GEOLOGY

of

BURKE COUNTY, NORTH DAKOTA

by
T. F. Freers
North Dakota Geological Survey
Grand Forks, North Dakota
1973

BULLETIN 55 – PART I
North Dakota Geological Survey
Edwin A. Noble, *State Geologist*

COUNTY GROUND WATER STUDIES 14 – PART I
North Dakota State Water Commission
Vernon Fahy, *Secretary and Chief Engineer*

Prepared by the North Dakota Geological Survey
in cooperation with the North Dakota State
Water Commission, the United States Geological Survey,
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ABSTRACT

Burke County is in northwestern North Dakota near the center of the Williston basin. It is underlain by sedimentary rocks of Paleozoic, Mesozoic, and Cenozoic age which range in thickness from about 9,400 to 11,700 feet, thickening southward and generally dipping gently to the south or southwest. The surficial deposits are glacial drift of Late Wisconsinan age except for scattered exposures of the Tertiary Sentinel Butte and Tongue River Formations in the northern part of the county and slough and spring deposits of the Coteau and Coteau escarpment areas.

Surficial deposits consist chiefly of glacial till and outwash with some areas of post-glacial sand, silt and clay. The county has been divided into four areas on the basis of topography. These areas are: 1) the Central Lowlands which is an area of generally low relief, 2) the Missouri Escarpment which is a steep northward sloping band south of the Central Lowlands, 3) the Missouri Coteau which is an area of moderate to high relief and 4) the Coteau slope which is an area of low to moderate relief.

INTRODUCTION

Purpose

This report constitutes Part I in a four-part series on the geology and ground water resources of Burke and Mountrail Counties, North Dakota. The series was prepared through the cooperation of the North Dakota Geological Survey, North Dakota State Water Commission, U. S. Geological Survey, and the Burke and Mountrail County Boards of Commissioners. Part II is a basic ground water and well survey, Part III deals with the ground water resources of the two counties, and Part IV is the geology of Mountrail County. Similar reports have been published for about half of the other counties of North Dakota.

The topography, stratigraphy, and geomorphology of Burke County are described in this report. The reader interested in an interpretation of the geologic history is referred to reports on Divide County (Hansen, 1967), Williams County (Freers, 1970), and southern Saskatchewan (Christiansen, 1956). The geologic history of Mountrail County will be dealt with extensively in Part IV of this bulletin.

Methods of Study

Field work for this report was completed by the author during the field seasons (May to November) of 1965 and 1966. Data gathered in the field were recorded on one inch to the mile (1:63,360) Burke County highway maps, 7.5-minute and 15-minute series U. S. Geological Survey quadrangle maps, and on aerial photographs, scale 1:20,000 or about one inch to 3¼ miles.

Most mapping was done by driving along all accessible section lines and examining the near-surface materials. Thorough examination of the air photos facilitated the identification of lithologic and geomorphic units that did not intersect section lines. These units were examined on foot to check their lithologies.

Almost all the lithologic identifications were of sediments within four to six feet of the surface. Additional sediments were obtained from hand auger samples, from samples collected with a truck-mounted power auger of the North Dakota Geological Survey, and from rotary drill cuttings provided by the North Dakota State Water Commission.

Previous Work

Dawson (1875) described the topography and glacial deposits of central North America along the international boundary between Canada and the United States. Chamberlin (1883) published a map of the Missouri Coteau including that portion in Burke County. In 1932, Alden described the glacial terrain of Burke County where he applied the term Altamont Moraine to the Missouri Coteau. Unpublished work by Alpha (University of North Dakota, 1935) dealt with the geology and ground water of a four-county area including Burke County.

Topography

The topography of Burke County can be divided into four basic areas: a) the Central Lowlands; b) the Missouri Coteau Escarpment; c) the Missouri Coteau; and d) the Coteau Slope. Some overlap occurs in these four areas and small areas of one type of topography may be found within another area. Figure 1 is a generalized contour map of the county on which the four different topographic areas are outlined. North of the 2,000-foot contour on figure 1, the surface slopes gently to the north. South of the 2,000-foot contour the surface rises over 400 feet in about 5 miles; it lies between 2,300 and 2,500 feet from there southward.

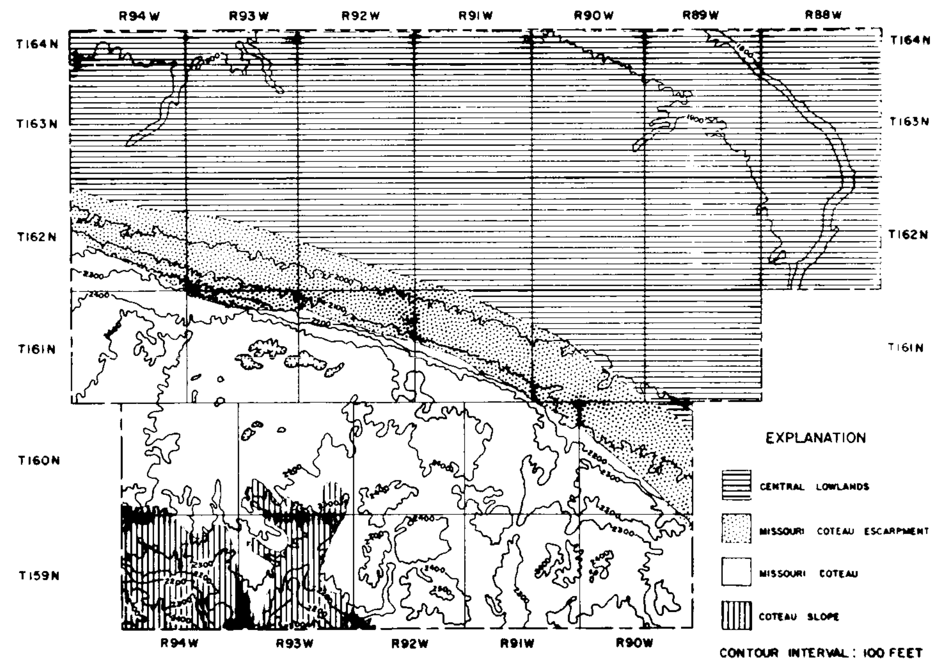

FIGURE 1. Generalized topographic map of Burke County showing the four physiographic areas.

Central Lowlands–The Central Lowlands (fig. 2) are a gently undulating glaciated plain with low relief. Drainage is generally good. Water runs off most areas into natural drainageways such as streams and coulees, but many shallow depressions retain water after heavy rains. Many knobs and ridges are scattered throughout the area. They are from a few feet to over 20 feet high. Most of the stream valleys that dissect the area are shallow, such as the East Branch of Short Creek above Short Dam. One valley, the Des Lacs (pl. 1), is deep.

Missouri Coteau Escarpment–Immediately south of the Central Lowlands, the land surface rises from about 2,000 feet to about 2,350 feet in 3½ miles. This rise is the Missouri Coteau Escarpment (pl. 2). The southernmost edge of the escarpment rises 150 feet or more in about 200 yards. From this steep scarp northward, the escarpment is a gently sloping smooth surface that is crossed by many steep-sided valleys. Drainage is integrated on the Missouri Coteau Escarpment.

Missouri Coteau–The Missouri Coteau is a hilly area with moderate to high relief and steep slopes (fig. 1). Hundreds of sloughs and undrained depressions are present with adjacent hills which rise as much as 150 feet above the low areas. Toward the southern edge of the Missouri Coteau, the relief becomes less and the slopes are gentler, but many hills and sloughs occur here too. The Missouri Coteau can be subdivided into two distinct topographic areas: Area A–high relief (50-150 feet) and steep slopes (average maximum slope 18°); and Area B–moderate relief (20-50 feet) and moderate slopes (average maximum slope 8°) (fig. 3). The differences between these two types of areas and their origins are discussed by Clayton (1967).

Little or no integration of drainage occurs on the Missouri Coteau except along streams such as Stony Creek or next to large lakes, such as Upper Lostwood Lake. All rainfall collects in sloughs and depressions throughout the area. The water that does not evaporate seeps into the ground and is one of the most important sources of ground water recharge in Burke County.

Coteau Slope–The Coteau Slope in southwestern Burke County is an area of low to moderate relief (5 to 50 feet) with gentle to moderate slopes (2° to 8°). Integration of drainage is variable although it tends to be more integrated southward. Streams in this area drain into the Missouri River System. Some deep, steep-sided river valleys with associated level terraces are found in the area (pl. 1).

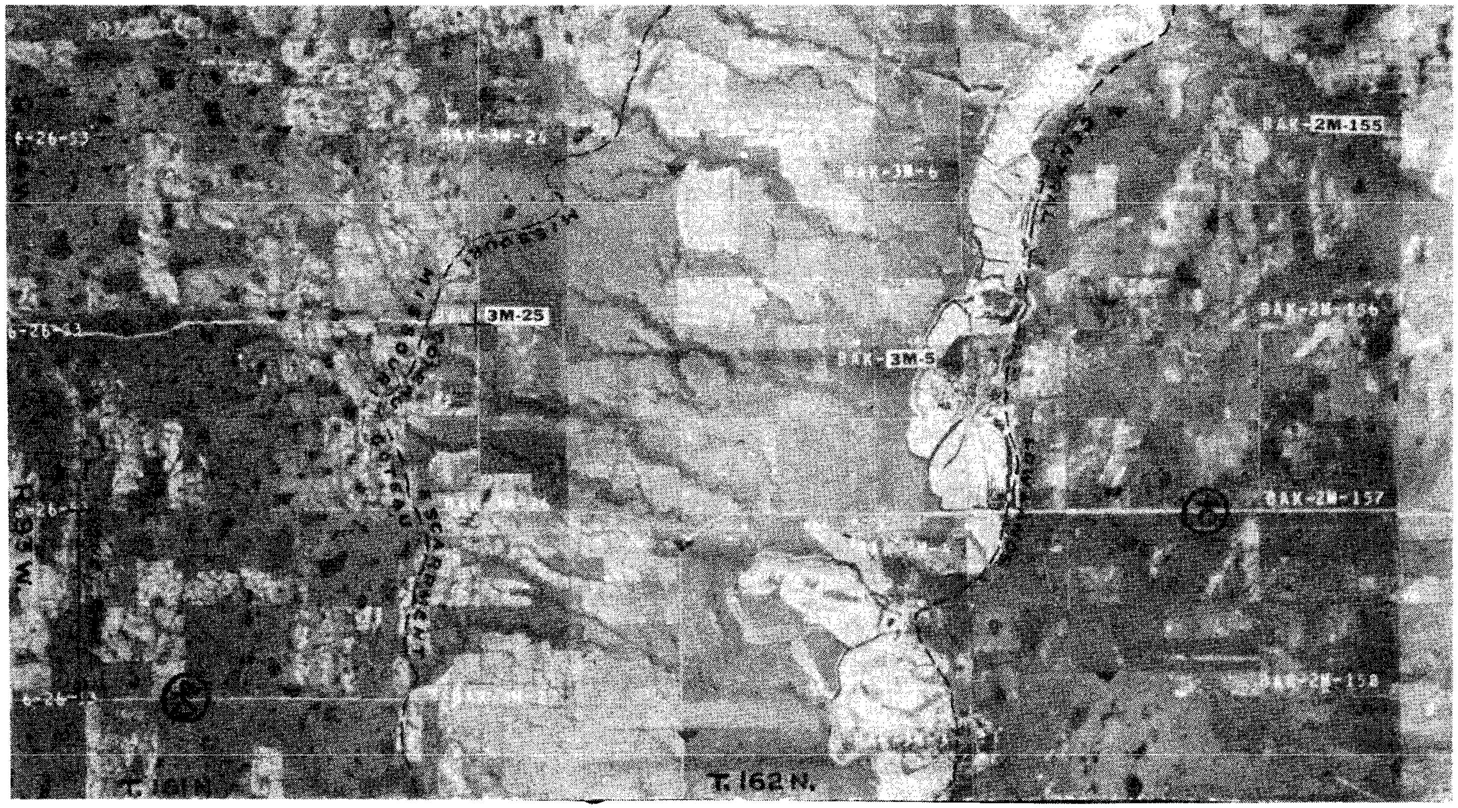

FIGURE 2. Air photo mosaic showing the Central Lowlands, Missouri Coteau Escarpment and the Missouri Coteau topographic areas.

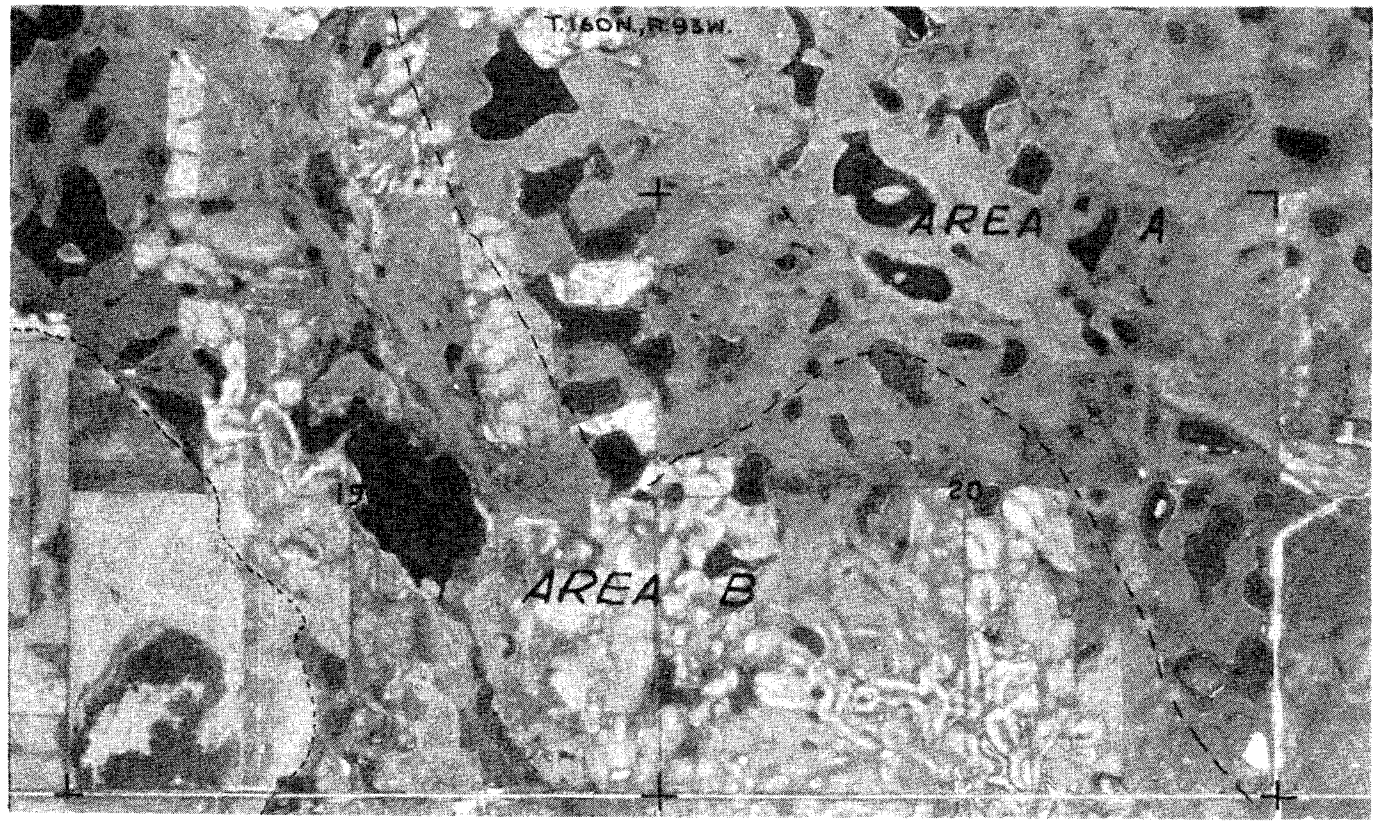

FIGURE 3. Air photo showing two basic topographic areas of the Missouri Coteau: Area A, high relief and steep slopes (average maximum slope 18°), and Area B, medium relief and moderate slopes (average maximum slope 8°).

Rock and Sediment

All but a small area of Burke County is underlain at the surface by sediment. Sediment can be described as any earthen material that is loose enough to be dug with a shovel or hoe and is called "soil" by civil engineers. The remainder of Burke County, less than 1 percent of the area, is underlain at the surface by rock, which is any hard earth material that cannot be dug with a shovel and does not disintegrate rapidly in water. This report is concerned primarily with sediment, as this is the dominant earth material within the upper 50 to 200 feet of the surface. Beneath the sediment, rock material is present for thousands of miles into the earth.

Civil engineers, soil scientists, and geologists use somewhat different systems of sediment and rock classification. One of the more easily understood sediment classifications lists all grain sizes from the smallest to the largest and then groups them under common names. For example, sand grains are as small as 1/16 millimeter and as large as 2 millimeters (fig. 4). Therefore, if a sediment consists of all grain sizes between 1/16 and 2 millimeters, it is a sand deposit. However, this does not commonly happen in nature as most sediments are mixtures.

Figure 4 lists grain sizes from clay to boulders and gives the common name for each category. This classification is good only for deposits that are so well sorted that they fall within a single category. This system is used in Burke County. A typical sediment in Burke County is composed of equal parts of sand, silt, and clay, and a small fraction of pebbles and boulders. Such sediment can be called various names, such as till, loam, stony loam, etc., but these names usually have more specific or alternate meanings. Therefore, in this report, the sediments are named as indicated in figure 4 with some degree of overlapping. Any material larger than sand grains may be present in any of the sediments; and, if they are present, they are mentioned. Boulder-clay contains pebbles, cobbles, and boulders as the name suggests.

Slough Sediment

The innumerable sloughs of Burke County contain black organic clay and silt deposits up to 25 or 30 feet thick. The slough sediments lie on the Coleharbor Formation. The slough clays are fairly uniform in appearance. The clay is dark gray to black with variable amounts of organic material. Some of the deposits have an unpleasant odor when freshly dug from the slough. Augering of the slough deposits has

MODIFIED WENTWORTH SCALE

		1				$1\frac{1}{4}$	$1\frac{1}{4}$ TO $2\frac{1}{2}$	$2\frac{1}{2}$ TO 10	> 10	INCHI
< $\frac{1}{256}$	< $\frac{1}{16}$	$\frac{1}{16}$ TO $\frac{1}{4}$	$\frac{1}{4}$ TO $\frac{1}{2}$	$\frac{1}{2}$ TO 2	2 TO 8	8 TO 32				MILLI
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	COBBLES	BOULDERS	
		SAND			GRAVEL					

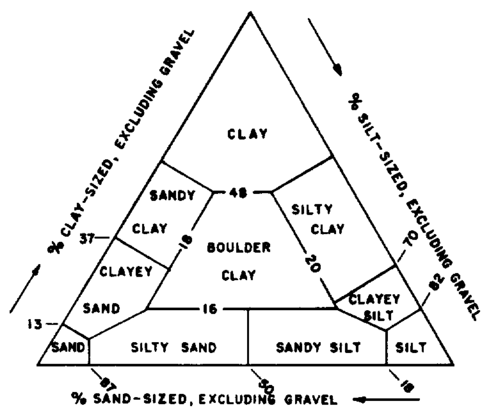

FIGURE 4. Classification chart used to classify sediments during field mapping in Burke County.

revealed that the upper parts of the sloughs are generally uniform silt and clay; near the bottoms of the sloughs the grain size tends to be larger. Some of the clays are dry on the surface and will support heavy equipment but they are moist at depth. Near the contact of the slough sediments with the Coleharbor Formation, the clay tends to be lighter colored and calcareous. The slough sediment is generally of Holocene Age, although some of the oldest deposits may be of Pleistocene Age.

Spring Deposits

Spring deposits that occur over only a fraction of a percent of Burke County are stratigraphically equivalent to the slough deposits. These deposits are in open-ended depressions below the Missouri Coteau Escarpment. Water seeping out of the ground in such areas commonly results in wet marshes with thick vegetation. Dead vegetation collects in the spring pits below water allowing peat to form. Little is known about the peat and, due to the small area involved, it is unlikely that it is of any economic value.

Coleharbor Formation

The Coleharbor Formation was first named in a publication by Bluemle (1971). The type section for the Coleharbor Formation is located south of Coleharbor, McLean County, North Dakota in sec. 22, T. 147 N., R. 84 W. The best exposures are along the wave-cut bluffs of Lake Sakakawea three miles north of Garrison Dam. This formation is widespread from central Minnesota to the western limit of the Keewatin ice sheet and from the Canadian Shield to the limit of glaciation in South Dakota.

Distribution–The Coleharbor Formation covers 98 percent of the surface of Burke County (pl. 1). Its thickness ranges from 0 feet near the coal mines south of Columbus to 483 feet just north of Columbus in a buried river valley. The average thickness of the Coleharbor Formation, based on information obtained from 89 test holes drilled to bedrock, is 161 feet although this is somewhat misleading as the holes were not drilled at random. North of the Missouri Coteau Escarpment, the depth to bedrock in most areas is less than 100 feet. South of the Missouri Coteau Escarpment, the depth to bedrock in most areas is greater than 100 feet (pl. 2).

The Coleharbor Formation is underlain by the Sentinel Butte or Tongue River Formation and overlain by slough, aeolian, spring, or alluvial deposits. Three main types of sediment occur in the Coleharbor Formation: boulder-clay, sand and gravel, and silt and clay. Each of these sedimentary types is found in layers or lenses in the formation.

Boulder-clay–The Coleharbor Formation is composed largely of boulder-clay. In the 89 holes drilled through the Coleharbor Formation by the North Dakota State Water Commission, it was found that 65 percent of the footage was boulder-clay. This figure is misleading as the holes were drilled primarily to find water-bearing sands and gravels. On the surface, boulder-clay covers 85 to 90% of the area of the county.

Boulder-clay is a mixture of varying amounts of sand, silt, and clay and a few percent of pebbles and boulders (fig. 4). The term "boulder-clay" is synonomous with the term "till" as used by soil scientists, most geologists, and highway engineers.

Boulder-clay is yellowish-gray (5Y 7/2) to olive gray (5Y 5/2) above the water table and dark olive gray (5Y 3.5/2) to olive gray (5Y 3/2) below the water table. The dark olive gray is commonly referred to as "blue clay" by water-well drillers. This color change is often a good marker to indicate when water has been penetrated by the drills.

The mineralogy of the boulder-clay is uniform. The clay-sized grains consist largely of montmorillonite and other clay minerals, as well as calcite, dolomite, quartz, and feldspar. The silt and sand fractions of the Coleharbor Formation are composed largely of quartz and feldspar with some limestone, dolomite, and shale. The gravel fraction (pebbles, cobbles, and boulders) consists largely of limestone, dolomite, and igneous and metamorphic rocks, shale, lignite, and claystone.

Secondary minerals (minerals that were deposited some time after the boulder-clay was deposited) are sometimes found within the boulder-clay. Among these are calcite, gypsum, limonite, manganese dioxide, and dolomite.

Calcite is deposited within the soil horizon of the boulder-clay in the form of caliche. Caliche is a hard, white mineral commonly found on the undersides of pebbles in the upper few feet of the boulder-clay. Gypsum is also common in the boulder-clay. It is found as selenite crystals in little holes or pockets or along joints in the boulder-clay. The crystals are usually less than a fourth inch long and are in clusters up to one-half inch across. Limonite is found everywhere in the boulder-clay above the water table. It is generally just a yellowish stain along joint faces or around roots. Less often seen are black deposits of manganese dioxide, which stain joint faces.

One unusual deposit, which is thought to be secondary, occurs in a 6-inch roadcut at the southwest section corner of sec. 6, T. 159 N., R. 94 W. in Burke County. The deposit is a 2-4-inch-thick moderate orange pink (5YR 8/4) band of powder in the boulder-clay about two feet below the land surface. The band, which is wavy for 35 feet along the outcrop, is horizontal in overall aspect. About one foot below this band is another similar band that is only about ten feet long on the exposure. Dr. Frank Karner, petrologist at the University of North Dakota, ran an X-ray analysis of the pink powder. His results (personal communication) indicated a high percentage of dolomite and calcite.

Jointing occurs in the boulder-clay throughout the county. Most of the joints are vertical though some are horizontal. The vertical joints intersect along the NE-SW or NW-SE strikes. One area of jointing that occurs at the foot of the Missouri Coteau Escarpment has been accentuated by upward water migration, which has caused trellis drainage patterns that are easily seen on the ground and on aerial photographs (fig. 5). These joints are parallel to the Missouri Coteau (pl. 1). They appear as a series of parallel light and dark lines about ½ mile wide on aerial photographs and they extend from sec. 23, T. 162 N., R. 92 W. to sec. 15, T. 161 N., R. 91 W. Springs are closely associated with the joints.

Sand and gravel–Twenty percent of the footage drilled during this project penetrated gravel and sand in the Coleharbor Formation. Again, this is misleading because of the selectivity in the drilling program. A closer estimate for the amount of gravel and sand in the Coleharbor Formation might be about 10 percent. The sand and gravel fraction of the formation is found as lenses or layers consisting of various mixtures of sand and gravel. Most of the sand and gravel is gravelly sand or sandy gravel with almost no pure gravel or sand deposits (pl. 1).

Grain-size composition of the sand and gravel is commonly highly variable within a particular deposit. However, certain areas in the county tend to have similar deposits. The sand and gravel deposits on the Missouri Coteau are generally the poorest sorted and those not on the Missouri Coteau and especially in river valleys are generally the best sorted. A few of the sand and gravel deposits on plate 1 have such poor sorting that large blocks or layers of boulder-clay are included.

The minerals contained in the sand and gravel fraction of the Coleharbor Formation are about the same as the sand and gravel grains in the boulder-clay except less soft minerals such as shale, lignite, and claystone occur. The sand is mostly quartz and feldspar with some shale and lignite. The gravel is largely limestone, dolomite, and igneous and metamorphic rocks with a small fraction of shale, concretions, petrified wood, and some chert.

FIGURE 5. Air photo of area of deformed bedrock and associated spring pits below the Missouri Coteau Escarpment in T. 162 N., R. 91 W., and R. 92 W. in Burke County. Arrows indicate springs.

Secondary mineral occurrences in the sand and gravel deposits are variable. In almost all deposits, calcium carbonate in the form of caliche coats the bottoms of the pebbles and stones in the upper one or two feet of a deposit. Figure 6 clearly shows the caliche deposits in the upper zone of the sand and gravel. Near the bottom of some gravel pits are rusty-colored deposits that coat the gravel and sand grains.

The sand and gravel is rarely horizontally layered, but, rather, the individual beds tend to dip. Deposits on the Missouri Coteau are commonly tilted, faulted, or curved. Jointing is not evident in any of the deposits.

Many of the sand and gravel deposits that are too small to show on the map (pl. 1) are indicated by a gravel pit symbol. One of the larger gravel pits is at Lignite where the sand and gravel is overlain by 3 to 5 feet of boulder-clay. A sand and gravel pit in the center of sec. 22, T. 161 N., R. 93 W., has a lot of faulting and folding of the beds.

Sand and gravel have high permeabilities and are the largest source of potable ground water in Burke County. In almost all cases where a sand and gravel deposit is penetrated below the water table, a high-quality water can be produced for domestic use.

Silt and clay–Test hole data indicate about 15 percent of the Coleharbor Formation is silt and clay. The surface area underlain by silt and clay is about 5 percent. However, two silt and clay deposits at North Gate and southeast of Bowbells are very thin. The bulk volume of silt and clay in Burke County is probably less than 5 percent.

The mineralogy of the silt and clay is the same as the silt and clay contained in the boulder-clay; that is, primarily clay minerals (especially montmorillonite), feldspar, calcite, dolomite, and quartz. Bedding or horizontal layering is common in the silt and clay. The individual beds range in thickness from one-tenth to one-half inch. On the Missouri Coteau, many of the beds are folded and faulted. The color of the silt and clay on or near the surface is yellowish gray (5Y 7/2) to light olive gray (5Y 5/2). More silt in the sediments results in yellower colors and more clay results in more green and gray colors. At greater depths below the water table, the color of the silts and clays are darker olive grays (5Y 4/1) or olive black (5Y 2/1).

On plate 1, the silt and clay deposits are not differentiated into grain-size sorting categories. The sediments are mostly silty clay or clayey silt, but toward the edge of the deposits there may be some sand present in significant quantities. Generally, a clayey silt occurs near the edge of a deposit and grades to a silty clay or clay at the center of the deposit.

FIGURE 6. Anticlinal sand and gravel beds with caliche deposition in the upper one to two feet. Located in the SE¼ NW¼, sec. 22, T. 161 N., R. 93 W.

Fossils–Fossil material was found in the Coleharbor Formation at eleven locations in Burke County. Table 1 lists the types of deposits at each location. Table 2 gives the fossil identifications. Ostracod identifications were by L. D. Delorme, Research Scientist, Groundwater section, Canada Department of Energy, Mines and Resources. The other identifications were made by Dr. Barry B. Miller, Kent State University, Kent, Ohio. The assemblages are similar to those found on the Missouri Coteau in other parts of North Dakota and Saskatchewan. Most of the fossils are ostracods, pelecypods, aquatic snails, and charophytes. Land snails were identified at three sites.

Identification of the Coleharbor Formation–The Coleharbor Formation is the only formation in Burke County that contains boulder-clay. The post-glacial alluvial fan deposits along the base of the Coteau Escarpment are easily confused with the boulder-clay. The main difference between the two is that the alluvial deposits are sandier, not as hard as the boulder-clay, and have some bedding. The alluvial fan sediments are primarily silty, clayey sand or silty sand with few or no gravel-size grains. The only other sediments that contain gravel are preglacial alluvium and post-glacial alluvium. The preglacial alluvium, which will be discussed later, is easily recognizable from the Coleharbor Formation gravel. The post-glacial alluvial gravel has the same mineralogy as the Coleharbor Formation gravel but it has more fine grained and organic materials, it is darker colored, and it is found only on valley bottoms. This type of sediment is almost never found in the Coleharbor Formation.

Age and origin–The Coleharbor Formation is a glacial deposit of Pleistocene age. It is no younger than 9,000 years old and probably no older than 250,000 years old. The sediments of the Coleharbor Formation were deposited directly from a glacier or by streams flowing from the glacier. These sediments were carried in the glacier from Canada and locally.

Boulder-clay is largely glacial till, which is a sediment that is deposited directly from a glacier with little or no movement by water. Boulder-clay on the Missouri Coteau slid and slumped to its present position when the glacier melted about 10,000 years ago. Sand and gravel were usually deposited by water flowing in, on, or in front of the glacier. Silt and clay were deposited in lakes and ponds.

Preglacial Alluvium

In three of the test holes drilled during this project, brown quartzitic gravel was penetrated immediately above bedrock. The gravel is well rounded suggesting an alluvial deposition. Nowhere in Burke County was such gravel seen at the surface. Little is known of these brown gravels in Burke County, but they are similar to the Wiota and Flaxville Gravels of Montana.

Test Hole NDSWC 2898, drilled in NW¼ NW¼ SW¼ sec. 21, T. 163 N., R. 93 W., penetrated 46 feet of gravel from 154 to 200 feet below the surface. This gravel is sandy and clayey with the gravel fraction consisting of 30 to 40 percent moderate brown (5YR 3/4) to dark reddish brown, chalcedony, jasper, and quartzite, 15 to 25 percent shale, and the remainder a silica-cemented moderate brown (5YR 3/2) to dark greenish gray (5.6Y 4/1) sandstone, light olive gray (5Y 6/1) limestone, blackish, whitish, and greenish granitics, and clear and milky quartz. Clearly this is not a strictly non-glacial deposit, but the large percentage of brown chalcedony, jasper and quartz suggests a western and southwestern origin for part of the deposit.

Test hole NDSWC 3385, drilled in the SE¼ SE¼ SW¼, sec. 14, T. 160 N., R. 93 W., penetrated 4 feet of gravel from 180 to 184 feet below the surface. This gravel is described as a fine to medium, moderately well-sorted, subangular and subrounded, dark brown gravel. Test hole NDSWC 3604, drilled in NW¼ NW¼ NW¼, sec. 20, T. 163 N., R. 94 W., penetrated 11 feet of fine to coarse, brown, interbedded, generally subrounded gravel with some limestone, dolomite, and granite.

Sentinel Butte and Tongue River Formations

Only two bedrock formations, the Sentinel Butte and Tongue River Formations, occur at the surface in Burke County. Both formations belong to the Fort Union Group. All outcrops, except for one in sec. 32, T. 159 N., R. 93 W., occur north of the Missouri Coteau Escarpment. The Sentinel Butte and Tongue River Formations are alike in many ways and they will be described together.

Distribution–The Tongue River Formation underlies the Sentinel Butte Formation in the southern half of Burke County and underlies glacial drift in the northeastern and northernmost parts of the county. The Sentinel Butte Formation crops out at many localities north of the Missouri Coteau Escarpment and the Tongue River Formation crops out at several localities near the Canadian boundary. The Sentinel Butte Formation underlies the Coleharbor Formation in most of the county.

The two formations consist of numerous alternating layers that range from a fraction of an inch to many feet in thickness and dip

	System	Sequence	Group or Formation		Dominant Lithology
Cenozoic	Tertiary	Tejas	Coleharbor		Sandy loam, sand and gravel
Cenozoic	Tertiary	Zuni	Fort Union Group	Sentinel Butte	Shale, clay, sandstone and lignite
Cenozoic	Tertiary	Zuni	Fort Union Group	Tongue River	Shale, sandstone and lignite
Cenozoic	Tertiary	Zuni	Fort Union Group	Cannonball-Ludlow	Marine sandstone and shale
Mesozoic	Cretaceous	Zuni	Hell Creek		Sandstone, shale and lignite
Mesozoic	Cretaceous	Zuni	Montana Group	Fox Hills	Marine sandstone
Mesozoic	Cretaceous	Zuni	Montana Group	Pierre	Shale
Mesozoic	Cretaceous	Zuni	Colorado Group	Niobrara	Shale, calcareous
Mesozoic	Cretaceous	Zuni	Colorado Group	Carlile	Shale
Mesozoic	Cretaceous	Zuni	Colorado Group	Greenhorn	Shale, calcareous
Mesozoic	Cretaceous	Zuni	Colorado Group	Belle Fourche	Shale
Mesozoic	Cretaceous	Zuni	Dakota Group	Mowry	Shale
Mesozoic	Cretaceous	Zuni	Dakota Group	Newcastle	Sandstone
Mesozoic	Cretaceous	Zuni	Dakota Group	Skull Creek	Shale
Mesozoic	Cretaceous	Zuni	Dakota Group	Fall River	Sandstone and shale
Mesozoic	Cretaceous	Zuni	Dakota Group	Lakota	Sandstone and shale
Mesozoic	Jurassic	Zuni	Morrison		Shale, clay
Mesozoic	Jurassic	Zuni	Sundance		Shale and sandstone
Mesozoic	Jurassic	Zuni	Piper		Limestone, anhydrite, salt and red shale
Mesozoic	Triassic	Absaroka	Spearfish		Siltstone, salt and sandstone
Paleozoic	Permian	Absaroka	Minnekahta		Limestone
Paleozoic	Permian	Absaroka	Opeche		Shale, siltstone and salt
Paleozoic	Pennsylvanian	Absaroka	Minnelusa		Sandstone and dolomite
Paleozoic	Pennsylvanian	Absaroka	Amsden		Dolomite, limestone, shale and sandstone
Paleozoic	Pennsylvanian	Absaroka	Tyler		Shale and sandstone
Paleozoic	Mississippian	Kaskaskia	Big Snowy Group	Otter	Shale, sandstone and limestone
Paleozoic	Mississippian	Kaskaskia	Big Snowy Group	Kibbey	Shale, sandstone and limestone
Paleozoic	Mississippian	Kaskaskia	Madison		Interbedded limestone and evaporites
Paleozoic	Mississippian	Kaskaskia	Madison		Limestone
Paleozoic	Mississippian	Kaskaskia	Bakken		Siltstone and shale
Paleozoic	Devonian	Kaskaskia	Three Forks		Shale, siltstone and dolomite
Paleozoic	Devonian	Kaskaskia	Birdbear		Limestone
Paleozoic	Devonian	Kaskaskia	Duperow		Interbedded dolomite and limestone
Paleozoic	Devonian	Kaskaskia	Souris River		Interbedded dolomite and limestone
Paleozoic	Devonian	Kaskaskia	Dawson Bay		Dolomite and limestone
Paleozoic	Devonian	Kaskaskia	Prairie		Halite
Paleozoic	Devonian	Kaskaskia	Winnipegosis		Limestone and dolomite
Paleozoic	Silurian	Tippecanoe	Interlake		Dolomite
Paleozoic	Ordovician	Tippecanoe	Stonewall		Dolomite and limestone
Paleozoic	Ordovician	Tippecanoe	Stony Mountain Formation	Gunton Member	Limestone and dolomite
Paleozoic	Ordovician	Tippecanoe	Stony Mountain Formation	Stoughton Member	Argillaceous limestone
Paleozoic	Ordovician	Tippecanoe	Red River		Limestone and dolomite
Paleozoic	Ordovician	Tippecanoe	Winnipeg Group	Roughlock	Calcareous shale and siltstone
Paleozoic	Ordovician	Tippecanoe	Winnipeg Group	Icebox	Shale
Paleozoic	Ordovician	Tippecanoe	Winnipeg Group	Black Island	Sandstone
Paleozoic	Cambrian	Sauk	Deadwood		Limestone, shale and sandstone
	Precambrian				

FIGURE 7. Stratigraphic column for Burke County.

gently to the south or southwest. The layers change laterally from one composition to another. The layers are composed of four general lithologic groups. They are: a) silt and clay; b) sand and sandstone; c) lignite; and d) limestone.

Silt and clay–The surface occurrences of the two formations in Burke County are insufficient to make a statistical analysis of the percentages of each lithology, but studies made in adjoining areas where the formations are widely exposed suggest that the Sentinel Butte Formation is composed of about 60 percent silt and clay and that the Tongue River Formation is composed of about 80 percent silt and clay.

Individual beds range from several inches to as much as 30 feet thick in Williams County (Freers, 1970). Most of the beds are silty clay or clayey silt and some are sandy silt, silt, or clay. Some of these are in the form of shale, mudstone, siltstone, or claystone. The silts are commonly yellowish gray (5Y 7/2) and less commonly light olive gray (5Y 5/2) on weathered outcrop. Some silt beds are conspicuously grayish yellow (5Y 8/4), much yellower than most adjacent beds. The clay and claystones are mostly yellowish gray (5Y 7/2) or light olive gray (5Y 5/2) and sometimes very light gray (N8), dark gray (N4), olive brown (5Y 4/4), olive black (5Y 2/1), or dusky yellow (5Y 6/4).

Mineralogically, the silt and clay beds are composed of about 20 percent quartz and feldspar, 20 to 30 percent clay minerals, mostly sodium montmorillonite, about 5 percent carbonate (calcite and dolomite) in the Sentinel Butte Formation and 10 percent in the Tongue River Formation, and minor amounts of other minerals such as limonite, gypsum, and marcasite.

Beds with high clay content have commercial value. The Baukol-Noonan Coal Company of Noonan, just across the county line in Divide County, processes a clayey bed into a lightweight aggregate. Bentonitic clays that are common in both formations may have some ceramic value. Brick has been made from similar clays in other parts of the state. Evaluations of the Sentinel Butte and Tongue River Formation clays have been made in the North Dakota Geological Survey Report of Investigation 33 (Hansen, 1959) and in a report by the Great Northern Railway Company (1958).

The silt and clay deposits have high porosities but low permeabilities. The little water that does move through the silt and clay beds moves along closely-spaced joints and fractures or along the contact with an overlying or underlying bed. Although virtually no water is recovered directly from silt and clay beds in Burke County, water does move slowly from these beds into more permeable beds such as sand or lignite.

Sand and sandstone–The Sentinel Butte Formation consists of about 35 percent sand, which occurs in layers, and the Tongue River Formation consists of about 15 percent sand. Thickness of the sand in Burke County is from a few inches to about 12 feet. The sand beds are not persistent laterally and commonly they pinch out within several hundred feet.

In weathered exposures of sand, the color is generally yellowish gray (5Y 7/2) to light gray (N7) with rust-colored stains. The sand grains are subangular. The sand is clayey to silty in places. Bedding is evident, especially in the weathered outcrops, and the sand beds are often cross-bedded. However, some of the sand appears to be massive and non-indurated with no evident bedding. The sand forms a hard surface with rills on exposed surfaces. Fresh, unweathered exposures of sand in coal mines tend to be softer and more easily eroded. The sand layers are highly permeable and are occasionally used as a source of water in Burke County.

The mineralogy of the sand is mostly quartz and feldspar with some heavy minerals and clay minerals. Secondary mineral deposits associated with the sand are limonite and gypsum. Concretions are common and layers of "ironstone" are prevalent in the weathered sands.

Lignite–Nearly all the lignite mined in North Dakota comes from the Tongue River and Sentinel Butte Formations. The lignite mined in Burke County is from the Sentinel Butte Formation. The thickness of the lignite beds ranges from a few inches to over 10 feet. Lignite is the most persistent lithology in the Fort Union Group and it can be correlated for miles using test hole data.

Lignite and its weathered equivalent, leonardite, range in color from black (N1) to brownish black (5YR 2/1) to reddish brown (10R 3/4). Brightly colored accessory minerals are often associated with exposed lignites. Many of the lignite beds have clay partings or stringers in them. The lignite can vary from almost 100 percent organic material to lignitic shales. On the outcrop, the lignite is soft and broken both along bedding planes and vertically. Unweathered lignite is hard, brittle, uniform and jointed or fractured. Petrified wood and gypsum are often associated with the lignite.

Lignite beds are important water-bearing formations. Many farm wells in other counties get water from lignite beds. Springs along rivers are associated with lignite beds. The high degree of fracturing in the lignite makes it very permeable.

Lignite has an increasing economic value in North Dakota. Burke County shares in this with the operation of three strip mines. Latest

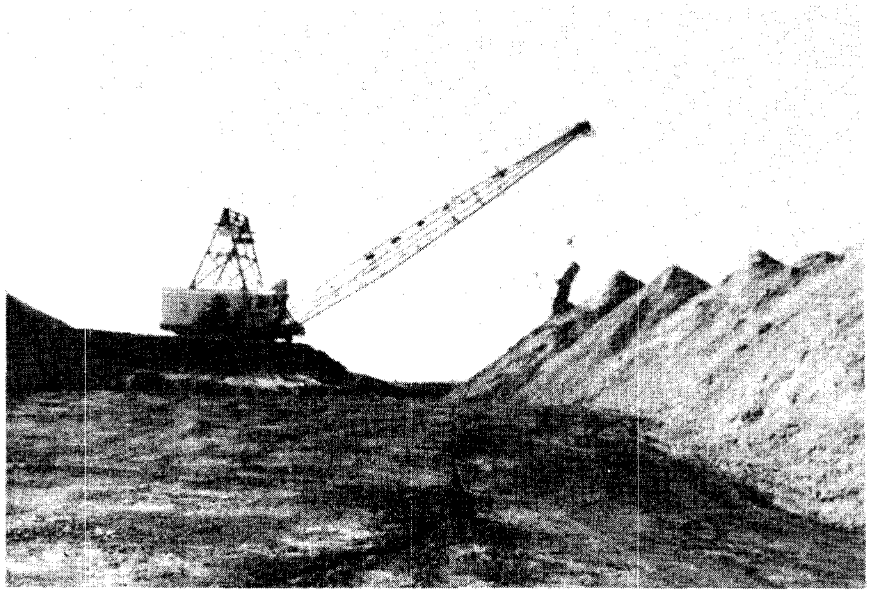

FIGURE 8. Larson Mine, Baukol-Noonan Coal Company. Foreground shows the top of the Noonan bed. Secs. 4, 5, 6, 7, 8, and 9, T. 162 N., R. 94 W.

FIGURE 9. Faulted Sentinel Butte Formation beds in T. 162 N., R. 92 W.

production figures for Burke County for the period July 1, 1970 to June 30, 1971 are 523,229 tons valued at $970,000.00. All of this coal is mined from the Noonan bed.

Limestone–Lenses and stringers of limestone are occasionally found in the Sentinel Butte and Tongue River Formations. The limestone is usually less than 2 feet thick and does not persist laterally more than a few hundred feet.

Topography–The contact between the Sentinel Butte and Tongue River Formations and the overlying sediments is highly irregular. Generally, the surface of these two formations gradually rises from an elevation of about 1,700 to 1,900 feet in the north to the center of the county (pl. 2). Near the center of the county, the bedrock rises two hundred feet in about six miles and then levels off. In the northwest corner of the county, a deep valley in the bedrock trends east and then northeast, leaving the county near Portal. Another valley that enters the county from the south near Upper Lostwood Lake trends north and then east just south of Bowbells. The lowest bedrock surface found is just north of Columbus where the bedrock elevation is 1,436 feet. The highest is 2,353 feet in sec. 35, T. 160 N., R. 92 W.

Structure–The Sentinel Butte and Tongue River Formations dip gently to the southwest at about 3° in most places. One area of unusually steep dips extends from sec. 23, T. 162 N., R. 93 W., 13 miles to sec. 15, T. 161 N., R. 91 W., and averages about 1 mile wide. The area is represented on plate 1 by the thin parallel dashed lines. The structural area was defined on the basis of direct and indirect evidence.

Direct evidence of the faulting and folding of the beds is easily seen in erosional cuts of springs and streams that cross the Missouri Coteau Escarpment. Figure 9 clearly shows the faulted, steeply-dipping beds and figure 10 shows a nearly vertical hogback that is the core of a spur ridge extending into a valley. Indirect evidence of faulting is seen as parallel striations on aerial photographs. These striations are low ridges and shallow linear depressions that probably have been caused by the upward migration of ground water along the faulted bedrock causing slight differential erosion. Figure 11 shows a ground photo of the vegetational differences due to the ridges and linear depressions. Figure 5, an aerial photograph, shows the striations leading into the faulted bedrock exposures. Figure 12, a ground photo of the west wall of the Bonsness mine, shows a fault with an apparent southward dip.

It was the intention of the author while in the field to prove, if possible, that the deformed bedrock was caused by glacial ice-shove or slump and not by diastrophism as suggested by Townsend (1950). The best possible way to show that it is ice-shove is to find glacial drift

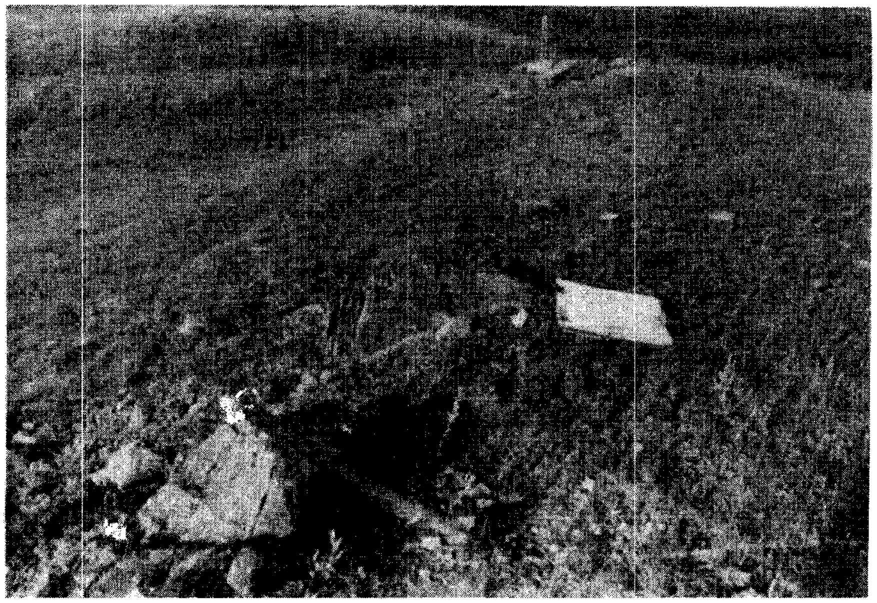

FIGURE 10. Nearly vertical hogback of Sentinel Butte Formation sandstone in NE¼ NE¼, sec. 31, T. 162 N., R. 92 W.

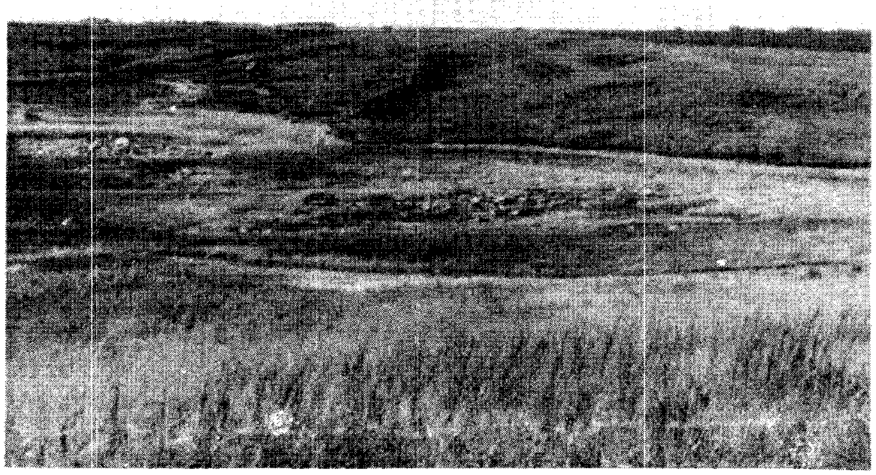

FIGURE 11. Low ridges and shallow depressions in glacial deposits caused by water seepage along deformed bedrock joints and cracks. SW¼, sec. 36, T. 162 N., R. 92 W.

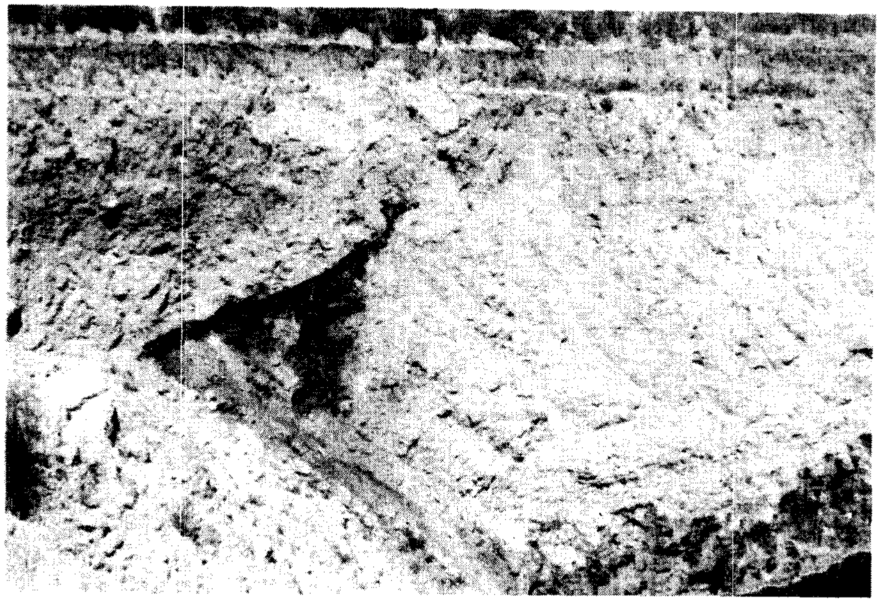

FIGURE 12. Fault in Sentinel Butte Formation on the west wall of the Bonsness coal mine. NW¼ NW¼, sec. 27, T. 162 N., R. 93 W.

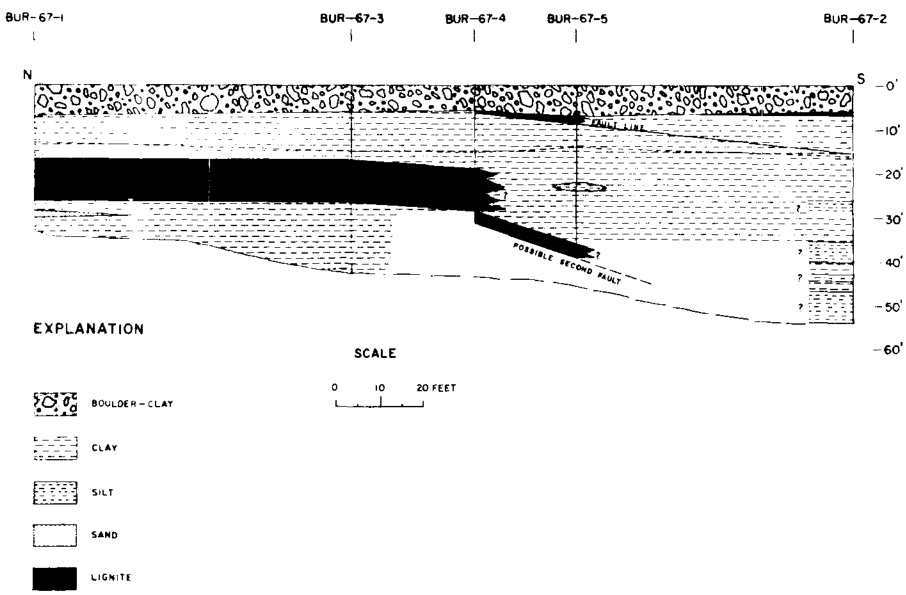

FIGURE 13. Cross section to a depth of 50 feet adjacent to the west wall of the Bonsness coal mine. This section is parallel to the wall shown in figure 12. Location: NW¼ NW¼, sec. 27, T. 162 N., R. 93 W.

incorporated in or under the deformed bedrock. That evidence was not found. A power auger was used to drill across the fault on the west end of the Bonsness mine to correlate beds across the fault. Maximum drill depth was 50 feet but the beds could not be correlated across the fault (fig. 13). It has been discovered since 1960, however, that a great deal of ice-shove or slumping has occurred in North Dakota and Saskatchewan (Bluemle, 1966, 1970). It is believed by the author that the deformation of these beds is due to ice-shove. Drilling of two 200- or 300-foot holes would easily resolve the problem.

Age and origin–Sentinel Butte and Tongue River Formation sediments were deposited over 65 million years ago during Paleocene Epoch. The Paleocene, which was the beginning of the Cenozoic Era, immediately followed the end of the period of dinosaurs.

The environment during the Paleocene Epoch in North Dakota was shallow marine in the part of the area where the Cannonball Formation was deposited. When the Cannonball Sea left North Dakota, a flat, swampy environment remained. It was on this flat, swampy area that the Sentinel Butte and Tongue River Formation sediments were deposited. Rivers meandered through the area depositing sand bars and silt and clay. In the swampy areas, away from the rivers, dense vegetation with large sequoia-like trees grew. This vegetation died and accumulated in the swamps and, over millions of years, was altered to lignitic coal. The limestone lenses probably were formed in backwater ponds by the precipitation of calcium carbonate by aquatic vegetation.

Subsurface Formations

The Tongue River Formation is the oldest exposed formation in Burke County. Beneath the Tongue River Formation are older sedimentary formations that occur to a depth of about 11,700 feet. These rest on crystalline Precambrian rocks. The general characteristics of the subsurface formations are given in figure 7. These formations generally dip southwestward toward the center of the Williston basin, which is an intracratonic structural and sedimentary basin. The rocks in the subsurface are grouped into five major sequences above the Precambrian. In descending order, they are: the Zuni, Absaroka, Kaskaskia, Tippecanoe, and Sauk Sequences (Carlson and Anderson, 1966).

Zuni Sequence–The Zuni Sequence is mostly clastic sediments that were deposited in Late Jurassic and Cretaceous seas. The sedimentary rocks of the sequence are up to 4,300 feet thick in Burke

County. The Jurassic rocks are mostly evaporites and red or green shale. Cretaceous rocks include siltstone, shale, and sandstone. No petroleum or gas is produced from rocks of the Zuni Sequence in Burke County.

Absaroka Sequence–The Absaroka Sequence includes Late Mississippian to Early Jurassic rocks. It is about 500 feet thick in Burke County. The rocks are sandstone, shale, carbonate, red shale, siltstone, halite, and anhydrite. No petroleum is produced from these rocks.

Kaskaskia Sequence–The Kaskaskia Sequence (Early Devonian to Late Mississippian) is up to 4,000 feet thick in Burke County and consists of limestone, dolomite, anhydrite, halite, shale, and siltstone. All of the oil produced from Burke County since 1953 has been from the Madison Formation (Mississippian).

Tippecanoe Sequence–The rocks of the Tippecanoe Sequence range from about 1,700 to 2,000 feet thick. They were deposited during Middle Ordovician to Early Devonian time. The rocks are mainly sandstone, shale, limestone, and some thin evaporite beds.

Sauk Sequence–Rocks of Late Cambrian to Early Ordovician age make up the Sauk Sequence, which is from 400 to 600 feet thick. The rocks are composed of shale, sandstone, and carbonate.

Precambrian rocks–Beneath the above-mentioned sedimentary rock is an unknown thickness of ancient igneous and metamorphic rocks. No wells have penetrated these rocks in Burke County.

LANDFORMS

The geologic map of Burke County, plate 1 of this publication, shows both the lithology and geomorphology of the area. The following discussion deals with some of the landforms in Burke County.

Erosional Landforms

Erosional forms are common in some areas, particularly areas such as the North Dakota badlands that have not been glaciated, but such landforms are not widespread in Burke County.

Stream-Eroded Topography–Stream-eroded ground moraine is found along the face of the Missouri Coteau escarpment in central Burke County (pl. 1). Similar stream-eroded topography occurs along Upper Des Lacs Lake and in several meltwater channels in the eastern part of the county. This stream-eroded topography is commonly covered by numerous boulders that remained when the water washed away the finer materials from the till; till or bedrock are at the surface in most washed areas. Scattered deposits of sand and gravel are found in a few places.

Meltwater Channels–Meltwater channels are erosional landforms that are found throughout the county (pl. 1). The largest of these is the one that now contains Des Lacs Lake. The valleys were cut by water that flowed from the melting ice sheets. Probably a significant amount of water that flowed through these valleys was derived from local precipitation as well.

Many of the meltwater channels in the southern half of the county, on the Missouri Coteau, are poorly defined due to collapse of the stagnant ice over and through which they were cut. Some of the areas shown as outwash on plate 1 are confined in places to fairly well defined valleys that are probably segments of meltwater channels.

Depositional Landforms

Most of the landforms in Burke County are of a depositional nature. Included in this category are the various types of moraine, ice-contact features, and outwash plains.

Ground Moraine–Ground moraine is a landform composed of a drift accumulation, chiefly till, that was deposited directly from a moving glacier behind its margin. In Burke County it is a gently undulating plain with many low knobs and shallow depressions resulting from the collapse of a thin layer of superglacial debris. The ground moraine occurs over approximately the northern half of Burke County (pl. 1).

Dead-ice Moraine–The dead-ice moraine of Burke County occurs on the Missouri Coteau. North of the dashed line on plate 1, relief is high and slopes are steep. South of the dashed line, relief is low to medium and slopes are moderate. The area of dead-ice moraine is characterized by knob and kettle topography, non-integrated drainage with numerous small ponds and sloughs and a bouldery surface on till. Relief may differ greatly within short distances, and boundaries of differing degrees of relief are difficult to delineate.

Disintegration ridges are, perhaps, the most diagnostic characteristic of the dead-ice moraine. They are rectilinear or circular ridges of glacial drift, mainly till, that were deposited between, around, or within depressions in blocks of stagnant glacier ice, through the process of mass movement from above and/or squeezing from below.

Such features are abundant on the dead-ice moraine of southern Burke County.

Closed disintegration ridges are the most common type of disintegration ridge found in Burke County. They are not easily seen in the field, but are obvious on air photos (fig. 3). They average about 15 feet in height and have circular to irregular shapes. Many of the closed disintegration ridges are breached at both ends, forming features that are easily recognized on air photos. Except for a few of the larger ones, which are shown on plate 1, the disintegration ridges were not differentiated.

Kettle Chains–Most of the kettle chains in Burke County occur in areas of dead-ice moraine. These may be defined simply as areas with high concentrations of kettles or potholes that follow a linear pattern. Many of the kettles contain sloughs or lakes. The kettles commonly follow a poorly defined valley or otherwise topographically low area. Some kettle chains overlie valleys that became filled with glacial ice, and others may simply represent areas where particularly large pieces of ice became incorporated in the drift. The longer kettle chains probably have the best chance of overlying gravel-filled valleys, and test drilling for water might be useful in these areas.

Outwash Plains–Areas underlain by gravel and sand are shown in yellow on plate 1. Some of the gravel and sand is undoubtedly glacial outwash, but paleobotanical evidence suggests that a significant percentage of the material was deposited by rivers and streams that were fed by the increased precipitation that occurred in early postglacial time. The relative percentages of glacial outwash materials and postglacial alluvium are not known and, for purposes of discussion, the deposits will be referred to here simply as outwash plains.

North of the Missouri Escarpment, the outwash plains are relatively flat areas with relief of 10 to 20 feet in a mile. Channel and meander scars, none of which continue for appreciable distances, are common. They are most easily seen on air photos. Boulders are rare on the surface.

Hilly areas underlain by gravel and sand are collapsed outwash. Such areas are most common on the Missouri Coteau but they were not differentiated from the uncollapsed outwash deposits. Collapsed outwash deposits consist of collapsed sediments of formerly flat outwash plains that were deposited on stagnant glacial ice. When the stagnant ice melted, collapse of the overlying materials occurred. In general, these areas are characterized by hilly topography with abundant undrained depressions, faulted bedding, and other collapse structures that can be observed in cuts.

Ice-contact Features–Most of the ice-contact features of Burke County are either eskers or kames, which are shown in red on plate 1. Eskers are long ridges of sand or gravel that were deposited by water flowing in valleys on the stagnant glacial landscape. When the ice melted, the resulting gravel deposits remained as esker ridges. Kames are mainly mounds of sand or gravel. The sorting in these deposits is widely variable.

Ice-walled Lake Plains–The blue areas on plate 1 are ice-walled lake plains, lake sediments that were deposited within the margin of the stagnant glacier. The surface on such deposits may be undulating, indicating that the lake existed on top of the stagnant ice and the materials that were deposited in the lake collapsed when the ice melted. The surface may be flat, indicating that the lakes in which silts and fine sands accumulated were surrounded by, but were not on, stagnant ice so that when the ice melted, surrounding areas collapsed and the lake topography was left intact. A few of these flat deposits have till rims at the edge indicating that debris slid from the adjacent ice into the lakes. On air photos the areas of collapsed lake topography are easily recognized as cultivated patches of ground of relatively low relief surrounded by uncultivated dead-ice moraine of higher relief.

Proglacial Lake Plains–Lake sediments that were deposited beyond or next to the glacier margin constitute proglacial lake plains. Proglacial lake plains occur near North Gate and east of Coteau. These areas are relatively flat.

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TABLE 1. Locations of fossil sites in Burke County.

Site 1	NW SW sec. 9, T. 159 N., R. 92 W. Perched lake plain (collapsed) at surface underlain by gravel.
Site 2	SW SW sec. 24, T. 160 N., R. 94 W. Ice-walled lake plain at contact between high and low relief dead-ice moraine overlain by a flow till.
Site 3	NW NW SW sec. 24, T. 160 N., R. 93 W. Perched lake plain at surface underlain by gravel.
Site 4	NW NE sec. 22, T. 160 N., R. 91 W. Silt deposits on top of a collapsed outwash.
Site 5	NE SE sec. 15, T. 162 N., R. 94 W. Five to six foot alluvial deposit on top of a paleosol which is developed on an outwash plain. Fossils are probably thermal maximum (hypsithermal) or post thermal maximum.
Site 6	SW SW sec. 13, T. 160 N., R. 92 W. Buried pond deposits beneath 7 to 16 feet of flow till.
Site 7	NW NE NW sec. 22, T. 160 N., R. 92 W. Very late glacial pond deposits high on a hill. Buried beneath (post glacial?) deposits of organic clays and silts - alluvial or aeolian.
Site 8	SW SE SW sec. 16, T. 160 N., R. 92 W. Collapsed pond deposits (under till).
Site 9	NE SW sec. 22, T. 161 N., R. 93 W. Silt deposits on top of collapsed outwash.
Site 10	NW NW sec. 6, T. 160 N., R. 93 W. Same setting as site 7.
Site 11	NE NE sec. 15, T. 162 N., R. 94 W. Same setting as site 5.

TABLE 2. Fossil species identified in Burke County.

Pelecypoda (Sphaeriidae)
- Pisidium casertanum (Poli)
- Pisidium compressum Prime
- Pisidium ventricosum fm. rotundatum Prime

Gastropoda

Land snails
- Vallonia gracilicosta Reinhardt
- cf. Succinea sp.
- Deroceras sp.
- Euconulus fulvus (Müller)

Aquatic snails
- Valvata tricarinata (Say)
- Valvata Lewisi Currier
- Lymnaea stagnalis appressa (Say)
- Lymnaea palustris elodes (Say)
- Fossaria cf. dalli (Baker)
- Helisoma anceps (Menke)
- Helisoma trivovis (Say)
- Gyraulus parvus (Say)
- Armiger crista (Linnaeus)
- Physa sp.

Ostracoda
- Candona actula Delorme, 1967
- Candona caudata Kaufmann, 1900
- Candona compressa (Koch), 1838
- Candona rawsoni Tressler, 1957
- Candona candida (Müller), 1776
- Candona distincta Furtos, 1933
- Candona ohioensis Furtos, 1933
- Candona sp.
- Cyclocypris ampla Furtos, 1933
- Cyclocypris ovum (Jurine), 1820
- Cypridopsis vidua (Müller), 1776
- Cyprinotus sp.
- Limnocythere herricki Staplin, 1963
- Limnocythere sappaensis Staplin, 1963
- Limnocythere trapeziformis Staplin, 1963
- Herpetocypris reptans (Baird), 1835
- Ilyocypris bradyi Sars, 1890
- Ilyocypris gibba (Ramdohr), 1808