and the glacial sediment represents about 60 million years that is not represented by any kind of material. We call such a break an *unconformity*. The glacial sediment, known also as *till*, is a clayey groundmass that contains abundant pebbles and cobbles and, in places, boulders. These include granite, chert, limestone, sandstone, and others.

2.7

Turn east where the north-south road ends.

0.8

Road curves to the south.

2.1

Continue southward across the cattle guard. We will descend into a badlands area to see a scoria pit. As we travel to the pit, note the ecology of the area. The road to the pit is exceptionally interesting, a wooded badlands area. Notice that the vegetation density is greater in some places than others. Trees follow draws and grow best on north-facing slopes. Bedrock is well exposed and the horizontal bedding is apparent. We will be stopping later to examine several specific aspects of this bedrock, but in the meantime, try to get an overall "feel" for the layering and the badlands topography.

0.3

Begin the descent of the hill (shift into low gear). Till is exposed at the top of the hill.

1.0

Cross cattle guard. Notice the horizontal layering in the bedrock and the differences in color among the various layers. The bluer layers tend to contain more clay, while the tan layers are sandier. The horizontal, reddish-brown layers (not the scoria) are ironstone.

0.4

Cattle guard.

0.4

Fork in road. STOP 2. Walk up the left fork to the top of the hill containing the scoria pit. The scoria here is of all types, reflecting the intensity of baking. In places it has fused and run like liquid. Certain portions of the pit look as though they were particularly efficient at conducting heat upward and these "columns" are more vivid shades of red or they are fused somewhat more. Notice the jointing that developed in the rock as it cooled. Can you explain this?

Turn around and return two miles unless you decide to utilize STOP 3, which is optional.

0.5

OPTIONAL STOP 3. A half hour spent clambering over the hillside, especially on the east side of the road, will probably turn up several items of interest. Watch for petrified wood, fossil oyster shells, large ironstone concretions, selenite crystals in the lignite beds. Notice the differences in the various horizontal layers. The popcorn-like surface you find in places is due to shrinking of bentonitic clays. WARNING! Be careful on these slopes, as they are steep and, if you step on loose rock, you may slip down a considerable distance.

0.5 Cattle guard. Turn east.

0.7 STOP 4. Gravel pit on the north side of the road. The gravel in this pit was deposited by water flowing from melting glacial ice. If the pit has been mined recently, you should be able to see the water-lain bedding—similar to that of the bedrock, but of much coarser material and much more recent in age. Look for granite, limestone, chert, agate, sandstone, and scoria cobbles as well as others.

1.1 Turn north on Williams County Road 42.

3.0 Valley of Long Creek. Watch for good exposures of glacial till overlying bedrock from here to Highway 1804.

2.2 Junction with State Highway 1804. Turn east.

4.1 Turn south toward Lewis and Clark Recreation Area.

0.7 Exposures of glacial sediment on the right side of the road.

0.2 Coal and gray siltstone on the left. Notice the rill pattern in the siltstone.

0.1 More coal on the left. Notice the boulders on the south end of this hill. These are glacial erratics.

0.3 STOP 5. Coal is exposed in the cut along the road. Tongue River Formation bedrock is exposed above and below the coal and till can be found at the top of the roadcut. Look for sulfur in the coal. The contact between the bedrock and the till is good here, affording an opportunity to see an outstanding unconformity.

0.5 Coal exposures. Pieces of partially petrified wood can be found with the coal here. It has a contorted appearance. You might be able to find leaf fossils too. The brownish cast of some of the coal is due to weathering; sufficient weathering transforms the coal to leonardite. This location is a possible stop if time allows.

0.6 Road to camping area.

0.1 STOP 6. On the left is scoria that is rather soft as it was not highly baked. Observe the variation in hues; these depend on both the composition of the material being baked (finer materials generally acquire deeper hues than do coarse ones, and the chemical composition contributes to variations in coloration) and intensity of heating. Walk to the top of the second ridge, the one overlooking the valley of Gamanche Creek. This ridge has harder rock at its crest than does the one nearer the road. It appears to be a partially baked sandstone. Notice the abundance of ground cedar in this area. Notice the meandering coarse of Gamanche Creek, the valley of which is now partially flooded by Lake Sakakawea.

On the west side of the road is unbaked sand, the same material as that which is baked east of the road. Notice the several light gray concretions. The orange bands are generally due to iron coloration, not baking, although some baking has occurred at the north end of the exposure. Observe the differing erosion patterns on the surface west of the road in contrast to that east of the road; the differences are due to differences in the hardness of the material. The material west is somewhat harder, due to baking. In the distance, in the steeper exposure a short distance to the southwest, can be seen some large concretions.

0.2

STOP 7. Abundant pieces of petrified wood are scattered over the surface in this area. The petrified wood has a whitish color from a distance. This petrified wood is partially coalified. If you break some of the pieces open, you will find coal inside.

0.3

Junction with road at recreation area. End of roadlog.

GEOLOGIC ROADLOG BETWEEN PORTAL AND MINOT, BURKE AND WARD COUNTIES
(total distance about 96 miles)

Distance Between Points (miles)

Begin roadlog at Portal, North Dakota. Drive south from Portal on U.S. Highway 52.

1.5

The oil wells in this area are in the Portal Field and produce oil from rocks of Mississippian age at a depth of about 4000 feet. This relatively flat area is covered by glacial deposits that are about 400 feet thick. The glacial sediment was deposited at the base of the moving glacier, and the resulting landform is ground moraine.

2.4

The high land on the south to southwest horizon is the Missouri Escarpment, which separates the Drift Prairie, the area you are on here, from the Missouri Coteau, the higher, more hilly land south of the escarpment. The Missouri Coteau is characterized by dead-ice moraine (see text).

3.7

Junction U.S. Highway 52 and State Route 5. Turn east, traveling over ground moraine that is slightly more rolling than that over which you have been traveling. The oil wells here are in the Lignite Field and produce from Mississippian age rocks at a depth of about 4100 feet.

7.1

Flaxton. Just east of Flaxton is a broad, shallow slough that occupies a valley that once carried melt water northeastward from melting stagnant glacial ice on the Missouri Coteau.

6.0

Junction of U.S. Highway 52 and State Route 5 with State Route 8. Continue eastward.

1.7

Mile marker 22. This area is still ground moraine, the glacial deposits here about 400 feet thick. The area between Lignite and Flaxton was covered by glacial deposits that are between 100 and 200 feet thick.

5.2

Junction of U.S. Highway 52 and State Highway 8 in Bowbells. Continue eastward on 52. The numerous small valleys throughout this area carried melt water generally north and eastward from the Missouri Coteau.

4.0

Burke-Ward county line.

1.3

Des Lacs Lake. The Des Lacs Lake occupies a large melt water trench that carried water from the melting glacier in Canada to Lake Souris in north-central North Dakota. The size of the trench suggests that large volumes of melt water flowed in it.

4.5

The small valleys in this area are melt water trenches. This area is ground moraine. The glacial sediment is about 400 feet deep.

5.4

Kenmare.

2.2

The large valley on the west (to the right) is the Des Lacs valley.

3.1

The small valleys here are the result of headward erosion from the Des Lacs valley since the end of the ice age.

0.8

Mileage marker 48.

1.3

Drive down into the Des Lacs valley.

1.5

Railroad overpass. The occasional bare areas are exposures of preglacial bedrock, the Paleocene Tongue River Formation.

3.2

Junction U.S. Highway 52 and State Route 50. Continue southeastward on U.S. 52.

2.8

Tongue River Formation bedrock is exposed along the road in several places.

2.1

Donnybrook.

1.6

In some places along the edge of the melt water trench, on the hills that form its sides, are rather extensive accumulations of gravel. This gravel was deposited there by the river that cut the melt water trench, at a time when the valley had not yet been cut to its present depth. The level at which the gravel is found is known as a terrace, and it is a remnant of the old river bottom.

1.1

Ward-Renville county line.

5.2

Renville-Ward county line.

1.4

Junction of U.S. Highway 52 and State Route 28 in Carpio. Continue on Highway 52.

4.9

Notice the gravel pits in the low, gravel terrace on the left.

3.3

Gravel exposures on the right.

0.4

Foxholm.

4.1

Drive off the valley floor up onto a gravel terrace.

0.2

Descend onto the floor of the valley again.

1.2

Junction U.S. 52 and U.S. 2.

4.9

Burlington.

1.3

Gravel pits on the right.

3.4

Farmers Union Minot Terminal oil storage. Mile marker 143.

1.4

Overpass. Climb out of valley on bypass.

2.2

Junction U.S. Highways 52, 2, and 83 south of Minot. End of roadlog.

GEOLOGIC ROADLOG FOR MOUNTRAIL AND BURKE COUNTIES
(total distance about 66 miles)

Distance Between Points (miles)

Roadlog begins at the junction of State Highways 23 and 8, seven miles east of Newtown. Drive north. This is steeply rolling glaciated terrain. The gullies are the result of headward erosion from the nearby Missouri River trench. Notice the numerous boulders, glacial erratics, in the area.

5.5

At highway mile marker 137, cross one of several small valleys that carry water southward to the Missouri River.

2.0

This area is a good example of a glaciated landscape, characterized by hummocky, closely-spaced hills and constructional topography that was built up by the glacier. Continuing to the north, the landscape becomes even more typical of dead-ice moraine.

5.1

Beldon.

3.1

Notice the numerous sloughs in the area. Undrained land is typical of dead-ice moraine.

7.6

Little Knife River valley. This valley carried water southwestward from the melting glacier.

1.4

Stanley.

0.6

Junction of U.S. Highway 2 and State Route 8 in Stanley. Turn north (right) on 8.

0.6

Mountrail County Courthouse.

0.5

Junction of U.S. Highway 2 and State Route 8 north of Stanley. Continue north on 8.

2.8

Cross a broad valley. White Lake is to the west. This valley is probably a large kettle hole, formed when a buried block of stagnant glacial ice melted, causing the overlying materials to slump down.

0.5

The rolling area here is a lake plain composed of silt and clay. When the large block of stagnant ice melted, the silt and clay that had been deposited in the lake slumped down, forming the rolling landscape present here today.

2.2

Large kettle hole, formed in the same way as the kettle that contains White Lake. The steep sides around the kettle hole are typical; they resulted when the glacial sediment dropped straight down as the buried block of ice beneath melted.

5.1

Lostwood. The gravel pits to the left are in glacial outwash that was deposited by water flowing from the melting glacier.

1.0

Back on glacial sediment (till).

2.2

This area is an exceptionally good example of dead-ice moraine, with numerous sloughs, closely-spaced hills, and abundant surface boulders.

1.9

Junction of State Routes 8 and 50 (to the east). Mountrail-Burke County line. Continue northward on Route 8 over dead-ice moraine.

2.2

Mile marker 175. This area is still dead-ice moraine, typical of the topography found on the Missouri Coteau.

8.9

At this point you descend the Missouri Escarpment, which marks the boundary between the Missouri Coteau and the Drift Prairie. Notice the drastic change in topography, from hilly dead-ice moraine to relatively level ground moraine. After you have traveled north a few miles, look back at the Missouri Escarpment.

5.8

Coteau. This area is ground moraine, composed of glacial sediment (till).

4.0

The hills about a mile north of the highway are spoil piles, left from coal mining. Lignite coal, of Paleocene age, underlies this area, but it is economical to mine it only in areas where the overburden is not too thick.

2.4

Bowbells.

0.9

Junction of U.S. Highway 52 and State Routes 8 and 5. End of roadlog.

GEOLOGIC ROADLOG FOR EASTERN McLEAN COUNTY
(total distance about 33 miles)

Distance Between Points (miles)

Start mileage at the Farmers Union Service Station in Turtle Lake, North Dakota. Drive east. This area is covered by glacial sediment (till).

0.1

Turn north on McLean County Road 27.

0.4

Turtle Lake sewage lagoon. An effective and safe lagoon should be located in impermeable material such as till. Till is exposed on the right side of the road.

0.4

Garrison Diversion canal.

0.6

Road curves to the right. This area is dead-ice moraine. Till is exposed in most places.

1.8

Prophets Mountains to the east. Road curves to the north.

0.3

STOP 1. Good exposure of typical till in roadcut. This till is compact. Notice the composition of the pebbles and cobbles (limestones and dolomites are the predominant pebble types along with various igneous types). Considerable shale suggests deposition from the northeast for this till. Watch for striated cobbles and pebbles (rocks that have scratches that were made by the glacier).

1.0

Till exposures in the roadcuts.

1.1

Junction with McLean County Road 9. Continue northward on Route 27. Dead-ice moraine of medium relief.

1.8

STOP 2. Stop at the roadcut south of the farm. Here can be seen gravel that was deposited by water flowing from the north. Gravel is extensive in the area a few miles east of here. It was deposited on top of stagnant ice, and when the ice melted the gravel slumped down, forming rolling relief. At this location, the water that deposited the gravel flowed in a valley from the northeast. Notice the composition of the gravel, which is fairly clean with little silt and clay.

0.2

Junction with McLean County 10. Continue northward. Notice the large amount of gravel in this area. Collapsed outwash area. Notice the lack of boulders on the surface.

0.9

Cottonwood Lake to the east.

0.5

Back on dead-ice moraine. Notice the boulders on the surface and the hillier topography than before.

1.7

Junction with McLean County Route 8. Route 27 turns east. Continue northward on dead-ice moraine.

0.6

Drive onto flat, boulder-free, elevated lake plain. At the time the lake existed, stagnant ice that occurred in the area surrounded the lake and kept it from draining. If you dug a hole in the lake plain, you would find silty clay. Notice the absence of boulders on the lake plain. This lake plain continues for about a mile.

1.3

Turn east, continuing over the lake plain for about a half mile.

0.5

Drive off the lake plain back onto dead-ice moraine with medium relief.

0.5

Turn north, continuing over dead-ice moraine.

2.1

Turn east, continuing over dead-ice moraine on McLean County Route 6.

2.0

Turn north on McLean County Route 6N. This area is dead-ice moraine. Notice the numerous glacial erratics in the fields.

2.0

The main road turns to the east here. Drive north on the trail for about 0.3 mile to the gravel pit.

0.3

STOP 3. Small gravel pit in an esker. This esker trends southwestward. It has a ridge-shaped configuration that is not too easy to see from this point (to observe the overall configuration requires a view from above). Notice the large cobbles and boulders that were transported by the melt water stream that formed the esker. Return to the main road and drive east.

1.8

Road curves around the slough.

1.5

Road curves to the north.

1.2

Junction of McLean County Routes 6N and 31. Continue northward on 31.

1.4

Road curves to right around lake.

2.7

Begin descent down the Missouri Escarpment. Notice the change in topography from dead-ice moraine to ground moraine, which is much less rugged. The large hill to the west is Dogden Butte. Dogden Butte is a huge block of material that was moved southward by the glacier from a short distance to the north. Similar features are present elsewhere in North Dakota. In many cases, a large block of material has been moved a short distance, usually less than a mile, by the glacier, resulting in a depression on the side of the hill from which the glacier came. A test hole drilled in Dogden Butte penetrated (from the top downward) 100 feet of glacial till, 212 feet of Tongue River Formation bedrock, 44 feet of till, sand and gravel, and then bedrock to the bottom of the hole.

1.3

Junction with McLean County 2. Turn east toward Butte.

2.8

Butte. End of roadlog.

GEOLOGIC ROADLOG BETWEEN NEWTOWN AND MANDAREE
(total distance about 32 miles)

Distance Between Points (miles)

Begin trip at the junction of North Dakota State Highways 23 and 1804 in Newtown. Drive west on 23. Notice the numerous exposures of Sentinel Butte Formation bedrock that can be seen along the highway.

1.7

Mileage marker 48. Large granite boulder on the north side of the highway. This is a glacial erratic that was carried here from Ontario by the glacier. Notice how the introduced grasses, sweet clover, and native rabbitbrush and sage over the roadcuts along the highway help to keep the soil in place.

0.2

Several glacial erratics on the ridge north of the highway.

0.2

Notice the slumping in the banks along the highway. Such slumping results when the roadcuts are constructed too steep.

0.6

Road to historical marker to the north at mileage marker 47. Drive to the top of Crow-Flies-High Butte, taking note of the glacial erratics on the road up the hill. STOP 1. The historical marker sign at the top of the butte is made of many different types of field stone, all glacial erratics. They include igneous, metamorphic, and sedimentary rocks such as granite, gneiss, and limestone. All of these rocks were carried here by glaciers from sources in Canada. The large boulder at the top of the parking lot is partly metamorphosed granite.

The Missouri River (now Lake Sakakawea) at this point makes a turn southward. It flowed eastward through the broad, low sag north of the observation point before it was diverted to its present route by the glacier. Glacial drift, till, and gravel block the old route of the river, which continued past Newtown and through what is now the Van Hook Arm of Lake Sakakawea.

Return to the highway. Notice the hard, boulder-like concretions in the bedrock on the south side of the road at mile 47. Notice too, how cottonwood trees, buffaloberry, wolfberry (buckbrush), and other shrubs mark the watercourses.

0.2

Lignite coal exposed on the left.

0.2

East end of the Four Bears Bridge over Lake Sakakawea.

0.9

West end of the Four Bears Bridge. The gravel on the north was deposited on the terrace you are now on while the Missouri River was being diverted.

0.7

Good exposures of bedrock along the highway. Notice the crust of sodium sulphate salt that forms on the surface in dry weather.

0.5

STOP 2. Abundant glacial erratics. Thin glacial drift lies on the bedrock topography in this area. Headward erosion from the Missouri River accounts for much of the relief. In the field to the left is native shortgrass prairie. Can you identify the grasses? What other native grassland plants do you find? Can you identify some of the introduced plants?

4.8

Antelope Oil Field. This is part of the Nesson Anticline, which is North Dakota's most important oil-producing area. Oil is produced in this area from three horizons of Mississippian and Devonian age. Wells range up to about 10,000 feet deep. As of January 1, 1974, over 26 million barrels of oil and over 47 billion cubic feet of natural gas had been produced from the Antelope Field.

Notice the scoria road metal in the area.

0.8

Junction of Highways 22 and 23. Turn south on Highway 22. Mileage marker 157. As you drive southward on Highway 22, you will cross several deep valleys, all of which were formed by headward erosion from the Missouri River trench.

0.6

The buttes on the southern and southwestern horizons are outliers of hard sandstone of the Golden Valley Formation, which lies on top of the Sentinel Butte Formation.

1.9

Begin descent into Clarks Creek Valley. Notice the exposures of Sentinel Butte Formation bedrock in the roadcuts and the badlands topography in the valley. The popcorn-like surface in places is caused by a loose surface mulch that develops when the bentonitic clays shrink as they dry.

1.0

Cross Clarks Creek. Can you identify the boxelder, ash, maple, and elm trees?

0.2

Lignite exposures on the left.

0.2

Massive, hard sandstone exposure on the right.

0.4

Drive onto the upland again. The prairie is farmed to the east and almost undisturbed on the west.

0.6

Begin descent into the valley. Notice the tubular, orange-colored channel sands to the east.

0.1

STOP 3. Mileage marker 152. Park the car in the ditch and walk down into the valley. Look for the birch trees. Notice also the elm, willow, oak, boxelder, and aspen trees in the valley. On the east look for iron concretions.

0.1

Channel sand deposit on the left.

0.9

Scoria exposure on the right. Notice the color contrast between the sage and the trees.

3.0

Mileage marker 148. Blue Butte on the left. Large boulders of sandstone that have fallen from the caprock on top of the butte lie on the butte slopes. The caprock on this particular butte is apparently a channel sandstone of the Sentinel Butte Formation. The top of Blue Butte is approximately 400 feet above the highway.

1.7

Begin descent into Bear Den Creek valley. Notice the good exposures of sandstone on the way down. Notice how the vegetation pattern is controlled by various zones in the slopes. On the right how many trees can you identify? Why are they so large in this area?

0.9

Scoria exposed on the left.

0.2

Lignite exposed on the left.

0.5

Landslide area.

0.4

Bridge over Bear Den Creek.

0.5

Notice the exposures of Sentinel Butte Formation bedrock in the badlands topography of the valley ahead.

1.0

On the roadcut to the east, notice the plants, especially sage, beginning to grow on fresh roadcut.

1.2

Junction of North Dakota Highways 22 and 73. Continue southward.

3.0

Cross-bedded sandstone.

0.4

Turn east toward Mandaree.

0.5

Occasional glacial erratics occur in the fields here. This area has scattered patches of thin glacial till on top of the bedrock. The area is near the edge of the early Wisconsinan glacial limit. The early Wisconsinan glacier apparently advanced as far as the Little Missouri River about 10 miles to the south, although it covered broad areas southeast of here. Prior to the advance of the glacier, the Little Missouri River flowed north into Williams County, but the glacier diverted it eastward.

0.8

Turn south into Mandaree.

0.5

School. End of roadlog.

GEOLOGIC ROADLOG FOR THE MINOT AREA
(total distance about 54 miles)

Distance Between Points (miles)

Trip begins at the junction of U.S. Highways 2, 52, and 83 at the south side of Minot. Drive south on U.S. 83. Minot is located in the Souris River valley, a large melt water trench that carried water to glacial Lake Souris at the end of the ice age.

1.5

This valley is a gully that was eroded back from the Souris River valley since the end of the ice age.

0.5

Typical ground moraine of the Drift Prairie. This area of glacial deposits is gently rolling, except near gullies, and characterized by numerous sloughs. The sloughs resulted when chunks of ice became buried in the glacial sediment as the glacier rode over the area. When the chunks of ice melted, after the glacier had left, depressions resulted where the ice chunks had been. The glacial sediment in this area is generally between 100 and 200 feet thick, but of this probably only the upper 5 to 15 feet was deposited by the most recent glacier; the lower glacial sediments were deposited by earlier glaciers.

1.5

This gully has some alluvial fill on its floor, material that has washed into the valley from nearby hillslopes. Note that the trees grow better on the alluvium, which retains water better than the slopes, which are glacial till.

4.4

Mileage marker 191.

4.3

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

2.2

Entrance to 786th Radar Squadron installation. The location of this radar installation is governed by the geology; the Missouri Coteau here is the highest point around.

1.8

State Highway 23 to Newtown. Continue southward on U.S. Highway 83 over dead-ice moraine topography.

0.5

Notice the series of lakes along the west side of the highway. These lakes occur in an elongate depression that probably coincides with a valley that was partially filled, and thereby blocked, by glacial deposits. This area is typical dead-ice moraine.

1.4

Mileage marker 181.

1.2

Turn east on Ward County Road 22.

0.4

STOP 1. The roadcut at the top of the hill exposes glacial till. Here you can observe the mixture of large and small pebbles and cobbles in a groundmass of silt and clay that constitutes typical till in this area. Dig back a few inches to expose fresh material. Till was deposited at the base of a moving glacier and at its margin. It consists of materials that were carried in the ice and ground up by grinding within the moving glacier.

0.1

This is typical dead-ice moraine topography. The hills are closely spaced, there is no drainage except locally, and potholes are abundant.

1.8

Gravel pit on the south side of the road. The gravel here contains considerable silt and clay and its quality is poor. Notice the bedding in the sand and gravel if any fresh excavations are available.

0.3

Small man-made dam on the north.

0.6

Ahead of you, to the east of here, is a broad, low valley that is about five miles across. This broad valley is probably a preglacial valley that was blocked by the glaciers and partially filled with glacial drift. The valley trended to the northeast.

2.9

Lowermost elevation of the above-mentioned valley along this road. A small, intermittent stream valley marks the bottom of the broader preglacial valley in this area. This small valley probably acted as a melt water route, carrying water from melting ice on higher ground to the south.

0.9

Junction with County Road W21. Continue eastward on W22.

0.7

Small melt water trench. Glacial till is exposed just east of the valley in a roadcut on the south.

1.9

Good dead-ice moraine topography.

0.4

Junction with County Road 23. Turn north.

0.4

Drive down the Missouri Escarpment off the Missouri Coteau.

1.3

Spoil piles on the left (west). Road curves to the right.

0.7

Exposure of reddish scoria on the left (west) in the cliff. The scoria is sediment that was baked by burning lignite, in this case the same bed that can be seen across the valley on the left. The term "scoria" is a misnomer, for true scoria is of volcanic origin. This material is more correctly termed "porcelanite," but since the word scoria is widely used in this area, it is used here.

0.2

STOP 2. Stop to observe scoria on the left across from bedrock cut on the right about halfway down the hill. This scoria consists of baked glacial sediment, that is till. Most scoria consists of baked preglacial sediment, or bedrock, and baked till is not common. Notice that the larger particles, pebbles and cobbles in the till, were not altered by the baking, only the silt and clay.

On the east side of the road is an exposure of Tongue River Formation bedrock with a bed of coal at the base.

0.2

STOP 3. Coal bed. Stop and dig into the lignite. This lignite bed is about 12 feet thick, although only about 6 feet is apparent here, the remainder covered by slumped debris from above. This coal bed burned in nearby areas, causing the nearby sediments to bake, resulting in the scoria found in several places (last stop). Consolidation Coal Co. is mining the coal in their mine a short distance from here.

0.2

Large roadcut exposure of Tongue River Formation sand and silt. Notice the hard layer of sandstone near the base of the exposure.

0.2

Melt water trench. The flat bottom in this valley is the result of a fill of washed in (alluvial) material.

0.1

Junction with Ward County Route 20. Till exposure on the right.

0.9

Junction with Ward County Route 20. Continue north on paved Route 23. This area is ground moraine again with a till cover that is generally less than 100 feet thick. Till is exposed in the ditch cuts in places.

2.1

Junction with Ward County Route 18. Till exposure at the corner. Continue northward on Route 23.

0.3

Valley. This melt water trench has a flat floor, the result of a deposit of alluvium—sand and silt. This alluvium acts as an aquifer (water-carrying material) and the resulting high water table has provided a good environment for trees and shrubs. The presence of willows is a good indicator of a high water table.

3.9

Descend into the Souris River valley. As you drive into the valley, notice the large gravel pit to the left across the highway. This gravel pit is on a terrace, an old level of the river that dates to the end of the ice age.

0.4

STOP 4. Large exposures of glacial till on the right (east). This exposure has several layers of till interlayered with sand. Notice the chunks of coal in the till and the various other cobbles and pebbles, which help to show its origin. Look for striated cobbles (rocks that have been scratched by the glacier).

0.3

Junction with U.S. Highway 52. Turn left (northwest) toward Minot. The hilly topography on the left as you turn the corner is landslide topography.

4.9

Landslide topography on the left. Landslides are large or small earth slippages due to an unstable conditon created by erosion of the foot of the slope or by water lubricating the plane along which the slippage can take place. Landslides are usually found along valley walls and are characterized by hummocky topography.

1.0

Road to Logan on the right. The Souris River valley, through which we are traveling, was carved in Pleistocene time, but probably prior to the last glaciation. We can infer this by noting that till covers the bedrock walls of the valley and underlies the valley fill, which is about 100 feet or more thick.

0.2

Drive out of valley onto upland. Second road to Logan. This area is ground moraine that has been dissected by headward erosion from the Souris River valley, just to the north.

2.2

Bell School.

2.6

Drive onto a gravel terrace. The gravel here consists of sand and gravel with boulders up to eight feet in length. The boulders suggest that this may be a terrace that was bordered on the north by glacial ice. It may have been formed by a stream flowing in a valley at the edge of the ice in the valley and the valley wall.

0.6

Junction with U.S. Highway 2. Gravel pit on the left.

2.1

Junction U.S. 2, 52, and 83. End of roadlog.

NATURAL SCIENCE OF THE WHITE SHIELD AREA
(total distance about 32 miles)

Distance Between Points (miles)

Start trip at White Shield school, driving south from the school on the paved road. For approximately the first three miles you will be driving over glaciated bedrock topography. The cover of glacial drift in this area is only a veneer. Notice the presence of a few boulders on the surface. These are conclusive evidence of glaciation.

0.9

White Shield Complex on east side of road.

0.2

Turn east (left). Notice the plowed fields, or wheat stubble in winter and the growing wheat in early summer. Large irrigators in the field ahead of us use water from wells that are drilled into the glacial deposits, aquifers composed of sand, gravel, and sandy till. The water table is close to the surface in the area through which you are driving and, in some places, ponds indicate that the water table is intersected. The average rainfall in the area is 17 inches per year.

1.3

STOP 1. Enter the windbreak to the east (left). Can you identify Douglas fir, blue spruce, boxelder? What other trees and shrubs do you find? Which of these could have been taken from beside neighboring streams? Which do not naturally grow in this area of McLean County?

Windbreaks provide natural shelter for wildlife. In winter, try to identify animal tracks that you will see. In summer, watch for these birds (and for their nests): western meadowlark, eastern kingbird, red-winged blackbird, lark bunting, chestnut-collared longspur, field sparrows, bluejays, and brown threshers.

0.1

We are driving through a broad low area. Note the presence of willows, cottonwoods, and other water-loving plants throughout this low area. They are indicators of a water table that is close to the surface.

0.6

Turn north (left) on gravel road.

0.1

Drive down into the broad, poorly-defined valley of the West Branch of Douglas Creek. This valley, or sag, apparently coincides with an ancient pre-glacial feature, perhaps a valley that carried a large stream before the area was glaciated. Several sloughs and lakes, including Blackwater Lake, occur in the sag. The glacial drift cover is much thicker in the sag than on the uplands to the north and south.

1.7

Road curves to northwest (left).

0.1

STOP 2. This is an excellent place to study natural history because it is native, although grazed, prairie. The cattle in this field grow fat on such mid-grasses as little blue-stem, needlegrass, June grass, prairie dropseed and side-oats grama. (An introduced grass, Kentucky bluegrass, also grows here.) These grasses ripen, or cure, on the stem. The buffalo that filled the biological niche now occupied by cattle grew fat on these same grazing lands.

Besides grasses, can you identify plants with composite flowers, such as salsify, the prairie rose, and the Woods rose? Can you find members of the pea family (legumes) such as Indian breadroot, clover (an introduced plant) and some of the sages?

This slough is a small pothole, formed when a block of buried glacial ice melted, causing the overlying materials to slump beneath the level of the surrounding land. Note the cottonwood trees and willows on the shores. Red-winged blackbirds live among the cattails at the pond's edge. The area north of here is part of an "end moraine" that formed at the margin of the glacier. The glacier covered the area north of here and its margin trended northeastward from here. Notice the change in topography as you drive over the end moraine. The closely-spaced, small hills are the result of materials being dumped at the edge of the glacier.

0.4

STOP 3. Road straightens out to north. Notice the increased abundance of boulders on the surface and the hummocky terrain, both typical of end moraine. Stop at small knob on the right to look at an exposure of typical glacial sediment (till). Notice the variety of textures ranging from clay-sized particles to boulders.

0.8

Turn west (left) on McLean County Road 6. To the southwest is the broad sag we have crossed. Note the rugged relief on the Hill farm to the northeast.

0.7

STOP 4. Small road cut on the right exposes glacial lake sediment. The lake, a small one, was dammed in contact with the glacier and it drained when the ice melted. Notice the nearly horizontal bands in the lake sediment.

0.4

Note this pothole lake with almost vertical banks. A large piece of glacial ice was buried here under an overlying blanket of glacial sediment and this ice melted over a period of perhaps two to three hundred years, causing the overlying load of sediments to collapse, forming the depression that you see. Because the depression intersects the water table, a lake fills it.

1.0

Highway. Continue to the west. This flat area is a lake plain that formed in a lake that filled this part of the sag (mile 0.1) during the glacial epoch. The lake probably covered about three square miles. Bedded silt, similar to that exposed at Stop 3, covers most of the lake plain. Notice the lack of boulders on the surface of the lake plain.

0.4

Drive off lake plain onto ground moraine. Ground moraine consists of glacial sediment, mainly till, that was deposited beneath the moving glacier.

0.5

Till exposure on the right.

3.7

STOP 5. Paint Hill. This large hill of sand and gravel was formed by water flowing from the ice into a hole in the glacier. Such hills are sometimes called "kames," but this rather flat hill is not typical of kames, which are normally cone-shaped. Inspect the gravel in the pit north of the road. Shale is common in the gravel. The gravel is rather "dirty" and poor in quality.

Walk about the grassy area near the top of the kame. Note the native grasses. Can you identify the wildflowers that you find? These are deep-rooted flowering herbs, called "forbs" by ranchers. Depending on the season, you will be able to find coneflower, prairie clover, wallflower, wild indigo, red mallow, vervain, brown-eyed Susan, fleabane, boneset, ironweed, and many species of sunflowers, asters, and goldenrod. Many Indian turnips grow here. Harvest these in July.

Rocks of many sizes are found here. Turn some of them over. Examine the white substance, "caliche" (calcium sulphate and calcium carbonate), found on the undersides. This is formed when rain flushes the tops of these rocks and deposits the dissolved minerals on the undersides of the rocks.

0.3

Note kettle hole. No lake is present because the water table is not intersected.

4.2

Turn south (left).

1.0

Turn east (right).

0.7

Turn south (left).

2.0

Highway. Continue to the south.

0.4

Windbreak of cottonwood and boxelder trees. Where did these come from?

1.0

What killed the cottonwood trees in the small lake behind Buffalo Rock Hall? Note the trend of this lake. It is an old river channel that intersects the water table.

1.4

Turn southeast.

0.3

Note buffalo berry bushes, with their very long thorns, and the Woods rose bushes, with much smaller thorns. Both the prairie rose and the Woods rose grow in this area. The latter is a deeper pink and grows on a much bushier plant.

0.2

Leave the main road and continue on the narrower road to the southeast into the "breaks" of the Missouri.

If you are following this field trip during the breeding season you will already have seen many different species of birds. The area ahead has a great diversity of native species because 1) except for grazing cattle, the land is undisturbed, and 2) there is a great diversity of micro-climates. On this land you can find marshes, mid-grass prairie and short-grass prairie, thickets of buffalo berry, wolfberry, roses and taller thickets of boxelder, black ash, and elm. Lake Sakakawea has many species of birds found on large mid-continent lakes in the temperate zone. Among the birds that have been identified in this area are the mourning dove, killdeer, sparrow hawk, Hungarian pheasant (imported), upland plover, yellow-shafted flicker, western kingbird, barn swallow, blue jay, black-billed magpie, bobolink, western meadowlark, red-winged blackbird, lark bunting, field sparrow, and chestnut-collared longspur.

0.3

Enter pasture to south (right). Note the silvery covering on many species of plants. This is a protective device evolved in the plants to prevent water transpiration and is an indicator of arid country. Farther west the skin of cacti is waxy, and offers an even greater resistance to water loss due to transpiration.

0.1

STOP 6. Some of the glacially deposited red rocks in this area contain deposits of iron. Also in this area you will begin to see pebbles of scoria. Usually these are flat, or angular, in contrast to the glacially-polished boulders and smaller stones that are found here and at other places we have stopped. Scoria deposits will be seen in places when we reach the banks of Lake Sakakawea.

Note the higher shrubs and trees that mark the water courses. Why are there no cottonwood trees in this area?

1.1

STOP 7. Collect cattails from this pond. In the spring the white tips of the cattails are delicious when boiled with salt and butter added. They taste something like cucumbers when raw.

0.4

Note worm-filled cocoons growing on buckbrush beside road. Can you identify these larvae?

0.7

Badland topography to the south (right) is carved from the Sentinel Butte Formation. "Badland" comes from the French "Les Mauvais terres a traverser," which was the French translation of the Lakota "Macosica" meaning "bad land to travel across."

1.0

Enter gate and continue following path. We are traveling through native prairie that has been heavily grazed. Can you give possible reasons for the circular patches of buckbrush?

Watch for Hungarian partridge, common in this area. Two turkey buzzards claim their territory above Nishu Bay ahead of us.

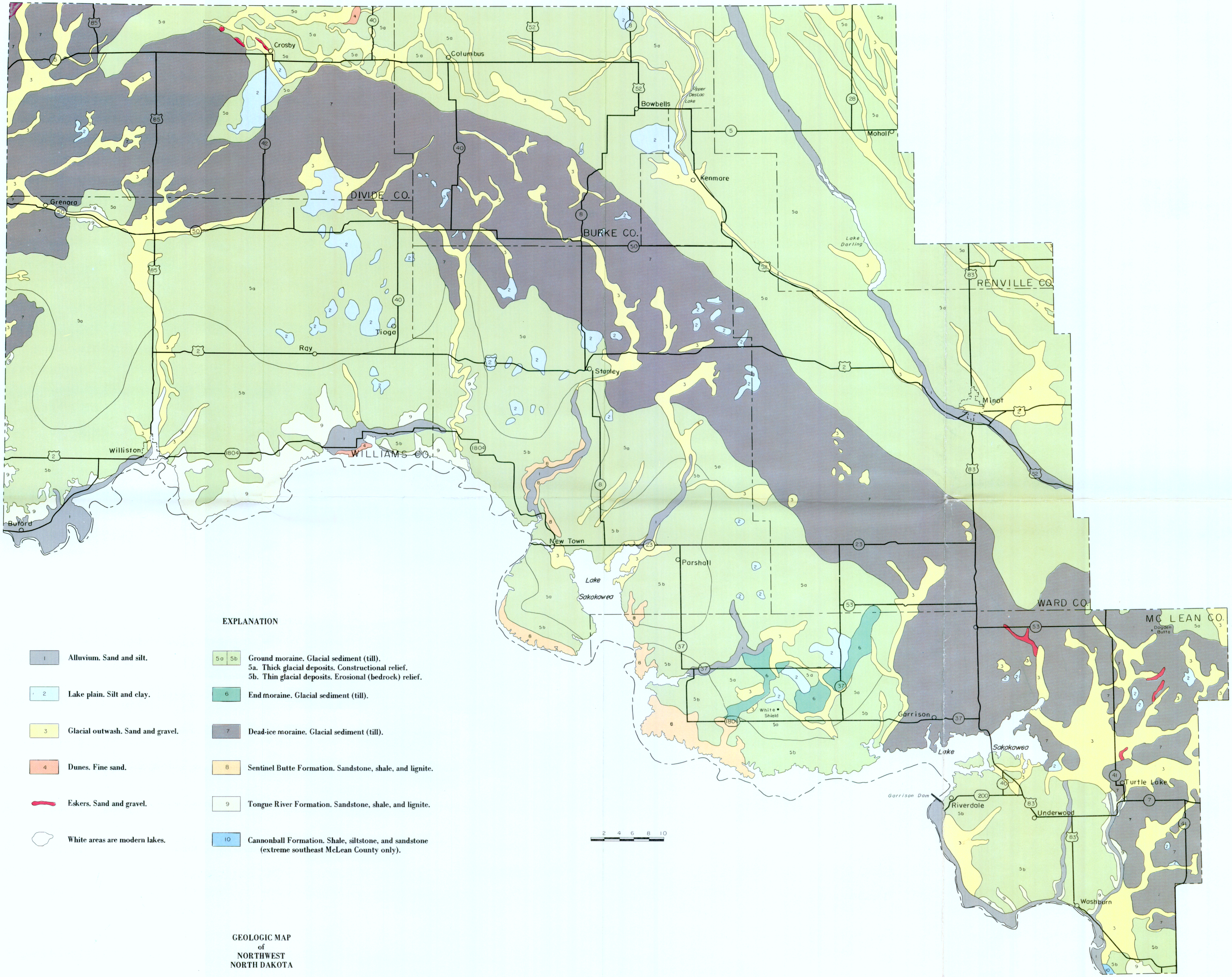
4.0

STOP 8. Leave cars on lane. Walk southwest over the native prairie down to the inlet of Lake Sakakawea. Note the varied types of grasses growing in response to micro-climates caused by such physical factors as the amount of sun exposure of various areas and the amount of moisture retained by the soil. As you approach the bay notice the outcropping Sentinel Butte Formation of rock. It is composed of layers of sand and sandstone, silt and claystone, lignite and ash with scoria above the ash left from burned lignite.

Lignite is economically important to North Dakota, and it also holds water. On the hill directly above some of the lignite is a growth of buckbrush, which requires more sub-surface water than does the mid-grass that is directly above the surrounding outcropping scoria. It is not known whether there is a direct correlation between the lignite and the presence of the moisture demanding shrubs on the slopes above it, but the relationship suggests that there is. Note the different colors of the scoria in the Sentinel Butte Formation. Also note that it overlies a layer of ash that can be correlated to the lignite in the same formation. When the lignite burned it turned to ash, and at the same time baked the clay above it into a natural brick. The ash occupies only a few inches, but the unburned lignite is several feet thick. Burned areas, therefore, are somewhat slumped.

On the shores of this inlet are many large angular pebbles of scoria bearing leaf imprints. What other water-washed materials do you find here? How can you tell if they come from some distance or perhaps fell from the overhanging cliffs? Look for strand lines in the sandy beach.

There have been prairie rattlesnakes on both sides of the Missouri River beyond the memory of man, but the prairie rattler on the east side had stayed on the river floodplain until his habitat was destroyed. With the damming of the Missouri River and the formation of Lake Sakakawea, the prairie rattlesnake retreated to higher ground, and now breeds fairly close to human habitations. A man was bitten in Garrison, North Dakota, in 1972. Large numbers of the hibernating snakes were removed from a den at Good Bear Hill, about twelve miles southwest of White Shield in McLean County, in winter 1972. We have seen their skins in an abandoned churchyard seven



EXPLANATION

- 1 — Alluvium. Sand and silt.
- 2 — Lake plain. Silt and clay.
- 3 — Glacial outwash. Sand and gravel.
- 4 — Dunes. Fine sand.
- Eskers. Sand and gravel.
- White areas are modern lakes.
- 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).
- 8 — Sentinel Butte Formation. Sandstone, shale, and lignite.
- 9 — Tongue River Formation. Sandstone, shale, and lignite.
- 10 — Cannonball Formation. Shale, siltstone, and sandstone (extreme southeast McLean County only).

GEOLOGIC MAP of NORTHWEST NORTH DAKOTA