GEOLOGY ALONG NORTH DAKOTA INTERSTATE HIGHWAY 94

NORTH DAKOTA EDUCATIONAL SERIES NO. 1

NORTH DAKOTA GEOLOGICAL SURVEY

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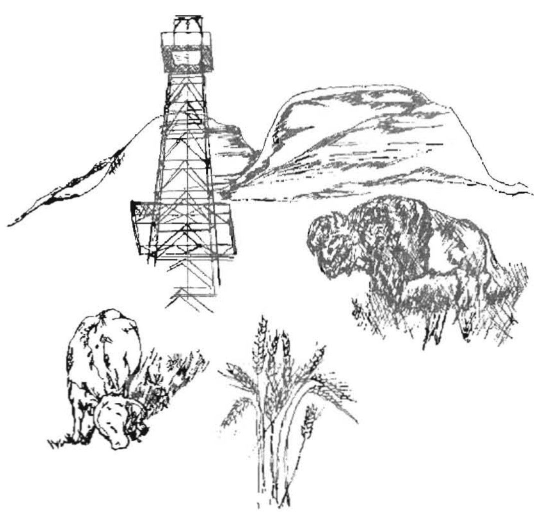
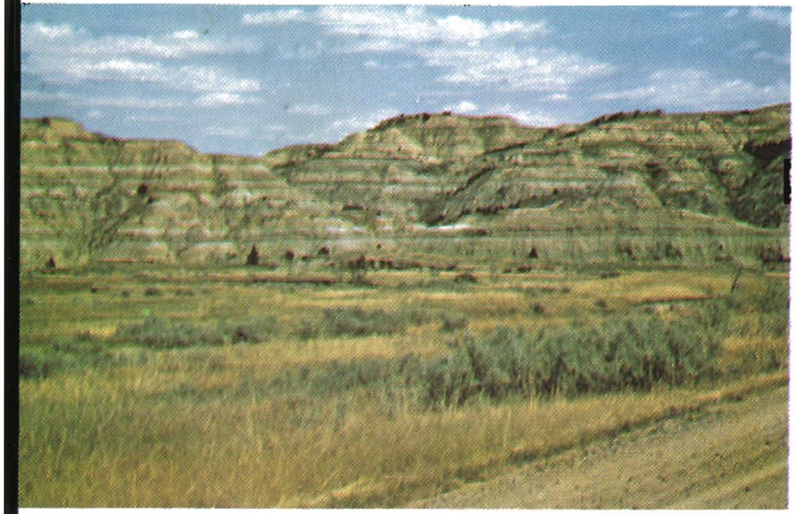
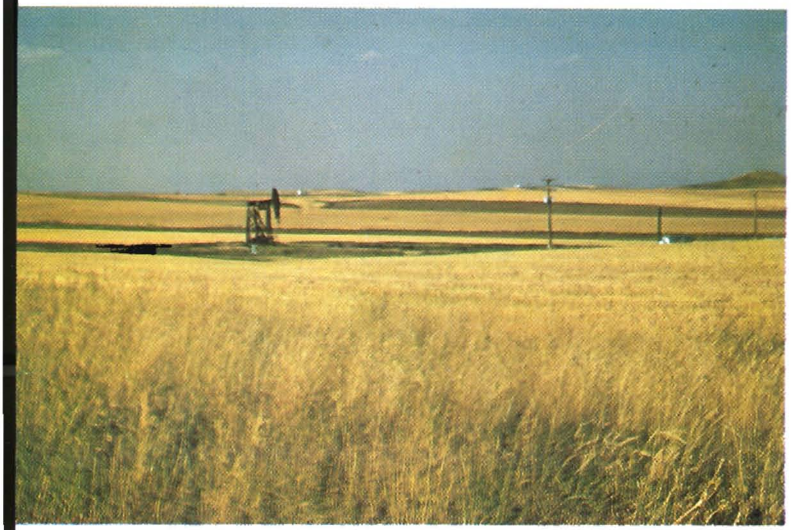


The modern, uncrowded highways of North Dakota carry you through a fertile, unspoiled land that lies beneath a broad, clear sky. We hope to deepen your perspective of our state by increasing your awareness of how the landscape along Interstate Highway 94 formed. Perhaps, by calling to your attention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

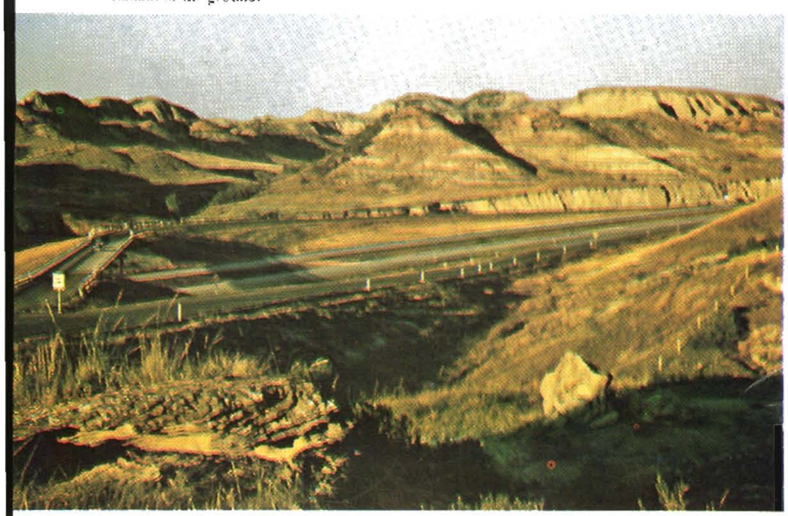
WILLIAM L GUY, Governor



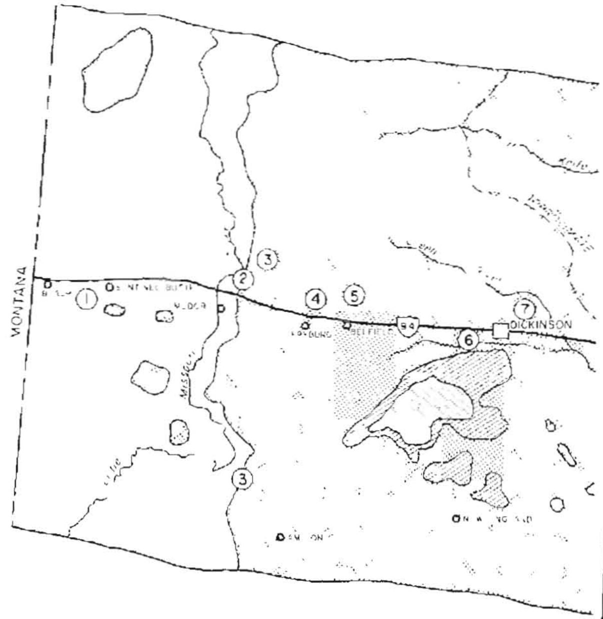
The flat, colorful layers of sand and silt that you see in the badlands consist of materials that accumulated on river floodplains and near the shores of shallow lakes and seas. The black layers of lignitic coal originated as forests that grew in swamps along the streams and near the lake shores. In places, petrified stumps and logs, remnants of these ancient forests, can be seen today. Some of the horizontal banding in the sediments probably represents ancient soils that gradually sank below sea level when the stream courses shifted, 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 94. The term "badlands" was derived from the French term "mauvais terres" meaning literally "bad terrain."



Mileage | Map Number

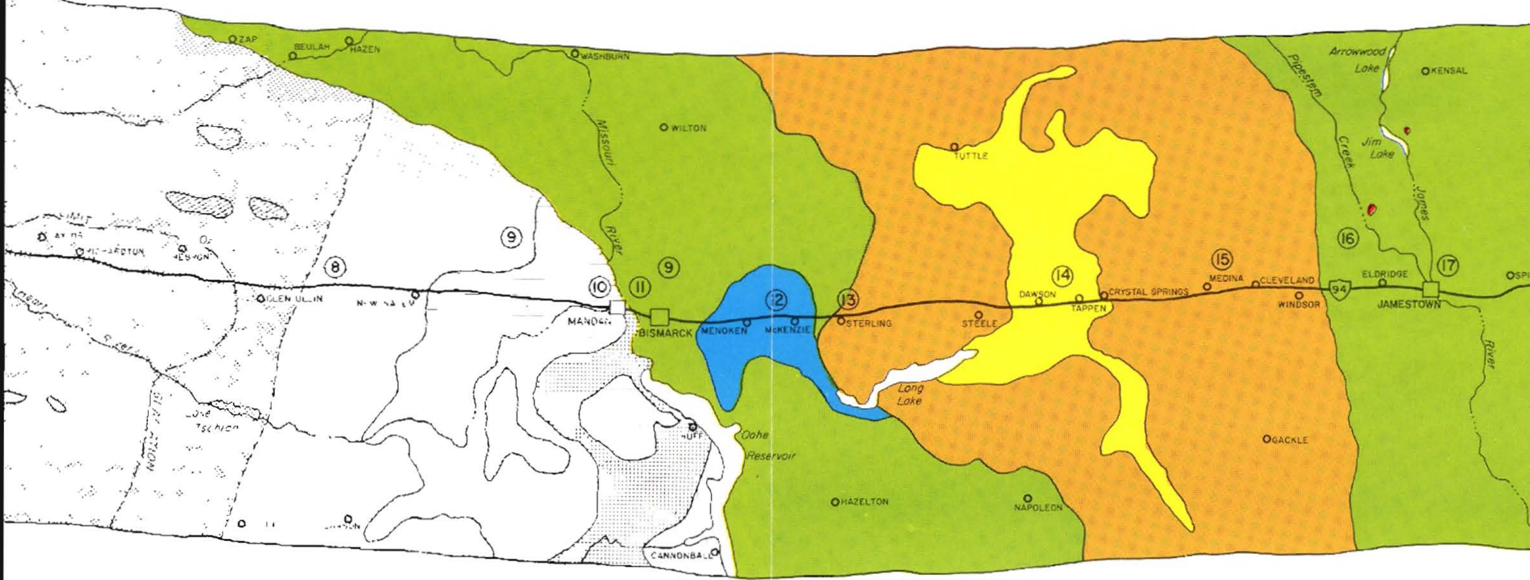
1 Sentinel Butte. The summit of Sentinel Butte is about 4 miles south of the town of Sentinel Butte. About 2 miles south of town take the left fork in the road. At the base of the butte (left side of road) is an excellent exposure of vivid red "scoria" (baked clays) interbedded with white layers of ash. The rocks on top of Sentinel Butte are hard, white limy claystones. They were deposited in fresh-water lakes during mid-Tertiary time about 20 million years ago. Fossil fish have been found on top of the butte, but they are scarce today because the rocks have been thoroughly picked over by collectors. Abundant chalcedony occurs in the gravel near the radio tower 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 occasional heavy rains coupled with a lack of vegetation cause rapid erosion of relatively soft sediments. For example, soil stripped from hills during the past 30 years or so has filled some of the valleys to depths of several tens of feet. Resistant layers of harder sandstones or scoria (the red zones) cap many of the buttes. The black bands are lignite coal. North Dakota has an estimated 350 billion 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 Paleocene age Sentinel Butte Formation, about 60 million years old. A few miles to the west, the sediments of the slightly older Tongue River Formation are more yellow. Notice the many pieces of petrified wood in the wall of the overlook. This petrified wood formed when stumps and logs were buried beneath silts and 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.

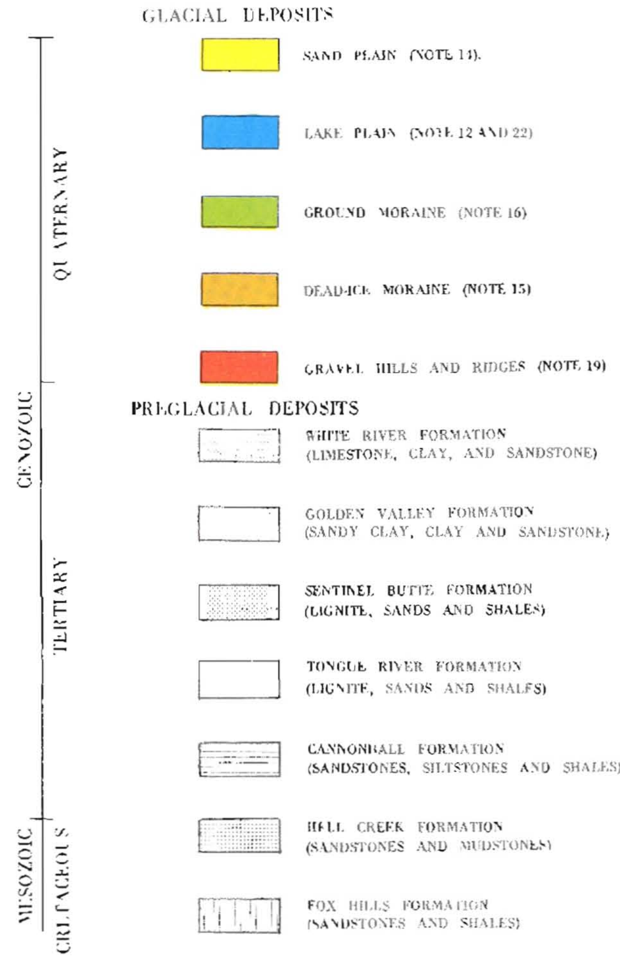
3 Burning coal veins. Two burning coal veins can be seen in the Medora area. One is a few miles north of I-94 in the South Unit of Theodore Roosevelt National Memorial Park. The other is eleven miles south of Belfield on U. S. Highway 85, then 24 miles west on gravel. As the lignite vein slowly burns, the overlying materials slump down and collapse. Considerable heat and some smoke are given off during the burning process. Lignite veins like these burned during prehistoric times, baking and fusing the overlying materials to a reddish brown color. The resulting material is locally referred to as "scoria," but true scoria is a volcanic rock. Lignite veins may be ignited by lightning or prairie fires and once started they burn for long periods of time if sufficient oxygen is available.

33 to 38 — 4 Fryburg Oil Field. Oil is being produced from rocks of Pennsylvanian and Ordovician age (250 to 500 million years old) in the Fryburg Oil Field. The wells in this field are as much as 13,750 feet deep. North Dakota has more than 1500 producing wells, several pipe lines, and the future is promising for petrochemical industries.



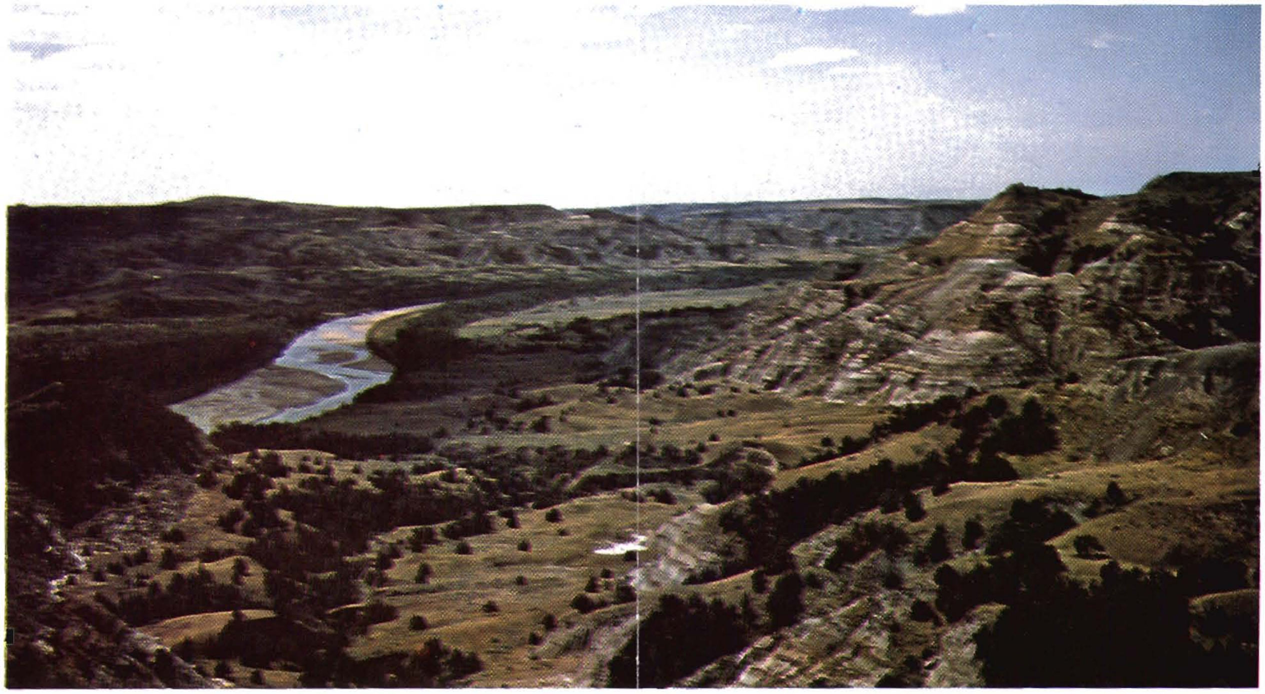
DESCRIPTION OF THE GEOLOGY ALONG I-94

Mileage	Map Number	
	5	Uranium Mine, no longer in operation. North 4½ miles from Belfield (Grassy Butte exit) and 1½ miles west. The lignites in this part of North Dakota contain uranium minerals. Lignite was once mined and burned leaving a uranium-rich ash that was further processed elsewhere to extract the uranium.
55 to 61	6	Dickinson Oil Field. Oil is being produced from rocks of Pennsylvanian age (about 250 million years old) in the Dickinson Oil Field. The wells here are as much as 9100 feet deep.
	7	In Dickinson, as in many other North Dakota communities, industry is closely tied to geology. Examples in Dickinson are the Bison Clay Products Company which uses clays of the Golden Valley Formation and the Husky Dominion Company which manufactures lignite briquettes. Tours of these two plants can be arranged locally. Another example of a geology-related industry is the brick plant at Hebron. Several tours are operated daily at the plant.
119	8	Glacial Boulders. 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 "igneous" (fiery) rocks 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 Nonglacial Topography. Be sure to notice the change from relatively smooth land east of the Missouri River to relatively more hilly land west of the river. The river marks the boundary between an area that is primarily 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 to the west of the glaciated area are larger and commonly farther apart. Boulders that were brought 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 in existence before the glacier covered them.
154	10	American 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 at 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.
152 to 158	11	Missouri River Valley. The eastbound traveler can stop at a rest area just west of Mandan and view the Missouri River valley in which the cities of Bismarck and Mandan are situated. This large valley was cut during the Ice Age when the glacier dammed the many streams that flowed northeastward at that time. As a result, all the water in the streams, along with meltwater from the glacier, was diverted southeastward along the edge of the glacier and the valley was cut.
169 to 176	12	McKenzie Lake Plain. The flat area around Menoken and McKenzie resulted when water was dammed ahead of the ice when it stood a few miles east of McKenzie. 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-lain silts and clays fill in the valleys that were present before the lake covered the area.
180	13	Older Glacial Topography Compared with Younger Glacial Topography. Sterling marks the approximate boundary 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 erosion has been going on for a longer period of time in the older area, probably about a hundred thousand years. To the east, where erosion has been in progress only about ten thousand years, the hills have not yet been worn down appreciably.
207 to 221	14	Kidder Sand Plain. The area for several miles around Tappen and Dawson is flat in places, rolling in others and everywhere surface by sand. The sand was deposited by streams that flowed on top of glacial ice which, when it eventually melted, resulted in collapse of the overlying materials. Drainage is very poor in the area and water flows only to the many potholes. Some of the small lakes that result are higher in dissolved solids, that is, they are saltier than the ocean. White areas of salts such as sodium sulphate can be seen on many of the lake bottoms when they are dry.
180 to 245	15	Dead-Ice Moraine. The area from Crystal Springs to Cleveland is dead-ice or "pothole" moraine that formed when thick layers of glacial debris—sand, silt, clay, gravel, and boulders—lying on top of the ice slumped down as the ice melted. 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 this one formed where large blocks of ice melted allowing the overlying sediments to collapse. In general, large depressions resulted where the ice was thick, hills where it was thin.
245 to 319	16	Ground Moraine. The area shown in green on the roadlog is flat ground moraine that formed beneath the moving glacier ice. It is surfaced mainly by till, a mixture of boulders, gravel, and sand in a groundmass of silt and clay. The till is generally quite firm and compact because the ice packed it as it moved over it. The ground moraine is modified in places by meltwater trenches such as the James and Sheyenne River valleys. Between Tower City and Jamestown there are numerous meltwater trenches of all sizes that cross Interstate Highway 94.
258	17	James River Valley. The highway crosses the south-trending James River valley at Jamestown. The James River flows in a large valley that was cut during the Ice Age by glacial meltwater. When the water flowed at its maximum discharge, the valley was full to both banks resulting in a river as large as the present day lower Mississippi. James River at mile 260.



Mileage	Map Number	
271		Meltwater trench.
273		Meltwater trench.
275½	18	Continental Divide, elevation 1490 above sea level. The Continental Divide lies between miles 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	19	Kames. Just south of the road at mile 283 a few miles west of Valley City are several high conical hills known as kames. They were formed when water flowed into holes near the edge of the glacier depositing gravel and sand. When the ice melted, the sand and gravel slumped down to form the conical hills. More kames lie a few hundred yards south of the road at mile 285.
290 to 295	20	Sheyenne River Valley. The highway crosses the Sheyenne River valley at Valley City. This valley, like the James River valley, was cut during the Ice Age by a huge 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.
313		Meltwater trench.
319 to 325	21	Beaches. In this interval are several beaches of the glacial Lake Agassiz. Although they are not conspicuous from the road, they can be observed as step-like rises toward the west. They mark former shorelines of Lake Agassiz and extend north-south for several hundred miles. Like modern beaches, they are composed mainly of sand and gravel that is used throughout the Red River valley.
325 to Red River	22	Agassiz Lake Plain. 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 zoologist, Louis Agassiz, whose research during the last century popularized the idea of the Ice Ages.

The fertile farmlands of eastern North Dakota formed when materials *transported southward by the glacier settled out as the ice melted.* This view of the landscape in Barnes County is typical of ground moraine.



SURFACE GEOLOGY OF NORTH DAKOTA

The pre-Ice Age rock formations that can be seen in western North Dakota consist mainly of siltstones and sandstones interbedded with layers of lignite coal and reddish "scoria." Nonglacial sediments are designated on the map by the lined areas. Where the sediments are well-exposed, as in the badlands near Medora, the layering effect is readily apparent. The pre-Ice Age sediments were deposited by ancient rivers and streams flowing from the Rocky Mountains during the youthful stages of these mountains. Weathering of those 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, while this deposition was going on, plants grew in swamps and were later converted to lignite. Some of the clays contain fossils of such things as snail and clam shells, petrified wood, and reptile and mammal skeletons. Most of the sands and clays exposed in western North Dakota were deposited about 65 million years ago.

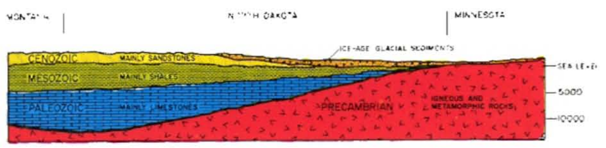
Later, when the area drained and was subject to erosion, the harder, more resistant sandstones locally remained as protective caps of buttes that formed as the softer silts and clays were eroded away. Partly because erosion has been going on much longer in the unglaciated areas of western North Dakota than in the glaciated areas of eastern North Dakota, and partly because the composition and quality of nonglacial sediments are different from the composition and quality of glacial sediments, the landscapes of western and eastern North Dakota differ markedly. The hills in the unglaciated areas are entirely the result of erosion of the surrounding layers of sands and clays, whereas the hills in the glaciated areas are primarily the result of dumping of sediments by the glaciers. In general, the nonglacial hills are larger and farther apart than are those in the glaciated areas. The valleys of the nonglacial areas are more intricately 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 doing its work during and since the Ice Age, a shorter time.

All of North Dakota, except for the southwest quarter, was covered by glaciers several times during the Ice Age that ended about 10,000 years ago. When the glaciers moved over the preglacial 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 (yellow 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 dead-ice moraine on the map (brown areas), so much sediment remained on top of the ice that it insulated and retarded the melting of the ice for several thousand years. When the ice finally did melt, the overlying materials slumped and slid forming deep potholes 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 glacier, 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 hilly land. Areas where the ice deposited sediment at its base as it moved along are less hilly, but still rather rolling. The till in such areas is generally hard and compact because it was packed by the ice that moved over it.

Finally, as the Ice Age ended, large lakes were dammed ahead of the melting ice because the preglacial drainage routes, which had been northward, were still blocked by ice. Large quantities of sands, 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 farther back, and broad, flat expanses of lake plains (shown in blue on the map) were left. Largest of these is the Agassiz lake plain in eastern North Dakota. Fossil beaches can be seen today along the former shorelines of the lake.

Sand and gravel, along with ground water, are the most important mineral resources associated with the glacial sediments of North Dakota. Small amounts of ceramic-quality clays, riprap boulders and sodium sulphate are also taken from the glacial sediments. Mineral resources found in the nonglacial sediments include the lignitic coals and associated uranium, high grade clays that are used in the manufacture of ceramics, leonardite, bentonite, potash, salt, petroleum, gas, and sulfur. Water is also taken from the nonglacial sediments, but it is commonly mineralized and of poorer quality than that found in the glacial sediments.



PLEISTOCENE SEDIMENTS INCLUDING TILL, OUTWASH AND LAKE SEDIMENT

CENOZOIC SEDIMENTS, MAINLY SILTSTONE AND SANDSTONE

MESOZOIC SEDIMENTS, MAINLY SHALE

PALEOZOIC SEDIMENTS, MAINLY CARBONATES

PRECAMBRIAN ROCKS, IGNEOUS AND METAMORPHIC CRYSTALLINE ROCKS

JANUARY	FEBRUARY	MARCH
BEGINNING OF PLANET EARTH (JANUARY 1)	NO LIFE	NO LIFE
APRIL	**MAY**	**JUNE**
NO LIFE	FIRST PRIMITIVE LIFE APPEARS ABOUT 3 BILLION YEARS AGO (LATE MAY)	A FEW VERY SIMPLE FORMS OF LIFE EXIST
JULY	**AUGUST**	**SEPTEMBER**
ONLY SIMPLE	FORMS OF	LIFE EXIST
OCTOBER	**NOVEMBER**	**DECEMBER**
PRIMITIVE LIFE	BEGINNING OF CAMBRIAN TIME 550 MILLION YEARS AGO.	

MOST OIL AND GAS FORMED IN NORTH DAKOTA IN EARLY DECEMBER

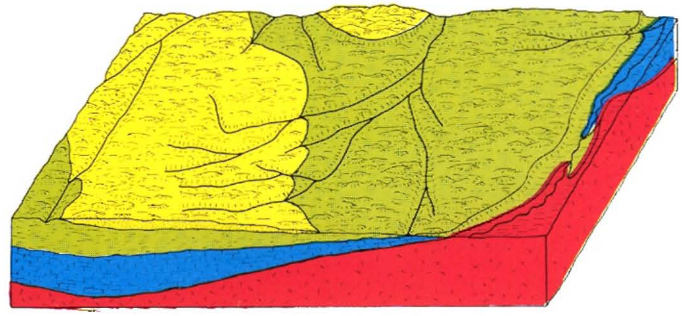
AGE OF DINOSAURS MID-DECEMBER

ICE AGE AT 10:00 PM DECEMBER 31

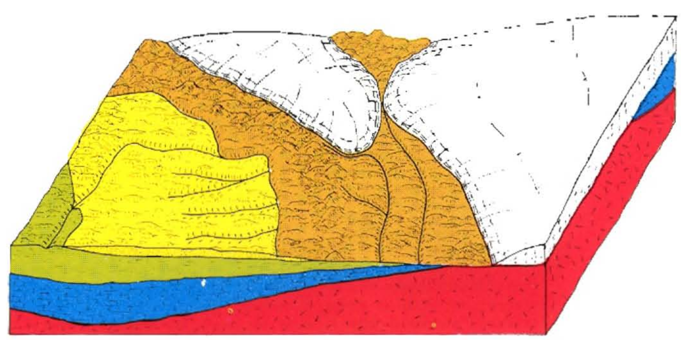
CALENDAR OF THE EARTH'S HISTORY

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 5 billion years of the earth's history compressed into a single year. The earliest life forms did not appear on the earth until late in May of the imaginary year and, until sometime in November, life was still very primitive (one celled organisms, etc.). Primitive man 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.

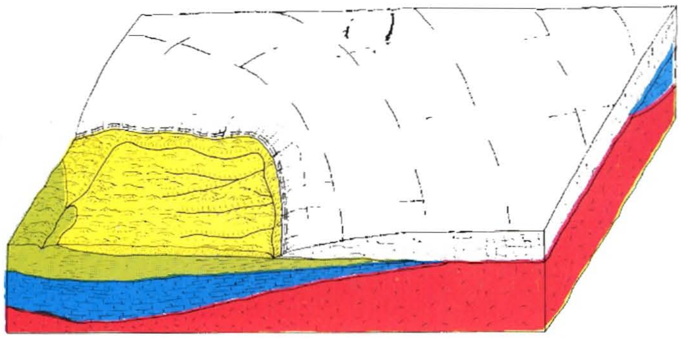
The glacial sediments of North Dakota are all of Pleistocene age (late December 31), and the nonglacial sediments at the surface in the western part of the state were deposited mainly during Cretaceous and Tertiary time (late December). At greater depths are rocks of Paleozoic age (late November and early December), limestone and mudstone, from which oil and gas are produced.



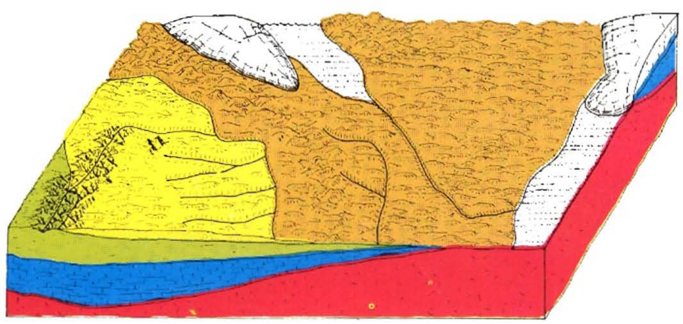
1. North Dakota just before the Ice Age. The main drainage routes are shown on this block diagram which also depicts the subsurface geologic formations. The locations of the streams shown here are speculative, but they reflect our knowledge that drainage was generally northeastward. Most of the land 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 southwest corner 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.



3. The glacier had melted back to the positions shown on the above block diagram by about 12,000 years ago. As it melted back it left from several tens to several hundreds of feet of gravel, silt, and till lying on the older, nonglacial rock formations. Water from the melting ice continued to cut valleys such as the James and Sheyenne valleys in the eastern part of the state.



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 represents 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 slumped 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.