The modern, uncrowded highways of North Dakota carry you through a fertile, unspoiled land that lies beneath a broad, clear sky. We hope to deepen your perspective of our state by increasing your awareness of how the landscape along Interstate Highway 94 formed. Perhaps, by calling to your attention some of the geologic features along the highway, we can add to the enjoyment of your trip.

William L. Guy
WILLIAM L. GUY, Governor
The flat, colorful layers of sand and silt that you see in the badlands consist of materials that accumulated over river floodplains and near the shores of shallow lakes and seas. The black layers of lignite coal originated in forests that grew on swamps along the streams and near the lake shores. In places, petrified stumps and logs, remnants of these ancient trees, can be seen today. Some of the horizontal banding in the sediments probably represents ancient soils that gradually sank below sea level when the streams ceased flowing, depositing more sediment over the surface.

Several oil wells, such as this one near Dickinson, can be seen from I-94 in western North Dakota. Over 350 million barrels of oil have so far been produced, and another 670 million barrels of recoverable crude oil reserves remain in the ground.

What was once a difficult journey on horseback is now an enjoyable, scenic ride on North Dakota's modern interstate highway. The term "badlands" was derived from the French term "mauvais terres" meaning literally "bad terrain."

Mileage  Map  Number
1  Scattered Butte. The amount of Scattered Butte is about 4 miles south of the town of Scattered Butte. About 2 miles south of town take the left turn on the road. At the base of the butte left side of road is an excellent exposure of red "wacke" (laidly strata) interbedded with white layers of silt. The rocks on top of Scattered Butte are hard, white limestones. They were deposited in freshwater lakes during mid-Tertiary time about 20 million years ago. Forests have been found on top of the butte, but they are scarce today because the rocks have been thoroughly pocked over by collectors. Abundant chert drusly occurs on the ground near the road today on top of the butte.

2  Theodore Roosevelt National Memorial Park. The traveler who has time will find it well worth his time to visit the Theodore Roosevelt National Memorial Park where some of the most scenic badlands in the United States can be seen. Badlands are formed in a semi-arid climate where an annual heavy rains coupled with a lack of vegetation cause rapid erosion of relatively soft sediments. For example, wind stripped from the top soil during the past 30 years or so has left some of the valleys to depths of several tens of feet. Resistant layers of hard sandstones or brecia (the red sand) cap many of the buttes. The black bands are lignite coal. North Dakota has an estimated 175 million tons of lignite, largest reserve of lignite in the world. The sediments that can be seen from the overlook are mainly gray sandstones of the Palaeocene age. Scattered Butte Formation, about 80 million years old. A few miles to the west, the sediments of the slightly younger Teton River Formation are more yellow. Notice the many pieces of petrified wood at the wall of the overlook. This petrified wood formed when stumps and logs were buried beneath alluvial clays and the wood cells were replaced by minerals. The trees that formed the petrified wood were very similar to the Sequoia trees found in California today.

24  Little Missouri River.

3  Burning coal mine. Two burning coal mines can be seen in the Medora area. One is a few miles north of I-94 in the South Unit of Theodore Roosevelt National Memorial Park. The other is eleven miles south of Belfield on U. S. Highway 85. These 2.4 miles west on gravel. As the lignite vented slowly, the overlying materials slump down and collapse. Considerable heat and smoke are given off during the burning process. Lignite vents like these burned during prehistoric times, felling and burning the overlying materials to a reddish brown color. The resulting material is locally referred to as "scoria." The term "scoria" means a volcanic rock. Lignite vents may be ignited by lightning or other fires and can start fires for long periods of time if sufficient oxygen is available.

33 to 38  Fryburg Oil Field. Oil has been produced from rocks of Pennsylvanian and Ordovician age (350 to 500 million years old) in the Fryburg Oil Field. The wells in this field are as much as 13,725 feet deep. North Dakota has more than 1,000 producing wells, several pipe lines, and the future is promising for petroleum industries.
DESCRIPTION OF THE GEOLOGY ALONG I-94

5 Loomis Mine, no longer in operation. North 4½ miles from Belfield (Grown Flat cut) and 1½ miles west. The igneous in this part of North Dakota contains uranium minerals. Lignite was once mined and burned leaving a subsurface coal that was further processed elsewhere to extract the uranium.

6 Dickinson Oil Field. Oil is being produced from wells at Permian basin age (about 250 million years old) in the Dickinson Oil Field. The wells are so much as 9,100 feet deep.

7 In Dickinson, as in many other North Dakota communities, industry is closely tied to geology. Examples in Dickinson are the Union Clay Products Company, which sells clay to the oil industry; and the Powder River Tobacco Company, which manufactures pipe tobacco. These three plants can be arranged locally. Another example of a geology-related industry is the brick plant at Hebron. Several towns are operated daily at the plant.

8 Glacial Boundaries. At the rest area 12 miles east of Glen Ullin, notice the boulders that were gathered from neighboring fields. They are rounded from traveling inside the glacier from central Canada. They are “green” (tarry) mucks because they were formed of hot molten material that cooled and solidified inside the earth (just as lava cools and solidifies outside of volcanoes today).

9 Glacial Compared with Vascular Geology. Notice the change from relatively smooth, hard east of the Wopashun River to relatively more hilly land west of the river. The river marks the boundary between an area that is presumably the result of action of the glaciers (east of the river) and an area that is of pre-glacial origin (west of the river). The hills in the west of the glaciated area are larger and commonly taller apart. Boundaries that were formed from Canada by the glaciers are present on both sides of the river and although there are scattered areas of glacial deposits west of the river, the shape of the hills in the area is due entirely to the nonglacial hills that were there before the glacier covered them.

10 Box Elder Oil Company Refinery. North of the highway at the west edge of Mandan, this, one of the two refineries in North Dakota, (the other is in Williston) processes much of the oil produced in the state. Tours are given Monday through Friday from 10 until 2. Groups larger than 12 require advance notice.

11 Wopashun Valley. The eastbound traveler can stop at a rest area just west of Mandan and view the Wopashun River valley in which the city of Bismarck and Mandan are situated. This large valley was cut during the Ice Age when the glacier dammed the many streams that flowed northeast at that time. As a result, all the water in the streams, along with meltwater from the glacier, was diverted southeast along the edge of the glacier and the valley was cut.

12 Meadezine Lake Planes. The flat area around Meadezine and Meadezine resulted when water was dammed ahead of the ice when it moved a few miles east of Meadezine. When the lake drained, the silts and clays that had been deposited on its floor were exposed. Lake sediments commonly result in flat topography because the water-dam silts and clays fill in the valleys that were present before the lake covered the area.

13 Older Glacial Topography. Compared with younger glacial topography, 'staging marks' the approximate boundaries between the older, more subdued glacial landscape to the west and the younger, more rugged glacial landscape to the east. The main reason for the difference in relief is that 'staging' has been going on for a longer period of time in the older area, probably about a thousand years. To the east, with erosion in progress for only about ten thousand years, the hills have not yet been worn down appreciably.

14 Little Glacial Topography. The area is characterized by the numerous and well-developed moraines and kettles that resulted from the melting of the retreating ice. The gently sloping moraines are composed of glacial till and outwash deposits.

15 Dead Ice Moraine. The area from Crystal Springs to Cleveland is characterized by "polish" moraine that formed when thick layers of glacial debris moved, causing the ice to compress them. Notice the large depressions in the dead ice moraine such as the one in which the town of Medina is located. Large depressions such as that one are formed where large blocks of ice melted allowing the overlying sediments to collapse. In general, large depressions resulted where the ice was thick, while areas of thin ice had relatively thin sediments.

16 Ground Moraine. The area shown in green on the reading is flat ground moraine that formed beneath the moving glacier ice. It is covered by till, a mixture of boulders, gravel, and sand in a groundmass of silt and clay.

17 James River Valley. The highway crosses the south-facing James River valley at Jamestown. The James River flows in a large valley that was cut during the Ice Age by glacier meltwater. When the ice melted, the meltwater discharge of the river was full to both banks resulting in a river as large as the present day lower Mississippi James River at mile 280.
274 Meltwater trench.
274 Meltwater trench.
275, 276 Continental Divide, elevation 1400 above sea level. The Continental Divide lies between mile 275 and 276. The area east of the divide is drained by the Red River of the North to Hudson Bay. West of the divide, drainage is southward to the Gulf of Mexico via the James and Missouri Rivers.
278 Meltwater trench.
283 Meltwater trench. Kames. Just south of the road at mile 263, a few miles west of Valley City are several high conical hills known as kames. They were formed when water flowed into lakes near the edge of the glacial deposits, depositing sand and gravel. When the ice melted, the sand and gravel dumped down to form the conical hills. Very kames are a few hundred yards south of the road at mile 265.
290 Moraine River Valley. The highway crosses the Moraine River valley at Valley City. This valley, like the James River valley, was cut during the last ice age by a large river of glacial meltwater. Many valleys in North Dakota that were cut by meltwater contain only small streams today that are far too small to have cut such large valleys.
305 Meltwater trench.
307 Small kame north of highway.
309 Meltwater trench.
311 Meltwater trench.
319, 321 Beaches. In this interval are several beaches of the glacial Lake Agassiz. Although they are not conspicuous from the road, they can be observed at step-like rises toward the west. They mark former shorelines of Lake Agassiz and extend north-south for several hundred miles. Like modern beaches, they are composed mainly of sand and gravel that is spread throughout the Red River valley.
325 Lake Agassiz. The very flat land from Fargo west to mile 325 is the lake plain that resulted when the glacial Lake Agassiz drained (see note 12). Lake Agassiz was named after a Swiss geologist, Louis Agassiz, whose research during the last century popularized the idea of the ice age.
326 The tilled lands of eastern North Dakota formed when materials transported southward by the glaciers settled out at the ice front. This view of the landscape in Barnes County is typical of glacial moraine.
SURFACE GEOLOGY OF NORTH DAKOTA

The pre-Ice Age rock formations that can be seen in western North Dakota consist mainly of schists and sandstones interbedded with layers of limestones and red beds. The Precambrian sediments are designated on the map by the lines ones. Where the sediments are well-exposed, as in the badlands near Medora, the layering effect is readily apparent. The Precambrian sediments were deposited by ancient rivers and streams flowing from the Rocky Mountains during the youthful stages of these mountains. Weathering of these newly uplifted Rocky Mountains produced sand and clay that was washed eastward onto the plains. It is these sands and clays that we see today in western North Dakota. At times, wind-deposited sand and gravel were later converted to loess. Some of the clays contain fossils of such things as mollusks, clam shells, pebbles, wood, and reptile and mammal skeletons. Most of the sands and clays exposed in western North Dakota were deposited about 65 million years ago.

Later, when the area drained and was subject to erosion, the harder, more resistant sandstones locally remained as protective caps of buttes that formed as the softer silt and clays were eroded away. Partly because erosion has been going on much longer in the unglaciated areas of western North Dakota than in the glaciated areas of eastern North Dakota, and partly because the composition and quality of the glacial sediments are different from the composition and quality of the glacial sediments, the landscapes of western and eastern North Dakota differ markedly. The sediments in the unglaciated areas are typically the result of erosion of the underlying layers of sand and clay, whereas the sediments in the glaciated areas are primarily the result of deposition of sediments by the glaciers. In general, the unglaciated hills are larger and further apart than are those in the glaciated areas. The valleys of the unglaciated areas are more intricate, carved because they are the result of small amounts of water eroding the area for many millions of years. The valleys of the glaciated areas were cut by large amounts of water during its work during and since the Ice Age, a shorter time.

All of North Dakota, except for the southwestern quarter, was covered by glaciers several times during the Ice Age that ended about 10,000 years ago. When the glaciers moved over the pre-glacial surface, they carried with them vast quantities of rock and soil that they picked up and pulverized into a mixture known as till. Water flowing from the ice deposited sand and gravel swallow areas on the map, and carved large valleys known as meltwater trenches. When the ice finally stopped moving, it melted and dropped its load of sediment. In areas shown as glacial moraines, on the map, some of the till remained on top of the ice that melted and extended the melting of the ice for several thousand years. When the ice finally did melt, the overlying materials settled and slid forming deep pitted areas, and generally a very irregular surface that has not changed much to the present day.

In some areas shown in green on the map, smaller amounts of sediment accumulated on the surface of the glaciers, while larger amounts of sediment accumulated near the edge of and beneath the glacier. In places, loose accumulations of rock debris piled up at the edge of the glacier, resulting in areas of especially hills land. Areas where the ice deposited sediment at its base; as it moved along are low hills, but still rather rolling. The till in such areas is generally hard and compact because it was passed by the ice that moved over it.

Finally, as the Ice Age ended, large lakes were dammed at the melting ice because the pre-glacial drainage routes, which had been waterproof, were still blocked by ice. Large quantities of sand, silts, and clays were deposited in these lakes by the many rivers that flowed into them. The water eventually drained out when the ice melted further back, and broad, flat expanses of lake plains, shown in blue on the map, were left. Largest of these is the Modern lake plains in eastern North Dakota. Forest beaches can be seen today along the former shorelines of the lakes.

Sand and gravel, along with ground water, are the most important mineral resources associated with the glacial sediments of North Dakota. Small amounts of tin, copper, and lead are also taken from the glacial sediments. Mineral resources found in the tillglacial sediments include the limestones and associated minerals, high grade clays that are used in the manufacture of ceramics, limestones, potash, salt, petroleum, gas, and sulfur. Water is also taken from the glacial sediments, but it is commonly mineralized and of poorer quality than that found in the glacial sediments.
1. North Dakota just before the Ice Age. The main drainage routes are shown on this block diagram which also depicts the subsurface geologic formations. The locations of the streams shown here are speculative, but they reflect our knowledge that drainage was generally northeastward. Most of the land surface was probably relatively smooth, particularly in the eastern half of the state where mudstones of Cretaceous age were exposed (green areas). Similar sediments also covered the northwest portion of the state. There may have been some badlands in the western part of the state where sands and sandstones of Tertiary age were exposed (orange areas). On the extreme eastern edge of the state, some limestones of Paleozoic age (blue areas) and some Precambrian granites (purple areas) were exposed.

We may better comprehend the immensity of geologic time by changing its scale so as to bring it within mental grasp. The above diagram represents the 4.6 billion years of the earth's history compressed into a single year. The earth's life forms did not appear on the earth until late in May of the imaginary year and, until someone in November, life was still very primitive—time filled with protoplasm, etc. Primitive men arrived on earth in the midst of the Ice Age at about 10:20 p.m. on December 31. Leif Ericson discovered America at 10 seconds before midnight on December 31.

The glacial sediments of North Dakota are all of Pleistocene age (late December 31) and the nonglacial sediments at the surface in the western part of the state were deposited mainly during Cretaceous and Tertiary time (late December). At greatest depths are rocks of Precambrian age (late November and early December), limestones and mudstones, from which oil and gas are produced.
2. North Dakota during the Ice Age at a time after the glaciers had already reached their maximum extent and begun to recede back into Canada. The brown on the following two diagrams represent areas that were covered by glacial deposits. The glacier ice at this time covered the area shown and acted as a barrier to the northeast-flowing streams, diverting them southeastward so that they combined to form the Missouri River. Water from the melting ice also contributed to the river. It seems likely that erosion had already done much of the work of carving the rugged badlands along the Little Missouri River.

4. North Dakota at the end of the Ice Age. Most of the ice had melted from the state, although in some areas large amounts of ice insulated by overlying sediments such as till and gravel still remained. When the insulated ice melted, the overlying materials dumped and slid into very hummocky topography. Water that was dammed by the melting ice in the Red River valley and west of the Turtle Mountains collected in large lakes (Lake Agassiz and Lake Souris). After the ice melted further back, the lakes drained. Very heavy precipitation continued for some time after the ice melted from the state, and considerable erosion occurred as many of the valleys were deepened.