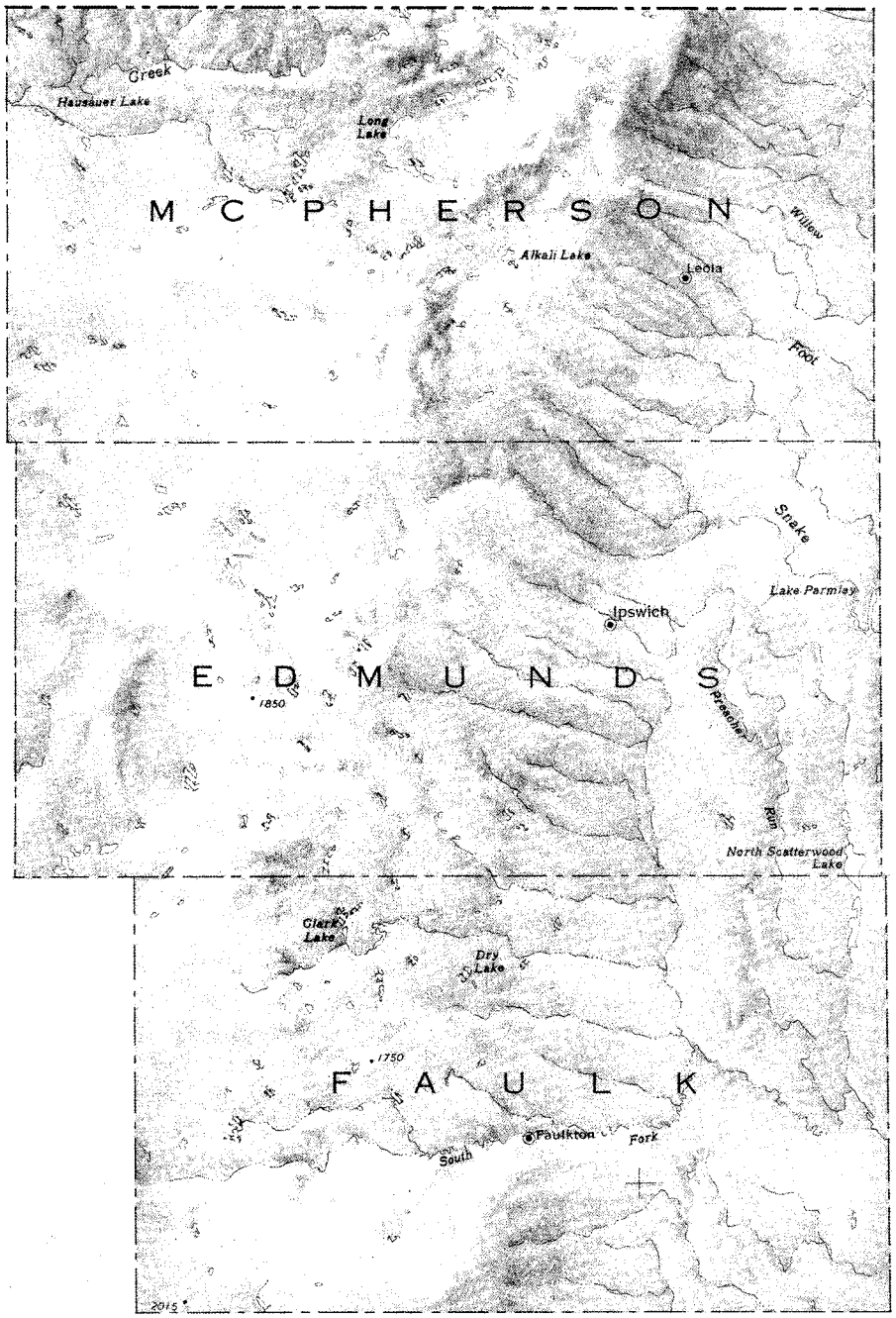
Bulletin 26

GEOLOGY AND WATER RESOURCES OF McPHERSON, EDMUNDS, AND FAULK COUNTIES, SOUTH DAKOTA

Part I: Geology



by Cleo M. Christensen

Prepared in cooperation with the Oahe Conservancy Sub-District,
McPherson, Edmunds, and Faulk Counties, and the United States Geological Survey

DEPARTMENT OF NATURAL RESOURCE DEVELOPMENT – GEOLOGICAL SURVEY 1977

STATE OF SOUTH DAKOTA
Richard Kneip, Governor

DEPARTMENT OF NATURAL RESOURCE DEVELOPMENT
Vern W. Butler, Secretary

GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

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ABSTRACT

McPherson, Edmunds, and Faulk Counties are located in north-central South Dakota and have an area of 3312 square miles. The two major topographic features present in the area are the Coteau du Missouri and the James Lowlands.

Pre-Pleistocene rocks ranging in age from Precambrian to Cretaceous are found in the subsurface of the mapped area, however, the Pierre Shale, which immediately underlies the glacial deposits, is the only pre-Pleistocene age rock exposed at the surface.

Pleistocene age deposits mantle the Pierre Shale bedrock throughout most of the three-County area and in some instances attain a thickness of nearly 600 feet. These deposits consist mostly of till and outwash-alluvium mixtures with minor amounts of lacustrine sediments.

The entire area was glaciated only in late Wisconsin time. Absolute dates based on radiocarbon isotope ratios from shells found within the glacial deposits indicate the presence of glacial ice within the study area from at least 14,000 to 9,000 years ago. Because material necessary for this type of absolute dating method is rare in the area, most Pleistocene stratigraphic relationships are based on physical characteristics of the deposits and regional correlations.

Resources of major economic value include large reserves of underground water and aggregate in the form of sand and gravel. Evidence collected thus far indicate no significant metallic resources or fossil fuel resources within the study area.

INTRODUCTION

Purpose

Investigation of the geology and water resources of McPherson, Edmunds, and Faulk Counties is one of a series of cooperative studies conducted through the combined efforts of the South Dakota Geological Survey and the United States Geological Survey (fig. 1). Each study is conducted with several goals in mind. Of primary concern is the location and evaluation of the mineral and water resources available in each of the counties studied. In addition, the knowledge gained from each study will be a most important contribution to understanding the regional geology of the State of South Dakota and surrounding areas.

Results of the investigation of McPherson, Edmunds, and Faulk Counties are published in three parts. Part I contains the geology, with special emphasis on deposits of Pleistocene age; Part II (Hamilton, in preparation) contains the water resources; and Part III (Christensen and Hamilton, in preparation) is a compilation of all basic data resulting from the investigation.

Location

McPherson, Edmunds, and Faulk Counties are located in north-central South Dakota and have an area of 3312 square miles (fig. 1). As a group they are bordered on the north by North Dakota, on the west by Campbell, Walworth, and Potter Counties, on the east by Brown and Spink Counties, and on the south by Hyde and Hand Counties.

Previous Investigations

Prior to this investigation the three-County area has been included in a number of reconnaissance studies dealing primarily with bedrock and general geology of South Dakota (Todd, 1894; Darton, 1909, and Rothrock, 1943). Earlier workers in the area concerned with Pleistocene deposits were Chamberlin (1883), Todd (1896), Rothrock (1924, 1932) and Gwynne (1951). Flint (1955) made a reconnaissance study of the Pleistocene deposits of eastern South Dakota which included McPherson, Edmunds, and Faulk Counties. In addition, several cities and towns within the area have been studied in detail with regard to ground-water supplies. These include the cities of Eureka (Steece, 1959; Steffen and Barari, 1975a), Faulkton (Christensen, 1962), Bowdle (Rukstad and Hedges, 1964), Ipswich (Pottratz, 1965), and Orient (Steffen and Barari, 1975b).

Method of Investigation

Information contained in this report results in part from geologic work done during five summer field seasons from 1968 to 1972. Additional drilling was completed during the early spring of 1973. The geology was mapped on conventional black and white aerial photographs having a scale of approximately 1:70,000 (about 1 inch = .9 miles) and was later transferred to a base map of the same scale. The map was later reduced to a scale of ½ inch equals 1 mile.

Information obtained from natural outcrops and manmade exposures of rock material was supplemented by numerous power auger holes, rotary holes, and hand-auger holes. Most subsurface information was obtained from examination of well cuttings and electric logs from holes drilled and logged by the South Dakota Geological Survey and United States Geological Survey. Supplemental information was obtained from the files of local well drillers, the United States Bureau of Reclamation, and from a well inventory which was conducted in the area as a part of the study (Christensen and Hamilton, in preparation).

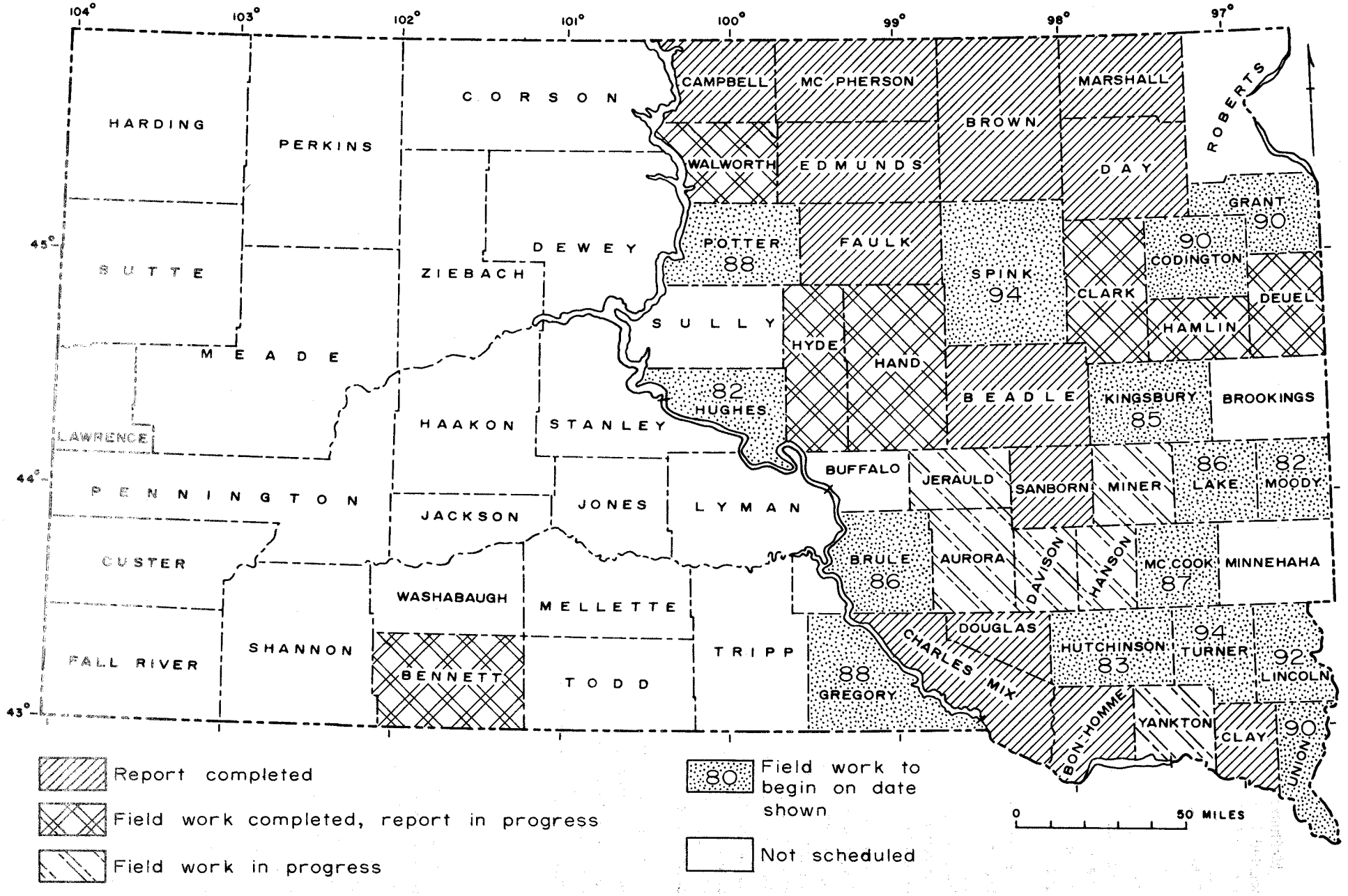


Figure 1. Schedule of county-wide ground-water studies in South Dakota.

Acknowledgements

The investigation and preparation of this report were performed under the supervision of Dr. Duncan J. McGregor, State Geologist. The writer wishes to thank the entire staff of the South Dakota Geological Survey for their advice and assistance throughout the project. Special thanks go to Lynn Hedges, Donald Jorgensen, Louis Hamilton, and Merlin Tipton for participation in numerous field conferences with the writer. Also performing a valuable service by assisting in the field and operating drilling equipment were Lloyd Helseth, Millard Thompson, Dwight Brinkley, John Hawley, Lyle Steffen, James Gropper, Steven Whittet, Thomas Bulfer, LeRoy Hemmish, and Carl Cripe. Many additional persons too numerous to mention assisted throughout the project.

Financial assistance was contributed by the South Dakota Geological Survey, the United States Geological Survey, the Oahe Conservancy Sub-District, and McPherson, Edmunds, and Faulk Counties. The study was initiated at the request of the Commissioners from the three-County area and their cooperation as well as that of the residents of the Counties is gratefully acknowledged.

Physiography

Two major topographic features are present in the mapped area (fig. 2). The most impressive of these is the Coteau du Missouri (Missouri Hill Country). This vast highland with its diverse topography extends north-south through North Dakota and South Dakota for a distance of several hundred miles. The deep, narrow trench of the Missouri River marks its western border and the James Basin lies to the east. The Coteau is nearly 75 miles wide at the northern border of McPherson County and narrows to less than 25 miles where it crosses the southern boundary of the State. In the mapped area, the Coteau exists in the western part of all three Counties.

The eastern part of the study area is occupied by the James Basin. This broad lowland is characterized by gently undulating to relatively flat topography generally 200 to 300 feet lower in elevation than the Coteau to the west. At the northern limits of the mapped area the boundary between these two topographic divisions is marked by a well-defined topographic change only a few miles in width (fig. 3). In contrast, the boundary becomes more difficult to distinguish south of central Edmunds County, giving way to a broad, gentle downslope toward the east.

STRATIGRAPHY

Stratigraghic Relations

Stratigraphic nomenclature used herein conforms to that accepted by the South Dakota Geological Survey (Agnew and Tychsen, 1965) and to the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961). Where conflicting nomenclature exists the terminology of the South Dakota Geological Survey has been used.

The following stratigraphic section lists all of the deposits that are present in the area in the order of their occurrence from the youngest deposit at the top of the list to the oldest at the bottom.

Quaternary System
- **Recent Series**
  - **Alluvium**
- **Pleistocene Series**
  - **Wisconsin Stage**
    - **Late Wisconsin**
  - **Pre-late Wisconsin Deposits**

Cretaceous System
- **Upper Cretaceous Series**
  - **Pierre Shale**
  - **Niobrara Marl**
  - **Carlile Shale**
  - **Greenhorn Limestone**
  - **Graneros Shale**
- **Upper and Lower Cretaceous Series**
  - **Dakota Formation**
- **Lower Cretaceous Series**
  - **Skull Creek Formation**
  - **Inyan Kara Group**
  - **Sundance Formation**
  - **Minnelusa Formation**

Pennsylvanian System
- **Reclamation (?) Limestone**

Mississippian System
- **Madison Group**

Ordovician System
- **Red River Limestone**
- **Winnipeg Formation**

Precambrian Rocks
- **Granite "wash" and granite**

Because a complete discussion of the stratigraphy above the granitic Precambrian basement rocks is well beyond the scope of this report, only those rocks of Upper Cretaceous age and younger will be discussed in any detail. Emphasis will be placed on the deposits of Pleistocene age. For information regarding lower subsurface stratigraphy the reader is referred to Schoon (1967).

Cretaceous Rocks

Within the study area Cretaceous rocks consist of shales, marls, limestones, and sandstones. In ascending order they are the Dakota Formation, Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Marl, and the Pierre Shale.

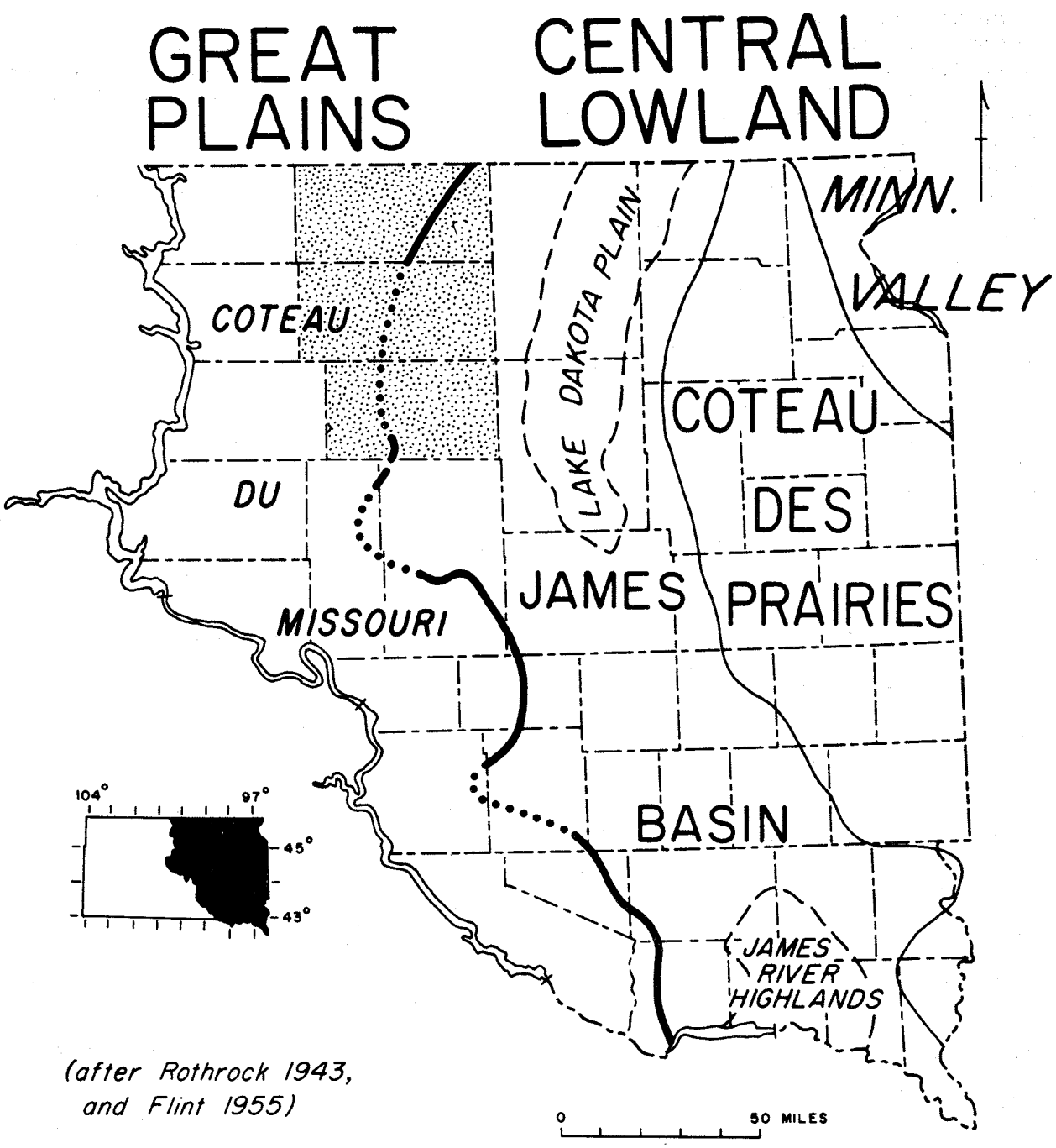
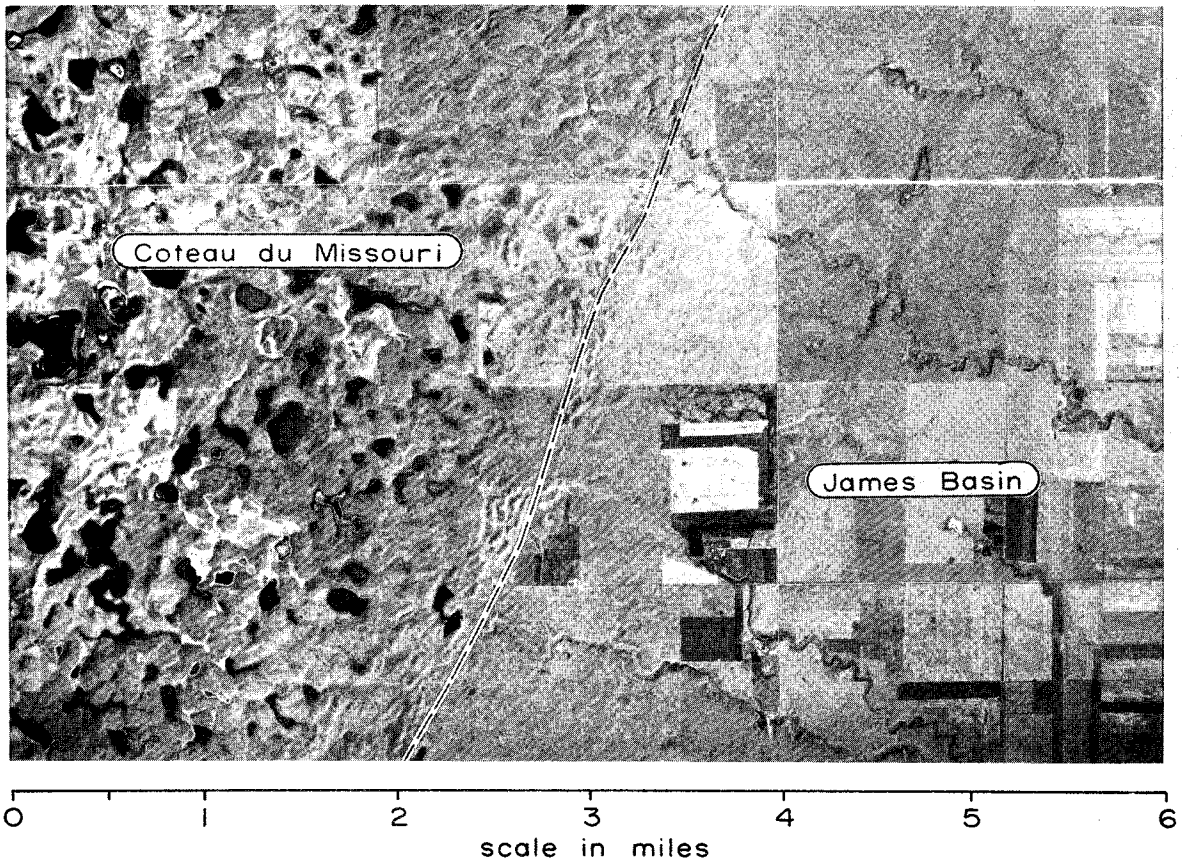


Figure 2. Map of eastern South Dakota showing the physiographic divisions and the location of the study area.



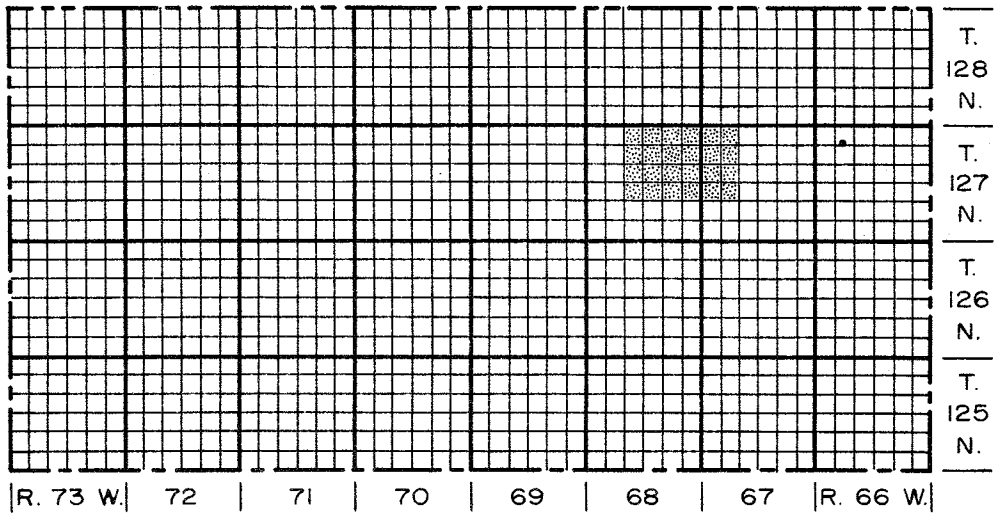


Figure 3. Aerial photograph of a part of Mc Pherson County showing the topography of the Coteau du Missouri and the James Basin.

Dakota Formation

The Dakota Formation was first described by Meek and Hayden (1861) from an exposure in Dakota County, Nebraska, and was designated by them as Formation No. 1 of the Cretaceous. It is composed of alternating beds of siltstone, sandstone, and shale; is varicolored and attains a maximum thickness of over 350 feet in the mapped area. Locally the Dakota is sometimes referred to as the "artesian basin" because of the abundance of flowing wells it feeds. The ground-water potential of the Dakota and other aquifers is discussed in detail by Hamilton (in preparation).

Graneros Shale

Graneros Shale overlies the Dakota Formation throughout the three-County study area, and is commonly a medium- to dark-gray, noncalcareous, silty shale interbedded with thin silt and sand layers.

Gilbert first described the Graneros from an exposure near Graneros Creek, Pueblo County, Colorado, in 1896, and the name was suggested by R. C. Hill (Agnew and Tychsen, 1965).

The Graneros is widespread throughout South Dakota and varys greatly in thickness. In the mapped area it has a maximum thickness of over 250 feet.

Greenhorn Limestone

Greenhorn Limestone overlies the Graneros Formation and is one of the best marker beds within the Cretaceous deposits of South Dakota. The Greenhorn is fossiliferous, and the most common fossil is *Inoceramus labiatus*. Aggregates of calcite prisms from the shells of this fossil aid in the recognition of the Greenhorn in well samples. Other characteristics of the Greenhorn that make it such a good marker are its diagnostic "kick" on the electric and radioactive logs and the rough manner in which it drills.

Gilbert first described the Greenhorn from an exposure near Greenhorn Station, 14 miles south of Pueblo, Colorado (Agnew and Tychsen, 1965).

Greenhorn Limestone underlies the entire three-County area and consists of about 20 feet of gray to cream-colored limestone possibly underlain by a small amount of calcareous shale.

Carlile Shale

The Carlile Shale was first described and named by Gilbert in 1896 from an exposure near Carlile Spring and Carlile Station, 21 miles west of Pueblo, Colorado (Agnew and Tychsen, 1965). Carlile Shale underlies the Niobrara Marl and consists of a medium-gray noncalcareous, plastic, fissile shale. It is sometimes slightly chalky and on occasion contains some traces of carbonized wood. In McPherson, Edmunds, and Faulk Counties the Carlile Shale reaches a maximum thickness of nearly 300 feet.

Niobrara Marl

Meek and Hayden first described the Niobrara from an exposure along the Missouri River near the mouth of the Niobrara River, Knox County, Nebraska, however, no type locality has been designated for this formation (Agnew and Tychsen, 1965).

In the mapped area the Niobrara consists of an upper marl unit which is dark gray in color and spotted with abundant calcareous specks, and a lower unit composed of light gray chalky marl. Locally the Niobrara Marl is referred to as Niobrara "chalk" or "chalk rock" because of its chalky appearance. Fossils are abundant in the Niobrara, with microfossils sometimes comprising most of the material found in the chalky zones. Among the common planktonic forms found are *Globigerina, Planomalina*, and *Heterohelix*. Macrofossils are also found in the formation and the two most common are *Ostrea congesta* and *Inoceramus gigantica*. Other fossils such as barnacles, fish, and mosasaur have been collected from exposures of Niobrara throughout the State. The Niobrara is about 100 feet thick in the three-County area.

Pierre Shale

Pierre Shale is exposed in several areas within McPherson and Edmunds Counties and is the only bedrock exposed. In McPherson County, exposures of Pierre can be found bordering Elm Lake (pl. 1), and in Edmunds County (pl. 2) Pierre is exposed in the vicinity of Lake Parmley near the town of Mina. Throughout the entire eastern one-third of all three Counties, the Pierre Shale is very close to the land surface, ranging in depth from a few feet to about 60 feet. Also, it is the first Cretaceous Formation found below the glacial and Recent deposits throughout the entire area.

The Pierre consists of blue-gray, calcareous to noncalcareous shale which locally contains bentonite beds and marl zones. Limestone concretions are common within the shale. The lower zones immediately above the Niobrara Marl are composed of black bituminous shale containing an abundance of organic matter. This particular unit is commonly mapped as the Sharon Springs Member and is a very diagnostic marker bed in the subsurface of the mapped area.

The Pierre Shale was first named the Fort Pierre Formation by Meek and Hayden (1861) and the name was shortened to Pierre by Darton as early as 1896. Within the confines of the present study area the Pierre Shale attains a maximum thickness of nearly 1000 feet.

Pleistocene Deposits

Pleistocene deposits mantle the bedrock throughout most of McPherson, Edmunds, and Faulk Counties. These glacial deposits are primarily till but do contain lesser amounts of stratified drift such as outwash and lacustrine sediments. Discussion of the Pleistocene is divided into two sections. The first contains the description of the various deposits, whereas, the second represents the writer's attempt to reconstruct the geomorphic events from the beginning of the Pleistocene Epoch up to the present time.

Because materials commonly used for absolute dating are rare in the area, most age relationships are based on the use of topography, physical characteristics, stratigraphic relationships and absolute dates from surrounding areas.

Pre-Late Wisconsin Deposits

Alluvium

The only sediments younger than Cretaceous in the three-County study area that can tentatively be assigned an age older than late Wisconsin are alluvial materials that exist only in the subsurface. These alluvial deposits are found along major pre-late Wisconsin stream valleys that are now covered entirely by younger sediments. Information pertaining to grain-size and lithology of the sediments can only be obtained by means of drilling records from test holes and from electric logs of those test holes. Because these alluvial sediments are often associated with outwash it is difficult to obtain definitive information with regard to grain-size and composition, especially when the samples are obtained from rotary drill holes.

In general, the deposits consist of varying amounts of sand and silt with minor amounts of clay and gravel. They characteristically contain a higher percentage of coal fragments and shale particles than is normally found in the outwash of late Wisconsin age. Where outwash is found in association with the alluvial sediments, material from the alluvium has been incorporated into the outwash making separation of the two units for stratigraphic purposes essentially impossible. For this reason, much of the material that is referred to as outwash within the valleys of the pre-late Wisconsin buried drainageways may in fact be older alluvium. Plate 3 illustrates a typical stratigraphic section within the valley of the now-buried Ancient Grand River lowlands (pl. 4). Test holes drilled into the buried valley, e.g., drill hole 4 (see app.) in SE¼SE¼SE¼SE¼ sec. 33, T. 122 N., R. 70 W., have penetrated about 300 feet of interbedded till, marl, outwash and alluvial deposits.

In areas where the alluvium consists primarily of silt or silty, sandy clay, overlain by outwash a definite distinction can be made between the two units. Plate 5 illustrates such a case in the vicinity of drill hole 21 located in SE¼SE¼SE¼SE¼ sec. 5, T. 120 N., R. 69 W. (see app.). Here the alluvium is primarily clay, and silty, sandy, clay containing some coal. Even though the overlying outwash also contains coal and shale pebbles, separation of the two units both on the basis of the grain-size of samples recovered, and mechanical logs is not difficult. Because of the clayey nature of the alluvium, mixing of the samples during drilling is not severe and good sample recovery is possible.

Hedges (1972), while working in Campbell County, immediately to the west of McPherson County, was able to distinguish between two units of valley-fill within the confines of the buried Ancient Grand River valley. He states (1972, p. 10):

> *"This deposit consists of a basal outwash sand and gravel unit and an overlying complex outwash-alluvium unit."*

The writer was not able to consistently make a similar distinction in the study area. Outwash is present both above and below the alluvial sequence, and in some cases the two are interbedded, however, the lower, basal outwash unit mentioned by Hedges (1972) is rare. In general, when two units can be found together, the lower unit is alluvium and the upper unit is outwash.

It is extremely difficult, if not impossible, to assign an age to these deposits. They of course are no younger than late Wisconsin because in all areas within the three Counties they are covered by late Wisconsin deposits. There is, however, no way to restrict them to a definite period of time within the Pleistocene Epoch because in all instances they rest directly upon Cretaceous Pierre Shale.

Late Wisconsin Deposits

Age, Thickness and Distribution of Glacial Drift

McPherson, Edmunds, and Faulk Counties are entirely covered by glacial drift (pls. 1, 2, and 6) with the exception of the exposures of Pierre Shale in the extreme eastern areas of McPherson and Edmunds Counties (pls. 1 and 2). Likewise, Recent alluvium covers the drift along all major and many minor drainageways. No major exposures of stratigraphic

significance exist within the mapped area, therefore all thickness information must be taken from test holes. In the test holes drilled, no data were found to indicate the presence of more than one drift sheet. Only late Wisconsin drift exists in the area and maximum thickness of the drift is nearly 600 feet. The thickest sections are in the Ancient Grand River Valley and contain not only till, but substantial thicknesses of valley-fill sediments (pls. 7 and 8). In the James Basin physiographic subdivision of the area (eastern one-half to one-third of all three Counties, see fig. 2) the drift mantle is thin. Average drift thickness along the eastern boundary of the Counties is approximately 20 feet (pl. 9). The drift gradually thickens toward the west and has an average thickness of about 60 feet immediately east of the Coteau du Missouri slope (pl. 9). Throughout the entire area of the Coteau du Missouri proper, drift thickness averages over 200 feet, ranging from as little as 100 feet in the vicinity of Eureka in McPherson County to as much as 550 feet near Loyalton in Edmunds County.

Careful inspection of the cross sections (pls. 3, 5, 7, 8 through 12, and 13) will allow the reader to grasp the major relationships of drift thickness throughout the entire three-County area. It is plain that the bedrock underlying the Coteau du Missouri was a primary controlling factor in the distribution of drift in this area of South Dakota. Further evidence of this fact is presented later in this report.

Lithology

Lithologic analyses were not conducted on any of the sediments comprising the drift in McPherson, Edmunds, or Faulk Counties.

Clayton (1962) conducted lithologic analyses of tills in North Dakota that correlate with the till at the surface in the study area. The tills studied by Clayton were found to contain about equal parts of silt, sand and clay and approximately 5 percent pebbles, cobbles and boulders. Pebble counts on the tills analyzed by Clayton showed 55 percent local rocks in the form of shale, siltstone and sandstone, 25 percent limestone and dolomite, and 20 percent igneous and metamorphic rocks. Outwash derived from the same ice-sheet was found to have essentially the same composition. Field observations by the writer indicate a close resemblance between the lithologies of the till at the surface in the study area and the surficial till analyzed by Clayton.

Recent Deposits

Alluvium

The only Recent deposits that exist within the confines of the study area are alluvial deposits associated with both major and minor drainageways. The alluvium consists primarily of silt and clay with minor amounts of sand and gravel deposited while the stream was in flood stage. Thickness ranges from a thin veneer of 1 to 2 feet along the minor streams to over 20 feet along some of the major streams such as Snake Creek in Faulk County.

Though all alluvium within the area is included for mapping purposes with deposits of Recent age, it is recognized that some of the alluvial deposits are, at least in part, Pleistocene in age. Specifically these are the deposits of alluvium that are now found in association with abandoned meltwater channels. Plates 1, 2, and 6 show an abundance of such channels, primarily in the eastern part of the three-County area. Although abandonment of these channels by the streams which formed them probably occurred near the end of the Pleistocene Epoch, many of the channels contain some flood water for very limited times during periods of extremely heavy precipitation. Thus, the greater part of the alluvial sediments within the channels are probably of Pleistocene age but are covered with a veneer of Recent alluvial sediments.

DEVELOPMENT OF LANDFORMS

Pre-Glacial Topography

The topography that was present in the study area prior to glaciation resulted primarily from the erosional action of an eastward flowing drainage system dissecting the Cretaceous shales comprising the Coteau du Missouri. Of primary importance in this system was the Ancient Grand River which flowed in a southeasterly direction through the three-County area (fig. 4). Taking into consideration slight modifications by the erosional action of glacial ice, plate 4 in general portrays the topography of the study area prior to late Wisconsin time. A view of the area during this period of geologic time would be strikingly similar to a present-day view of any major stream valley and associated highlands west of the Missouri River. It was an area characterized by sparsely vegetated shale uplands sloping to the east and cut by the trench of the Ancient Grand River.

Bedrock Control of Ice Movement

Configuration of the bedrock topography has exercised a great deal of control over the movement of glacial ice in all of eastern South Dakota and surrounding states. This is especially true in the north-central section of the State. Prior to invasion by the late Wisconsin ice, the James Basin area existed as a broad lowland containing a major drainage system. To the east was the drift covered Coteau des Prairie and to the west the shale hills comprising the Coteau du Missouri. The late

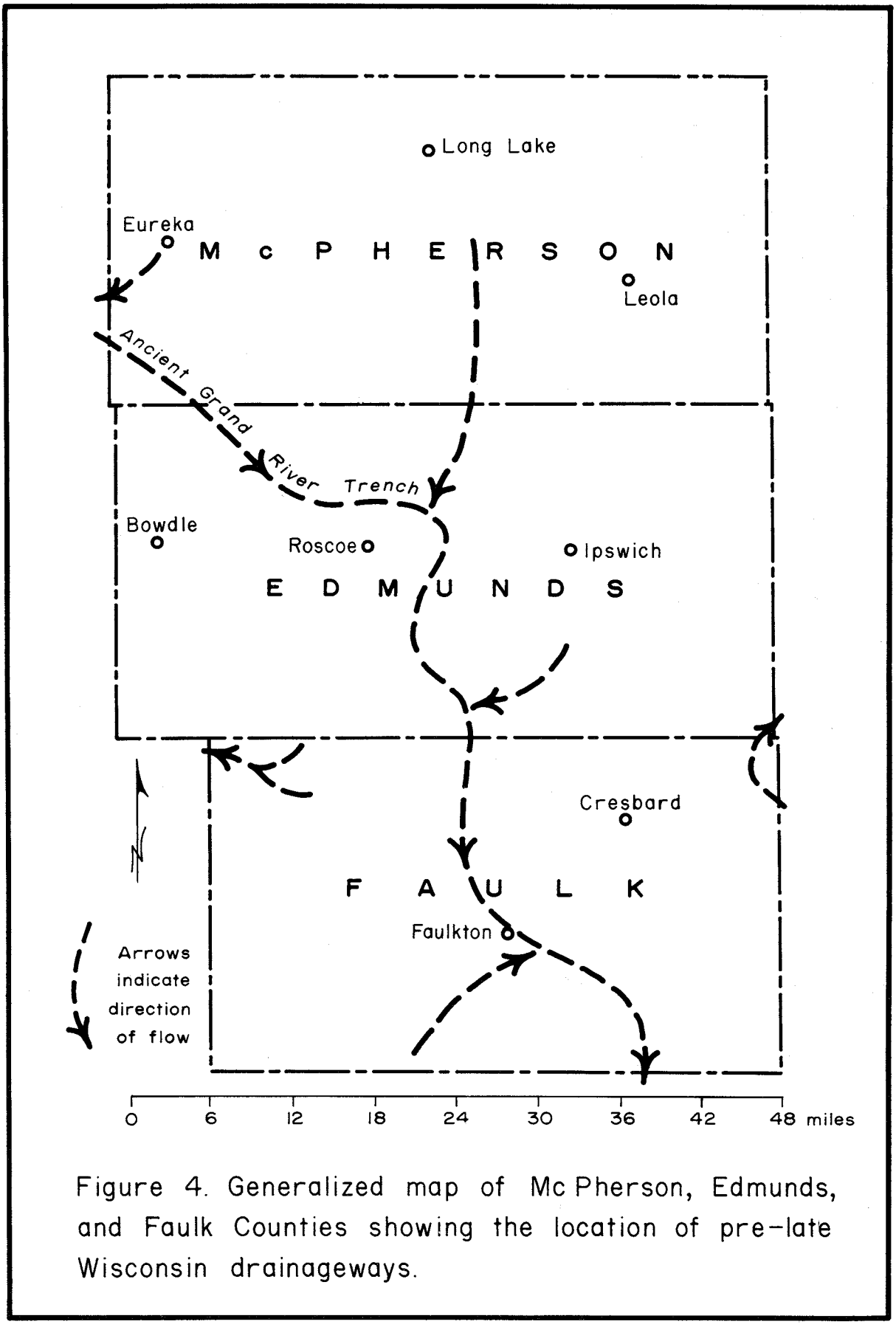


Figure 4. Generalized map of Mc Pherson, Edmunds, and Faulk Counties showing the location of pre-late Wisconsin drainageways.

Wisconsin ice sheet invaded South Dakota from the north via the James lowland and moved in a southerly direction down this broad, low area essentially unimpeded to the south. The ice was, however, confined on both sides by the highlands of the two Coteaus. This lobe of ice, thus confined and referred to as the James Lobe, was responsible for the vast majority of late Wisconsin glacial deposits that now are found within the State. The only exceptions to this are deposits of Des Moines Lobe drift in the extreme northeastern reaches of the State along the eastern flank of the Coteau des Prairie.

As the James Lobe ice moved in a southerly direction restricted by the highlands on either side, it encroached onto the highlands to a point determined by the elevation of the highlands and thickness of the ice. Where the ice intersected one of the major east-flowing streams a small sub-lobe protruded into the stream valley and moved upstream. Such was the case in the study area when the late Wisconsin ice reached the valley of the Ancient Grand River. Flow of the Ancient Grand River was blocked and ice of the Bois Cache sub-lobe (Todd, 1885) moved in a northwesterly direction through the three-County area. Eventually, ice of the James Lobe, Bois Cache sub-lobe, and other possible minor sub-lobe all coalesced and spread out over the uplands reaching an area beyond the present Missouri River. Influence of the bedrock topography upon expansion of the ice and subsequent progressive stagnation back toward the axis of the ice lobes is well documented by location of end moraines and their relationship to the general bedrock topography (fig. 5).

Glacial Modification of Bedrock Topography

Present-day landforms in the study area are largely the result of the modification of pre-existing landforms by the action of glacial ice and deposition of associated sediments. Higher topographic areas are in general the reflections of high bedrock areas that have been increased in altitude by the addition of drift. Lower topographic areas have been filled to a great extent by drift but are still readily visible in most cases. The overall effect of glaciation has therefore been an increase in the altitude of the land surface, as well as a smoothing of the topography.

GLACIAL LANDFORMS

Landforms Associated with Stagnant Ice

Glacial landforms associated with wide-spread glacial stagnation result from the deposition of stagnation drift; a term given to all material deposited by the waning ice. In McPherson, Edmunds, and Faulk Counties the glacial landforms associated with stagnation drift are stagnation moraine, lake plains, collapsed outwash and disintegration ridges. The size, shape, distribution, and lithology of each landform is dependent upon a complex relationship of physical factors. Of primary importance is the amount and thickness of englacial and superglacial drift and the relative abundance of water available to aid in sorting the material. Thus, deposits of highly variable textural characteristics may have nearly identical landforms. Because of the highly variable lithologic possibilities of the deposits comprising individual landforms, the lithologic characteristics of each landform will be discussed from the standpoint of geomorphology as opposed to lithology.

Stagnation Moraine

The majority of the stagnant ice deposits in the three-County area consists of stagnation moraine. For the purposes of this report and the accompanying maps (pls. 1, 2, and 6) stagnation moraine is defined as primarily till consisting of a heterogeneous mixture of boulders, sand, silt and clay, characterized by a rugged, hummocky topography (fig. 6). The area covered by stagnation moraine is basically that area comprising the Coteau du Missouri (pls. 1, 2, and 6). The moraine is a mass of knob and kettle topography. Abundant depressions result from ice blocks which were either buried or partly buried within the drift.

Till within the stagnant ice area results in part from material carried within the ice when it first entered the area prior to stagnation, and in part from superglacial drift deposited on top of the stagnant ice but derived from the active ice in the James Lowland. Drift within the area mapped as stagnation moraine averages about 250 feet in thickness throughout the area and in general conforms to the topography of the underlying bedrock (pl. 7).

Lake Plains

Two types of lake plains exist in the mapped area. The first type, shown on plates 2 and 6 by the symbol Qwll are flat-lying features with barely distinguishable boundaries. Sediments within these lake plains consist of clay, silt and fine sand deposited by meltwaters during the final stages of melting of the stagnant ice. A good example of such a feature is located in Edmunds County west of the town of Roscoe in T. 123 N., R. 71 W. Here the flat lake plain is easily noticed in contrast to the surrounding stagnation moraine even though the shoreline of the feature is in many places difficult to distinguish.

The second and more common type of lake plain found in the area is an easily recognized feature throughout the portion of all three Counties that contains stagnation drift, however, they are most common in McPherson County. These are high-level ice-walled lake plains which are usually among the highest topographic features present. Several

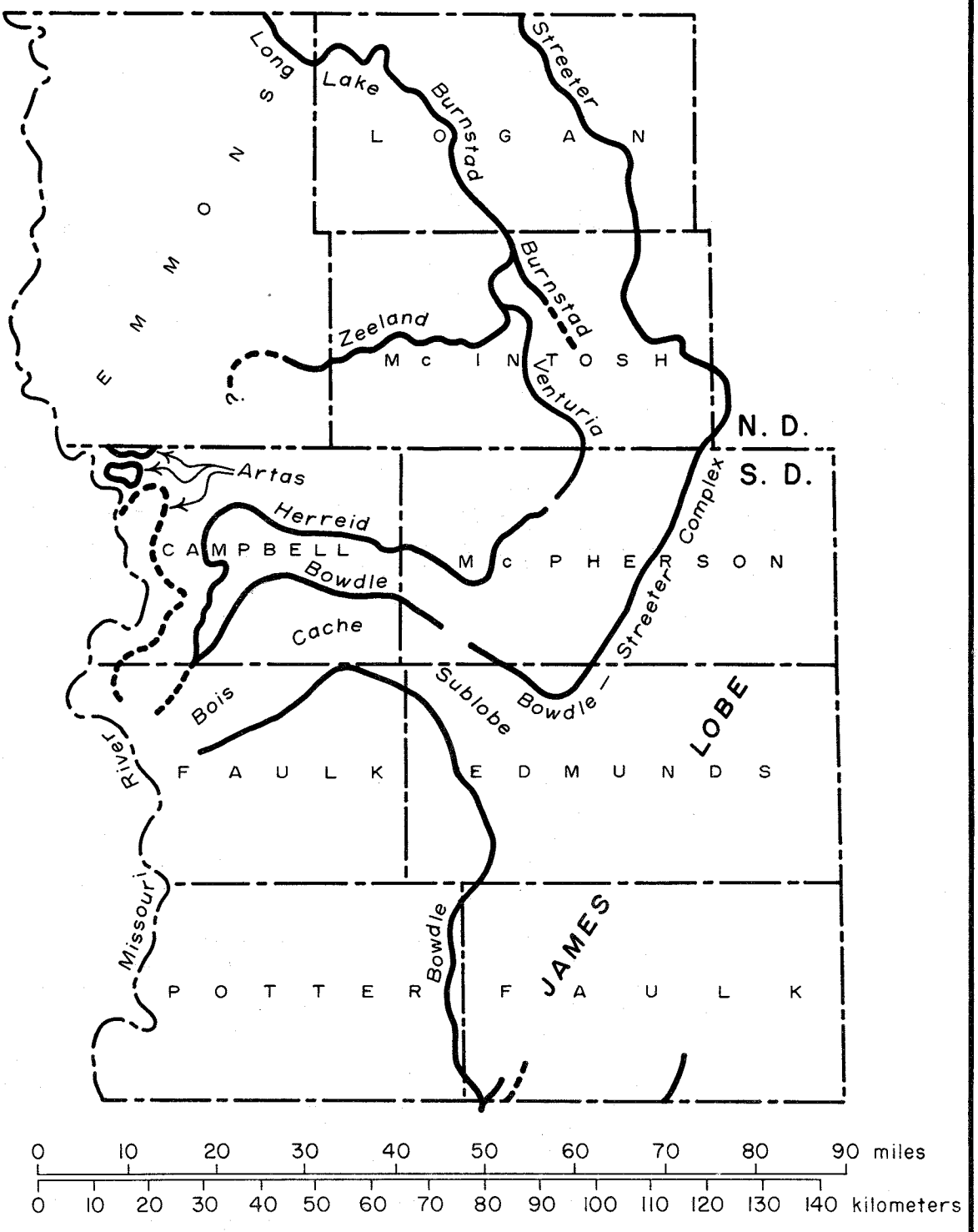


Figure 5. Map showing general relationships of the major end moraines in south-central No. Dak. and north-central So. Dak. (modified in part from Hedges, 1972, figure 7)

Figure 6. Photograph of typical stagnation moraine topography in the mapped area.

excellent examples of these perched lake plains can be found in McPherson County (pl. 1). The lake plains are characterized by relatively flat tops (although some may be partly collapsed) that can be seen from great distances (fig. 7) and resemble the flat-topped buttes of the Fox Hills Sandstone common to the area west of the Missouri River in Corson County. The similarity is so striking that some earlier workers have indeed mistaken the lake plains for bedrock controlled buttes. Ice-walled lake plains, as the name indicates, were formed as the result of material being deposited in a lake completely surrounded by stagnant ice. Those which have very flat surfaces had their lower reaches on till or bedrock; whereas, those with undulating or collapsed surfaces were bottomed on ice. Collapsing naturally occurred as the ice melted. The reader who is interested in the method of formation of the various types of glacial lakes associated with stagnant ice is referred to Clayton and Cherry (1967) for a very excellent summation of the subject.

At several locations within the study area, large amounts of sand and gravel are found in association with the ice-walled plains. In some instances the sand and gravel can be found overlying the finer grained lacustrine sediments, while in other cases sand and gravel is the lower unit and is overlain by clays and silts. Where sand and gravel exists at the surface of an ice-walled plain, the deposit has been mapped as an ice-walled outwash plain and is distinguished on plate 1 by the map symbol Qwloi. An excellent example of such a deposit can be found in the western part of McPherson County in T. 127 N., R. 73 W. Depositional history of the ice-walled outwash plain is unclear at the present time. The coarser grain size may simply represent a change in water velocity and type of material entering the lake, or it may represent isolated remnants of a much more extensive area of stream deposited outwash.

All of the ice-walled lake plains or low-level lake plains were not test-drilled so it is impossible to determine a maximum thickness of the deposits. A test hole in NW¼NW¼NW¼NW¼ sec. 33, T. 126 N., R. 70 W., (see app., drill hole 165) penetrated 55 feet of lake sediments comprised mostly of clay and this is thought to be a representative thickness.

In a number of locations steep walled ice-contact faces mark the edges of the ice-walled lake plains. The angle of repose of the face in each case depends on

Figure 7. Photograph of ice-walled lake plain in Mc Pherson County.

the grain size on the material present within the lake plain. The steeper faces are found in association with lake plains containing clay and silt deposits, whereas, ice-walled plains containing sand and gravel either at the surface or around the periphery, tend to portray a somewhat lower angle of repose at the face. Mass movement has greatly altered many of the faces where sand and gravel is found, leaving them with a step-like appearance (fig. 8). Slope angles on the faces of the ice-walled outwash plains are approximately 35 degrees, while those on the ice-walled lake plain faces containing primarily clay and silt are much steeper and on occasion approach 60 degrees.

Collapsed Outwash

Collapsed outwash is absent in Faulk County but is present in several areas in western Edmunds County (pl. 2). In McPherson County there is abundant collapsed outwash (pl. 1). In areas where stagnation moraine is thick and massive the associated collapsed outwash has a very hummocky and irregular surface. Thickness of outwash in these areas ranges from less than 10 feet to over 100 feet, and topographic variations of up to 100 feet are not uncommon on the outwash surface. A good example of this topographic variation can be found in sections 13, 14, 15, and 16, T. 127 N., R. 70 W., in McPherson County. In other parts of the mapped area where stagnation occurred at a later date and the deposits are thinner, topographic variations on the outwash surface are on the order of a few tens of feet or less.

In areas of massive stagnation drift, collapsed outwash is characterized by large depressions containing permanent lakes and sloughs. It is easy to recognize these areas of collapsed outwash because of the larger size of the lakes and sloughs as compared to the lakes and sloughs in the surrounding stagnation moraine (fig. 9), even though the topography of the two deposits are somewhat similar. The relative size of the open water bodies thus was an aid to geologic mapping in the area.

Most of the collapsed outwash was deposited as superglacial material on top of the stagnant ice. Contributions of the sediments that comprise the outwash were probably from the stagnant ice itself as well as from the active ice which was attempting to override the Coteau from the east. Meltwaters responsible for transportation of the sediments must have been flowing at a relative high velocity because

Figure 8. Photograph showing the step-like appearance on the side of an ice-walled outwash plain.

the majority of the outwash sediments are within the gravel size-range. In McPherson County outlet for the meltwaters was to the west via Spring Creek. Collapsed outwash covers much of the area from northeast of the town of Long Lake to a point between Ranges 71 and 72 west. Here the collapsed nature of the outwash gives way to a valley-train deposit that continues into Campbell County (pl. 1). The western extent of the collapsed outwash coincides with the western edge of the massive part of the stagnation moraine. Northwest of the stagnation moraine and collapsed outwash, the drift is much thinner and is probably part stagnation moraine and part ground moraine. In this area the ice was thinner during deposition of the outwash hence little collapsing could occur.

Disintegration Ridges

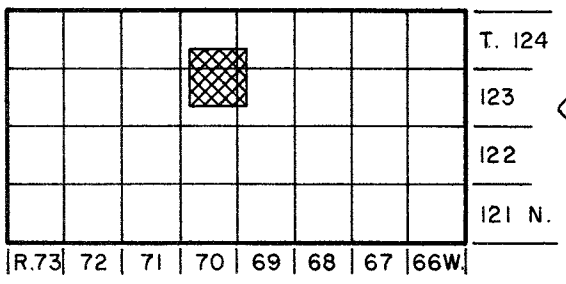
Most areas of stagnation drift abound with various shapes of disintegration ridges. Many are linear (fig. 10) on the order of a few tens of feet to over one mile in length and from a few feet to nearly 20 feet in height. In addition, many circular or roughly circular disintegration ridges can be found within the area of stagnation drift. Individual circular ridges (sometimes called doughnuts) vary in size from a few hundred square feet to many acres and reach heights of nearly 20 feet. The ridges may be composed of till, sand, gravel or a combination of lithologies. Grain size does not seem to be one of the critical factors in the formation of such features.

Although the normal variety of disintegration features is present (pls. 1 and 2) in McPherson and Edmunds Counties, only those features composed of stratified or water-washed material were singled out for mapping purposes. This was because a certain economic importance can be attached to the features that are composed mainly of sand and gravel.

Landforms Associated with Active Ice

End Moraine

Use of the term "end moraine" has, over the years caused a tremendous amount of confusion because of lack of consistency in its application. It is the writer's belief that the term, as a result, has become totally meaningless unless defined by each author for the specific area in which he is working. With this in mind, the following definition of end moraine is



Map of Edmunds County showing location of aerial photo

Figure 9. Aerial photograph showing size relationship of ice-block lakes in collapsed outwash versus stagnation moraine.

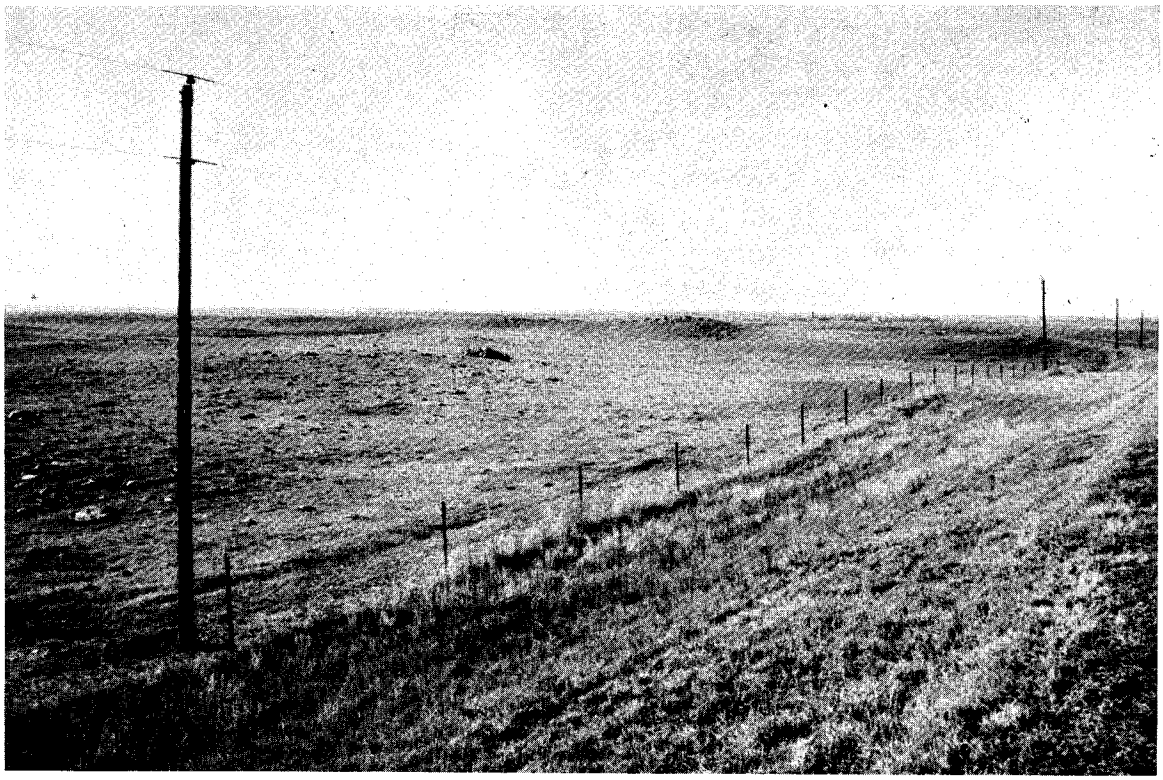


Figure 10. Photograph of several parallel disintegration ridges in central Mc Pherson County.

presented for use throughout this report. End moraine is a deposit of glacial drift composed primarily of till, portraying constructional topography, showing some lineation, and deposited near or at the margin of active ice. The definition presented here in no way suggests any element of vast differences in time from one end moraine to another, nor does it suggest great age variations between drift located on either side of any particular end moraine.

Herreid End Moraine

The end moraine farthest to the northwest in the study area is the Herreid end moraine. Named by Hedges (1972), in Campbell County the Herreid correlates with the Venturia moraine in North Dakota (Clayton, 1962) and is nearly continuous through McPherson County (fig. 5).

Throughout most of its length in McPherson County and in much of the surrounding area, the Herreid end moraine is best described as a low, non-descript ridge. It represents at best, a minimum of constructional deposition but does mark the edge or margin of active ice at one point in time. It was formed during a short-lived pause during progressive stagnation of the ice from its maximum advance. The ice was halted at this particular point because the main body of ice was stagnating farther to the east on the Coteau. Thus, before any major constructional features could be built, stagnation had taken place and the contribution of material to the ice marginal areas was halted.

The importance of the Herreid-Venturia end moraine complex in McPherson County (fig. 5) can best be explained by examining its unique position with respect to the other deposits in the area (pl. 1). This moraine complex marks the boundary between massive stagnation drift to the east and an area of ground moraine and very low-relief stagnation drift to the west. The complex also forms the boundary between collapsed outwash to the east and valley-train outwash to the west. These general relationships suggest that the area of the Herreid-Venturia end moraine complex was the boundary between thicker ice and more massive build-up of superglacial deposits on the central Coteau, and that area to the west that contained only very thin ice and a discontinuous cover of thin, superglacial drift.

Bowdle End Moraine

The Bowdle end moraine (Hedges, 1972) is not significant because of any age relationships it implies to drift on either side of its axis. Rather its importance is attached to the position it occupies with respect to what was once active and stagnant ice.

The Bowdle end moraine extends as a nearly continuous, rather massive ridge from east-central North Dakota (where it is termed the Streeter Moraine) through the mapped area, and into south-central South Dakota. Throughout its entirety it forms the general boundary between stagnation drift on the west and deposits associated with active ice in the James Lobe to the east. From the North Dakota border southward through McPherson County and barely into Edmunds County the Bowdle moraine is a very distinct ridge of from 1 to about 4 miles in width (pl. 1). After entering Edmunds County for a distance of some 7 or 8 miles the moraine bends toward the northwest and re-enters McPherson County forming the north limb of the Bois Cache sub-lobe. From the vicinity of this hinge area the moraine widens for a few miles and then narrows to two individual limbs each about 1 mile in width. Near this same area, lineation normally present as ridges along the crest of the moraine begins to disappear and eventually all traces of the moraine become lost in the jumble of stagnation drift (pl. 1). Approximately 7 miles farther to the northwest (pl. 1) the Bowdle moraine is again visible and portrays its characteristic lineation. Here the moraine marks the boundary between stagnant ice deposits associated with the Bois Cache sub-lobe and the thick massive stagnant ice deposits of the Coteau proper. The Bowdle moraine then continues into central Campbell County, forms an arcuate pattern (fig. 5) and re-enters Edmunds County on the south side of the Bois Cache sub-lobe. The moraine then continues its southward trend through Edmunds County and into Faulk County while still exhibiting well-defined lineation.

In Edmunds County immediately south of the town of Bowdle the moraine splits into two distinct ridges. These ridges enclose an area of stagnation drift covering an areal extent of about 50 square miles (pl. 2) which contains all of the features common to the massive stagnation moraine in McPherson County. To the south of this area the two limbs of the moraine again merge and continue on a southerly trend.

Well-defined, recessional end moraines are found to the east of the Bowdle moraine in Faulk County (fig. 5) and the area immediately to the south of Faulk County. In areas of high bedrock, such as 4 miles west of Orient, in southern Faulk County, these recessional end moraines become very distinct (pl. 6).

Ground Moraine

For the purposes of this report ground moraine is defined as drift deposited directly from glacial ice during both the accumulation and ablation stages of the ice sheet. It is recognized that the main body of till comprising the ground moraine within the study area probably results from ablation of the ice and was therefore deposited by simply being let down on the underlying bedrock as the ice sheet melted. Thus, the term ground moraine used herein does not necessarily imply a mode of deposition but instead refers to drift that has a smooth to gently rolling surface, is essentially free of distinct closed depressions or lineations, and portrays none of the characteristic features of either end moraine or stagnation moraine.

Most of the James Basin within the three-County area consists of ground moraine. Any readily noticeable topographic variations on the surface of the ground moraine are the result of erosion by streams and creeks that traverse the area.

Thickness of the till within the ground moraine portion of the study area varies from a few feet near the eastern edge to about 60 feet near the Coteau du Missouri, with the average thickness being about 40 feet.

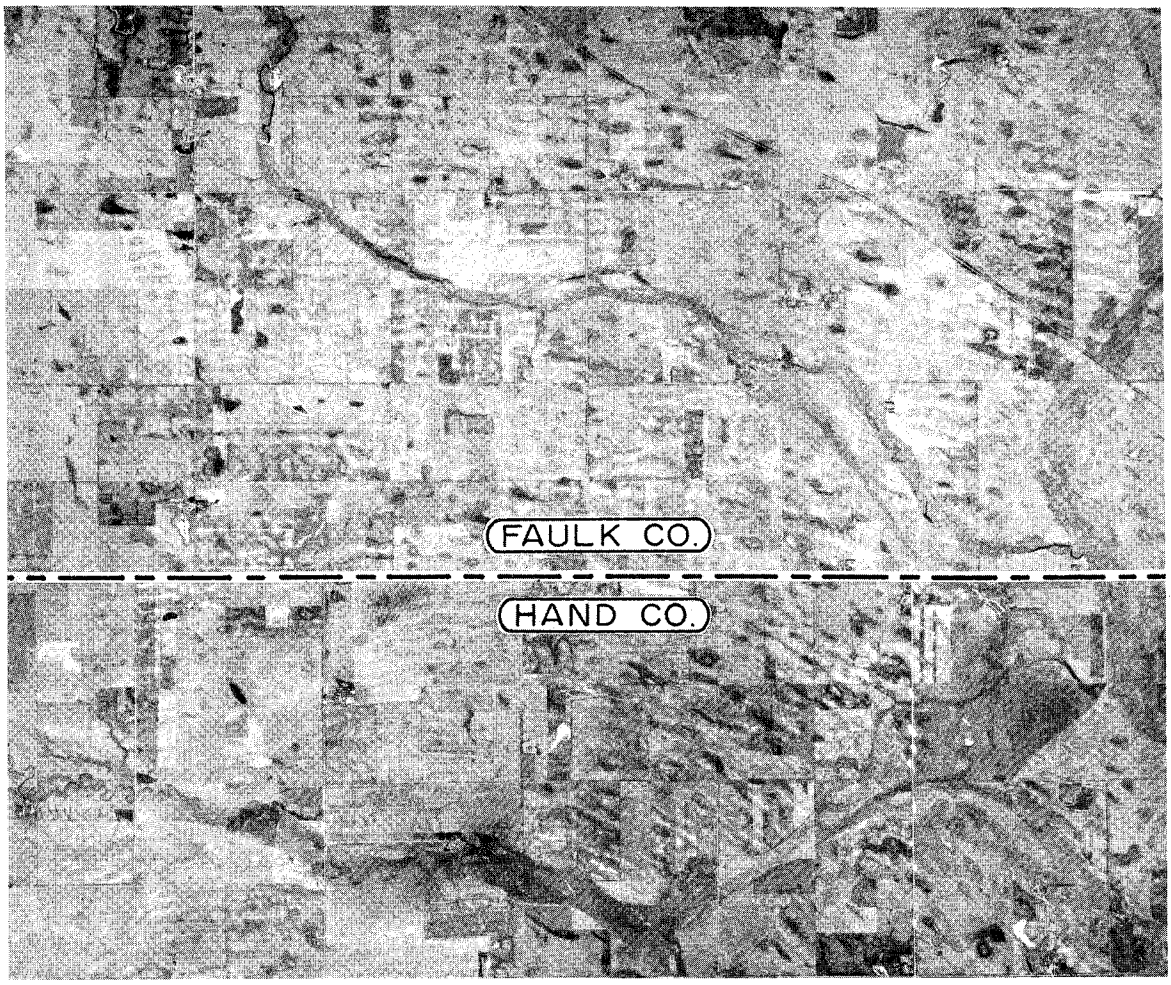
Washboard Moraine

Washboard moraines, or as they are sometimes called, minor moraines (Gwynne, 1951) cover a rather extensive area in Edmunds and Faulk Counties (pls. 2 and 6). Confined entirely to the James Basin area of the two Counties, these moraines represent minor stillstands in the retreat of the late Wisconsin ice sheet. When viewed from the air, the area encompassed by these moraines resembles a giant washboard; hence, their name (fig. 11). Vast numbers of these moraines exist throughout the James Basin in both South Dakota and North Dakota. Indeed they are so numerous that their origin may represent annual seasonal fluctuations in the ice front during the waning phase of glaciation.

In one instance a stillstand near Scatterwood Lake in southeastern Edmunds and northeastern Faulk Counties (pls. 2 and 6) resulted in the deposition of a significant recessional moraine. It is mentioned in association with the washboard moraines because of its construction during the final recessional phase of late Wisconsin ice in the area.

Outwash

Late Wisconsin outwash deposits are relatively abundant in many parts of the study area and are represented by a wide variety of landforms and



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Map of Faulk and Hand Counties showing photo location

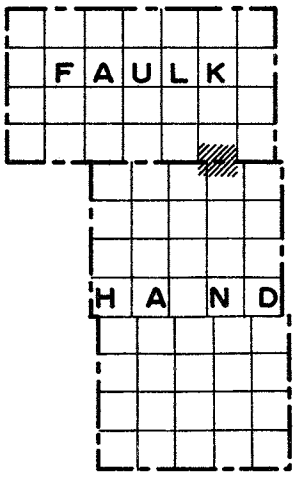

Figure 11. Aerial photograph showing linearity associated with washboard moraines in southern Faulk County.

lithologies. The various deposits will be discussed according to their landform classification as shown on plates 1, 2, and 6.

Valley Train Deposits

Valley train deposits of outwash in general can be defined as those deposits confined to a valley and showing a characteristic flat surface and well-defined contact with the valley walls. Such deposits exist in both Edmunds and McPherson Counties (pls. 1 and 2) but are not found in Faulk County.

In Edmunds County, one small valley train outwash is present in the extreme western area about 6 miles north of the Faulk-Edmunds County boundary. The valley train is now occupying what was once a major meltwater channel (pl. 2). Presently the valley contains up to 30 feet of fine sand to extremely coarse gravel that was deposited as a result of drainage from the ice sheet when it occupied a position now marked by the Bowdle moraine.

Two closely allied areas of valley train outwash exist in McPherson County north of the city of Eureka (pl. 1) and trend in an east-west direction continuing into Campbell County. These two valleys which are now occupied by Spring Creek and one of its major unnamed tributaries, carried much of the meltwater from the massive stagnation area immediately to the east. As was mentioned earlier in this report, the eastern limit of the valley train outwash deposits are in contact with the western edge of the Herreid moraine and mark the boundary between stagnation areas to the east, and active ice areas to the west. The significance of the location of all of the features just mentioned will be discussed in detail in the section of this report dealing with geomorphic development.

Terrace Outwash Deposits

Terraces and terrace remnants represent a very minor percentage of the total outwash deposits in the study area, but are located in each of the three Counties. Of the few terraces that do exist, the most extensive are located about 7 miles northeast of Miranda in Faulk County. Although excellent as sources of aggregate the geologic significance of any of the terraces in the three-County area is minimal. The location, size, and age relationship of all of the terraces can be seen by referring to plates 1, 2, and 6.

Eskers

Two eskers in extreme western Edmunds County (pl. 2) are important only from the standpoint of their geologic rarity in the study area, and as a source for a poor grade of aggregate. The eskers have a length of nearly one and one half miles, are about 15 feet high (fig. 12) and cross to form an X-shaped configuration in the end moraine in sections 6 and 7, T. 121 N., R. 73 W. The eskers probably formed as a result of subglacial drainage associated with the outer margin of the ice during the formation of the Bowdle end moraine.

Stratified Drift

Two isolated deposits of ice-contact stratified drift are located in the study area. One of these, a small deposit in section 5, T. 128 N., R. 66 W., McPherson County, results from sand and gravel being deposited against an ice face during the construction of the Bowdle moraine (pl. 1).

The second deposit, located in Faulk County (pl. 6) about 3 miles northwest of the town of Rockham, is attributed to deposition in a fissure at the front of the melting ice. This deposit consists of fine to medium sand with lesser amounts of clay and gravel and covers an area of about one and one half square miles. Maximum thickness of the deposit is about 30 feet.

Landforms Associated with Both Active and Stagnant Ice

In general most glacial landforms are related to either stagnant or active ice, however, several geomorphic features in the three-County area originally formed in association with either or both of these ice modes.

Coteau Slope Moraine

The Coteau slope moraine is an area of till which divides the stagnant ice and active ice areas in much of eastern McPherson County (pl. 1). Many of the characteristics of the Coteau slope moraine resemble those common to stagnation moraine, yet lineation is not uncommon. In short, the Coteau slope moraine is a hodgepodge of common glacial morainic features and the entire area represents a gradual transition from the ground moraine of the James Basin to the stagnation moraine of the Coteau proper. It is possible that a part of the geomorphic development of the Coteau slope moraine is related to mass wasting in the form of landslides and mudflows but no such deposits were recognized in the field.

Ground and Stagnation Moraine

In northwestern McPherson County (pl. 1) an area has been mapped as a combination of both ground and stagnation moraine and is shown on plate 1 by the symbol Qwltgs. The area shows some characteristic features of stagnation but is much more gently undulating than most stagnation areas and, therefore resembles ground moraine. The area is

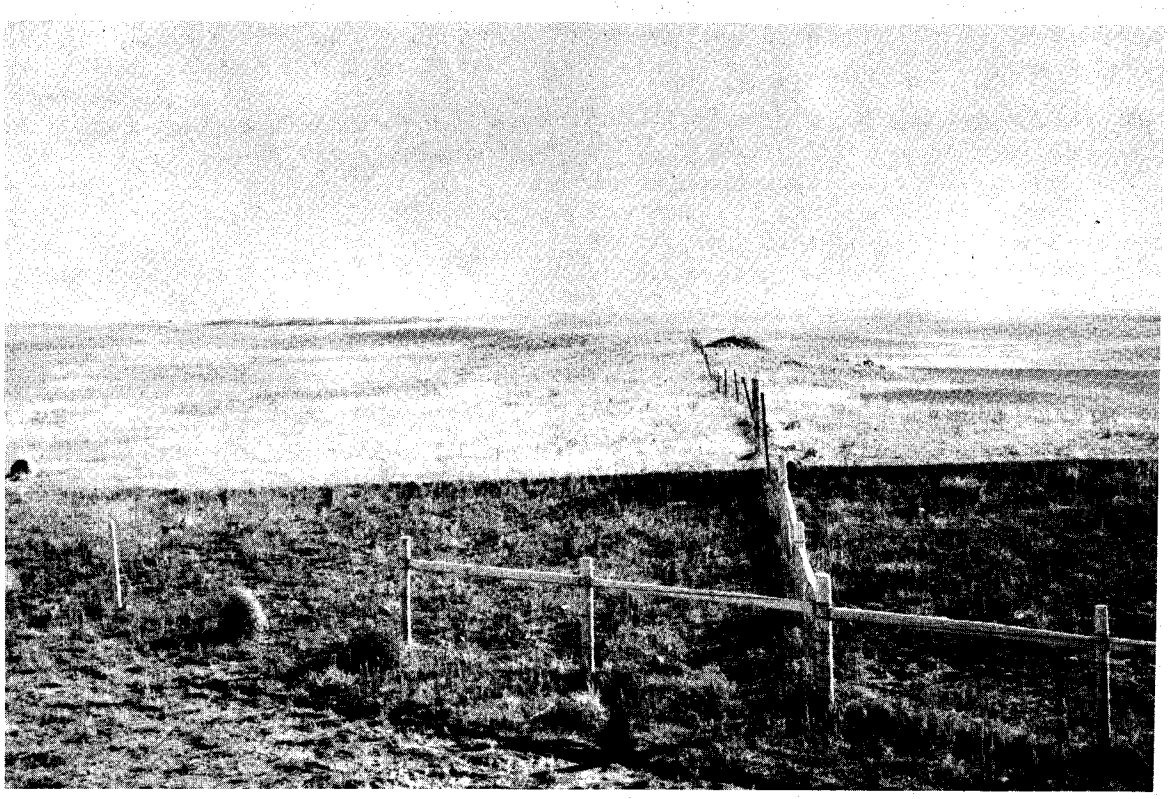

Figure 12. Photograph of esker in western Edmunds County.

mostly ground moraine deposited as ablation drift behind the Zeeland Moraine (fig. 5). Some englacial and superglacial drift must have been present in the ice, but it did not contribute greatly to the drift accumulation.

Meltwater Channels

Throughout the entire study area meltwater channels are numerous. These channels are associated with both active and stagnant ice. Meltwater channels shown on plates 1, 2, and 6 may presently contain an abundance of outwash sediments or may be completely devoid of such sediments. This depends largely upon the final history of the stream which carved the channel. The channel may have become choked with sediment as the stream velocity decreased or it may have had most of the sediment removed by the torrents of meltwater in the very final stages of development. If, in the latter case, the stream is suddenly diverted, the channel will be left with very little in the way of stream deposited sediments.

GEOMORPHIC DEVELOPMENT

Pre-Late Wisconsin Topography and Drainage

Immediately prior to invasion of late Wisconsin ice, the area that is now McPherson, Edmunds, and Faulk Counties, had a surface expression characterized by a northwest to southeast slope (pl. 4). The surficial rocks were primarily Cretaceous Pierre Shale covered only by Pleistocene alluvium along the major drainageways. The eastern part of all three Counties were lowlands similar to their present-day configuration, and these lowlands extended up the Ancient Grand River trench to the northwest (fig. 13). Partially dissected shale highlands occupied the remainder of the area.

Primary drainage from the area was via the Ancient Grand River, which had its headwater in northwestern South Dakota and traveled toward the southeast throughout the three-County section of its route. The scene depicted would have looked very similar to a present-day scene from along the Grand River in east-central Corson County.

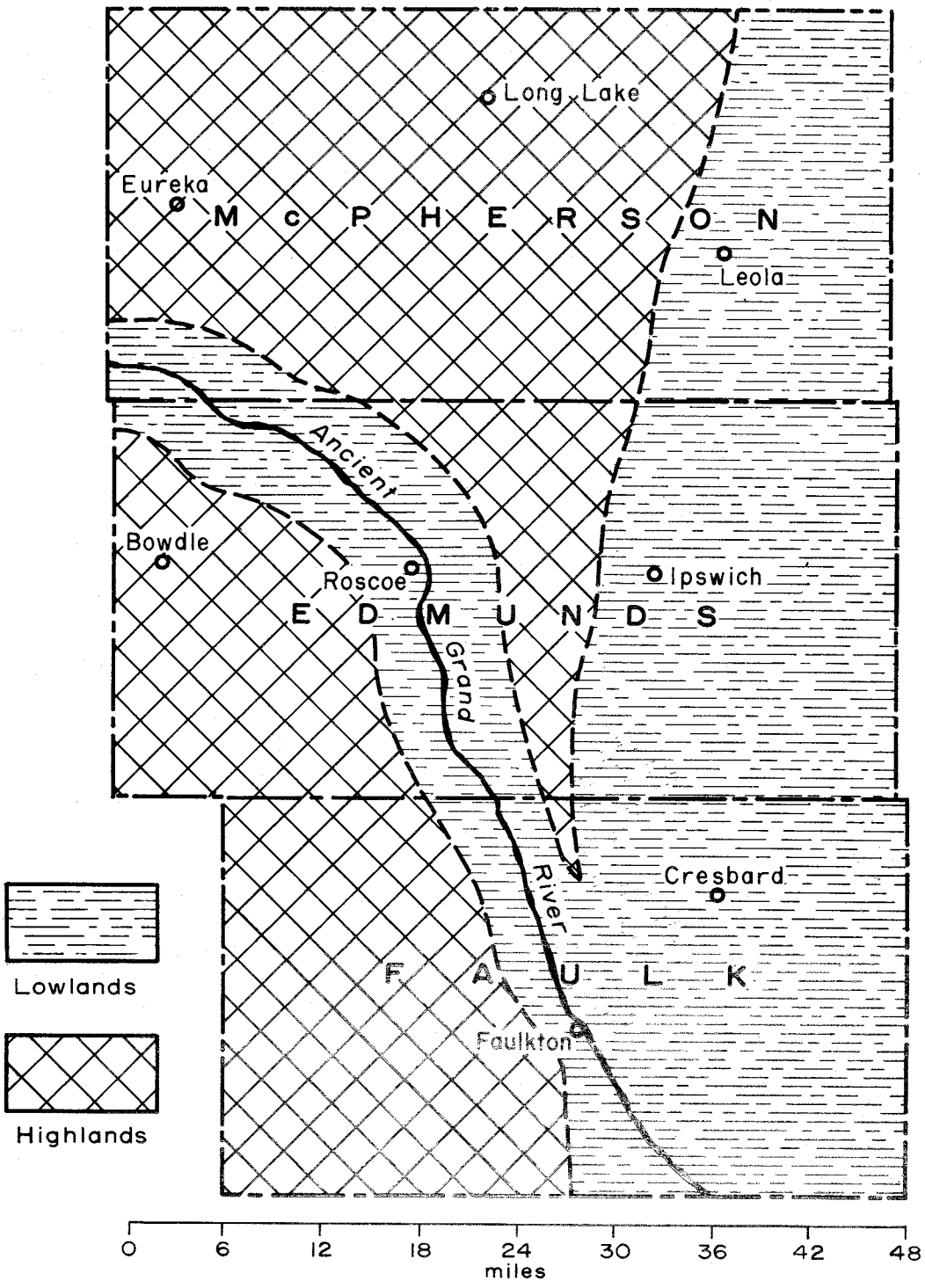

Figure 13. Generalized map of Mc Pherson, Edmunds, and Faulk Counties prior to invasion of late Wisconsin ice.

Late Wisconsin Glaciation

The only ice sheet to enter the mapped area and, indeed the north-central part of South Dakota, was of late Wisconsin age, for no deposits of glacial origin older than late Wisconsin have been proven to exist within that portion of the State. All of the drilling and mapping data from the three-County study area, as well as similar data from nearby Campbell County (Hedges, 1972), indicate the presence of only late Wisconsin age till.

Late Wisconsin age ice first entered the mapped area about 17,000 years ago by way of the lowlands along the eastern edge of McPherson and Edmunds Counties (fig. 14). At this time ice existed from eastern McPherson County across the present-day James River Basin to the western edge of the Coteau des Prairie in Marshall County, and northward into North Dakota. This tongue of ice was the beginning of the James Lobe which was to eventually cover most of eastern South Dakota. Although not completely isolated from the main mass of late Wisconsin ice farther to the east and north, the James Lobe acted somewhat independently and can be considered with only minimal reference to the Des Moines Lobe east of the Coteau des Prairie.

The James Lobe ice was confined between the two Coteaus in eastern South Dakota and moved along the James Basin on its trek southward to the Nebraska border. As the ice sheet thickened and expanded, it began to encroach laterally onto both Coteaus. The Ancient Grand River was blocked as the lobe of ice moved farther to the south and expanded laterally (fig. 15). Ponded water began to form in the blocked drainageways. During periods of low meltwater flow from the ice, alluvial and lacustrine sediments were deposited in the ponded water; whereas, periods of high meltwater flow resulted in deposition of substantial thicknesses of outwash (pl. 5, drill hole 21). Many areas within the blocked Ancient Grand River drainageway received a variety of sediments, depending upon the amount and velocity of meltwaters present, and the exact location of the ice front as a sub-lobe of ice moved up the drainageway toward the northwest (pl. 3, drill hole 4). Sediments within the Ancient Grand River trench as well as other similar trenches in South Dakota consist of till, marl, lacustrine silts and clays, alluvium or outwash.

Approximately 15,000 years ago late Wisconsin ice covered all of the study area, and had moved westward by encroachment onto the highlands, to a line a few miles beyond the present-day Missouri River. Expansion of the ice in this westerly direction had begun at an elevation of about 1000 feet above sea level in the James Basin and reached an elevation of over 2000 feet near the present-day Missouri River. The ice did not possess the necessary energy to move beyond this elevation, and subsequently stagnated throughout the main part of the Coteau du Missouri. Although absolute thickness of the ice is impossible to determine, it must have been relatively thin on the western edge and thickened to perhaps several hundreds of feet near the center of what is now McPherson County. Some distance behind the ice front a second and very poorly formed end moraine was built between the very thin ice to the west and the stagnation area to the east (fig. 16). The Herreid moraine which occupies this position is also shown on plate 1. Although ice did reach beyond the present position of the Herreid end moraine to the area of the Zeeland moraine (fig. 5) in North Dakota (Clayton, 1962) and the Artas moraine (fig. 5) (Hedges, 1972) it existed for only a relatively short period of time and was not of any substantial thickness. Little, if any, superglacial drift was deposited on the ice between the Herreid moraine and the Zeeland-Artas moraine complex.

While stagnant ice occupied much of the highlands of the Coteau du Missouri, active ice continued to move down the James Basin. The James Lobe was active enough to contribute superglacial drift to marginal areas of the highlands and this superglacial drift reached a thickness of several hundred feet in central McPherson County. The drift, thus deposited on top of the stagnant ice effectively insulated the ice and severely retarded melting. Radiocarbon dates from superglacial drift in McPherson County range in age from $14,190 \pm 220$ (I-6361) to $9,220 \pm 300$ (W-2305) indicating the presence of stagnant ice on the Coteau du Missouri for at least 5,000 years.

Stagnation Drift

The massive build-up of stagnation drift on the Coteau du Missouri was due in part to material within the ice at the time it first overrode the Coteau, and in part to material contributed by the active ice that continued to move down the James Basin and encroach upon the margins of the highlands.

Contribution of sediments and meltwater from the active ice to the superglacial drift area can best be shown by a discussion of ice-walled sediments within the stagnation moraine. Plates 1 and 2 clearly show the location of such sediments in McPherson and Edmunds Counties and at first glance a general distribution pattern can be seen. That is, the ice-walled sediments are confined to a rather narrow belt immediately to the west of the Bowdle Moraine. This area would have received abundant sediment-laden meltwater from the active James Lobe ice occupying the lowlands immediately to the east. The meltwater pouring from the active ice lobe onto the stagnant ice would have sought out any openings in the stagnant ice and deposition of sediment would

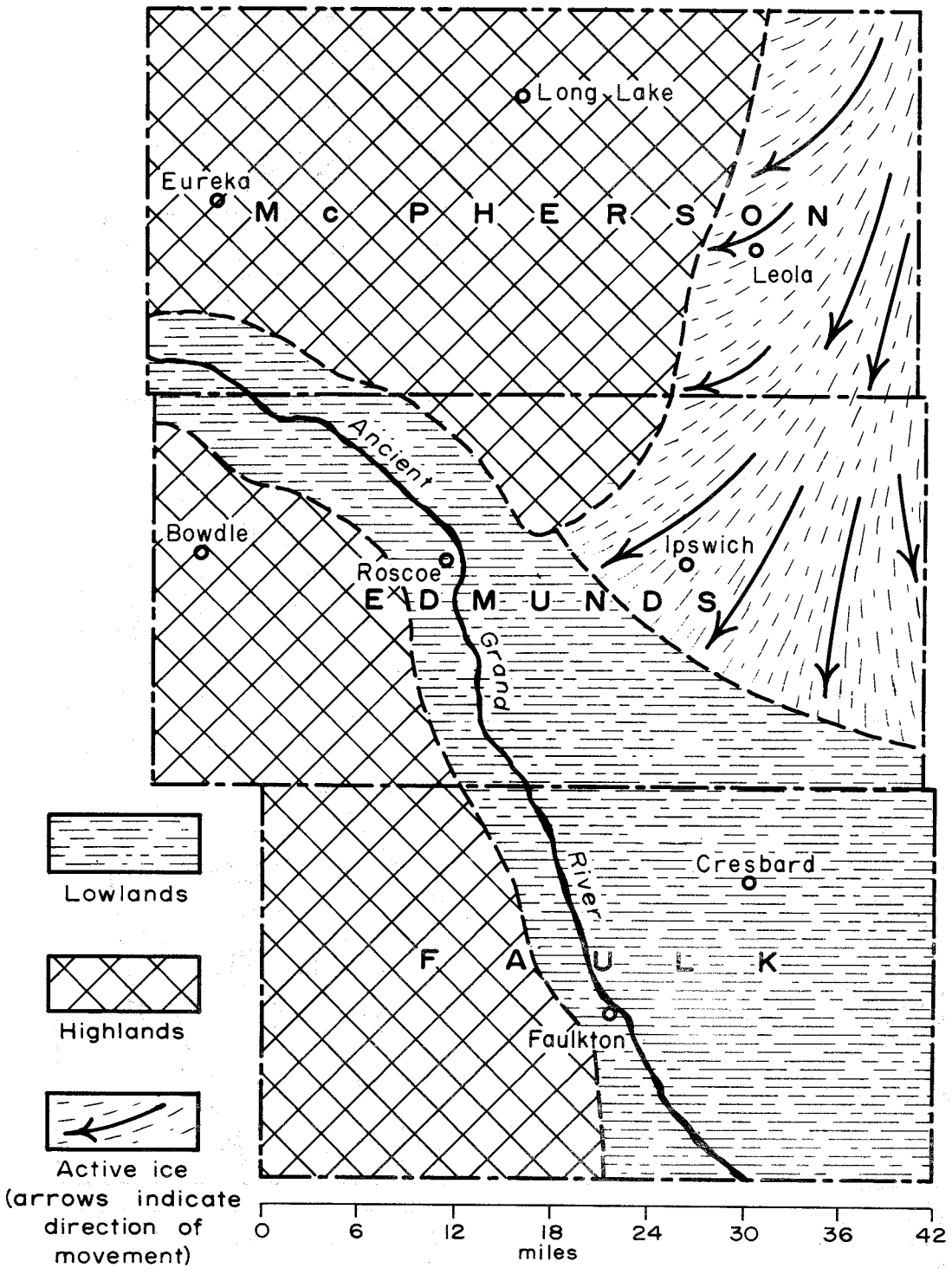

Figure 14. Initial entrance of late Wisconsin ice into Mc Pherson, Edmunds, and Faulk Counties.

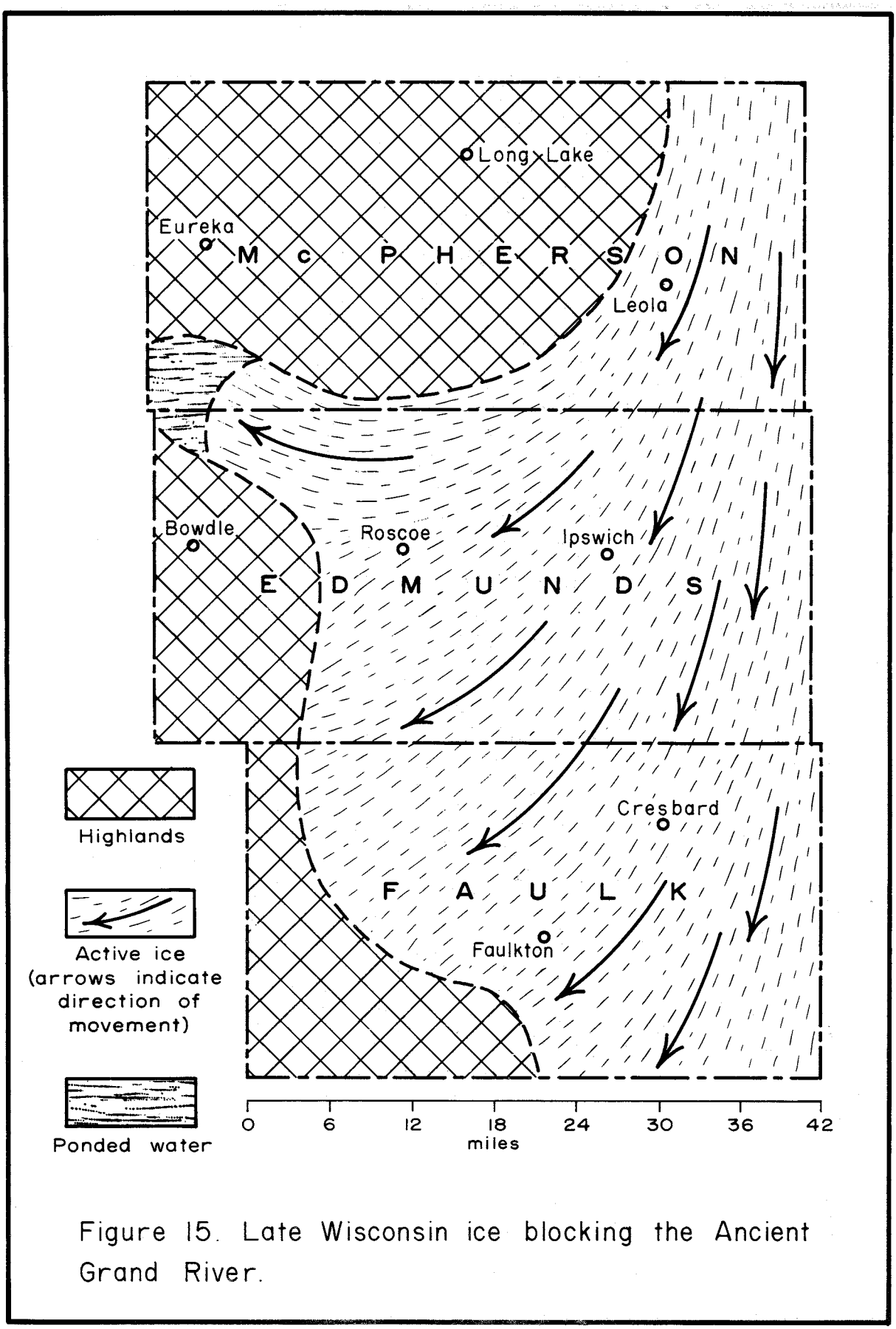

Figure 15. Late Wisconsin ice blocking the Ancient Grand River.

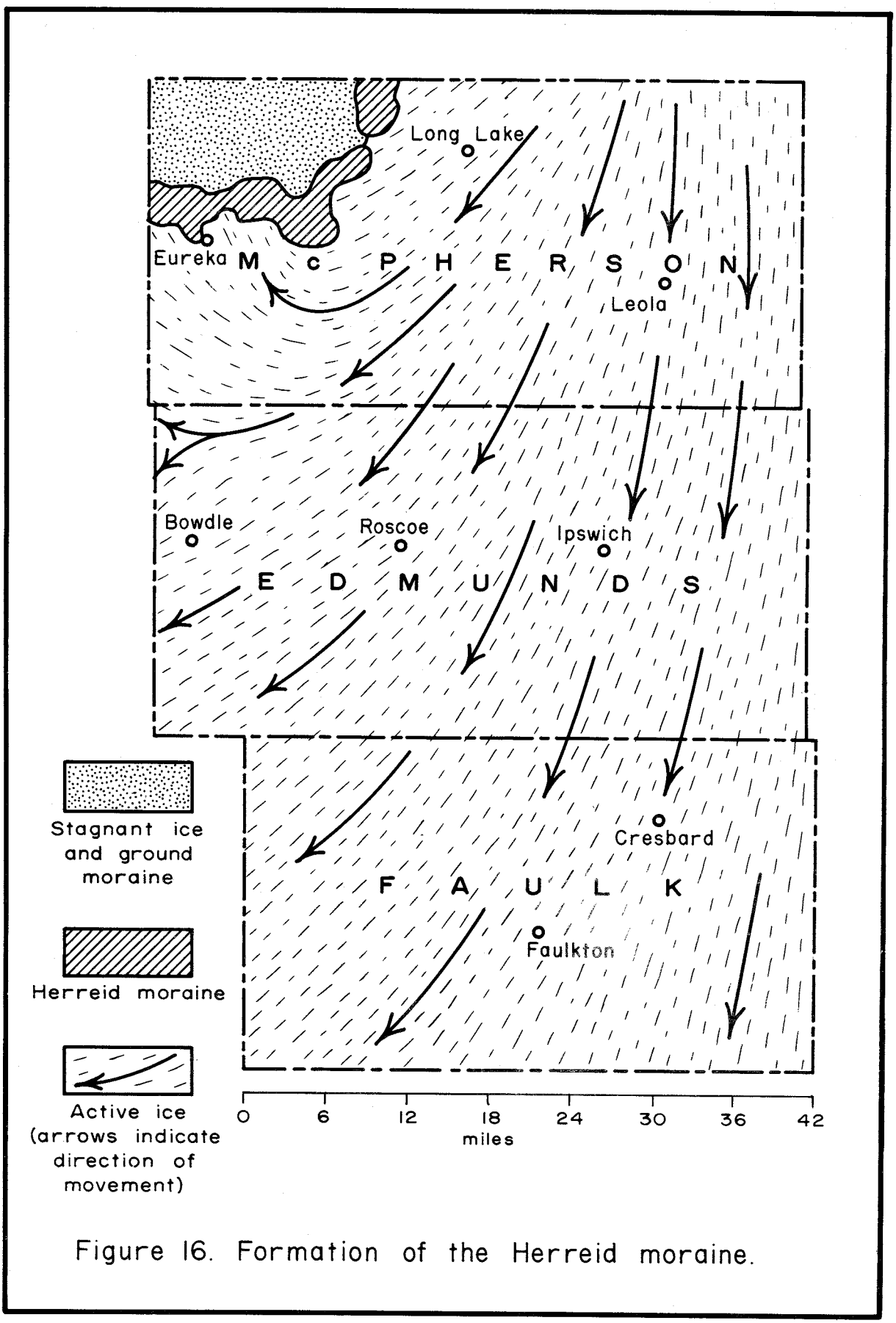

Figure 16. Formation of the Herreid moraine.

have occurred almost immediately. It is believed that the many ice-walled plains were formed in this manner. Later as the stagnation area received additional sediment and became essentially drift covered, streams began to form and drainage from the ice was confined to more classical examples of streams and associated tributary systems.

Bowdle Moraine

Between the stagnant ice on the Missouri Coteau and the active James Lobe ice to the east, was built the most impressive moraine within the three-County area (fig. 17). Where present the Bowdle Moraine remains today as the separation line between massive stagnant ice deposits to the west, and active ice deposits to the east. Formation of the moraine was controlled directly by the position of the stagnant ice on the Coteau du Missouri. As was mentioned previously, active ice continuing to move along the James Basin was not able to override the substantial thickness of stagnant ice. Because of the confinement between the two areas of stagnant ice on the Coteau du Missouri and the Coteau des Prairie the James Lobe ice behaved, in many respects, like a large valley glacier. Morainal material was deposited along the lateral margin of the ice lobe similar to lateral morainal deposition along the margin of a valley glacier.

Collapsed Outwash

Meltwaters from the active James Lobe ice were directed toward the west across the stagnant ice area (fig. 18). These meltwaters contained sediments being removed from the ice as well as sediments being sorted from the Bowdle Moraine during and after its formative stage. Eventually, because of erosion of the ice by the meltwaters and the build-up of superglacial drift over the remainder of the stagnant ice, the meltwaters became confined to definite channels. Outwash sediments, thus confined to stream channels, were left throughout the stagnant ice area (pls. 1 and 2) when the meltwaters subsided. As the stagnant ice melted during the 5,000 years that followed, the overlying sediments were let down and collapsing occurred. As much as 100 feet of relief can now be seen on the outwash bodies in the vicinity of Long Lake, McPherson County, as a result of this collapsing.

Valley Train Outwash and Meltwater Routes

Immediately beyond the massive stagnation area on the Coteau du Missouri (west of the Herreid Moraine) in McPherson County collapsed outwash gives way to valley train outwash (pl. 1). During deposition of outwash sediments only those that were deposited on the massive stagnant ice were subject to later collapsing. Beyond the Herreid Moraine the stagnant ice was thin and in many cases nonexistent. In these areas, outwash deposition occurred on earlier deposited ground moraine containing no incorporated ice and collapsing could not occur.

Meltwaters routed across the stagnation area from the active ice in the James Basin as well as water from blocked drainage from the west, had only one escape route from the area. This route of necessity was along the western edge of the ice front. Meltwaters from McPherson County and the surrounding areas and stream waters from the western portion of the State ponded near the ice front until a sufficient elevation was reached to cause overflow of the former drainage divides. The underlying Cretaceous sediments were easily eroded and the early stage of the Missouri River trench began to form. This drainage route became firmly established and remained to drain much of the study area long after the active ice had retreated from the James Basin.

Late Wisconsin Deglaciation

Deglaciation of the James Basin

Deglaciation during late Wisconsin time began with rapid fluctuation of the James Lobe ice in the southern part of eastern South Dakota. Relatively thin by the time it reached the Nebraska-South Dakota boundary, the ice sheet was highly susceptible to any climatic changes. When the necessary changes did occur, melting and retreat of the ice were rapid. Having reached its maximum southern extent between 14,000 to 15,000 years ago, the ice had completely abandoned the James Basin of South Dakota approximately 11,000 years before present.

Recessional End Moraines

Though deglaciation of the James Basin was rapid, several major stillstands did occur and resulted in larger than normal recessional end moraines. The first of these stillstands in the study area is represented by a well-developed recessional end moraine just east of the Bowdle Moraine in southwestern Faulk County (pl. 6). If traced on the surface from this area of Faulk County into Potter County to the west, the recessional moraine eventually merges with the Bowdle Moraine. The angle of mergence strongly suggests recessional conditions of the ice during the construction of the moraine, although the time of construction must have been very early in the waning stage of late Wisconsin glaciation.

The second major stillstand is represented by a very conspicuous recessional moraine constructed on a bedrock high about 2 miles west of the town of Orient in southern Faulk County (pl. 6). This moraine can be traced some distance to the south in Hyde County.

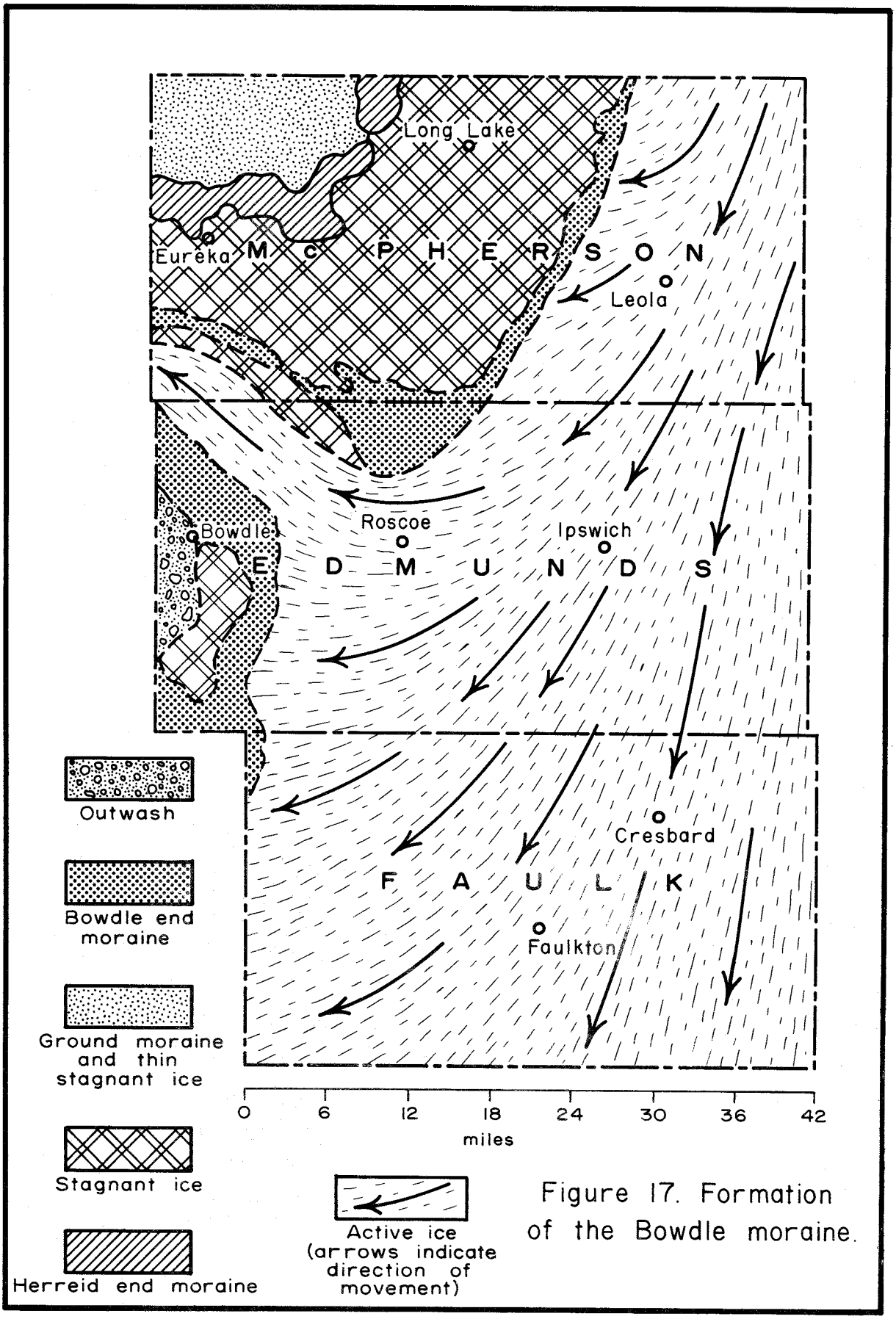

Figure 17. Formation of the Bowdle moraine.

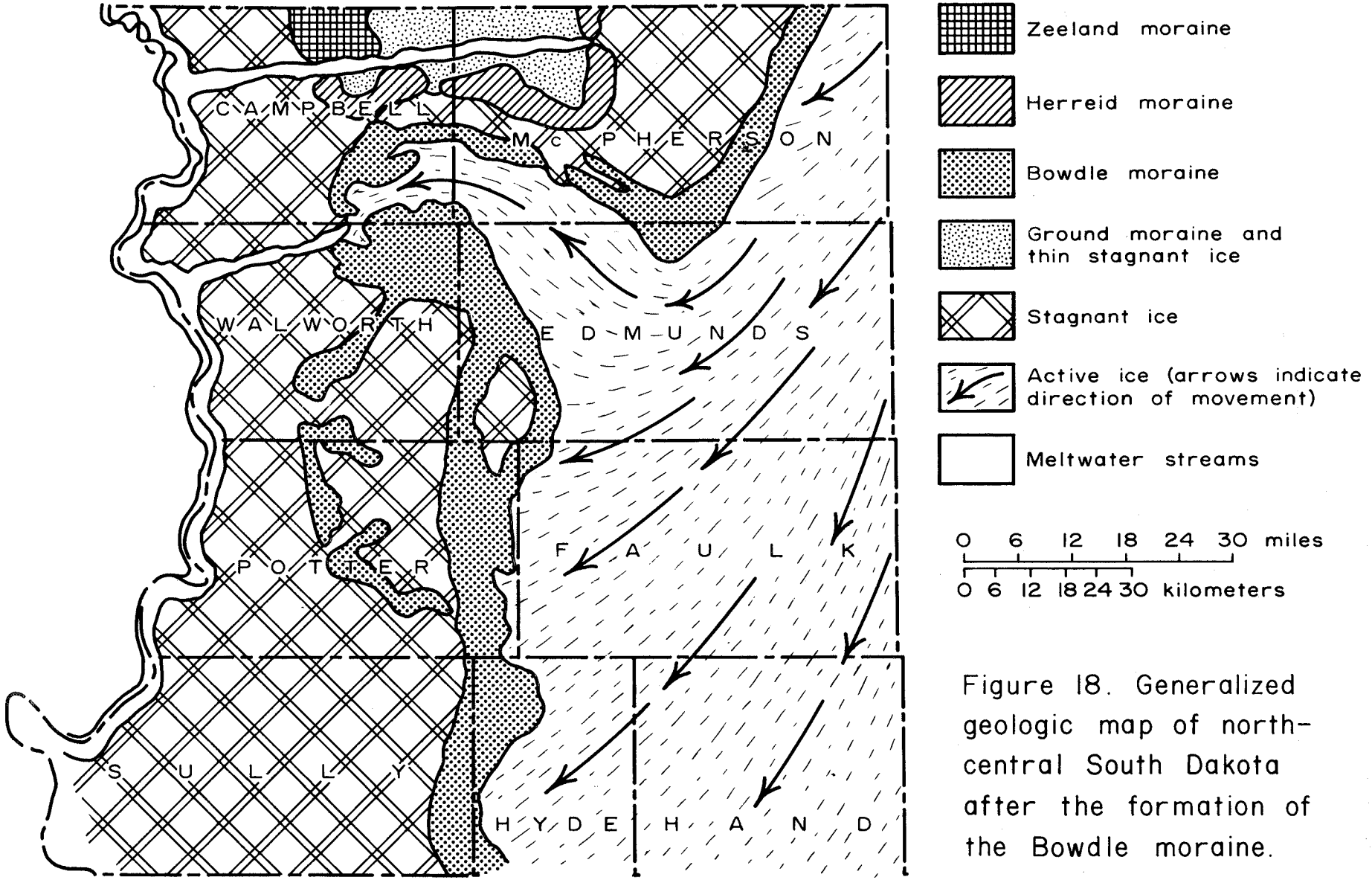

Figure 18. Generalized geologic map of north-central South Dakota after the formation of the Bowdle moraine.

Still a third major stillstand occurred near the vicinity of Scatterwood Lake in northeastern Faulk and southeastern Edmunds Counties (pls. 2 and 6). Here a larger than normal recessional end moraine was constructed which continues for some distance northward through Brown County. Scatterwood Lake began as a large ice block that was left to melt surrounded by the moraine.

Throughout the remainder of the study area recessional moraines are common but much more subdued than in the three cases just described. Areas of abundant, successive lineations have been mapped as washboard moraine in both Faulk and Edmunds Counties (pls. 1 and 6), and are numerous in many other counties within the James Basin. Indeed, several thousand such lineations representing very minor topographic highs exist in the James Basin and may reflect the normal annual fluctuation of the ice margin brought about by seasonal changes in temperature (Gwynne, 1951).

Ice-Marginal Channels

While the late Wisconsin ice covered eastern South Dakota, drainage from the ice, as was mentioned earlier, was directed over the stagnant ice areas on both the Coteau du Missouri and the Coteau des Prairie. However, as the active ice began to retreat from the James Lowlands, the pattern changed. The large deglaciated area south of the James Lobe ice sheet became the lowest area in eastern South Dakota. Meltwaters would naturally flow down gradient from the melting ice sheet.

Meltwater channels were common along the southern edge of the ice front, and the channels appear to have migrated northward with the ice. The channels would follow the ice front for some distance and then begin a southward journey away from the ice. This pattern would prevail while the ice retreated for a short distance (5 or 6 miles) northward. Then the southward extension of the channel would become choked with sediment and movement of meltwaters to the south would cease. A complete reversal of flow would then occur and the meltwaters would flow toward the north and east until they would again reach the ice front. They would continue eastward along the ice front until a new path southward could be established. Thus, the low point of the Basin was eventually reached and a firmly entrenched route to the south was established via the James River. The present-day drainage of the area is a strange appearing modified dendritic pattern which flows southeast and then northeast, continually changing directions every 5 or 6 miles, until finally intersecting the James River near the center of the Basin (pl. 6). Flint (1955, pl. 1) very accurately portrays this for the entire James Basin.

The exact cause of this strange, almost circular, drainage pattern is not clearly understood (Helgerson and Christensen, 1975). It may be a simple fact of choking off of the southward flowing streams by low-water flow and deposition before they could be firmly established. Likewise, the above conditions, in conjunction with isostatic rebound of the Cretaceous Shales due to unloading of the weight of the ice may have been a contributing factor. It should also be noted that very little rebound would have been necessary because the regional slope of the Basin prior to late Wisconsin glaciation was to the north. Any stream flowing to the south was flowing directly against what had been the natural slope of the land surface prior to invasion by the late Wisconsin ice.

Deglaciation of the Coteau du Missouri

By the time ice had completely left the James Lowlands, a substantial thickness of ice covered by superglacial drift still remained on the highlands of the Coteau du Missouri. Melting of this massive area of stagnant ice was a very slow process. Effectively insulated as it was, a period of approximately 5,000 years was required before all of the ice disappeared. Radiocarbon dates, mentioned earlier in the report, on material taken from collapsed outwash sediments on the Coteau range in age from 14,190 years before present to 9,220 years before present. The younger date is from shells collected from collapsed outwash sediments at a depth of about 6 feet below land surface. Collapsing, caused by melting of buried ice, was still proceeding at this point in time.

Meltwaters from the stagnant ice area on the highlands were prevented from entering the James Basin throughout much of the mapped area because of the presence of the Bowdle-Streeter Moraine. For this reason, the previously established routes to the west across the stagnation drift and finally into the now firmly established Missouri River continued to be the predominant routes. This fact is further in evidence when one considers the absence of alluvial, colluvial or other similar deposits along the eastern flank of the Coteau du Missouri throughout the three-County area. In addition the major outwash bodies not connected with stagnation drift are found west of the stagnation area indicating the presence of large volumes of meltwater exiting in that direction.

Recent Geomorphic Development

Since the close of the Pleistocene Epoch, geomorphic development has not changed the picture of the landscape to any great extent. Drainage, other than in the James Basin, is essentially nonintegrated and occurs mostly as internal drainage via grassy waterways to local sloughs and potholes. An integrated drainage system is becoming

well-developed in the James Basin portion of the three-County area but is largely the result of drainageways that began during the melting of the James Lobe ice.

Some lowering of the landscape must have occurred since the close of the Pleistocene Epoch because lakes, potholes, and sloughs are partially filled with material from adjacent higher land. Deposition throughout the Recent Epoch has been confined to the addition of a varied amount of alluvium along the major streams (pls. 1, 2, and 6).

ECONOMIC GEOLOGY

Mineral Resources

Water

The largest single mineral commodity available in the three-County study area is water. In the form of ground water this commodity is available in abundance. As part of the investigation of the three Counties, a complete hydrologic study was completed. The technical results of the study are available as Part II of this bulletin (Hamilton, in preparation). A short summary of the overall ground-water conditions including locations of aquifers, quantity of water, and quality of water can be obtained by reading Hamilton (1974).

Sand and Gravel

Another important part of the overall study of the area was the location of sand and gravel resources. Many hundreds of test holes were drilled for the specific purpose of sand and gravel exploration. The results of the sand and gravel investigation are available from the County Extension Offices within the study area.

Other Mineral Commodities

Although exploration for various mineral commodities other than those previously mentioned has taken place on several occasions, to date no other economically minable mineral deposits such as oil, gas, ceramic clay, or metals have been located in the mapped area.

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APPENDIX – LOGS OF DRILL HOLES

Logs listed in this appendix were used to compile the cross sections (pls. 3, 5, 7, 8, 9, 10, 11, 12, and 13) that are located in the map pocket. Additional logs that were used for descriptive purposes within the text are also listed.

Drill Hole 1
Location: NW NW NW NW sec. 6, T. 121 N., R. 73 W.
Elevation: 1911 feet

Description	Depth Feet
Topsoil, brown	0- 1
Gravel, medium to coarse	1- 45

* * * *

Drill Hole 2
Location: SE SE SE SE sec. 31, T. 122 N., R. 71 W.
Elevation: 1844 feet

Description	Depth Feet
Clay, yellow-brown, pebbly	0- 33
Clay, gray, silty, pebbly (dark-brown till at 39 feet); coal at 45 to 52	33- 53
Clay, gray, pebbly, a few thin sand and gravel lenses, some coal	53-179
Clay, gray, pebbly, gravelly; many shale pebbles; some gravel stringers 1 to 2 feet thick; some coal	179-238
Clay, gray, pebbly; some shale pebbles	238-260
Shale, dark-gray; some bentonite	260-290

* * * *

Drill Hole 3
Location: NW NW NW NW sec. 6, T. 121 N., R. 70 W.
Elevation: 1738 feet

Description	Depth Feet
Clay, dark-brown, rocks, pebbles, till	0- 21
Clay, gray, pebbly with some rocks	21-120
Clay, dark-gray, gravel stringers, sandy	120-150
Clay, dark-gray, silty, with very fine sand	150-157
Clay, dark-gray, pebbly, with very fine sand	157-211
Gravel and sand	211-215
Clay, dark-gray, pebbly, sandy, till, some gravel stringers 2 to 3 feet thick at 255	215-310
Sand, with gravel, some dark-gray clay	310-343
Clay, light-gray to whitish-gray, marl, very sandy	343-371
Gravel with some clay layers	371-439
Shale, dark- to medium-gray, and clay, sandy	439-480
Marl, light- to medium-gray, some dark-gray mottling, very calcareous, some sandy cuttings, much gravel caving from above	480-490

Drill Hole 3 -- continued.

Clay, medium-gray, very sandy, much coal	490-570
As above and oxidized till, several shale pieces, sandy	570-598
Shale, black, greasy, earthy, (Sharon Springs?), also shale, medium-gray	598-620

* * * *

Drill Hole 4
Location: SE SE SE SE sec. 33, T. 122 N., R. 70 W.
Elevation: 1685 feet

Description	Depth Feet
Clay, dark-brown, pebbly till	0- 28
Clay, dark-gray, pebbly, some rocks, till	28-165
Clay, dark-gray to light-gray, with very fine sand (some rocks) at 179	165-207
Clay, dark-gray, very sandy, goes into mud, have shale reworked in the clay, very tough	207-246
Clay, dark-gray, very sandy with alternating layers of clay and sand lenses. Some gravel lenses also.	246-304
Sand and gravel, medium to coarse, has some clay	304-332
Clay, dark-gray, very sandy with alternating layers of clay and sand lenses. Some gravel, whitish clay, marl present, also some organic material	332-427
Gravel and sand, some gray clay	427-465
Clay, gray, gravelly, sandy	465-514
Clay, yellow, till(?)	514-518
Clay, gray, gravelly, sandy	518-554
Whitish, marly, calcareous, drills fast, chatters some (chalk?)	554-590

* * * *

Drill Hole 5
Location: SE SE SE SE sec. 31, T. 122 N., R. 69 W.
Elevation: 1690 feet

Description	Depth Feet
Clay, dark-brown, gravel layers from 5 to 8 feet, clay is sandy with pebbles	0- 18
Clay, dark-gray, pebbly, sandy, very fine, some rocks	18- 35
Clay, gray, silty, pebbly, some rocks	35-126
Shale, hard, blocky, some bentonite	126-155
Shale, good cuttings	155-170

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Drill Hole 6
Location: SE NE NE NE sec. 1, T. 121 N., R. 69 W.
Elevation: 1550 feet

Description	Depth Feet
Gravel, dry, pea-sized mixed with coarse sand	0- 4

Drill Hole 6 -- continued.

Clay, yellow-brown, moist, till	4- 21
Clay, gray, moist, till	21- 65
Clay, gray, very compact, till	65- 73
Clay, blue-gray, very moist, some scattered rocks	73- 84
Shale, blue-gray, almost dry, very compact	84- 89

* * * *

Drill Hole 6a
Location: SE SE SE SE sec. 33, T. 122 N., R. 68 W.
Elevation: 1508 feet

Description	Depth Feet
Silt, clayey, some fine sand, oxidized, humic to 1.5 feet, water-laid silt and sand at 31 to 31.5 feet; partly water-laid at 32.5 to 35.5 feet, till	0- 37
Silt, clayey, unoxidized, sandy at 53.5 to 54 feet, till	37- 64
Silt and clay, water-laid, unoxidized, has "varved" appearance	64- 65
Silt, clayey, unoxidized, sandy at 70 to 71 feet, till	65- 75
Shale, silty (Pierre Formation), poor recovery	75- 80

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Drill Hole 7
Location: SW SW SW SW sec. 31, T. 122 N., R. 67 W.
Elevation: 1467 feet

Description	Depth Feet
Silt, water-laid, some fine sand, humic, oxidized	0- 3
Sand, water-laid, fine to medium, oxidized silty at 3 to 4 feet and 11 to 12.5 feet, quite permeable	3- 13
Silt, clayey, some sand, oxidized, till	13- 20
Sand, water-laid, silty, oxidized, slightly permeable	20- 24
Silt, clayey, some fine sand, oxidized, till	24- 27
Silt, water-laid, some clay, oxidized	27- 29
Silt, clayey, sandy and gravelly at 32 to 33 feet, oxidized, till	29- 33
Silt, clayey, some sand, scattered very thin layers of water-laid silt and sand, unoxidized, till	33- 82
Lost sample	82- 84
Silt, clayey, some sand, scattered thin layers of water-laid sand and silt, unoxidized, till	84- 97
Sand, coarse, gravel and silt, may be till, thin layer of silt till at 101 and 101.3 feet, unoxidized	97-102
Silt, clayey, unoxidized, till	102-103
No sample (hit rock)	103-104
Shale	104-106

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Drill Hole 8
Location: SE SE SE SE sec. 32, T. 122 N., R. 67 W.
Elevation: 1465 feet

Description	Depth Feet
Topsoil, light-brown, pebbly, silty, dry	0- 1
Clay, brown, pebbly, silty, dry	1- 4
Clay, brown, silty, dry to moist	4- 10
Clay, brown, soft, sandy	10- 15
Clay, gray, soft, sandy, a few isolated boulders, moist	15- 36
Clay, gray, drilling harder, quite compact, moist	36- 56
Clay, gray, contains sand (coarse), very compact dry	56- 84

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Drill Hole 9
Location: NE NE NE NE sec. 4, T. 121 N., R. 67 W.
Elevation: 1458 feet

Description	Depth Feet
Silt, clayey, water-laid, oxidized, humic to 2 feet	0- 3
Silt, clayey, some fine sand, oxidized, (mottled 25 to 27 feet), few inches of gravel at 20 feet, till	3- 29
Silt, clayey, some fine sand, unoxidized, water-laid fine to medium sand and silt at 35.3 to 36 feet and fine sand and silt at 38 to 39 feet, till	29- 48
Silt, sandy and gravelly, many shale pebbles, unoxidized, till	48- 53
Clay, silty, unoxidized, till	53- 58
Shale, silty, gray, hard (Pierre Formation)	58- 60

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Drill Hole 10
Location: SE SE SE SE sec. 34, T. 122 N., R. 67 W.
Elevation: 1456 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 22
Clay, brown to dark-brown, till	22- 33
Clay, brown to dark-brown, with some large gravel, till	33- 43
Clay, dark-brown to gray-brown, till	43- 48
Clay, dark-brown to gray-brown, saturated, till	48- 61
Shale	61- 70

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Drill Hole 11
Location: SE SE SE SE sec. 36, T. 122 N., R. 36 W.
Elevation: 1428 feet

Drill Hole 11 -- continued.

Description	Depth Feet
Silt, clayey, oxidized, humic to 2 feet, concentration of carbonates at 3 to 3.5 feet, till	0- 19
Shale, silty (Pierre Formation), mottled (partly oxidized)	19- 22

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Drill Hole 12
Location: SE SE SE SE sec. 33, T. 122 N., R. 66 W.
Elevation: 1402 feet

Description	Depth Feet
Silt, clayey, oxidized, humic to 1.5 feet, till	0- 10
Lost sample	10- 18
Silt, clayey, unoxidized, till	18- 24
Sand and silt, water-laid, fine, unoxidized slightly permeable. Less silt, more permeable at 31 to 32 feet and 33 to 36 feet, interbedded with silt and carbonaceous matter at 35 to 37.5 feet	24- 38
Clay, silty, and clayey silt, unoxidized, many shale pebbles, till	38- 74
Shale (Pierre Formation), has some thin bentonite layers	74- 78

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Drill Hole 13
Location: NE NE NE NE sec. 3, T. 121 N., R. 66 W.
Elevation: 1385 feet

Description	Depth Feet
Sand, yellow-brown, fine to medium	0- 6
Clay, yellow-brown, sandy, till	6- 17
Clay, dark-brown to gray-brown, till	17- 46
Clay, with large rocks, dark-brown to gray-brown, till	46- 50
Clay, dark-brown to gray-brown, saturated, till	50- 80
Clay, dark-brown to gray-brown, saturated, with methane gas, till	80- 92
Shale	92-100

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Drill Hole 14
Location: NE NE NE NE sec. 1, T. 121 N., R. 66 W.
Elevation: 1345 feet

Description	Depth Feet
Topsoil	0- 1
Clay, very dark-maroon, dry to moist, silty	1- 10
Clay and gravel??, dark-brown, some coarse sand and some fine gravel	10- 27

Drill Hole 14 -- continued.

Description	Depth Feet
Sand??, light-gray, fine to medium, saturated	27- 31
Clay, gravelly, quite compact, dark-gray	31- 44
Clay, gray, sandy, soft, moist	44- 64
Shale, black, moist, contains a few isolated patches of bentonite and a few very isolated small pebbles	64- 84

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Drill Hole 15
Location: SW SW SW NW sec. 6, T. 120 N., R. 72 W.
Elevation: 1949 feet

Description	Depth Feet
Clay, yellow	0- 45
Clay, gray, gravelly	45-125
Gravel	125-145
Clay, gray, gravelly	145-183
Gravel	183-185
Clay, gray, gravelly	185-220
Gravel, sandy	220-360
Clay, brownish, some shale cuttings	360-364
Shale, dark-gray	364-380

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Drill Hole 16
Location: NE NE NW NW sec. 2, T. 120 N., R. 72 W.
Elevation: 1880 feet

Description	Depth Feet
Clay, very sandy, pebbly, red-brown	0- 17
Clay, brownish-gray, varicolored, sandy, rocks with some gravel stringers	17- 32
Clay, light-gray, sandy, pebbly; till	32- 94
Sand, with clay layers, looks poor mixed with light- to dark-gray clay	94-105
Clay, dark-gray, pebbly, rocks	105-120
Clay, dark-gray, sand lenses with some medium gravel, rock at 132 feet	120-165
Clay, with sand and gravel, dark-gray gravelly till	165-230
Clay, dark-gray, very sandy, tough drilling pebbles	230-268
Drilling smoothed out, lower pressure, cut mud, did not receive good shale sample until 285 feet	268-305

* * * *

Drill Hole 17
Location: NE NE NE NE sec. 5, T. 120 N., R. 71 W.
Elevation: 1768 feet

Description	Depth Feet
Clay, light-gray to light-brown, silty, pebbly	0- 15
Clay, gray, pebbly, gravelly	15-200
Gravel, very rocky	200-210

Drill Hole 17 -- continued.

Clay, gray, very silty	210-233
Clay, gray, very silty and sandy with coal	233-250
Clay, gray, gravelly, shale pebbles, coal	250-275
Clay, gray, very tough, may be reworked shale	275-297
Shale, gray, bentonitic, noncalcareous	297-320

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Drill Hole 18
Location: NE NE NE NE sec. 1, T. 120 N., R. 71 W.
Elevation: 1740 feet

Description	Depth Feet
Clay, grayish-brown, silty, few pebbles	0- 8
Clay, reddish-brown, highly oxidized, pebbly	8- 20
Clay, dark-gray, sandy and pebbly	20-140
Clay, dark-gray, sandy and pebbly, clay rich	140-150
Clay, dark-gray, pebbly	150-172
Rock, below rock hard shale, then till	172-175
Clay, gray, till	175-190
Clay, gray, gravelly in spots, coal	190-265
Clay, dark-gray, very sandy, some gravel	265-272
Clay, dark-gray, compact, sandy	272-305
Rock	305-310
Sand and gravel, with clay that has a white marl intermixed with it	310-313
Clay, bluish-gray, compact, shale	313-320

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Drill Hole 19
Location: NW NW NW NW sec. 8, T. 120 N., R. 70 W.
Elevation: 1740 feet

Description	Depth Feet
Topsoil, black	0- 1
Clay, yellow-brown, pebbly, till	1- 58
Clay, gray, pebbly, till	58-253
Bedrock, shale	253-275

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Drill Hole 20
Location: NW NW SW SW sec. 32, T. 121 N., R. 69 W.
Elevation: 1620 feet

Description	Depth Feet
Clay, brown, pebbly	0- 34
Clay, gray, slightly pebbly	34-122
Gravel	122-125
Clay, gray, gravelly	125-165
Gravel	165-169
Clay, gray, gravelly	169-171
Gravel, sandy	171-320
Shale, light-gray, silty; some black organic sand at about 335 feet. Poor samples.	320-415

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Drill Hole 21
Location: SE SE SE SE sec. 5, T. 120 N., R. 69 W.
Elevation: 1604 feet

Description	Depth Feet
Clay, brown, sandy, banded brown, then light-gray	0- 17
Clay, rust-brown, to very dark-brown, silty, with pebbles	17- 18
Clay, dark-gray, gravel layers	18- 42
Gravel, coarse to very coarse	42- 47
Clay, dark-gray, gravelly, with sand	47- 58
Clay, dark-gray, pebbly, sandy	58-151
Sand, very fine to fine, gray, coal pebbles	151-195
Sand, dark-gray, very fine to fine, with clay, coal and shale pebbles	195-275
Clay, gray, sandy with coal	275-320
Clay, gray, silty, sandy, some coal	320-350
Clay, gray, silty, some gravel	350-405
Shale, with Sharon Springs starting at 420 feet, Niobrara Chalk(?) around 440 feet	405-440

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Drill Hole 22
Location: NE NW NW NW sec. 2, T. 120 N., R. 69 W.
Elevation: 1560 feet

Description	Depth Feet
Clay, yellowish-brown, silty, pebbly	0- 29
Gravel, coarse, unsorted, dirty	29- 35
Clay, gray, silty, pebbly	35- 65
Clay, gray, gravelly	65- 72
Clay, gray, silty, pebbly	72-155
Shale, reworked	155-165
Clay, gray, gravelly	165-230
Gravel, a few clay stringers	230-245
Gravel	245-265
Shale	265-290

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Drill Hole 23
Location: NE NE NE NE sec. 6, T. 120 N., R. 68 W.
Elevation: 1513 feet

Description	Depth Feet
Topsoil, black	0- 1
Clay, yellow, slightly moist, till	1- 19
Clay, gray, till	19- 43
Sand, fine, gray with clay present but fairly clear saturated and viscous, (scattered rocks 43 to 45 feet)	43- 58
Clay, gray, slightly sandy, saturated	58- 98
Clay, gravelly, gray-brown, compact, till	98-112
Clay, dark-gray, very compact, few pebbles, till	112-124

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Drill Hole 24
Location: NW NW NW NW sec. 3, T. 120 N., R. 68 W.
Elevation: 1479 ± 2 feet

Description	Depth Feet
Silt, oxidized, clayey, concentration of carbonates at 0 to 1.5 feet, sandy and partly water-laid sand and silt at 29.5 to 32.5 feet; rocky (poor recovery) at 35 to 37.5, till	0- 41
Silt, unoxidized, very clayey. Gravelly at 50 to 51 feet, 55 to 57 feet, and 70 to 71 feet. Partly water-laid sand at 62.5 to 65 feet, till	41- 75
Rock, lost core	75- 80
Sand, water-laid, fine, and silt alternating with clay till. Poor core recovery	80- 89
Silt, clayey. Water-laid silt at 109 to 110 feet, till	89-117
Shale, laminated, gray	117-125

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Drill Hole 25
Location: SW SW SW SW sec. 36, T. 121 N., R. 68 W.
Elevation: 1460 ± 2 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 10
Clay, brown, till	10- 34
Clay, gray-brown, till	34- 40
Sand, fine to medium, saturated, till	40- 54
Clay, gray-brown, sandy, saturated, till	54- 69
Clay, gray-brown, with sand, saturated, till	69- 79
Clay, gray-brown, very sandy, saturated, till	79- 84
Clay, gray-brown, sandy, saturated, till	84- 94
Clay, gray-brown, saturated, till	94-109
Shale	109-111

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Drill Hole 26
Location: NW NW NW NW sec. 5, T. 120 N., R. 67 W.
Elevation: 1455 feet

Description	Depth Feet
Silt, water-laid, and clay, concentrations of salts at 1.5 to 2 feet	0- 2
Silt, oxidized, clayey, till. Varved silt at 14.5 to 15.5 feet. Partly water-laid sand at 19.5 to 25 feet. Some till not oxidized at 19.5 to 25 feet.	2- 25
Clay, unoxidized, silty, with scattered thin layers of water-laid fine sand and silt, till	25- 29
About half silty clay till and half water-laid fine to medium sand in alternating thin layers. Mostly sand at 30 to 31.5 feet and 33 to 34 feet.	29- 35
Lost core, driller reports fine sand	35- 40
Clay, silty, till, with widely scattered thin layers of water-laid fine sand and silt. Clay, silty, till, at 55 to 56.5 feet. Water-laid fine sand and silt at 53.5 to 54.5 feet and 79 to 80 feet. Water-laid silt at 73 to 75 feet and 85 to 92.5 feet. Some fine sand at 87.5 to 91 feet.	40- 98
Shale, gray	98-105

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Drill Hole 27
Location: SW SE SW SE sec. 35, T. 121 N., R. 67 W.
Elevation: 1412 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 26
Clay, brown, till	26- 29
Clay, gray-brown, till	29- 49
Clay, gray-brown, with some gravel, till	49- 51
Clay, gray-brown, till	51- 54
Clay, dark-brown, till	54- 63
Clay, gray-brown, saturated, till	63-114

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Drill Hole 28
Location: NE NE NE NE sec. 2, T. 120 N., R. 67 W.
Elevation: 1398 ± 2 feet

Description	Depth Feet
Silt, oxidized, very clayey, till, humified to 1 foot, concentrations of salts at 1 to 3 feet and 5 to 6 feet	0- 25
Lost core	25- 30
Clay, unoxidized, silty, till. Water-laid medium sand at 86 to 86.5 feet. Very thin sand lense (2 in.) at 92.5 feet. Varved silt at 93 to 94 feet	30- 95
Sand, oxidized, medium to coarse, and calcareous mud, hard when dry, permeable	95-100
Sand, unoxidized, fine, some silt, slightly calcareous, permeable	100-109
Clay, unoxidized, till	109-110
Silt and clay, water-laid, unstratified. Sandy at 111 to 112 feet with poor core recovery. Possible scattered thin sandy layers	110-140
Clay, silty, mostly shale particles, till	140-142
Clay, gravelly, some pebbles appear weathered, till	142-150
Wash sampled. Pebbles. Probably same as 142 to 150 feet	150-160
Clay and silt, hard, calcareous, laminated, may be bedrock	160-165
Shale, black and green, bentonitic	165-175

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Drill Hole 29
Location: SW SW SE SW sec. 32, T. 121 N., R. 66 W.
Elevation: 1380 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 9
Clay, dark yellow-brown, till	9- 16
Clay, brown, till	16- 20
Clay, brown, sandy, saturated, till	20- 27
Clay, dark-brown, till	27- 56
Clay, dark brown-black, dense, till	56- 64
Clay, dark brown-black, saturated, till	64- 69
Clay, dark-brown, till	69- 86
Clay, dark-brown, saturated, till	86-114

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Drill Hole 30
Location: NE NW NW NE sec. 4, T. 120 N., R. 66 W.
Elevation: 1371 ± 5 feet

Description	Depth Feet
Silt, clayey, oxidized, till. Concentrations of salts at 1 to 2.5 feet	0- 15
Sand, water-laid, fine, and some silt. Laminated, permeable. Coarser with some cementation at 29 to 32 feet. Oxidized.	15- 32
Sand, unoxidized, fine, and silt	32- 34
Sand, oxidized, medium to fine, much silt	34- 36
Clay, unoxidized, silty, till, partly water-laid fine sand and silt at 65 to 67 feet. Gravelly at 90 to 92 feet	36- 94
Sand, water-laid, fine to medium, and some silt, laminated permeable. Much clay and carbonaceous matter at 105 to 107 feet	94-107
Clay, silty, till	107-108
Clay, laminated, hard, calcareous, probably bedrock	108-120
Shale, hard, black and green, some bentonite	120-125

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Drill Hole 31
Location: SE SE SE SE sec. 34, T. 121 N., R. 66 W.
Elevation: 1350 feet

Description	Depth Feet
Topsoil, black	0- 3
Clay, yellow-brown, pebbly, till	3- 21
Sand, yellow-brown, very fine sand, slightly moist	21- 23
Sand, gray, very fine, slightly moist	23- 33
Clay, gray, sandy, moist, becoming a clay till, very compact after 40 feet	33- 54
Clay, gray, sandy clay, viscous	54- 65
Clay, gray, gravelly till, soft, very moist	65- 71
Clay, sandy, gray, saturated, soft	71-105
Clay, gray, very compact, pebbly, almost dry, till	105-130

Drill Hole 31 -- continued.

Shale, blue-gray, very compact	130-134

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Drill Hole 32
Location: SE SE SE SE sec. 2, T. 120 N., R. 66 W.
Elevation: 1330 feet

Description	Depth Feet
Sand, fine to medium, yellow-brown	0- 2
Clay, dark-brown to gray-brown, till	2- 30
Sand, fine to coarse, dark-brown, saturated, with some gravel, fine to medium	30- 75
Clay, dark-brown, till	75- 77

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Drill Hole 33
Location: SW SW SE SW sec. 36, T. 121 N., R. 66 W.
Elevation: 1349 ± 3 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 15
Clay, brown, sandy, saturated, till	15- 24
Clay, gray-brown, sandy, saturated, till	24- 40
Clay, gray, with fine sand, saturated, till	40- 50
Sand, gray-brown, fine, saturated	50- 54
Sand, gray-brown, fine to medium, saturated	54- 64
Sand, dark gray-brown, fine to medium saturated	64- 69
Sand, dark gray-brown, fine, saturated	69- 74
Sand, dark gray-brown, fine to medium, saturated	74- 84
Sand, fine to medium, gray-brown with pieces of lignite coal, saturated	84- 89
Sand, gray-brown, fine to medium with some gravel (lignite fragments)	89-119

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Drill Hole 34
Location: SE SE SE SE sec. 36, T. 121 N., R. 66 W.
Elevation: 1357 feet

Description	Depth Feet
Topsoil	0- 2
Clay, brown, very sandy, moist	2- 10
Clay, dark-brown, sandy, silty, wet	10- 20
Clay, dark-brown, sandy (coarse to very coarse), gravelly (fine to medium), saturated??	20- 27
Grayish, contains some gravel, fairly compact	27- 42
Sand, saturated, fine, gray, not much clay	42- 61
Clay, soft, gray, probably very sandy	61- 80
Sand, saturated, fine to medium, dark-gray	80-101

Drill Hole 34 -- continued.

Description	Depth Feet
Clay, gravelly, and pebbly, black, contains much shale, probably reworked shale	101-113
Shale, black, moist, fairly easily to drill, contains a few small pebbles and in some places contains dry white blotches and small brown streaks	113-149

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Drill Hole 35
Location: SE SE SE SE sec. 13, T. 126 N., R. 74 W.
Elevation: 1855 feet

Description	Depth Feet
Clay, brown	0- 7
Gravel	7- 13
Clay, silvery brown, till	13- 17
Clay, gray, till	17-117
Sand, coarse, much shale fragments	117-125
Gravel	125-140
Clay, gray, lake bed, gravel stringers near bottom	140-155
Clay, gray, till?	155-215
Gravel, some clay stringers	215-238
Clay, gray, silty in places, gravel stringers	238-325
Silt, some gravel and clay	325-335
Sand, very fine, gray, silty to clayey	335-473
Gravel	473-475

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Drill Hole 36
Location: SW SW SW SW sec. 15, T. 126 N., R. 73 W.
Elevation: 1846 feet

Description	Depth Feet
Clay, yellow, pebbly, till	0- 5
Gravel	5- 8
Clay, yellow, pebbly, till, gravelly in spots	8- 22
Clay, gray, silty, pebbly, till	22- 81
Sand and gravel, drills like there may be some clay mixed in	81-115
Clay, gray, silty, pebbly, till, gravelly in spots	115-145
Clay, gray, silty, pebbly (a lot of shale pebbles), shaly, till, gravelly in spots	145-218
Silt, gray	218-295
Clay, gray, shaly, pebbly, till, gravelly in spots	295-327
Silt, gray	327-348
Clay, gray, shaly, pebbly (reworked shale??); also getting up a marl, greenish-gray, calcareous	348-426
Gravel	426-435
Shale, dark-gray, very smooth, greasy	435-455

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Drill Hole 37
Location: SE SW SW SW sec. 14, T. 126 N., R. 73 W.
Elevation: 1838 feet

Description	Depth Feet
Clay, yellow-brown, silty, sandy	0- 18
Clay, gray, silty, pebbly, till	18- 78
Gravel, sandy, gravel, medium to coarse	78- 90
Clay, gray, very gravelly and silty	90-140
Clay, gray, pebbly, reworked shale	140-183
Shale cuttings	183-215

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Drill Hole 38
Location: SW SW SW SE sec. 14, T. 126 N., R. 73 W.
Elevation: 1832 feet

Description	Depth Feet
Clay, brown, sandy, pebbly, till	0- 17
Clay, gray, sandy, pebbly, till; a few thin gravel stringers	17- 78
Sand and gravel, lot of shale pebbles	78- 93
Clay, gray, sandy, pebbly, gravelly in spots, till	93-164
Sand and gravel, lot of shale pebbles	164-180
Shale, dark-gray, very smooth, greasy	180-200

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Drill Hole 39
Location: SE SE SE SE sec. 14, T. 126 N., R. 73 W.
Elevation: 1846 feet

Description	Depth Feet
Clay, brown, sandy, pebbly, till	0- 23
Clay, gray, pebbly, till	23- 53
Sand and gravel	53- 55
Clay, gray, pebbly, till	55- 60
Sand and gravel, some clay stringers, a lot of shale pebbles	60-108
Clay, gray, sandy, pebbly, shaly, till (poor sample return because of all the sand and gravel)	108-164
Sand and gravel	164-175
Shale, gray, very smooth, greasy	175-200

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Drill Hole 40
Location: SE NE NE NE sec. 20, T. 126 N., R. 72 W.
Elevation: 1916 feet

Description	Depth Feet
Clay, yellowish-brown, gravelly, till; the first 10 feet were very sandy and gravelly	0- 22

Drill Hole 40 -- continued.

Clay, gray, silty, pebbly, till	22- 30
Sand and gravel, coarse	30- 46
Clay, gray, silty, pebbly, till	46- 50
Sand and gravel, coarse	50- 56
Clay, gray, gravelly, till	56- 60
Clay, gray, pebbly, till; gravel stringers	60-164
Clay, gray, shaly, till	164-212
Gravel, coarse, clean, good	212-228
Clay, yellow, oxidized?	228-235
Gravel, coarse	235-242
Shale, bedrock	242-275

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Drill Hole 41
Location: NW NW NW NW sec. 24, T. 126 N., R. 71 W.
Elevation: 1957 feet

Description	Depth Feet
Topsoil, black	0- 3
Clay, light-gray, silty, pebbly, till	3- 15
Clay, gray, silty, pebbly, till	15-125
Sand, medium to coarse	125-140
Shale, bedrock	140-170

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Drill Hole 42
Location: NE NE NE NE sec. 22, T. 126 N., R. 70 W.
Elevation: 1996 feet

Description	Depth Feet
Topsoil, brown	0- 1
Clay, hard, fatty, yellowish-brown, pebbly	1- 30
Gray, silty, clay, pebbly (boulders at 105 feet)	30-125
Clay, gray, silty, gravelly (gravel stringers)	125-179
Gravel, sandy	179-196
Clay, gray, gravelly	196-203
Shale cuttings	203-230

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Drill Hole 43
Location: SW SW SE SE sec. 18, T. 126 N., R. 69 W.
Elevation: 1934 feet

Description	Depth Feet
Loess or lake silt	0- 7
Clay, brownish-yellow, pebbly, till	7- 30
Clay, gray, pebbly, silty, sandy, till	30-173
Sand and gravel	173-190
Clay, gray, pebbly, silty, sandy, till	190-249
Sand and gravel with clay	249-253
Clay, gray, pebbly, very sandy, till	253-361
Clay, bluish-black, compact, shale	361-380

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Drill Hole 44
Location: SW SW SW SW sec. 15, T. 126 N., R. 69 W.
Elevation: 1925 feet

Description	Depth Feet
Topsoil, black	0- 1
Brown clay mixed with some sand and gravel	1- 12
Clay, gray, pebbly, gravelly in spots, till	12- 53
Sand and gravel (good clean gravel)	53- 57
Clay, gray, pebbly, till, gravelly in spots	57- 74
Clay, gray, gravelly, till	74- 76
Drilled real fast but no return, drilled like sand or silty clay	76- 94
Clay, gray, pebbly, gravelly in spots, till	94-108
Clay, gray, silty to sandy (lake deposit??)	108-126
Clay, gray, pebbly, gravelly in spots, till	126-145
Sand, gravelly	145-151
Clay, gray, pebbly, till, gravelly in spots	151-326
Gravel, lots of coal, some clay	326-342
Bedrock, shale	342-365

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Drill Hole 45
Location: NW NW NW NW sec. 19, T. 126 N., R. 68 W.
Elevation: 1980 feet

Description	Depth Feet
Brownish-yellow clay, pebbly, till, gravelly in spots	0- 34
Clay, gray, silty, sandy, pebbly, till	34- 50
Sand, gray, with clay layers	50- 65
Clay, gray (lake clay or alluvium), clay rich	65- 85
Sand and gravel, medium to coarse	85- 90
Clay, gray (lake clay or alluvium), clay rich	90-108
Sand and gravel, medium to coarse with shale pebbles	108-110
Clay, gray, silty, gravelly, till, with shale pebbles with some thin gravel stringers, drills real easy	110-130
Clay, gray, good gravelly till	130-140
Clay, gray, pebbly, till	140-171
Rocks	171-175
Clay, gray, silty, pebbly, till, drills easy	175-190
Shale	190-215

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Drill Hole 46
Location: NE NE NE NE sec. 20, T. 126 N., R. 68 W.
Elevation: 1872 feet

Description	Depth Feet
Topsoil	0- 1

Drill Hole 46 -- continued.

Clay, light-tan, with reddish-brown streaks, moist, silty	1- 4
Clay, tan, silty, moist	4- 13
Clay, very dark-brown, silty, moist, a very few small pebbles	13- 15
Clay, gray, moist, silty, some very small pebbles	15- 60
Clay, gray, much softer, sandy, pebbly	60- 76
Clay, gray, moist at bottom, hit a real hard compact brown clay, with many pebbles (coarse sand-fine gravel), could not drill it	76-119

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Drill Hole 47
Location: SE SE SE SE sec. 15, T. 126 N., R. 68 W.
Elevation: 1745 feet

Description	Depth Feet
Topsoil	0- 1
Clay, light silver-brown, soft, silty, moist	1- 5
Clay, brown, soft, silty, moist	5- 16
Clay, dark brownish-gray, moist, silty, a few small pebbles	16- 19
Clay, gray, sandy, pebbles, soft, moist, wet	19- 25
Clay, light-gray, soft	25- 31
Clay, gray, very gravelly fine, medium to coarse gravel, soft, moist, coarse sand also	31- 40
Clay, gray, soft, sandy, moist	40- 51
Clay, gray, drilling harder, moist, sandy, quite compact	51- 64
Shale, deep black, moist, hard to drill	64- 79

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Drill Hole 48
Location: SE SE SE SE sec. 13, T. 126 N., R. 68 W.
Elevation: 1624 feet

Description	Depth Feet
Topsoil	0- 1
Clay, light-tan, contains streaks of yellow and white, silty, moist	1- 5
Clay, brown, sandy, moist	5- 15
Clay, dark-brown, sandy, moist	15- 19
Clay, gray, soft, sandy (coarse to very coarse sand), some gravel	19- 25
Clay, gray, contains much gravel (fine to medium)	35- 50
Clay, (shale??), drilling very hard, when pulled augers, found black shale on bit, plus some brown pebbly clay that looked like weathered shale	50- 64

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Drill Hole 49
Location: NE NW SW SE sec. 17, T. 126 N., R. 67 W.
Elevation: 1582 feet

Description	Depth Feet
Topsoil, black	0- 1
Clay, yellow, silty, pebbly, slightly moist, till	1- 7
Clay, gravelly, yellow-brown, till	7- 9
Clay, brown, pebbly, slightly moist, till	9- 17
Clay, gray, unoxidized, pebbly, slightly moist, till	17- 20
Clay, gray, more compact than above, high clay content with more gravel from 35 to 37 feet, till	20- 37
Clay, dark-gray, slightly moist, compact	37- 42
Shale	42- 46

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Drill Hole 50
Location: SW SW SW SW sec. 14, T. 126 N., R. 67 W.
Elevation: 1528 feet

Description	Depth Feet
Clay, black, white streaks, soft, moist, few pebbles	0- 6
Gravel, coarse, coarse sand, saturated, also some clay	6- 16
Gravel and clay, gray, much gravel, moist, soft	16- 25
Shale, black, moist, hard drilling	25- 34

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Drill Hole 51
Location: SE SE SE SE sec. 17, T. 126 N., R. 66 W.
Elevation: 1495 feet

Description	Depth Feet
Topsoil	0- 2
Clay, light-brown, turning dark-brown at 5 feet, soft, sandy, moist to wet	2- 7
Clay, gray, quite gravelly (fine to medium gravel), soft, moist (greatest concentration of gravel from 7 to 10 feet)	7- 15
Shale, black, moist to dry	15- 19

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Drill Hole 52
Location: NE NE NE NE sec. 24, T. 126 N., R. 66 W.
Elevation: 1463 feet

Description	Depth Feet
Clay, yellowish-brown, fine sand, dry, few pebbles	0- 1

Drill Hole 52 -- continued.

Clay, brownish, silty, moist, some fine sand	1- 8
Sand, yellowish-brown, soft, sand fine, moist	8- 10
Clay and gravel, brown	10- 14
Sand and clay, brown, soft, moist, fine sand	14- 19
Sandy clay, grayish, moist, fine sand	19- 26
Clay, gray with few yellow streaks (weathered shale??), very hard to drill	26- 29

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Drill Hole 53
Location: SW SW SW SW sec. 19, T. 123 N., R. 73 W.
Elevation: 1980 feet

Description	Depth Feet
Clay, gray	0- 4
Clay, gray, till	4- 9
Clay, black, saturated, till	9- 19
Clay, blue, till	19- 64
Sand, fine, gray-brown	64- 92
Shale	92- 99

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Drill Hole 54
Location: SE SE SE SW sec. 19, T. 123 N., R. 73 W.
Elevation: 1983 feet

Description	Depth Feet
Clay, sand, unsorted, brown	0- 12
Clay, blue, till	12- 39
Clay, blue, saturated, till	39-104
Shale	104-109

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Drill Hole 55
Location: SW SW SW SW sec. 20, T. 123 N., R. 73 W.
Elevation: 1969 feet

Description	Depth Feet
Clay, sand, gravel, brown, unsorted	0- 22
Clay, gray	22- 74
Clay, gray, saturated	74-115
Shale	115-135

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Drill Hole 56
Location: SE SE SE SE sec. 20, T. 123 N., R. 73 W.
Elevation: 1983 feet

Description	Depth Feet
Sand, gravel, unsorted, some clay, dry	0- 8

Drill Hole 56 -- continued.

Sand, clay, unsorted, saturated	8- 24
Clay, blue, till	24- 89
Clay, gray	89-130
Shale	130-140

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Drill Hole 57
Location: NE SE NW sec. 28, T. 123 N., R. 73 W.
Elevation: 1990 feet

Description	Depth Feet
Clay, sand, gravel, unsorted	0- 19
Clay, sand, gravel, saturated	19- 24
Clay, blue	24- 54
Clay, blue, becoming more sandy	54- 91
Sand, gray, fine to very fine	91- 99
Shale	99-104

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Drill Hole 58
Location: SE SE SE NE sec. 28, T. 123 N., R. 73 W.
Elevation: 2004 feet

Description	Depth Feet
Loam, gray, silty	0- 5
Sand, light-brown, medium to fine, gravelly, dry, calcareous	5- 10
Sand, light-brown, medium to very fine, dry, calcareous	10- 28
Clay, gray, clay, silty, moist (chunky) calcareous, till	28- 60
Clay, light-gray, soft, saturated, calcareous (ribbons)	60- 70
Clay, light-brown, soft, calcareous (ribbons)	70- 80
Sand (Sand, light-brown, medium to very fine, moderately sorted on flights from 60 to 101 feet)	80-102
Shale, dark gray, hard	102

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Drill Hole 59
Location: NE NE NE SE sec. 23, T. 123 N., R. 73 W.
Elevation: 2008 feet

Description	Depth Feet
Clay, brown, till	0- 9
Clay, blue, till	9- 64
Drills like shale	64- 79

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Drill Hole 60
Location: SE SE SE SE sec. 20, T. 123 N., R. 72 W.
Elevation: 1921 feet

Description	Depth Feet
Topsoil, black	0- 2
Clay, yellowish-brown, pebbly	2- 17
Clay, gray, pebbly	17-129
Gravel, real fine	129-140
Clay, gray, pebbly, gravelly, sandy	140-170
Clay, gray, silty, pebbly, very sticky, good for make doughnuts on drill stem	170-216
Shale	216-245

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Drill Hole 61
Location: SE NE NE NE sec. 27, T. 123 N., R. 72 W.
Elevation: 1904 feet

Description	Depth Feet
Clay, light-brown, clay, pebbly (chunky), calcareous, till	0- 35
Clay, gray, clayey, silty, calcareous (chunky), till	35- 62
Clay, gray, clayey, silty, hard, calcareous (chunky) [Hard drilling 62 to 93 feet], till	62- 93
Clay (weathered) [at 93 feet very hard, cannot drill further]	93-
(Off bit — light-brown silty clay, calcareous, and rounded chert pebbles and granules)	

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Drill Hole 62
Location: NE NE NW SW sec. 19, T. 123 N., R. 71 W.
Elevation: 1872 feet

Description	Depth Feet
Clay, gravelly, brown, till	0- 20
Clay, gray, very clayey, soft, till	20- 60
Clay, very sandy, gravelly, till	60- 90
Clay, gray, clayey, some gravel, till	90-100
Clay, gray, mostly clay, some gravel, till	100-120
Clay, gravelly, shale and chert fragments, till	120-125
Clay, gray, some chert and hard shale pebbles, till	125-147
Clay, gravelley, till	147-150
Clay, gray, chert and shale pebbles, till	150-180
Clay, sandy, gray, gravelly, till	180-200
Clay, gray, very sandy, gravelly, slightly calcareous, till	200-265
Sand, gravelly, silty	265-270
Gravel, sandy, silty	270-280
Clay, gray, clayey, very gravelly and sandy (large rocks 310 to 315 feet), till	280-325
Shale, dark-gray, mica or gypsum flakes, some gravel and brown clay	325-350

Drill Hole 62 -- continued.

(Samples at 10-foot intervals. Samples were not washed)

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Drill Hole 63
Location: SW NW SW NW sec. 30, T. 123 N., R. 70 W.
Elevation: 1811 feet

Description	Depth Feet
Clay, dark-brown, mottled yellow-gray, pebbly with rocks, till	0- 45
Clay, dark- to light-gray, pebbly, sandy, rocks, till	45- 85
Sand, some clay, very poor, dark-gray, very sandy	85- 98
Clay, dark-gray, pebbly and sandy, an occasional rock till	98-195
Clay, dark-gray, sandy, till, tough, very sandy, very fine, silt	195-240
Clay, dark-gray, shale pebbles with very fine sand which is consolidated, some sand layers here 2 feet thick	240-265
Clay, dark-gray, very gravelly, sandy	265-280
Clay, dark-gray, sandy, pebbly, some rocks, tough till	280-320
Gravel, coarse	320-324
Clay, bluish-black, shale	324-350

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Drill Hole 64
Location: NE NE NE NE sec. 29, T. 123 N., R. 70 W.
Elevation: 1765 feet

Description	Depth Feet
Topsoil, black	0- 1
Clay, brown, pebbly	1- 27
Clay, gray, pebbly	27-232
Clay, gray, gravelly	232-238
Gravel	238-242
Clay, gray, gravelly	242-251
Gravel	251-257
Clay, gray, gravelly, gravel stringers	257-277
Gravel	277-281
Clay, gray, gravelly, gravel stringers, (rock at 340 feet)	281-342
Clay, gray, pebbly, some rocks	342-382
Gravel, very coarse, lost circulation, twisted bit off so abanboned hole	382-440

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Drill Hole 65
Location: NW NW NW NW sec. 26, T. 123 N., R. 70 W.
Elevation: 1794 feet

Description	Depth Feet
Clay, yellow-oxidized	0- 25

Drill Hole 65 -- continued.

Clay, gray, pebbly, silty	25-170
Clay, gray, gravelly till with coal	170-180
Clay, gray, silty, pebbly	180-208
Gravel, medium-to-coarse	208-210
Clay, gray, silty, pebbly	210-220
Gravel	220-223
Interbedded clay and gravel	223-260
Gravel, medium-to-coarse	260-268
Clay, bluish-black, shale	268-305

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Drill Hole 66
Location: NE NE NE NE sec. 25, T. 123 N., R. 70 W.
Elevation: 1756 feet

Description	Depth Feet
Clay, light-brown, silty, mottled orange, very calcareous	0- 25
Clay, brown-gray, clay, mottled orange saturated, pebbly, calcareous, till	25- 45
Clay, gray, clay, till	45- 97

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Drill Hole 67
Location: NE NE NE NE sec. 30, T. 123 N., R. 69 W.
Elevation: 1737 feet

Description	Depth Feet
Clay, yellowish-brown, pebbly	0- 31
Clay, gray, pebbly, gravelly	31-158
Shale block, not cuttings, reworked(?)	158-168
Shale cuttings, drills hard and smooth	168-185

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Drill Hole 68
Location: SW SW SW SE sec. 23, T. 123 N., R. 69 W.
Elevation: 1651 feet

Description	Depth Feet
Clay, buff, pebbly, moist	0- 14
Clay, brown, pebbly, moist	14- 22
Clay, gray, pebbly, moist	22-102
Pierre Shale	102-104

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Drill Hole 69
Location: NW NW NW NE sec. 30, T. 123 N., R. 68 W.
Elevation: 1595 feet

Description	Depth Feet
Clay, buff, pebbly, moist	0- 14
Clay, dark-brown, pebbly, moist	14- 24
Clay, gray, pebbly, moist	24- 82
Pierre Shale	82- 84

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Drill Hole 70
Location: NW NW NE NE sec. 29, T. 123 N., R. 68 W.
Elevation: 1559 feet

Description	Depth Feet
Clay, buff, pebbly, moist	0- 9
Clay, dark-brown, pebbly, moist	9- 14
Clay, gray, pebbly, moist	14- 67
Pierre Shale	67- 70

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Drill Hole 71
Location: NE NE NE NW sec. 27, T. 123 N., R. 68 W.
Elevation: 1521 feet

Description	Depth Feet
Clay, brown, pebbly, moist	0- 39
Clay, gray, pebbly, moist	39- 58
Pierre Shale	58- 64

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Drill Hole 72
Location: NW NW NW NE sec. 26, T. 123 N., R. 68 W.
Elevation: 1512 feet

Description	Depth Feet
Clay, buff, pebbly, moist	0- 24
Same only many pebbles	24- 34
Clay, brown, pebbly, moist	34- 49
Clay, brown, sand (30%), saturated	49- 54
Pierre Shale	54- 59

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Drill Hole 73
Location: SE SE SE SW sec. 24, T. 123 N., R. 68 W.
Elevation: 1500 feet

Description	Depth Feet
Clay, dark-brown, pebbly, moist	0- 19
Clay, gray, pebbly, moist	19- 44
Clay, gray, very dry (Pierre Shale?)	44- 49

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Drill Hole 74
Location: NE NE NE NW sec. 30, T. 123 N., R. 67 W.
Elevation: 1480 feet

Description	Depth Feet
Sand, buff, medium, moist	0- 6
Clay, buff, pebbly, moist	6- 13
Sand, gray, medium, saturated	13- 24
Clay, gray, medium sand (30%), saturated	24- 39
Clay, gray, very dry (Pierre Shale?)	39- 44

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Drill Hole 75
Location: NE NE NW NW sec. 29, T. 123 N., R. 67 W.
Elevation: 1477 feet

Description	Depth Feet
Clay and sand, buff, moist	0- 7
Sand, buff, coarse, clay (10%), saturated	7- 9
Sand, gray, fine, gray clay (30%), saturated	9- 34
Clay, gray, fine sand (25%), saturated	34- 48
Pierre Shale	48- 54

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Drill Hole 76
Location: SW SW SW SW sec. 22, T. 123 N., R. 67 W.
Elevation: 1478 feet

Description	Depth Feet
Clay, yellow-brown to light-brown, till	0- 12
Clay, medium-gray-brown, saturated, till	12- 30
Shale, dark-gray	30- 35

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Drill Hole 77
Location: SW SW SW SW sec. 20, T. 123 N., R. 66 W.
Elevation: 1455 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 10
Shale (shale bits on drill bit)	10- 14

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Drill Hole 78
Location: NW NW NW NW sec. 27, T. 123 N., R. 66 W.
Elevation: 1452 feet

Description	Depth Feet
Clay yellowish-brown, soft, moist, quite pebbly, fine sand	0- 5
Clay, brown, soft, moist, pebbly, fine sand	5- 14
Clay, gray, quite hard, a few shale pebbles, brown streaks, dry, larger pebbles at bottom	14- 24
Shale, hard, black, very dry	24- 29

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Drill Hole 79
Location: NE SW NW NW sec. 25, T. 123 N., R. 66 W.
Elevation: 1430 ± 2 feet

Description	Depth Feet
Shale and yellow clay	0- 10

Drill Hole 79 -- continued.

Shale	10- 657
Greenhorn lime	657- 670
Shale	670-1020
Dakota Sand alternate shale streaks	1020-1120
Shale	1120-1376
Lakota Sand and shale streaks	1376-1396

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Drill Hole 80
Location: SE SE SE SE sec. 4, T. 127 N., R. 73 W.
Elevation: 1829 feet

Description	Depth Feet
Topsoil, black	0- 2
Clay, brown	2- 3
Gravel, coarse	3- 8
Clay, gray, shaly, gravelly, lot of reworked shale pebbles	8- 26
Gravel, fine	26- 31
Clay, gray, gravelly, till, shaly, rock at 153 feet	31-153
Shale cuttings have a mud collar, return is bad, cut mud at 170 feet	153-200

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Drill Hole 81
Location: SE SE NE NE sec. 11, T. 127 N., R. 73 W.
Elevation: 1804 feet

Description	Depth Feet
Topsoil, black, organics, silty	0- 1
Silt, dark-gray, soft compact, some pebbles	1- 7
Silt, gray-brown, soft compact, some medium sand pebbles	7- 10
Sand, gray-brown, very silty, medium sand	10- 15
Clay?, gray-brown, slightly sandy or pebbly, very soft (till?)	15- 30
Sand and gravel, gray-brown, fine sand and fine gravel with much silt or clay	30- 36
Gravel, brown, clean, coarse sand and fine gravel	36- 43
Gravel, brown, clean, medium to coarse	43- 50
Clay, gray, pebbly, compact, till	50- 77
Clay, gray, very fine sandy, pebbly, till	77- 86
Sandy clay, gray, much fine sand with about equal amount clay	86- 95
Clay, gray, pebbly, compact, till	95-119

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Drill Hole 82
Location: SW SW NW NW sec. 8, T. 127 N., R. 72 W.
Elevation: 1834 feet

Description	Depth Feet
Topsoil, black, organics, soft, dry, loose	0- 2

Drill Hole 82 -- continued.

Description	Depth Feet
Silt, black, some fine sand, dry, loose	2- 3
Silt, black, compact, sandy, dry	3- 4
Sand, brown, fine some silt	4- 5
Sand and gravel, brown, coarse sand to fine gravel, some fine sand	5- 7
Clay, yellow-brown, compact, pebbly, till	7- 13
Clay, gray compact, slightly pebbly, till	13- 40
Shale, gray-black, compact, sheety, hard	40- 54

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Drill Hole 83
Location: NW NW NW SE sec. 2, T. 127 N., R. 72 W.
Elevation: 1875 feet

Description	Depth Feet
Sand and gravel, dark-brown, mixed fine sand to fine gravel, some silt or clay	0- 2
Sand and gravel, yellow-brown, mixed fine sand to fine gravel, some silt or clay	2- 9
Sand, brown, fine and medium, fairly clean	9- 12
Sand, gray-brown, very fine with some pebbles	12- 25
Shale, gray-black, hard, compact, "sheety"	25- 39

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Drill Hole 84
Location: SE SE SE NE sec. 11, T. 127 N., R. 71 W.
Elevation: 1918 feet

Description	Depth Feet
Topsoil, brown, silty, fine sandy, pea-size gravel	0- 1
Sand and gravel, light-brown, fine sandy, silty, pea-size gravel	1- 8
Sand, brown, fine, some silt or clay and pebbles	8- 11
Sand, red-brown, fine, no pebbles	11- 13
Sand, gray-brown, fine, moist, no pebbles, slightly compact	13- 16
Clay, brown, moist, some fine sand, no pebbles, gray streaks	16- 23
Clay, gray-brown, fine sandy, soft (till?)	23- 30
Sandy clay?, gray, much fine sand, some medium sand (till?)	30- 37
Sand, fine and medium sand, some gray clay	37- 68
Shale, gray-black, hard, compact, "sheety"	68- 74

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Drill Hole 85
Location: SE NE SE SE sec. 5, T. 127 N., R. 70 W.
Elevation: 1903 feet

Description	Depth Feet
Topsoil, black, organics, silty, dry	0- 1

Drill Hole 85 -- continued.

Description	Depth Feet
Sand and gravel, brown, fine sand, silty, pea-size gravel and some coarse, dry	1- 8
Sand, rusty-brown, wet, fine, a lot of clay	8- 23
Sand, gray-brown, wet, fine to medium, lots of clay	23- 29
Clay, gray, fairly compact, till, pebbly	29- 63
Shale, black-gray, hard, compact, no pebbles, sheety	63- 69

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Drill Hole 86
Location: SE SE SE SE sec. 4, T. 127 N., R. 69 W.
Elevation: 1962 feet

Description	Depth Feet
Clay, yellow, pebbly, till	0- 15
Clay, gray, silty, pebbly, till, gravel stringers from 80 feet down, with very sandy clay in spots	15- 90
Clay, gray, very silty, sandy, does not drill too fast	90-140
Clay, gray, silty pebbly, some thin gravel stringers	155-182
Bedrock, shale	182-215

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Drill Hole 87
Location: NW NW NW NW sec. 7, T. 127 N., R. 68 W.
Elevation: 2000 feet

Description	Depth Feet
Clay, yellowish-brown (boulder at 9 feet)	0- 22
Clay, gray, pebbly, gravel stringers	22-160
Same, but drilling much tougher (no gravel stringers), some reworked shale pebbles	160-169
Gravel, coarse	169-170
Clay, gray, pebbly, gravelly, boulders at 174-176	170-226
Shale cuttings (some are brownish-oxidized)?	226-245

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Drill Hole 88
Location: SW SW SW SW sec. 6, T. 127 N., R. 67 W.
Elevation: 1847 feet

Description	Depth Feet
Clay, light-brown, dry to moist silty, pebbly	0- 5
Clay, dark-brown, silty, moist	5- 20
Clay, light-brown, very sandy, soft, moist to wet	20- 25
Clay, light-gray, soft, contains some small pebbles and some gravel, moist to wet	25- 35
Clay, gray, same as above, only has no or very little gravel, very sandy	35- 81
Shale, black, moist to dry	81-104

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Drill Hole 89
Location: SW SW SW SW sec. 4, T. 127 N., R. 67 W.
Elevation: 1680 feet

Description	Depth Feet
Clay, yellowish-brown, pebbly, dry, silty	0- 9
Clay, dark-brown, pebbly, dry, silty	9- 20
Clay, very dark-brown, no pebbles, silty, moist	20- 25
Shale??, very hard drilling, weathered shale??, possibly unweathered shale	25- 29

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Drill Hole 90
Location: SW SW SW SW sec. 2, T. 127 N., R. 67 W.
Elevation: 1597 feet

Description	Depth Feet
Clay, dark-brown, silty, moist, contains some gravel from 0 to 5 feet	0- 17
Clay, dark brownish-gray, moist, silty	17- 19
Clay, gray, silty, pebbly	19- 36
Shale, black, dry to moist, drills very hard	36- 39

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Drill Hole 91
Location: SW SW SW SW sec. 6, T. 127 N., R. 66 W.
Elevation: 1556 feet

Description	Depth Feet
Topsoil	0- 1
Clay, light-tan, soft, sandy, silty, contains some coarse sand	1- 7
Clay, dark-brown, weathered shale??	7- 9
Shale, black, dry, very hard to drill	9- 14

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Drill Hole 92
Location: SW SW SW SW sec. 4, T. 127 N., R. 66 W.
Elevation: 1527 feet

Description	Depth Feet
Topsoil, dark	0- 1
Clay, yellow, a few pebbles, moist, soft, some fine sand	1- 7
Clay, reddish-brown, pebbly, some fine sand, dry	7- 9
Shale, black, very dry and hard	9- 14

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Drill Hole 93
Location: NW NW NW NW sec. 11, T. 127 N., R. 66 W.
Elevation: 1500 feet

Drill Hole 93 -- continued.

Description	Depth Feet
Topsoil	0- 1
Clay, gravel, brown, dry to moist, medium to coarse gravel, with some small boulders some very coarse sand	1- 6
Clay, dark-brown, with black streaks, contains some small shale pebbles (weathered shale??)	6- 10
Shale, black, dry to moist	10- 14

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Drill Hole 94
Location: NW NW NW NW sec. 7, T. 127 N., R. 65 W.
Elevation: 1485 feet

Description	Depth Feet
Topsoil, dark-brown	0- 2
Clay, brown, pebbly, soft, some fine sand, dry	2- 6
Clay, brown, sandy, fine sand, some pebbles, moist	6- 7
Clay, dark-brown, with gray streaks, hard (weathered shale?)	7- 10
Shale, black, very hard, dry	10- 14

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Drill Hole 95
Location: SE SE SE SE sec. 1, T. 124 N., R. 73 W.
Elevation: 1851 feet

Description	Depth Feet
Clay, yellow-brown, pebbly, till	0- 17
Clay, gray, pebbly, till	17- 68
Clay, gray, pebbly, gravelly, till	68-108
Gravel, fine to medium	108-119
Clay, gray, gravelly, till	119-200
Clay, gray, sandy and pebbly, till, gravelly in spots, coal	200-274
Gravel, fine to medium	274-281
Clay, gray, sandy and pebbly, till	281-285
Bedrock, shale	285-305

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Drill Hole 96
Location: SE SE SE SE sec. 5, T. 124 N., R. 72 W.
Elevation: 1836 feet

Description	Depth Feet
Clay, silty, pebbly, yellowish-brown, gravel stringers	0- 12
Clay, gray, pebbly	12-102
Clay, gray, pebbly, more gravelly	102-164

Drill Hole 96 -- continued.

Clay, gray, pebbly, gravel stringers	164-180
Cut mud and sample contains more sand and gravel than is true	180-
Clay, gray, pebbly, gravel stringers	180-183
Gravel, small size, contains shale pebbles	183-186
Clay, gray, sandy, gravelly, gravel stringers, shale pebbles	186-293
Rock	293-
Clay, gray, gravelly, shale pebbles	293-300
Gravel	300-302
Clay, gray, gravelly, pebbly	302-356
Rock	356-356
Clay, gray, gravelly, pebbly	356-375
Gravel, pretty good coarse	375-378
Gravel stringer 1 to 2 feet thick, with about the same of gray clay (stringers 1 to 2 feet thick)	378-398
Gray, clay, pebbly	398-407
Gravel stringers, gray clay, pebbly	407-423
Coal, black	423-426
Clay, gray, gravelly, pebbly	426-435
Boulders	435-435
Shale	435-455

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Drill Hole 97
Location: SW SE SE SE sec. 2, T. 124 N., R. 72 W.
Elevation: 1891 feet

Description	Depth Feet
Clay, yellow, silty, pebbly	0- 18
Clay, gray, silty, pebbly, till	18- 95
Clay, very silty (lake clay?)	95-105
Clay, gray, till, some sand and coal stringers	105-110
Coal, sand, gravel, very good, medium to coarse	110-118
Clay, gray, silty	118-126
Sand and gravel with coal, medium to coarse, interbedded with very soft (lake clay?)	126-140
Clay, very sandy and silty (lake clay?)	140-150
Clay, gray, soft, very silty, sandy, till	150-165
Clay, gray, tougher, till	165-178
Sand and gravel, coarse	178-187
Clay, gray	187-230
Clay, interbedded with gravel, very good gravelly till	230-250
Clay, gray, same as above, but not quite so gravelly	250-265
Clay, interbedded with gravel, very good gravelly till	265-300
Gravel, medium to coarse	300-316
Shale	316-335

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Drill Hole 98
Location: SW SW SW SW sec. 6, T. 124 N., R. 70 W.
Elevation: 1897 feet

Description	Depth Feet
Clay, yellowish-brown, pebbly	0- 27

Drill Hole 98 -- continued.

Clay, gray, pebbly	27- 80
Clay, gray, till with some gravel stringers	80- 94
Gravel, medium to fairly coarse	94-115
Clay, gray, pebbly, till	115-128
Gravel, medium to coarse with coal	128-132
Clay, gray, silty, pebbly	132-165
Clay, gray, gravelly till	165-190
Clay, gray, silty, pebbly, had some sand on the 230-foot stem	190-230
Clay, gray silty, till, some rocks	230-262
Sand and gravel, fine to medium, clayey, interbedded with clay layers	262-290
Clay, silty and sandy	290-302
Clay, till, very tough, some sand and gravel	302-307
Gravel, medium to coarse	307-311
Clay, medium-gray, sandy	311-314
Sand, coarse	314-316
Drills like clay, not getting true sample?	316-350
Gravel, coarse	350-380
Shale	380-395

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Drill Hole 99
Location: NE NE NE NE sec. 7, T. 124 N., R. 69 W.
Elevation: 1821 feet

Description	Depth Feet
Black topsoil	0- 1
Clay, yellowish-brown, pebbly, silty	1- 28
Clay, gray, pebbly	28- 60
Same but more gravelly	60-126
Gravel	126-129
Clay, gray, pebbly, rock at 135 feet, put on rock bit	129-208
Gravel, medium to coarse	208-210
Clay, medium-gray, gravelly, till	210-220
Gravel, medium to very coarse	220-235
Clay, medium-gray, gravelly, tough, many small rocks, till	235-287
Gravel, medium to very coarse	287-321
Shale, noncalcareous, hit hard rock layer from 321 to 323 and again from 325 to 326 with what drilled like clay stringers in between	321-350

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Drill Hole 100
Location: SW SW SW SW sec. 1, T. 124 N., R. 69 W.
Elevation: 1726 feet

Description	Depth Feet
Topsoil, black, slightly moist	0- 1
Clay, yellow-brown, slightly moist, silty till	1- 5
Clay, yellow-brown, slightly moist pebbly till	5- 35
Clay, gray, few pebbles, slightly moist (some scattered rocks and gravel - 35 to 40 feet), till	35- 61

Drill Hole 100 -- continued.

Description	Depth Feet
Gravel	61- 62
Clay, viscous, slightly sandy, gray	62- 82
Shale, blue-gray, compact (some reworked material 82 to 88 feet)	82- 93

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Drill Hole 101
Location: NE NE NE NE sec. 9, T. 124 N., R. 68 W.
Elevation: 1600 feet

Description	Depth Feet
Clay, yellow-brown to brown, till	0- 30
Clay, medium gray-brown to gray, till	30- 71
Shale	71- 74

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Drill Hole 102
Location: NE NE NE NE sec. 11, T. 124 N., R. 68 W.
Elevation: 1555 feet

Description	Depth Feet
Clay, dark-brown, till	0- 4
Gravel, fine to coarse, with sand, brown, saturated	4- 7
Clay, yellow-brown to brown, till	7- 15
Clay, medium gray-brown, till	15- 46
Shale, dark-gray	46- 49

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Drill Hole 103
Location: NW NW NW NW sec. 8, T. 124 N., R. 67 W.
Elevation: 1515 feet

Description	Depth Feet
Clay, yellow-brown to brown, till	0- 24
Clay, gray-brown, till	24- 27
Clay, gray-brown, saturated, till	27- 37
Shale	37- 39

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Drill Hole 104
Location: SE SE SE SE sec. 3, T. 124 N., R. 67 W.
Elevation: 1488 feet

Description	Depth Feet
Topsoil	0- 2
Clay, yellow-brown, till	2- 11
Clay, yellow-brown, saturated, till	11- 14
Clay, gray-brown, till	14- 22
Shale, dark-gray	22- 24

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Drill Hole 105
Location: SE SE SE SE sec. 1, T. 124 N., R. 67 W.
Elevation: 1467 feet

Description	Depth Feet
Topsoil (clay, black)	0- 5
Sand, yellow-brown, with clay	5- 10
Clay, gray, till	10- 17
Shale, dark-gray	17- 20

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Drill Hole 106
Location: SW SW SW SW sec. 3, T. 124 N., R. 66 W.
Elevation: 1462 feet

Description	Depth Feet
Topsoil	0- 2
Clay, yellow-brown, till	2- 12
Shale, dry, dark-gray	12- 15

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Drill Hole 107
Location: NE NE NE NE sec. 12, T. 124 N., R. 66 W.
Elevation: 1453 feet

Description	Depth Feet
Topsoil	0- 3
Clay, yellow-brown, till	3- 16
Shale, dark-gray	16- 20

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Drill Hole 108
Location: SE SE SE SE sec. 26, T. 120 N., R. 72 W.
Elevation: 1865 feet

Description	Depth Feet
Clay, yellow-brown, sandy, till	0- 11
Brown clay, pebbly, till	11- 28
Clay, gray	28- 34
Clay, gray, silty, pebbly	34-156
Clay, gray, silty, pebbly, gravel stringers	156-180
Clay, gray, pebbly	180-260
Clay, gray, pebbly, gravel stringers	260-335
Shale cuttings (shale is very hard, Kelly chatters)	335-350

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Drill Hole 109
Location: NE NE SE SE sec. 28, T. 120 N., R. 71 W.
Elevation: 1788 feet

Description	Depth Feet
Clay, yellow	0- 38

Drill Hole 109 -- continued.

Clay, gray	38-109
Clay, gray, gravelly	109-155
Gravel, nearly all shale pebbles	155-160
Clay, gray, gravelly	160-185
Gravel	185-200
Clay, gray, gravelly, some gravel stringers	200-220
Gravel	220-230
Gravel, contains some clay, and some shale pebbles	230-289
Gravel, coarse, many boulders	289-328
Shale	328-350

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Drill Hole 110
Location: NW NW NW NW sec. 36, T. 120 N., R. 71 W.
Elevation: 1751 feet

Description	Depth Feet
Black topsoil	0- 2
Clay, light-brown, pebbly, till, gravelly in spots	2- 22
Clay, gray, pebbly, till, gravelly in spots	22- 35
Clay, gray, pebbly, gravelly, till, coal	35- 55
Clay, gray, pebbly, gravelly in spots, till, gravel stringer 151 to 152 feet	55-152
Clay, gray, gravelly, lots of coal, till	152-163
Clay, gray, pebbly, gravelly in spots, till, gravel stringer 276 to 277 feet	163-283
Gravel	283-286
Clay, gray, pebbly, gravelly in spots, till	286-305
Clay, gray, gravelly, till	305-309
Clay, gray, pebbly, till, gravelly in spots, lots of shale pebbles	309-318
Bedrock, shale	318-335

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Drill Hole 111
Location: SE SE NE NE sec. 31, T. 120 N., R. 70 W.
Elevation: 1720 feet

Description	Depth Feet
Clay, yellow, pebbly, silty	0- 24
Clay, very silty, yellow colored (loess??)	24- 39
Clay, yellow, very gravelly	39- 43
Clay, gray, silty, pebbly, very gravelly in places	43-265
Gravel and clay stringers interbedded	265-273
Clay, gray, pebbly, gravelly	273-358
Boulders	358-365
Clay, gray, gravelly, some boulders	365-395
Shale, gray	395-410

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Drill Hole 112
Location: SE SE SW SW sec. 27, T. 120 N., R. 70 W.
Elevation: 1700 feet

Drill Hole 112 -- continued.

Description	Depth Feet
Black, topsoil	0- 1
Clay, yellowish-brown, pebbly, till, changes to brown in color at 5 feet, gravelly in spots	1- 45
Clay, gray, pebbly, till, gravelly in spots	45-277
Shale cuttings	277-290

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Drill Hole 113
Location: SE SE SE SE sec. 25, T. 120 N., R. 70 W.
Elevation: 1640 feet

Description	Depth Feet
Topsoil, black	0- 4
Clay, yellowish-brown, pebbly	4- 48
Clay, gray, pebbly	48-142
Clay, gray, silty, sandy, pebbly	142-203
Clay, gray, gravelly, some shale pebbles	203-218
Gravel, many shale pebbles, a few clay stringers	218-230
Clay, gray, very silty, looks like lake deposit	230-252
Clay, gray, pebbly	252-256
Gravel, coarse, wide variety of composition, much limestone and shale pebbles, angular to sub-rounded, rocky	256-329
Clay, gray, sandy and pebbly, a few gravel stringers, black organic sandy clay in the zone	329-340
Gravel, coarse	340-350
Clay, gray, sandy, pebbly, gravel stringers, rock at 354-355	350-417
Marl, very light-gray, moderately calcareous	417-426
Shale, dark-gray to black, plastic, waxy	426-455

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Drill Hole 114
Location: NW NW NW NW sec. 35, T. 120 N., R. 69 W.
Elevation: 1556 feet

Description	Depth Feet
Clay, yellow, silty	0- 28
Clay, gray, pebbly	28- 41
Gravel	41- 44
Clay, gray, gravelly	44-150
Sand	150-152
Clay, gray, silty, sandy, pebbly, rocky	152-246
Clay, light-gray, very calcareous	246-249
Gravel, coarse, 40 percent hard shale pebbles	249-263
Shale, reworked	263-274
Clay, gray, gravelly	274-304
Shale, dark-gray	304-320

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Drill Hole 115
Location: SE SE SE SE sec. 28, T. 120 N., R. 68 W.
Elevation: 1490 feet

Description	Depth Feet
Silt, clayey, oxidized, humic, 1.5± some sand, till. Calcareous at 2.4 to 5 feet (hard pan)	0- 30
Silt, clayey, very little sand, partly oxidized, mottled, till. Sand, fine 39.5 to 40 feet, water-laid	30- 42
Silt, clayey, till, little sand, unoxidized, very gravelly 49 to 50 feet. Very sandy 68 to 70 feet, poor recovery. Sandy 70 to 74 feet, gravelly 75 to 80 feet, poor recovery	42-100
Clay, silty, probably till, unoxidized "shale" pebbles and pebbles	100-102
Shale, silty (probably Pierre Formation) massive	102-104

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Drill Hole 116
Location: SE SE SE SE sec. 25, T. 120 N., R. 68 W.
Elevation: 1449 feet

Description	Depth Feet
Silt, clayey, humic to 1.5 feet?, oxidized. till Carbonates at 4 to 5 feet	0- 10
Silt, sandy, oxidized, rudely stratified (partly water-laid), till. Sand (coarse) at 12 to 14 feet, gravel at 15 to 15.5 feet. Sand water-laid at 15.5 to 17 feet moderately permeable	10- 18
Silt, clayey, till, oxidized, water-laid, fine sand and silt at 21 to 22 feet and 23 to 24 feet, slightly permeable	18- 25
Silt, clayey, some sand, unoxidized, till	25- 40
Sand, water-laid, fine, silty, unoxidized	40- 41
Silt, clayey, some sand, unoxidized, till Water-laid fine sand and silt at 45.5 to 46 feet. Very silty coarse sand and gravel 67.5 to 72.5 feet (poor recovery)	41- 82
Shale, broken, with a few pebbles	82- 83
Shale (probably Pierre) bentonitic at 84.5 to 86 feet, soft at 86 to 88 feet	83- 89

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Drill Hole 117
Location: SE SE SE SE sec. 30, T. 120 N., R. 67 W.
Elevation: 1448 ± 1 foot

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 19
Clay, yellow-brown, saturated, till	19- 29
Sand, fine, with yellow-brown till	29- 34
Clay, sandy, brown, saturated, till	34- 39
Clay, gray-brown, dense, till	39- 47

Drill Hole 117 -- continued.

Clay, gray-black, dense, till	47- 94
Shale	94- 99

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Drill Hole 118
Location: SE SE SE SE sec. 28, T. 120 N., R. 67 W.
Elevation: 1416 feet

Description	Depth Feet
Silt, sandy and clayey, till. Oxidized, humic to 2 feet ±. (Silty 2.5 to 3.5 feet clay till). Concentration of carbonaceous material at 4 feet	0 - 22
Silt, clayey, mottled, partly oxidized, till	22 - 26
Silt, clayey, unoxidized, till	26 - 26.5
Sand, fine to medium, silty, with silty clay beds, oxidized	26.5- 27
Core loss, driller reports silty clay	27 - 28
Silt, clayey, till, unoxidized, small beds of water-laid silt and clay 39 to 40 feet	28 - 67.5
Sand, fine to medium, silty, small clay beds. Water-laid 67.5 to 71.5 feet, very silty 68 to 69.5 feet, 69.5 to 70 feet (slightly permeable) mostly medium sand, silty clay 70 to 71.5 feet	67.5- 71.5
Silt, clayey, till	71.5- 73
Clay, silty, (probably disturbed shale-Pierre Formation) calcareous	73 - 76
Shale, slightly silty, light- to dark-gray	76 - 78

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Drill Hole 119
Location: SW SW SW SW sec. 25, T. 120 N., R. 67 W.
Elevation: 1396 feet

Description	Depth Feet
Silt, sandy and clayey, till, humic to 1.5 feet, hard pan at 2 to 2.5 feet, oxidized, sandy 13 to 13.5 feet, slightly permeable	0- 20
Silt, silty clay, and clayey, unoxidized, till	20- 49
Shale, slightly silty (Pierre Formation)	49- 50

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Drill Hole 120
Location: SW SW SW SW sec. 29, T. 120 N., R. 66 W.
Elevation: 1378 feet

Description	Depth Feet
Clay, silty, till, sandy in part, oxidized humic to 1.5 feet, carbonates at 3 to 4 feet	0- 15
Silt, sandy, till, some clay, wash sampled in part. Oxidized	15- 19
Silt, clayey, till, unoxidized, some fine sand	19- 23
Sand, coarse, fine to medium gravel, loose	

Drill Hole 120 -- continued.

Description	Depth Feet
core. Silt binder, unoxidized, moderately permeable	23- 27
Silt, sandy and clayey, till, unoxidized	27- 34
Silt, sandy and clayey, till, interbedded with water-laid fine sand and silt	34- 38
Sand, water-laid, fine, interbedded with thin beds of silt and very fine sand. More clay 40 to 42 feet. May be slightly permeable	38- 42
Silt, clayey, till, some fine sand, coarse sand 48 to 48.5 feet	42- 50
Shale, broken, silty, calcareous, probably in place	50- 51
Shale, silty, firm	51- 52

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Drill Hole 121
Location: NE NE NE NE sec. 33, T. 120 N., R. 66 W.
Elevation: 1363 feet

Description	Depth Feet
Soil, black	0- 1
Clay, light red-brown; oxidized, very wet at 10 feet, gray at about 20 feet, till	1- 27
Silt, light-gray, fine sand about 20 percent	27- 42
Sand, medium, silty, saturated; fine sand and very silty below 55 feet	42- 62
Gravel, pea-size, sandy	62- 65
Silt, sandy, fine, saturated	65- 75
Silt, clayey, green-gray, hard; some sand stringers between 80 to 95 feet	75-114
Shale	114-119

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Drill Hole 122
Location: SW SW SW SW sec. 26, T. 120 N., R. 66 W.
Elevation: 1341 feet

Description	Depth Feet
Clay, silty, till. Humic 1 foot (brownish-gray color to 4 to 5 feet), hard pan at 4 to 5 feet, till, oxidized. Much sand and silt, little clay 6 to 10 feet. Coarse sand, fine to medium gravel at 10 to 13.5 feet	0- 15
Silt, clayey, till. Unoxidized, some very fine sand, water-laid silt, some clay 18 to 19.5 feet, 20 to 21 feet	15- 23
No core, driller reports rocks	23- 25
Silt, clayey, till. Sandy 33 to 36 feet (very sandy 33 to 34 feet)	25- 50
Shale, broken to 52 ±, silty in part, calcareous (Pierre)	50- 54

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Drill Hole 123
Location: SE SE SE SE sec. 26, T. 120 N., R. 66 W.
Elevation: 1350 ± 2 feet

Drill Hole 123 -- continued.

Description	Depth Feet
Topsoil	0- 1
Clay, brown, till	1- 4
Clay, yellow-brown, till	4- 9
Clay, brown, till	9- 20
Clay, gray-brown, saturated, till	20- 34
Clay, gray, saturated, till	34- 49
Clay, gray, sandy, saturated, till	49- 60
Sand, fine, saturated	60- 69
Sand, fine to medium, saturated	69- 74
Sand, medium, saturated	74- 79
Sand, medium to coarse, saturated	79- 94
Sand, medium to coarse, with some fine gravel, saturated	94-105
Shale	105-109

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Drill Hole 124
Location: SE SW SW SW sec. 8, T. 118 N., R. 72 W.
Elevation: 1913 feet

Description	Depth Feet
Clay, yellowish-brown, pebbly	0- 32
Clay, gray, pebbly	32-170
Clay, gray, gravelly, with coal	170-230
Clay, gray, a few gravel stringers	230-260
Clay, gray, rocky	260-280
Gravel	280-284
Clay, gray, gravelly in places	284-337
Shale	337-350

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Drill Hole 125
Location: SW SW SW SW sec. 10, T. 118 N., R. 72 W.
Elevation: 1900 feet

Description	Depth Feet
Topsoil, brown	0- 2
Clay, yellow	2- 30
Clay, gray, gravelly	30-200
Gravel	200-207
Clay, gray, gravelly, many gravel stringers	207-244
Gravel	244-248
Clay, gray, very gravelly	248-268
Gravel	268-271
Clay, gray, gravelly	271-286
Shale, dark-gray	286-320

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Drill Hole 126
Location: NE NW NW NW sec. 18, T. 118 N., R. 71 W.
Elevation: 1855 feet

Description	Depth Feet
Topsoil	0- 2

Drill Hole 126 -- continued.

Clay, yellowish-brown, pebbly	2- 45
Clay, gray, pebbly, soft, gravelly in places	45-142
Coal, gravel	142-150
Clay, gray, gravelly	150-195
Clay, gray, pebbly, gravelly	195-295
Gravel	295-312
Shale, dark-gray	312-335

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Drill Hole 127
Location: SE SE SE SE sec. 9, T. 118 N., R. 71 W.
Elevation: 1802 feet

Description	Depth Feet
Topsoil	0- 2
Clay, yellow	2- 38
Clay, gray	38- 49
Gravel	49- 51
Clay, gray, gravelly, sandy	51-204
Sand	204-210
Clay, gray, pebbly, gravelly	210-276
Shale	276-290

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Drill Hole 128
Location: SE SE SE SE sec. 11, T. 118 N., R. 71 W.
Elevation: 1766 feet

Description	Depth Feet
Sand, fine gravel	0- 5
Clay, brown, pebbly, till	5- 15
Clay, gray, sandy, pebbly, till, drill easy	15- 67
Gravel, coal	67- 77
Clay, gray, sandy, pebbly, till	77- 82
Sand, gravel, lots of clay with it	82-105
Clay, gray, sandy, gravelly, lots of coal	105-156
Bedrock, shale	156-170

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Drill Hole 129
Location: SW SE SE SE sec. 7, T. 118 N., R. 70 W.
Elevation: 1743 feet

Description	Depth Feet
Topsoil	0- 2
Clay, yellow	2- 28
Clay, gray, pebbly, gravelly	28-144
Gravel, composed of shale pebbles	144-150
Clay, gray, gravelly	150-161
Gravel	161-164
Shale, dark-gray	164-185

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Drill Hole 130
Location: NE NE NE NE sec. 16, T. 118 N., R. 70 W.
Elevation: 1720 feet

Description	Depth Feet
Clay, yellow, silty, sandy, gravelly, till	0- 25
Clay, gray, silty, pebbly, till	25-126
Sand and gravel, medium to coarse, clean	126-129
Clay, gray, pebbly, gravelly, till	129-167
Clay, gray, pebbly, much reworked shale, many shale pebbles, silty. Rock at 191. A few thin gravel stringers	167-231
Shale, dark-gray	231-245

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Drill Hole 131
Location: NE SE SE SE sec. 11, T. 118 N., R. 70 W.
Elevation: 1710 feet

Description	Depth Feet
Clay, yellow, pebbly, gravelly in places	0- 32
Clay, gray, silty, pebbly, gravelly	32-145
Gravel	145-150
Clay, gray, gravelly	150-190
Gravel	190-195
Shale, reworked, gravel stringers	195-198
Shale, dark-gray	198-215

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Drill Hole 132
Location: SE SE SE SE sec. 7, T. 118 N., R. 69 W.
Elevation: 1655 feet

Description	Depth Feet
Clay, buff, sandy	0- 27
Clay, gray, sandy	27-130
Interbedded clay and fine gravel	130-140
Clay, gray, sandy	140-149
Sand, coarse, black (coal fragments)	149-156
Clay, gray, very sandy	156-190
Gravel, pea-size (clayey?)	190-197
Clay, gray, sandy	197-214
Pierre Shale	214-240

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Drill Hole 133
Location: NE NW NW NE sec. 16, T. 118 N., R. 69 W.
Elevation: 1600 feet

Description	Depth Feet
Clay, buff, sandy	0- 27
Clay, gray, sandy	27- 91
Gravel, pea-size	91- 93
Clay, gray, sandy	93-148
Sand, very coarse and gravel, pea-size	148-155

Drill Hole 133 -- continued.

Clay, gray, sandy	155-250
Sand, coarse	250-255
Gravel, pea-size	255-266
Pierre Shale	266-280

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Drill Hole 134
Location: SE NE SE NE sec. 15, T. 118 N., R. 69 W.
Elevation: 1575 feet

Description	Depth Feet
Till	0- 285
Pierre	285- 425
Niobrara	425- 660
Carlile	660- 785
Greenhorn	785- 810
Graneros	810-1155
Dakota	1155-1283

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Drill Hole 135
Location: NE SW NW sec. 14, T. 118 N., R. 69 W.
Elevation: 1574 feet

Description	Depth Feet
Clay, buff, sandy	0- 29
Clay, gray, sandy	29- 64
Gravel, pea-size	64- 83
Clay, gray, silty, sandy	83- 87
Gravel, pea-size	87- 93
Silt? alluvium?	93- 97
Gravel, pea- to nut-size	97-105
Clay, gray, sandy	105-215
Gravel, nut-size	215-219
Boulder, 1 foot in diameter	219-220
Pierre Shale	220-240

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Drill Hole 136
Location: SW SW SW NW sec. 13, T. 118 N., R. 69 W.
Elevation: 1564 feet

Description	Depth Feet
Clay, buff, sandy	0- 33
Clay, gray, sandy, few cobbles	33-110
Sand, coarse, black, much coal, some pea gravel	110-115
Clay, gray, sandy	115-130
Sand, coarse and fine gravel; may be interbedded with clay	130-137
Clay, gray, sandy	137-144
Gravel, pea-size	144-149
Gravel, coarse, may be interbedded with clay	149-160
Clay, gray, pebbly	160-165

Drill Hole 136 -- continued.

Gravel, pea-size	165-172
Pierre Shale	172-180

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Drill Hole 137
Location: NE NE NE SE sec. 13, T. 118 N., R. 69 W.
Elevation: 1545 feet

Description	Depth Feet
Clay, buff, sandy	0- 35
Clay, gray, sandy	35- 54
Gravel, fine to coarse	54- 58
Clay, gray, sandy	58- 70
Sand, coarse, and pea-size gravel, many coal fragments	70- 75
Clay, gray, sandy	75-123
Sand, gray, coarse, some pea-size gravel	123-134
Clay, gray, sandy, interbedded with thin gravels	134-150
Gravel, pea- to nut-size	150-163
Pierre Shale	163-170

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Drill Hole 138
Location: SW NW NW NW sec. 16, T. 118 N., R. 68 W.
Elevation: 1485 feet

Description	Depth Feet
Clay, yellow, very silty	0- 3
Sand and gravel	3- 7
Clay, yellow, silty, pebbly	7- 13
Clay, gray, slightly silty, pebbly	13- 16
Clay, gray, sand stringers	16- 22
Sand and gravel	22- 30
Clay, gray, silty, sandy, pebbly	30- 42
Sand, gray	42- 45
Clay, gray, interbedded with sand, gray, gravelly, much coal	45- 90
Gravel, medium to coarse, sandy	90-100
Clay, gray	100-103
Sand, silty, clay, gravelly	103-110
Clay, gray	110-115
Sand and gravel	115-120
Rocks and very coarse gravel	120-132
Clay, sandy, gravelly, some rocks	132-140
Mostly coarse gravel and sand, could not hold circulation to bedrock	140-200

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Drill Hole 139
Location: NW NW NW NW sec. 15, T. 118 N., R. 68 W.
Elevation: 1489 feet

Description	Depth Feet
Silt, clayey, till, Concentration of carbon-	

Drill Hole 139 -- continued.

Description	Depth Feet
ates at 7.5 to 8.5 feet. Very sandy at 14 to 16 feet, oxidized	0 - 17
Silt, clayey, till. Unoxidized	17 - 23.5
Sand, fine to medium, silty, contains some carbonaceous material, slightly permeable, unoxidized	23.5- 25
Silt, clayey, till. Very sandy in part, unoxidized	25 - 26
Silt, fine sand and clay interbedded, slightly permeable	26 - 30
Sand, well sorted, medium, some coarse sand (wash sampled). Oxidized, permeable	30 - 35
Silt, clayey, till, very sandy and gravelly	35 - 38
Sand, well sorted, medium to fine, some silt, Probably moderately permeable, oxidized	38 - 42
Clay, till, very pebbly, unoxidized	42 - 44
Silt, clayey, till, unoxidized	44 - 73.5
Sand, fine, and silt interbedded with clay. Slightly permeable	73.5- 75
Clay, silty, till, with numerous thin beds of water-laid fine sand, silt and clay, very pebbly till and sandy in part at 88 to 103 feet	75 -104
Sand and small gravel, poorly sorted (wash sample) permeable	104 -107
Silt, clayey, till, contains many beds of coarse sand at 109 to 113 feet	107 -118
No core recovery, probably same as 107 to 118 feet	118 -122
Silt, clayey, till, contains numerous thin beds of water-laid silt, clay and fine sand	122 -128
No core, driller reports sand	128 -133
Fine to medium sand with silt and some clay, much carbonaceous material. Probably water-laid, permeable	133 -137
Sand, poorly sorted, and fine gravel, water-laid, permeable (wash sampled)	137 -155
Wood fragments, carbonized	155 -160
Sand, poorly sorted, and small pebbles, many hard shale pebbles. Permeable, wash sampled	160 -165
Sand, coarse, small pebbles, many coal fragments and shale pebbles. Permeable, wash sampled	165 -175
Sand, coarse, and fine gravel, permeable	175 -187
Small pebbles, some clay, probably till, largely composed of shale	187 -191
Shale, silty, broken in part, contain much aragonite	191 -193

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Drill Hole 140
Location: NE NE NE NE sec. 15, T. 118 N., R. 68 W.
Elevation: 1470 feet

Description	Depth Feet
Clay, yellow, pebbly	0- 10
Sand and gravel	10- 15
Clay, gray	15- 25
Clay, gray, with gray sand stringers, some coal	25- 37

Drill Hole 140 -- continued.

Description	Depth Feet
Sand and gravel, some coal, some shale pebbles	37- 40
Clay, gray, silty, sandy, gravel stringers	40- 75
Clay, gray, pebbly, gravel stringers, shale pebbles, coal	75- 95
Clay, gray, very gravelly, sandy, coal	95-123
Shale, bentonitic	123-132
Marl, light-gray, calcareous	132-140

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Drill Hole 141
Location: NE NE NE NE sec. 13, T. 118 N., R. 68 W.
Elevation: 1441 feet

Description	Depth Feet
Silt, clayey and sandy, till, oxidized	0 - 20
Silt, clayey and sandy, till, unoxidized, but oxidized at very sandy streaks at 21, 23, and 24.5 feet	20 - 25
Clay, silty, oxidized, till	25 - 25.5
Sand, fine, and silt, some clay, only slightly permeable, laminated	25.5- 30
Sand, poorly sorted, with small pebbles. Contains some silt and clay. May be very sandy till but is at least in part water-laid. Slightly to moderately permeable	30 - 38
Silt, clayey, till. Sandy at 42.5 to 43 feet. Shale at 57 to 57.5 feet. Water-laid silt and fine sand at 56 to 57 feet; at 54 to 55 feet	38 - 58
Shale, silty. Calcareous in part	58 - 68

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Drill Hole 142
Location: NW NW NW NW sec. 16, T. 118 N., R. 67 W.
Elevation: 1415 ± 2 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 14
Clay, brown, till	14- 19
Clay, gray-brown, till	19- 28
Clay, gray-brown, saturated, till	28- 29
Clay, gray, sandy, saturated, till	29- 34
Clay, gray, saturated, till	34- 43
Shale	43- 45

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Drill Hole 143
Location: SW SW SW SW sec. 10, T. 118 N., R. 67 W.
Elevation: 1402.27 feet

Description	Depth Feet
Silt, sandy and clayey, till. Oxidized, badly weathered, sandy streak 22 to 23 feet and at 23.5 feet	0- 24

Drill Hole 143 -- continued.

Description	Depth Feet
Silt and fine sand, some clay; water-laid; unoxidized some till	24- 25
Silt, clayey, till; very sandy at 23 to 33 feet, 34.5 to 35 feet, 38 feet	25- 40
Shale, silty - broken in part	40- 44

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Drill Hole 144
Location: NW NW NW NW sec. 14, T. 118 N., R. 67 W.
Elevation: 1398 ± 3 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 24
Clay, yellow-brown, sandy, till	24- 29
Clay, brown, sandy, till	29- 32
Clay, brown, sandy, saturated, till	32- 36
Shale	36- 38

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Drill Hole 145
Location: SE SE SE SE sec. 12, T. 118 N., R. 67 W.
Elevation: 1379 feet

Description	Depth Feet
Clay, silty and sandy; water-laid, humic, oxidized	0 - 3
Sand, silty, some clay; probably water-laid, looks like till in part	3 - 5.5
Clay, silty, till, to clayey silt till; water-laid silt and sand at 5.9 to 6.0 feet, at 14 to 15 feet, oxidized at 17 to 18 feet	5.5- 19.5
Unoxidized clayey silt till	19.5- 20.5
Silt, fine sand and clay, laminated; unoxidized; not very permeable	20.5- 23
Silt, clayey, till, unoxidized	23 - 24
Shale, silty, firm — calcareous	24 - 29

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Drill Hole 146
Location: NE SE NE SE sec. 8, T. 118 N., R. 66 W.
Elevation: 1360 ± 2 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 4
Clay, brown, till	4- 8
Clay, brown, with some gravel, till	8- 9
Clay, brown, with fine sand, saturated, till	9- 20
Clay, brown, with fine sand and boulders, till	20- 24
Sand, coarse with fine gravel and boulders	24- 28
Shale	28- 29

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Drill Hole 147
Location: SE SE SE SE sec. 9, T. 118 N., R. 66 W.
Elevation: 1353.41 feet

Description	Depth Feet
Silt, fine sand, some clay; oxidized. Humic to 3 feet, laminated 3 to 5 feet	0- 5
Sand, poorly sorted, and silt, slightly permeable, oxidized	5- 6
Clay, sandy and gravelly, silty, till, core loose in part, oxidized	6- 9
Gravel, poorly sorted. Probably permeable	9- 11
Clay, silty, till, much gravel, oxidized	11- 12
Shale, silty, calcareous; black to gray	12- 22

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Drill Hole 148
Location: SW SW SW SW sec. 12, T. 118 N., R. 66 W.
Elevation: 1357 feet

Description	Depth Feet
Silt, sandy and clayey, till. Humic to about 2 feet, very sandy in part at 3 to 4 feet, 15 to 16 feet, 20 feet. Water-laid silt at 21 to 21.5 feet	0 - 22.5
Silt, clayey, till. Unoxidized with water-laid silt and clay at 23 to 24.5 feet, 27.5 to 28.5, 29 to 30 feet. Fine sandy and silt at 33.5 to 34 feet	22.5- 35
Shale, silty. Aragonite common; black to gray, shale, Pierre Formation	35 - 45

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Drill Hole 149
Location: SW SW SW SE sec. 34, T. 117 N., R. 72 W.
Elevation: 1940 feet

Description	Depth Feet
Clay, yellow, pebbly	0- 18
Clay, gray, pebbly	18- 63
Gravel and sand	63- 77
Clay, gray, very gravelly	77- 85
Gravel and sand	85- 96
Clay, gray, extremely sandy, some gravel	96-112
Clay, gray, sandy, pebbly	112-134
Gravel, coarse, clean, some sand	134-137
Clay, gray	137-185
Boulder (granite)	185-187
Shale	187-200

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Drill Hole 150
Location: SE SE SE SE sec. 33, T. 117 N., R. 71 W.
Elevation: 1925 feet

Description	Depth Feet
Roadfill	0- 2

Drill Hole 150 -- continued.

Clay, yellowish-brown	2- 34
Clay, gray, pebbly	34- 94
Gravel, coarse, clean	94-105
Clay, gray, gravelly	105-178
Shale	178-200

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Drill Hole 151
Location: NW NW NW NW sec. 6, T. 116 N., R. 70 W.
Elevation: 1960 feet

Description	Depth Feet
Clay, yellowish-brown, pebbly	0- 26
Clay, gray, sandy, pebbly (silty and sandy from 80 to 90 feet)	26-219
Shale, dark-gray to light-gray	219-245

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Drill Hole 152
Location: SW SW SW SW sec. 36, T. 117 N., R. 70 W.
Elevation: 1981 feet

Description	Depth Feet
Clay, brown, pebbly, sand and gravelly in spots, till	0- 17
Sand and gravel	17- 55
Clay, gray, pebbly, till, gravel stringer at 65 feet	55- 65
Clay, gray, pebbly, very shaly, looks like reworked shale?? Gravel stringer 116 feet, boulder 117 feet, gravel stringer 132 feet	65-138?
Some brown (oxidized) about 155 feet--drills and looks like shale only it is brownish in color also	138-275
Chattering is reworked shale pebbles, couple of small rocks	275-380

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Drill Hole 153
Location: SW SW SW SW sec. 32, T. 117 N., R. 69 W.
Elevation: 1935 ± 5 feet

Description	Depth Feet
Topsoil	0- 1
Clay, yellow-brown, till	1- 4
Clay, yellow-brown, gravel lenses, till	4- 20
Clay, yellow-brown, till	20- 24
Clay, brown, till	24- 29
Clay, gray-brown, till	29- 46
Clay, gray-brown, saturated, till	46- 49
Clay, gray-brown, sandy, saturated, till	49- 59
Clay, gray-brown, very sandy, saturated, till	59- 72
Clay, gray-brown, with some gravel, till	72- 76
Shale	76- 79

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Drill Hole 154
Location: SE SE SE SE sec. 35, T. 117 N., R. 69 W.
Elevation: 1626 ± 2 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 12
Clay, brown, saturated, till	12- 14
Clay, dark-brown, dense, saturated, till	14- 34
Clay, gray-brown, sandy, saturated, till	34- 43
Clay, gray-brown, with fine sand, till	43- 44
Clay, gray-brown, sandy, saturated, till	44- 54
Shale	54- 55

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Drill Hole 155
Location: SE SE SE SE sec. 31, T. 117 N., R. 68 W.
Elevation: 1558.02 feet

Description	Depth Feet
Silt, clayey, till. Oxidized. Humic to 0.5 feet. Concentration of carbonates at 1.0 to 2.0 feet	0 - 25
Silt, clayey, till. Unoxidized	25 - 38
Sand, water-laid, fine, and silt. Laminated. Unoxidized. Slightly permeable	38 - 39.5
Silt, clayey, till. Unoxidized	39.5- 42
Clay, water-laid, and a little silt. Laminated. Unoxidized	42 - 44
Silt, clayey, till. Unoxidized	44 - 50
Shale, greenish to black. Bentonite at 53.5 feet (Pierre Formation)	50 - 60

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Drill Hole 156
Location: SW SW SW SW sec. 33, T. 117 N., R. 68 W.
Elevation: 1529 ± 2 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 9
Clay, yellow-brown, sandy, saturated, till	9- 14
Clay, yellow-brown, till	14- 24
Clay, brown, till	24- 39
Clay, gray-brown, till	40- 47
Shale	47+

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Drill Hole 157
Location: SE SE SE SE sec. 34, T. 117 N., R. 68 W.
Elevation: 1488 ± 2 feet

Description	Depth Feet
Topsoil	0- 2
Clay, yellow-brown, till	2- 29
Clay, brown, till	29- 35
Clay, brown, sandy, saturated, till	35- 54
Clay, gray-brown, very sandy, saturated, till	54- 55

Drill Hole 157 -- continued.

Description	Depth Feet
Clay, yellow-brown, sandy, with gravel, saturated, till	55- 69
Shale	69- 74

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Drill Hole 158
Location: SW SE SW SE sec. 36, T. 117 N., R. 68 W.
Elevation: 1420 feet

Description	Depth Feet
Topsoil	0- 1
Clay, brown, saturated, till	1- 6
Sand, coarse, to fine gravel, saturated	6- 14
Sand, medium to coarse with some fine gravel	14- 25
Clay, gray-brown, with some fine to coarse gravel, saturated, till	25- 34
Clay, gray-brown, sandy, saturated, till	34- 60
Gravel, coarse to very coarse, with some till, saturated	60- 69
Clay, gray-brown with gravel, saturated, till	69- 72

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Drill Hole 159
Location: SW SW SW SW sec. 32, T. 117 N., R. 67 W.
Elevation: 1429 ± 2 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 4
Clay, yellow, brown, sandy, till	4- 19
Clay, yellow-brown, sandy, saturated, till	19- 34
Clay, brown, sandy, saturated, till	34- 39
Clay, gray, sandy, saturated, till	39- 66
Shale	66- 69

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Drill Hole 160
Location: SW SW SW SW sec. 33, T. 117 N., R. 67 W.
Elevation: 1422.38 feet

Description	Depth Feet
Silt, oxidized, sandy, till, with some clay. Concentration of salts at 0.5 to 5.0 feet. Humified to 0.5 feet. Very rocky; hard to drill, some water-laid medium sand at 20.0 to 20.5 feet. Mottled (partly oxidized) at 21.0 to 22.5 feet	0 - 22.5
Silt, unoxidized, sandy and clayey, till. Scattered lenses of sand and/or gravel. Three-inch layer of oxidized sand at 25 feet	22.5- 30.5
Sand, unoxidized, silty, till. Very pebbly	30.5- 34
Gravel, clay and silt. Wash sample	34 - 40

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Drill Hole 161
Location: SW SW SW SW sec. 36, T. 117 N., R. 67 W.
Elevation: 1385 feet

Description	Depth Feet
Topsoil, black	0- 2
Clay, yellowish-brown, silty, pebbly, till	2- 18
Clay, gray, pebbly, till	18- 22
Sand and gravel, coarse	22- 33
Clay, gray	33- 36
Sand and gravel, shale pebbles	36- 45
Clay, gray, gravel stringers, 1 and 2 feet thick, with rocks	45- 85
Gravel, coarse	85- 88
Clay, gray, pebbly, gravel stringers	88-110
Gravel, coarse, large rock at 122 feet	110-123
Clay, gray, gravelly, till, shale pebbles (reworked)	123-160
Shale cuttings (reworked)	160-162
Gravel	162-165
Clay, gray gravelly, shale cuttings (reworked)	165-166
Gravel	166-168
Shale cuttings	168-175

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Drill Hole 162
Location: NE SE NE NE sec. 1, T. 116 N., R. 67 W.
Elevation: 1388 feet

Description	Depth Feet
Silt, till, oxidized slightly sandy to sandy. Concentration of salts from 0.0 to 4.0 feet	0 - 15
Silt, till, unoxidized slightly sandy	15 - 28
Silt, unoxidized water-laid	28 - 30.5
Sand, water-laid, fine, and silt alternating with sand, till, unoxidized	30.5- 34
No core - shot rock	34 - 36
Sand, till, and sand, water-laid fine, unoxidized	36 - 38.5
Shale, crumpled, with scattered pebbles, unoxidized	38.5- 40.5
Shale, gray, with lime concretions (Pierre Shale)	40.5- 46

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Drill Hole 163
Location: SE SE SE SE sec. 33, T. 117 N., R. 66 W.
Elevation: 1375 ± 2 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 19
Clay, gray-brown, till	19- 29
Clay, brown, sandy, till	29- 39
Shale	39- 44

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Drill Hole 164
Location: SW SW SW SW sec. 36, T. 117 N., R. 66 W.
Elevation: 1365 ± 2 feet

Description	Depth Feet
Clay, yellow-brown, till	0- 18
Clay, gray-brown, till	18- 27
Clay, gray, saturated, till	27- 32
Clay, dark, gray, saturated, till	32- 38
Clay, gray, saturated, till	38- 40
Clay, gray, with yellow-brown till, saturated	40- 45
Clay, yellow-brown, saturated, till	45- 50
Clay, gray, saturated, till	50- 60
Shale, dark-gray	60- 64

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Drill Hole 165
Location: NW NW NW NW sec. 33, T. 126 N., R. 70 W.
Elevation: 1990 feet

Description	Depth Feet
Clay, yellowish-brown, slightly sandy, clay rich, lake clay	0- 25
Clay, gray, clay rich, lake clay	25- 55
Clay, gray, silty, pebbly, till, thin gravel stringers starting at 82 feet	55-105
Clay, gray, silty, clayey, till	105-116
Clay, gray, pebbly, till, gravel in spots	116-180
Gravelly till, limestone and shale pebbles	180-186
Clay, gray, clayey, shaly, silty (alluvium?)	186-195
Clay, gray, pebbly, till	195-217
Coarse sand and gravel coarse	217-223
Clay, gray, shaly	223-235
Shale	235-260

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