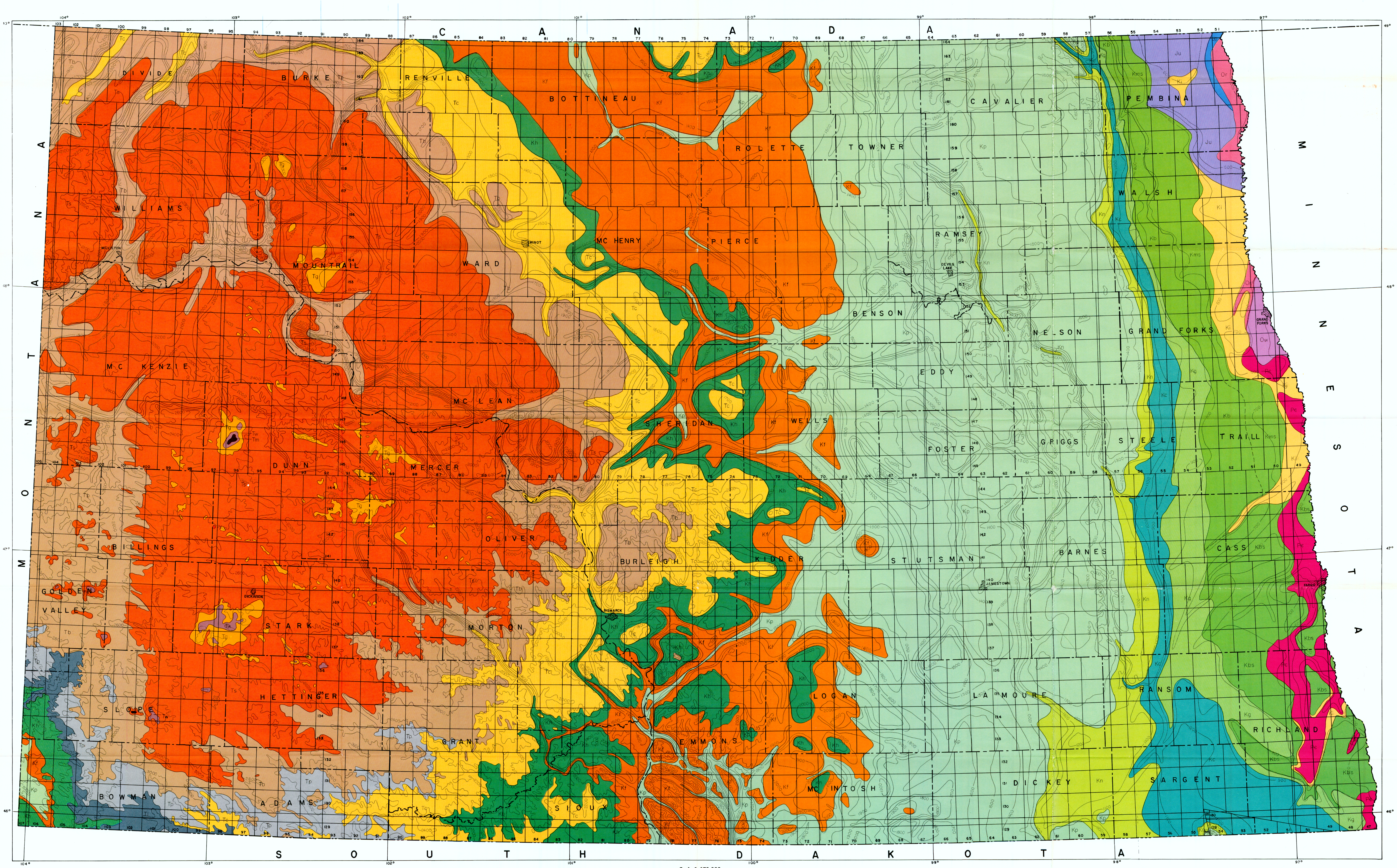
GEOLOGIC AND TOPOGRAPHIC BEDROCK MAP OF NORTH DAKOTA

Miscellaneous Map 25
1983

By
John P. Bluemle

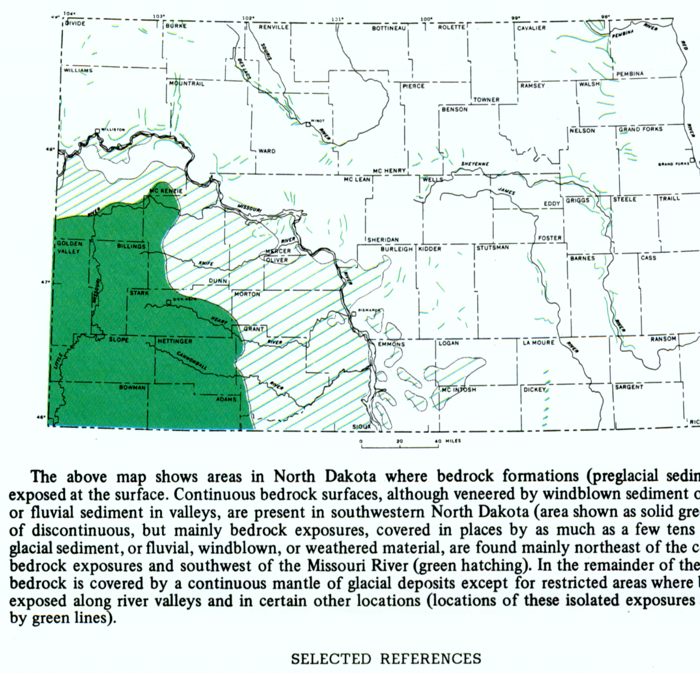
NORTH DAKOTA GEOLOGICAL SURVEY
Don L. Halvorson, State Geologist



Scale 1:670,000

10 0 10 20 30 40 MILES

AREAS OF BEDROCK EXPOSURE IN NORTH DAKOTA



The above map shows areas in North Dakota where bedrock formations (preglacial sediments) are exposed at the surface. Continuous bedrock surfaces, although veneered by windblown sediment on uplands or fluvial sediment in valleys, are present in southwestern North Dakota (area shown as solid green). Areas of discontinuous, but mainly bedrock exposures, covered in places by as much as a few tens of feet of glacial sediment, or fluvial, windblown, or weathered material, are found mainly northeast of the continuous bedrock exposures and southwest of the Missouri River (green hatching). In the remainder of the state, the bedrock is covered by a continuous mantle of glacial deposits except for restricted areas where bedrock is exposed along river valleys and in certain other locations (locations of these isolated exposures are shown by green lines).

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DISCUSSION

The bedrock surface in North Dakota is covered in many places by overburden of the Coleharbor Group and Oahe Formation. This Quaternary- and Holocene-age overburden consists of unconsolidated deposits of glacial sediment, river alluvium, and wind-blown material. It ranges from a residual soil veneer in much of southwestern North Dakota, to as much as several hundred feet of glacial and fluvial sediment in certain eastern and northern parts of the state. The topography on the bedrock surface, depicted on this map, developed as the culmination of a series of geologic events spanning a long period of time. The overall configuration of the bedrock surface was shaped mostly by running water during a lengthy period of Tertiary erosion. During the Quaternary Period following that, glaciers advanced over parts of North Dakota many times, modifying the bedrock surface. Erosional periods, during interglacial episodes and since the end of Wisconsinan time, have further modified the preglacial surface.

The distribution of the latest Cretaceous and early Tertiary deposits reflects the shape of the Williston Basin. The youngest, preglacial bedrock deposits are Eocene and Oligocene deposits (Golden Valley Formation and White River Group), which occur near the center of the basin. These and other Tertiary and Cretaceous formations are known from surface exposures in western North Dakota.

Progressively older bedrock formations subcrop beneath the covering of glacial sediment eastward toward the edge of the Williston Basin. In extreme eastern North Dakota, beneath the Red River Valley, Precambrian rocks directly underlie the glacial deposits in places. The western edge of the Red River Valley is a 400- to 600-foot "scarp" that formed during the long period of Tertiary erosion. Several Cretaceous formations subcrop along this scarp.

Bedrock formations exposed at the surface in North Dakota (see inset map) range from the Upper Cretaceous Greenhorn Formation and all younger formations. The Upper Cretaceous Greenhorn and Carlile Formations are exposed in only a few places in northeastern North Dakota in the Pembina River Valley. The Upper Cretaceous Niobrara Formation is exposed in several places in eastern North Dakota: in the Pembina River Valley, along the Pembina Escarpment, and in the Sheyenne River Valley in southeastern North Dakota. The Upper Cretaceous Pierre Formation is exposed in numerous places in eastern, southern, and southwestern North Dakota. Exposures of all younger Cretaceous and Tertiary bedrock formations occur as continuous areas over much of southwestern North Dakota. No bedrock formations beneath the Greenhorn Formation are exposed in North Dakota.

Among the principal topographic features shown on this map are the deeply buried valleys carved into the bedrock surface in areas of thick glacial sediment. Some of these are the ancestral northeastward extensions of modern rivers such as the Cannonball and Knife River valleys. Others are diversion trenches that were carved by streams when they were diverted during the several episodes of glaciation that affected North Dakota.

The regional northeasterly and northerly preglacial bedrock slope toward Hudson Bay is readily apparent on the map. Prior to glaciation, North Dakota was drained by a few well-developed river systems, among them a river flowing northward through the lowland that today corresponds to the Red River Valley. This river was probably joined by tributaries from South Dakota, such as the Grand-Moreau-Cheyenne river system, as well as certain preglacial northwestern Minnesota rivers. A second large river system included the northeastward extension of the modern Cannonball and Knife Rivers of southwestern North Dakota. These rivers, along with other smaller ones, combined to form a major drainage basin which probably included more than half of North Dakota. This river entered Manitoba just east of the Turtle Mountains. A third major river system nearly coincided with the north-trending portion of the route of the modern Little Missouri River, which, however, flowed through a broad lowland at that time, not badlands. This river continued northward into Canada (Christiansen, 1965; Klassen et al., 1970), draining a broad area of western North Dakota, eastern Montana, and southern Saskatchewan and Manitoba.

Numerous narrow, but deep, valleys carved into the bedrock surface trend at, or nearly at, right angles to the regional northeasterly slope. Most of these valleys formed as a result of the diversion of preglacial river systems by advancing glaciers. The largest glacial diversion trench is the one through which the Missouri River flows today (Bluemle, 1972). It is not yet possible to determine the number, sequence, or specific routes (except locally) of glacial diversions that occurred during the Pleistocene Epoch in North Dakota during the several separate glacial events.

Many of the pre-Pleistocene preglacial bedrock valleys in North Dakota can be distinguished from Pleistocene bedrock valleys (valleys eroded into the bedrock by streams that were diverted by advancing glaciers) in one or more of the following ways: (1) preglacial valleys contain sand and gravel consisting mainly of rock types from western source areas (mainly quartzite and chert), but glacial bedrock valleys contain sand and gravel consisting mainly of rock types from northern source areas (igneous, metamorphic, and carbonate); (2) the preglacial valleys are commonly several miles wide (4 to 10 miles) and they have gently sloping sides, whereas the valleys eroded by streams diverted by glaciers are commonly narrow (a mile or less) and they have more steeply sloping sides; (3) a dendritic drainage pattern is typical of a preglacial drainage developed on flat-lying, preglacial sediments; and (4) many of the glacial drainages trend at right angles, or nearly so, to the regional, northeasterly slope on the bedrock surface in North Dakota.

Erosion by glaciers also disrupted the preglacial surface on the divides between valleys somewhat, although just how much cannot be determined. The earliest glaciers presumably advanced over a surface that was deeply weathered, in some places, resulting in considerable erosion. To the extent that such erosion occurred, the surface depicted on the map is a scoured one not really shaped like the surface that existed prior to the earliest glaciation. Subsequent glaciers probably expended much of their energy rearranging previously deposited glacial sediments.

Generally, the glacial diversion trenches that were eroded into the bedrock surface are narrow and deep, and commonly the deeply buried ones in eastern North Dakota have little or no surface expression. An example of a buried trench without surface expression is the one in Towner and Ramsey Counties that extends from the Canadian boundary east of Hansboro, southward past Crary, where it splits into several separate segments, some of which do have surface expression. This buried trench is more than 600 feet deep in places and generally less than a mile wide. It formed when the north-trending preglacial drainage east of the Turtle Mountains in Towner County and to the north in Canada was blocked by glacial ice and diverted southward, presumably along the edge of the glacier. It has not been determined when this diversion occurred.

The deep diversion trenches in western North Dakota have considerable surface expression, although they are commonly partially filled with several tens to several hundreds of feet of alluvium. Examples of such trenches can be seen in southern Mercer and northwestern Grant Counties.

The topography on the bedrock surface is somewhat dependent upon the relative resistance to erosion of the various bedrock types. This is most obvious in areas not covered by glacial deposits; buttes such as the Killdeer Mountains owe their existence to the layers of resistant Oligocene and Miocene sandstone and carbonate caprocks.

The relief on the bedrock formations buried beneath the glacial sediment is more subdued than it is in unglaciated areas. Buried preglacial valleys such as the downstream extensions of the Cannonball and Knife Rivers are well defined in places where they are developed on the Fox Hills and Hell Creek Formations, but east of the Fox Hills-Pierre contact the valleys tend to lose their well-defined aspect and, indeed, their routes beneath the glacial cover are difficult to determine in places. This may simply be because the softer shale of the Pierre Formation is more easily eroded (the preglacial valleys may never have been especially well defined in the areas of soft bedrock), or it may be because glaciers advanced over eastern North Dakota more often than they did in the west, thereby resulting in more erosion of the bedrock in the eastern part of the state. It may be, too, that early or mid-Pleistocene glaciers diverted the flow of water away from the lower reaches of the rivers, while flow continued in the upper reaches as far as the point of diversion. This may have allowed deeper, better defined valleys to develop in the undiverted parts of the valleys, while the abandoned downstream parts, which were already blocked by a covering of glacial sediment, remained as they were. The undiverted upper reaches of the rivers may also have supported somewhat larger streams than prior to diversion because the climate during the Pleistocene was presumably cooler and more moist than was the preglacial climate.

Any attempt to "decipher" the array of trenches shown on this map is complicated by the fact that many additional glacial diversion trenches are cut into the glacial sediment itself, but not into the bedrock surface. Since they are not carved in bedrock, these diversion trenches, or parts of such trenches, do not appear on the map. Consequently, some of the trenches shown on the map appear to go nowhere; they simply lead from an area where they are incised into the bedrock to a lower area where they bottom in glacial sediment rather than in bedrock.

Thrusting by the glacier has modified the bedrock surface substantially in some places, Sheridan County, for example, resulting in closed depressions or hills that do not represent the true shape of the preglacial bedrock surface. Although it is hoped that most such anomalies have been identified and the configuration and composition of the bedrock surface has been interpreted taking thrusting into account, it is possible that some thrust features were not recognized. In such areas, the out-of-place bedrock blocks, not the undisturbed bedrock surface itself, will be shown.

USES OF THE MAP

This map was prepared to provide an accurate portrayal of the bedrock surface of North Dakota. It should be useful as a tool in interpreting the geologic history of North Dakota during late Tertiary and throughout Quaternary time. The drainage pattern shown on the bedrock surface is the result of a complex sequence of preglacial and glacial events. An understanding of the intricacies of that drainage pattern, as well as of the stratigraphy of the glacial deposits contained in the valleys, will likely be one of the principal prerequisites required of geologists before they are able to accurately reconstruct North Dakota's Pleistocene history. This map should contribute measurably in that effort.

The value of the map is augmented when it is used in conjunction with land-surface maps as a means of studying hydrologic, environmental, and geologic problems. For example, the map can be used as an aid in locating supplies of groundwater, which occur in gravel and sand within the glacial deposits and in alluvium that overlies the bedrock in deep valleys in unglaciated areas.

Valleys cut into the bedrock and filled with glacial sediment are favorable locations for locating groundwater at relatively shallow depths because they commonly contain extensive deposits of gravel and sand. Detailed studies of some of these aquifer systems have been conducted in counties for which the groundwater studies are completed. This map provides insight into the regional relationships of the trenches, which, coupled with a knowledge of the hydrologic characteristics of the bedrock formations that occur beneath the glacial deposits, will help geologists more accurately interpret the broader hydrologic systems.

Information on the bedrock surface is especially valuable to state, regional, and local planners concerned with environmental problems such as the location of landfill sites. The thickness and hydrologic properties of the material overlying the bedrock surface is an important consideration in insuring the protection of aquifers from potential sources of contamination such as landfills, mining operations, and oil well drilling.

ACCURACY OF THE MAP

The most important source of information used in compiling this map was the test-hole data obtained during drilling by the North Dakota State Water Commission as part of a series of comprehensive county groundwater studies of North Dakota. These studies have been under way since about 1960. Agencies cooperating in the groundwater studies are: (1) the North Dakota Geological Survey, which has been responsible for describing the geology in the counties involved; (2) the North Dakota State Water Commission, which has conducted extensive test drilling; (3) the County Commission (or its equivalent) for each of the counties involved; and (4) the United States Geological Survey, which has been responsible for describing the groundwater hydrology.

Additional geologic and topographic control for the map was obtained by use of the North Dakota Geological Survey power auger; by study of exploratory oil well geophysical logs; by study of exploratory coal drilling data; and by examination of surface exposures. In certain areas, assorted sources of data such as Works Progress Administration well schedules, commercial water-well driller's records, Minuteman Missile site drilling data, and seismic information were utilized in compiling the map.

The accuracy of the map is dependent upon the density and reliability of the control points. The map is essentially precise in those parts of southwestern North Dakota where surface exposures are widespread and control is nearly continuous. The map is less precise in areas of thick glacial overburden, where only a few test holes have penetrated as deep as the bedrock surface.

The relief on the bedrock surface southwest of the Missouri River is greater in most places than it is north and east of the river. To avoid unnecessary crowding of the contours, a 200-foot interval is used southwest of the Missouri River. Elsewhere, a 100-foot contour interval is used.

The accuracy of the bedrock contacts shown on the map, particularly in areas where the thick covering of glacial overburden necessitates indirect observation of the bedrock surface, is considerably improved over previous bedrock maps of North Dakota. This improved accuracy, the result of large amounts of additional data, is especially important in some eastern parts of the state where the location of the contacts between the relatively flat-lying bedrock formations are strongly affected by the subglacial topography.

The following descriptions of the lithologic units are generalized insofar as they refer to the units statewide rather than in the areas of subcrop shown on the map.

	UPPER AND MIDDLE TERTIARY ROCK, UNDIVIDED––Butte caprock consisting of fluvial or lacustrine sandstone or limestone of Oligocene, Miocene, or Pliocene age; may include the White River Group in some areas or the Killdeer Formation (informal unit) on the Killdeer Mountains; as thick as 120 metres (400 feet).
Tw	**WHITE RIVER GROUP (OLIGOCENE)**––Brule Formation: Pinkish siltstone, clay, and sand; river and lake sediment; as thick as 50 metres (150 feet). Chadron Formation: Light-colored sand with quartzite and porphyry pebbles, overlain by dark clay; river and lake sediment; as thick as 30 metres (100 feet).
Tg	**GOLDEN VALLEY FORMATION (EOCENE AND PALEOCENE)**––Upper member: Yellowish-brown micaceous sandstone, sand, silt, and clay; fluvial sediment; as thick as 60 metres (200 feet). Lower member: White or yellow clay, silt, and sand; a weathering zone developed on underlying unit; as thick as 20 metres (65 feet).
Ts	**SENTINEL BUTTE FORMATION (PALEOCENE)**––Grayish-brown silt, sand, clay, sandstone, and lignite; river, lake, and swamp sediment; as thick as 200 metres (600 feet).
Tb	**BULLION CREEK FORMATION (PALEOCENE)**––Yellowish-brown silt, sand, clay, sandstone, and lignite; river, lake, and swamp sediment; as thick as 200 metres (600 feet).
Tp	**SLOPE FORMATION (PALEOCENE)**––Grayish-brown and yellowish-brown silt, sand, clay, sandstone, and lignite; river, lake, and swamp sediment; as thick as 100 metres (300 feet).
Tc	**CANNONBALL FORMATION (PALEOCENE)**––Olive-brown sand, shale, and sandstone; marine shoreline and offshore sediment; as thick as 120 metres (400 feet).
Tl	**LUDLOW FORMATION (PALEOCENE)**––Grayish-brown and yellowish-brown silt, sand, clay, sandstone, and lignite; river, lake, and swamp sediment; as thick as 100 metres (300 feet).
Kh	**HELL CREEK FORMATION (UPPER CRETACEOUS)**––Gray sand, silt, clay, and sandstone; river sediment; as thick as 150 metres (500 feet).
Kf	**FOX HILLS FORMATION (UPPER CRETACEOUS)**––Olive-brown sand, shale, and sandstone; marine shoreline and offshore sediment; as thick as 120 metres (400 feet).
Kp	**PIERRE FORMATION (UPPER CRETACEOUS)**––Dark-gray shale; marine offshore sediment; as thick as 700 metres (2,300 feet).
Kn	**NIOBRARA FORMATION (UPPER CRETACEOUS)**––Light-brown to dark-gray calcareous shale; marine offshore sediment; as thick as 75 metres (250 feet).
Kc	**CARLILE FORMATION (UPPER CRETACEOUS)**––Dark-gray shale; marine offshore sediment; as thick as 120 metres (400 feet).
Kg	**GREENHORN FORMATION (UPPER CRETACEOUS)**––Dark-gray calcareous shale; marine offshore sediment; as thick as 45 metres (150 feet).
Kb	**BELLE FOURCHE FORMATION (UPPER CRETACEOUS)**––Medium- to dark-gray, silty to sandy shale; marine offshore sediment; as thick as 105 metres (350 feet).
Kbs	**BELLE FOURCHE–SKULL CREEK, UNDIVIDED (LOWER TO UPPER CRETACEOUS)**––Belle Fourche Formation (as described above). Mowry Formation: Medium- to dark-gray shale; marine offshore sediment; as thick as 55 metres (180 feet). Newcastle Formation: Light-gray, fine- to medium-grained sandstone; marine shoreline and offshore sediment; as thick as 45 metres (150 feet). Skull Creek Formation: Medium-gray to dark-gray shale; marine offshore sediment; as thick as 40 metres (140 feet).
Kms	**MOWRY–SKULL CREEK, UNDIVIDED (LOWER TO UPPER CRETACEOUS)**––Mowry, Newcastle, and Skull Creek Formations (as described above).
Ki	**INYAN KARA (LOWER CRETACEOUS)**––Light-gray, fine to coarse sandstone and gray shale; river, lake, and nearshore marine sediment; as thick as 135 metres (450 feet).
Ju	**UNDIFFERENTIATED JURASSIC SEDIMENTS**––Dark-gray, greenish, and varicolored shale with local limestone (Swift and Rierdon Formation equivalents); mainly nearshore marine sediments; as thick as 180 metres (600 feet).
Jp	**PIPER FORMATION EQUIVALENT (JURASSIC)**––White to buff, brown, or gray limestone, gypsum, and anhydrite; offshore marine sediments; as thick as 190 metres (625 feet).
Or	**RED RIVER FORMATION (ORDOVICIAN)**––Yellowish- to brownish-gray limestone and dolomite; offshore marine sediment; as thick as 215 metres (700 feet).
Ow	**WINNIPEG GROUP (ORDOVICIAN)**––Light-gray to greenish-gray shale and light-gray sandstone; marine nearshore and offshore sediment; as thick as 125 metres (400 feet).
pC	**PRECAMBRIAN ROCKS**––Greenschists and amphibolites; banded iron formation; stretched pebble conglomerates; metabasalt; serpentinite; felsic tuff; mylonite; intermediate felsic plutonic rocks; migmatite; layered gneiss.