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Geology of Northwestern McKenzie County, North Dakota

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GEOLOGY OF NORTHWESTERN MCKENZIE COUNTY, NORTH DAKOTA

Senior Thesis

by

Nena Salomon

May 2, 1974
GEOLOGY OF NORTHWESTERN McKENZIE COUNTY, NORTH DAKOTA

ABSTRACT

The geology of 465 square kilometers adjacent to the confluence of the Yellowstone and Missouri Rivers in northwestern McKenzie County, North Dakota was mapped and the following interpretations were made. During late Pliocene or early Pleistocene time, the Yellowstone River deposited gravel (unit A) containing chert and volcanic and plutonic rocks; the upper surface of the gravel is about 90 meters above the present flood plains of the Yellowstone and Missouri Rivers. Subsequent downcutting was interrupted by a glacial advance that deposited sediment (unit B) across the entire area. The glacier dammed the Yellowstone River, forming a lake in which evenly bedded silt and clay (unit C) were deposited. As the glacier retreated, a series of outlet channels drained the lake. Yellowstone drainage was re-established and gravel (unit D) derived from local bedrock was deposited by tributaries of the Yellowstone River. Drainage was again disrupted by two additional glacial advances that deposited sediment (units E and F) over the entire area. As the last glacier retreated, gravel (unit G) containing chert and volcanic, plutonic, and carbonate rocks was deposited in a series of meltwater channels. The upper surface of this gravel is graded to about the level of the lowest terrace along the Yellowstone River. This terrace is underlain by gravel of unit G. Renewed downcutting established the present flood plains of the Yellowstone and Missouri Rivers and their tributaries.
INTRODUCTION

The geology of 465 square kilometers in northwestern McKenzie County, North Dakota (T. 151 N. to T. 152 N.; R. 102 W. to R. 104 W.) (Fig. 1) was mapped during the summer of 1973. The sediment exposed in this area is described in this paper and a historical interpretation of the area is presented. My local conclusions are related to the regional conclusions of Alden (1932) and Howard (1960), who mapped large areas of eastern Montana and western North Dakota.

METHODS OF STUDY

Aerial photographs and 7½ minute topographic maps (1:24,000, contour interval 20 feet) were used for base maps, and the soil map of McKenzie County (Edwards, 1942) was used as a reference source. All section-line roads were traveled and much of the area was covered on foot. Numerous exposures were examined and described, and samples were collected from many. Where exposures were sparse, a hand auger was used to obtain samples.

A geologic map of the area was compiled at a scale of 1:63,360 (Pl. 1). Lithologic contacts indicated by a solid line are within 0.1 mile of the actual contact. Contacts indicated by a dashed line are commonly more than 0.1 mile from the actual contact. Many of the contacts are observable on aerial photographs.

Samples of glacial sediment were analysed to determine the grain size and the lithology of the coarse-sand fraction (1 mm to 2 mm). Samples of gravel were analysed to determine the lithology of the pebble fraction (8 mm to 19 mm). Locations of all sample sites are listed in Appendix A and some of the pertinent outcrops are described in Appendix B. Grain size (sand-silt-clay) was determined using the sieve-pipette method employed by the North Dakota Geological Survey. Seventy-five samples were analysed and the results are tabulated in Appendix C. The lithology of the coarse-sand fraction was determined using a binocular microscope and separating the grains into three categories: crystalline (igneous...
Figure 1. Location map of study area in northwestern McKenzie County, North Dakota. Location of preglacial Missouri (1), Yellowstone (2), and Little Missouri (3) Rivers from Bluemle (1972).
and metamorphic rock types), carbonate (limestone and dolomite), and shale.

Seventy-five samples were examined and an average of 200 grains from each sample was counted. The results are tabulated in Appendix C. The 8 mm to 19 mm fraction of gravel was used because fractions of smaller sizes were biased by the absence of less resistant sedimentary rocks and the fractions of larger sizes were biased by the small number of pebbles. Pebbles were separated into eight categories: chert, quartzite, plutonic (granite and granitic rocks), volcanic (andesite, rhyolite, and basalt), limonitic, carbonate (limestone and dolomite), sedimentary (shale and siltstone), and "scoria" (Appendix D). A minimum of 300 pebbles was counted in each of 17 samples. At least 300 pebbles are needed to give the least acceptable variation between samples of the same gravel collected at a single outcrop.

DESCRIPTION OF LITHOSTRATIGRAPHY

Twelve lithostratigraphic units were recognized within the study area (Fig. 2). Two of these units, the Tongue River and Sentinel Butte Formations, are formal stratigraphic units and were mapped as a single unit, the Fort Union Group. The remaining ten units are informal stratigraphic units (units A, B, C, D, E, F, G, H, I, and J). Four of these units (units B, C, D, and I) are not present on the geologic map (Pl. 1) because of their restricted occurrence and thinness.

Lithostratigraphic units below the Fort Union Group are not exposed at the surface in the study area. A stratigraphic cross section of the bedrock underlying the area was constructed using radioactivity logs obtained from three wells (Pl. 2).

Fort Union Group

The Fort Union Group (Paleocene) is exposed in bluffs 30 to 50 meters high along the Yellowstone and Missouri Rivers and in numerous valleys throughout the
Cross Section widths are approximately 8 kilometers.

Figure 2. Schematic cross sections across the Yellowstone River valley and Charbonneau Creek valley in northwestern McKenzie County, North Dakota. The average thickness of stratigraphic units is indicated along the left side of the explanation.
study area. The Tongue River Formation, predominantly yellow in color, occurs in the western half of the area, and the Sentinel Butte Formation, predominantly gray in color, occurs in the eastern half of the area. Royce (1967) mapped the contact between the Tongue River and Sentinel Butte Formations (Pl. 3), and it generally agrees with my observations.

A topographic map of the upper surface of the Fort Union Group was constructed (Pl. 3), using data obtained from contacts drawn on topographic maps. A high area, trending northeast-southwest, occurs in the center of the eastern part of the study area. A low area north of this upland appears to parallel the present valleys of the Yellowstone and Missouri Rivers, and within this paper will be informally called the Yellowstone low. A low area south of the upland appears to parallel the valley of Camp Creek and the lower part of Charbonneau Creek, this will be informally called the Charbonneau low.

No sections were measured and described in the Fort Union Group, but a few beds appeared to be traceable throughout the study area. Electric logs obtained from wells in the northeastern corner of the area indicate that unique electric-log characteristics can be traced over a distance of 20 kilometers.

Unit A

Unit A consists of sand and gravel. The sand is medium grained, moderately sorted, and consists of quartz fragments (80 to 90 percent) and lithic fragments (10 to 20 percent). The sand occurs above and below the gravel and is interbedded with it. The sand underlying the gravel ranges in thickness from 1 to 3 meters. Sand locally overlying the gravel ranges in thickness from 1 to 17 meters. The gravel consists of medium to coarse pebbles, which are well rounded. The gravel is heavily iron stained, giving it a distinct rusty-brown color. The pebbles are predominantly chert and plutonic and volcanic rocks (Table 1). Carbonate rocks are generally absent, and nowhere exceed 2 percent of the gravel. Petrified
Table 1. Average Lithology of Gravel

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>4</td>
<td>3</td>
<td>20</td>
<td>14</td>
<td>32</td>
<td>27</td>
<td>.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>5</td>
<td>19</td>
<td>2</td>
<td>21</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>7</td>
<td>23</td>
<td>16</td>
<td>49</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

*Qtz. (quartzite), Plu. (plutonic), Vol. (volcanic), Cb. (carbonate), Sed. (sedimentary), Lim. (limonitic)*
wood and Montana agate commonly occur in the gravel. The pebbles are generally imbricated and dip southward.

As observed in outcrops, unit A overlies the Fort Union Group and underlies units E and F. This unit is known to underlie unit B because rock types occurring in the gravel of unit A are found in the sediment of unit B.

Unit A occurs between the Yellowstone and Missouri Rivers and Charbonneau Creek. This unit generally appears to be restricted to the Yellowstone and Charbonneau lows, occurring on the upper surface of sediment of the Fort Union Group. In the Yellowstone low, the upper surface of the gravel of unit A is about 90 meters above the present flood plains of the Yellowstone and Missouri Rivers. In the Charbonneau low, the upper surface of the gravel is 10 to 30 meters lower than the surface of the gravel in the Yellowstone low. The variation in surface elevation and thickness of this sediment (Pl. 4) is the result of glacial erosion. The average thickness of sediment of unit A is 10 to 30 meters.

Unit A consists of fluvial sediment. The lithology of the gravel of unit A suggest it was deposited by the Yellowstone River rather than the Missouri River, because gravel deposited by the Yellowstone river contains abundant quartzite, volcanic rock, and chert. Gravel deposited by the Missouri River contains abundant quartzite, chert, and quartz (Howard, 1960, p. 19).

The regional extent of unit A is unknown. The age of unit A is uncertain, but it is probably late Pliocene or early Pleistocene. This age is suggested because no glacial sediment has been found beneath unit A and the absence of carbonate pebbles in the gravel strongly suggests that no glacial sediment was present in the area at the time of the deposition of unit A. If the area had been glaciated, carbonate pebbles brought from the north or northeast would be present and abundant carbonate pebbles should occur in the gravel.

Alden (1932, p. 51) recognized a surface, the No. 2 bench, occurring along
rivers and streams throughout eastern Montana and western North Dakota. He suggested an early Pleistocene age for the No. 2 bench (1932, p. 44). Within the study area, the gravel of unit A underlies this bench.

Howard (1960, p. 51) recognized the gravel in unit A and named it the "Cartwright Gravel" after exposures (GG-40?) along a road 5 to 6 miles north of the town of Cartwright in northwestern McKenzie County, North Dakota. He defines the "Cartwright Gravel" as belts and patches of gravel marking either higher levels of present streams or the paths of former streams. He states (1960, p. 19) that the lithology varies depending on whether the gravel was deposited by the Yellowstone or Missouri Rivers. The "Cartwright Gravel" occurs along the Missouri, Little Missouri, and Yellowstone Rivers and along numerous streams in eastern Montana and western North Dakota.

Unit B

Unit B consists of pebble-loam and minor amounts of interbedded gravel and sand. The term "pebble-loam" is defined as sediment composed of nearly equal amounts of sand, silt, and clay that contains pebbles, cobbles, and boulders. Pebble-loam is the descriptive equivalent of the term "till." Till is not used in this paper because of its combined descriptive and genetic definition. In the study area, the genetic equivalent of pebble-loam is glacial sediment. The pebble-loam of unit B is light gray to light yellow in color and is very hard. Iron-stained joints cause the pebble-loam to break into small, irregular chunks or large, blocky chunks when disaggregated. The pebble-loam contains abundant carbonate pebbles, pebbles from the Fort Union Group (lignite, siltstone, limonitic concretions, and "scoria"), and a few shale pebbles. The grain size and coarse-sand lithology of unit B are shown in Table 2.

Sediment of unit B was found in three outcrops. Its average thickness is 3 meters. In these outcrops it unconformably overlies the Fort Union Group and underlies unit E. The contact between units B and E is gradational. Unit B is
Table 2. Average Grain Size and Coarse Sand Lithology of Pebble-loam

<table>
<thead>
<tr>
<th>Unit</th>
<th>No. of Samples</th>
<th>*Grain Size (Sd-St-Cy)%</th>
<th>**Coarse Sand Lithology (Cr-Cb-Sh)%</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>14</td>
<td>28-39-32</td>
<td>77-21-4</td>
</tr>
<tr>
<td>E</td>
<td>56</td>
<td>24-39-37</td>
<td>62-34-4</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>27-40-32</td>
<td>54-25-20</td>
</tr>
</tbody>
</table>

* Sd (sand), St (silt), Cy (clay)
** Cr (crystalline), Cb (carbonate), Sh (shale)
known to overlie unit A because rock types occurring in gravel of unit A are found in pebble-loam of unit B. The reason for placing unit B beneath unit C will be discussed in the historical interpretation of these units.

Unit B consists of glacial sediment and a minor amount of fluvial sediment. Pebble-loam of unit B is correlated with the "early Wisconsinan drift" described by Howard (1960, p. 27-36). This correlation is based on outcrop characteristics and lithology of the coarse sand of unit B and the "early Wisconsinan drift" occurring in Jones cut, a railroad cut 8 kilometers north of the study area. Howard described (1960, p. 98-101) the outcrop in detail and called the lowermost pebble-loam the "early Wisconsinan drift," which he mapped as the surface sediment over most of northwestern McKenzie County. However, this pebble-loam is not the surface sediment over this area. Pebble-loam of units E and F is extensively exposed at the surface.

The age and regional extent of unit B is not known. Based on my field observations, sediment of unit B appears to be similar to the sediment of the Medicine Hill Formation of central North Dakota (Ulmer and Sackreiter, 1973).

Unit C

Unit C consists predominantly of evenly laminated silt and clay. Laminae of sand and beds, as thick as 3 cm, of fine gravel consisting of siltstone, lignite, and limonitic concretions are interbedded with the silt and clay. The laminae are very distinct. In some places they are slightly contorted. Lignite fragments and iron staining commonly occur along the bedding planes.

This unit was found in two outcrops along Charbonneau Creek. The base of the unit was not exposed, but outcrop thickness was about 8 meters. Unit C underlies unit D and the contact is erosional. Unit C overlies unit B; this relation is discussed in the historical interpretation of these units.
Unit C consists of lacustrine sediment. The age and regional extent of this unit is unknown. The relation of sediment of unit C to sediment deposited in glacial Lake Glendive in eastern Montana (Howard, 1960, p. 81-83) is not known.

Unit D

Unit D consists of gravel and minor amounts of sand, silt, and clay. The lower part of this unit is poorly sorted gravel consisting of fine to medium pebbles. The pebbles are predominantly limonitic concretions, sedimentary rocks, and "scoria," (Table 1) all of which are locally derived from the Fort Union Group. The gravel is interbedded with and overlain by sand, which is fine to medium grained and moderately sorted. The sand consists of quartz fragments (60 to 80 percent) and lithic fragments (20 to 40 percent). The sand becomes finer grained upward and is interbedded with and overlain by silt and clay. The silt and clay are evenly bedded and contain laminae of lignite fragments.

The thickness of unit D ranges from 2 to 5 meters. In outcrops, unit D overlies unit C and underlies unit E.

Unit D occurs in the Charbonneau Creek valley. The upper surface of this unit is very irregular and ranges from 7 to 20 meters above the present flood plain of Charbonneau Creek. The base of this unit slopes toward the west.

Unit D consists of fluvial sediment probably deposited by a tributary of the Yellowstone River. Large numbers of pebbles in the gravel were derived from the Fort Union Group, suggesting that the tributary had a local drainage basin. Many of the pebbles are soft shales, siltstones, and mudstones, which could not be transported very far. The age and regional extent of unit D is not known.

Unit E

Unit E consists of pebble-loam and minor amounts of interbedded silt, sand, and gravel. The pebble-loam is dark brown, friable, and in some places contains pencil-sized, columnar joints. At some outcrops, the pebble-loam appears to have
a granular texture, consisting of closely packed spherical particles. The pebble-loam contains abundant carbonate pebbles and very few volcanic pebbles, chert, shale pebbles, or pebbles derived from the Fort Union Group. The grain size and coarse-sand lithology of unit E are shown in Table 2.

Unit E overlies unit D along Charbonneau Creek and overlies unit A on the upland area north of Charbonneau Creek. Unit E underlies unit F. This contact is gradational and nearly impossible to pick in the field unless a boulder lag occurs between the two units.

Unit E occurs at the surface or underlies unit F throughout the study area, but its regional extent is unknown. The thickness of unit E ranges from 1 to 8 meters.

Unit E consists of glacial sediment and a minor amount of fluvial sediment. The age of this unit is unknown. Based on my field observations, unit E appears to be similar to the sediment of the Horseshoe Valley Formation of central North Dakota (Ulmer and Sackreiter, 1973).

Unit F

Unit F consists of pebble-loam and minor amounts of interbedded gravel, sand, and silt. The pebble-loam contains pencil-sized, columnar joints and appears to have a granular texture in some outcrops. It is friable and dark brown in color. The pebble-loam contains abundant carbonate pebbles and very few volcanic pebbles, chert, shale pebbles, or pebbles derived from the Fort Union Group. The grain size and coarse-sand lithology of unit F are shown in Table 2.

The contact between unit F and the underlying unit E is gradational and nearly impossible to determine unless a boulder lag occurs at the contact. A boulder lag was found in the northwest corner of the study area (Appendix B: G-1, G-3) and commonly contains crystalline, carbonate, and sandstone boulders. Some of the boulders are striated in a northeast-southwest direction. While
mapping, I was generally unable to differentiate units E and F, so I mapped them as a single unit.

The sediment of unit F underlies sediment of unit G, but throughout most of the study area, sediment of unit F occurs at the surface. The thickness of unit F ranges from 0.5 to 2 meters. Lineations occurring on the upland north of Charbonneau Creek are composed of pebble-loam and minor amounts of sand and gravel of unit F. Colton (1958) called these features ice-crack moraines. He suggested (1958, p. 105) they were formed by plastic glacial sediment being forced into overlying, stagnating ice, a situation similar to the formation of clastic dikes. These lineations are washboard moraines, which were formed by overriding and shearing of ice along the base of an active glacier (Clayton and Moran, in press). Within the study area, the washboard moraines trend northwest-southeast. Their orientation suggests a glacial advance from the northeast. This agrees with the northeast-southwest striations on the boulder lag underlying sediment of unit F.

Unit F consists of glacial sediment and a minor amount of fluvial sediment. The sediment of unit F was deposited by a glacier advancing from the northeast. Pebble-loam of unit F is correlated with the "middle Wisconsinan drift" described by Howard (1960, p. 34-36). This correlation is based on outcrop characteristics and coarse-sand lithology of unit F and the "middle Wisconsinan drift" recognized by Howard. He incorrertly stated (1960, p. 31) that the drift was not identified south of the Missouri River valley. Sediment of units E and F were mapped as the surface sediment over most of the study area.

The age and regional extent of unit F is unknown. Based on my field observations, sediment of unit F appears to be similar to sediment of the Snow School Formation of central North Dakota (Ulmer and Sackreiter, 1973).
Unit G

Unit G consists of gravel, sand, and silt. The gravel is poorly sorted and contains carbonate, volcanic, and plutonic rocks, and chert (Table 1). The amounts vary but the proportion of carbonate pebbles is generally greater than 10 percent. The pebbles are generally coated with calcium carbonate. The gravel is interbedded with and overlain by sand containing mostly quartz fragments (80 to 90 percent), but in some places lithic fragments are abundant (30 to 40 percent). Generally silt is interbedded with the sand. The average thickness of unit G is 11 meters.

Along Charbonneau Creek, the upper surface of the gravel of unit G is about 13 meters above the present flood plain of Charbonneau Creek. This distance increases to 33 meters in some places, depending on how much the surface has been truncated. This surface occurs only on the north side of the creek and appears to have been formed by streams flowing south into the Charbonneau Creek valley. Where gravel of unit A outcrops in the source area of unit G, the carbonate rock content decreases to 2 percent, and it is difficult to differentiate the gravel of the two units.

Along the Yellowstone River, the upper surface of the gravel of unit G is about 13 meters above the present flood plain of the Yellowstone River. The distance ranges from 3 to 13 meters depending on how much the surface has been truncated. This gravel is moderately sorted and contains about 5 percent carbonate rock.

Unit G consists of fluvial sediment, closely associated with the last glacial retreat in the area. The age and regional extent of this unit is not known.

Alden (1932, p. 59) recognized a surface, which he called the No. 3 bench, occurring along rivers and streams throughout eastern Montana and western North Dakota. Within the study area, the upper surface of gravel of unit G coincides
with the No. 3 bench. Alden stated that the No. 3 bench was underlain by the
glacial sediment occurring in the area (1932, pl. 1). This agrees with my
observations.

Howard (1960, p 21-22) recognized the gravel of unit G and called it the
"Crane Creek Gravel" for exposures along Crane, Creek, near the town of Crane in
Richland County, Montana. He described it as gravel capping the broadest terrace
along the Yellowstone River, which occurs 5 to 17 meters above the present flood
plain. He stated that the "Crane Creek Gravel" occurs in 3 places along the
Missouri River and that the lithology of the gravel varies depending on whether
it was transported by the Yellowstone or Missouri Rivers (1960, p. 22-23). The
"Crane Creek Gravel" underlies the glacial sediment in northwestern McKenzie
County, according to Howard (1960, pl. 1). Based on outcrops along the Yellowstone
River and Charbonneau Creek, the "Crane Creek Gravel" and sediment equivalent to
it truncates or overlies all the glacial sediment in this area.

Unit H

Unit H consists of medium-grained to coarse-grained silt. It is dark brown
and contains columnar joints. Pebbles are generally absent except where the silt
has been reworked by animals. A dark-gray layer containing abundant organic
debris occurs near the base of the silt and is traceable in the western and
southern part of the area. The dark layer is 6 to 12 cm thick and generally
occurs about 0.7 meters below the present surface.

The silt of unit H occurs throughout the study area except on the present
flood plains and lower terraces. It is draped over the pre-existing topography.
The thickness of this unit ranges from 0.2 to 1 meter. It is thickest where it
overlies pebble-loam and thinnest where it overlies gravel. The Williams soils
that cover most of the upland area north of Charbonneau Creek (Edwards, 1942)
are generally developed on silt of unit H and not pebble-loam of units E or F.
According to Edwards (1942, p. 34), Williams soils develop from glacial sediment and no mention is made of nonglacial sediment.

Unit H consists of wind-blown sediment. It is correlated with the Oahe Formation of North Dakota (Clayton and others, in preparation). The gray layer near the base of unit H possibly correlates with the lower part of the Riverdale Member. The Riverdale Member was deposited during late Holocene time (Clayton and others, in preparation).

Unit I

Unit I consists prediminantly of light to dark brown silt, which is vaguely bedded and contains abundant organic debris. It is interbedded with dark-gray clay, poorly sorted sand (50 to 80 percent quartz fragments and 20 to 50 percent lithic fragments) and gravel containing carbonate, volcanic, and plutonic rocks, limonitic concretions, and quartzite. The gravel is poorly sorted and is heavily coated with calcium carbonate. In a few depressions within the study area, unit I consists of dark-gray, silty, sandy clay that is massive. Unit I ranges in thickness from 2 to 5 meters. Farland, Cheyenne, and McKenzie soils (Edwards, 1942, p. 38-41, 74) typically form on the exposed sediment of this unit.

Unit I consists of colluvium and alluvium associated with terraces and alluvial fans along Charbonneau and Camp Creeks and the Yellowstone and Missouri Rivers. This unit is probably Holocene in age.

Unit J

Unit J consists predominantly of clay and silty clay which is vaguely bedded and contains abundant organic debris. It is commonly interbedded with silt, sand, and gravel. The sand is fine to medium grained, and quartz fragments are more abundant than lithic fragments. Sedimentary structures such as planar bedding and small and large scale curved cross-stratification are found in the sand. The gravel contains carbonate, limonitic, volcanic, and plutonic rocks and quartzite.
Cherry, Havre, and Banks soils (Edwards, 1942, p. 45, 46, 54) typically develop on the exposed sediment of this unit.

In outcrops, unit J ranges in thickness from 1 to 5 meters. Borings from railroad bridges across the Missouri River near Nohly, Montana, and across the Yellowstone River near Cartwright, North Dakota, indicate that (Howard, 1960, p. 71) sediment of the Fort Union Group occurs about 8 meters below the surface. Both of these bridges are near vertical bluffs of sediment of the Fort Union Group. The rivers are actively eroding these bluffs, so 8 meters probably does not represent the true valley depth of the Missouri and Yellowstone Rivers.

Unit J consists of alluvium occurring in the present valleys of the Yellowstone and Missouri Rivers and their tributaries.

HISTORICAL INTERPRETATION

Evidence for several stages in the evolution of the Yellowstone River drainage system was found in the study area. During late Pliocene or early Pleistocene time, the Yellowstone River flowed northward over a surface about 90 meters above its present flood plain. Subsequent downcutting was interrupted by a glacial advance that dammed the river, forming a lake. The lake was drained by several outlet channels and the Yellowstone drainage was re-established. Two additional glacial advances disrupted the drainage. Meltwater channels were formed as the last glacier retreated. This meltwater deposited gravel whose upper surface is graded to the level of the lowest well-developed terrace along the Yellowstone River. Renewed downcutting established the present flood plains of the Yellowstone and Missouri Rivers and their tributaries.

During late Pliocene or early Pleistocene time, the Yellowstone River flowed northeast into Hudson Bay (Bluemle, 1972, p. 2189). Within the study area, the river flowed over a surface about 90 meters above the present flood plain, depositing
sand and gravel of unit A. The valley occupied by the river during this time was associated with the Yellowstone low. The lithology of the gravel of unit A is very similar to the lithology of gravel being deposited in the Yellowstone River today. This suggests that the drainage basin of the Yellowstone during late Pliocene or early Pleistocene time was very similar to the present Yellowstone drainage basin.

The earliest glacial advance in the study area is represented by pebble-loam of unit B. The pebble-loam contains abundant fragments of lignite, siltstone, limonitic concretions, and "scoria" from the Fort Union Group. This suggests that the Fort Union Group was extensively exposed to glacial erosion during this time. The occurrence of shale fragments from the Pierre Formation, which outcrops north and northeast of the study area, suggest that bedrock was exposed outside the study area. The exposure of bedrock to glacial erosion suggests that no thick glacial sediment existed in or around the study area. Whether the glacier that deposited pebble-loam of unit B was the first to advance into the area, or if it followed a period of erosion during which pre-existing glacial sediment had been removed, is not known.

The glacier dammed the river forming a lake in which silt and clay of unit C was deposited. The thickness of unit C, 8 meters, indicates a persistant lake. The only way such a lake can form in the Yellowstone valley is by damming of the river. This damming was done by a glacier. Pebble-loam of unit B represents the earliest known glacier, so it seems logical to assume that this glacier dammed the Yellowstone River forming the lake in which silt and clay of unit C were deposited. The relation of this sediment to sediment deposited in glacial Lake Glendive in eastern Montana is unknown.

Considerable downcutting by the Yellowstone River preceded the glacial damming of the river. The position of the Yellowstone at this time is not known, but it was considerably lower than the upper surface of unit A. In some outcrops,
pebble-loam of unit B occurs only 7 meters above the present flood plain of the Yellowstone River (Fig. 2). Uneroded sand and gravel of unit A underlies pebble-loam 90 meters above the present flood plain suggesting that glacial erosion was not responsible for the variation in elevation. The upper surface of unit C occurs about 10 meters above the present flood plain of the Yellowstone, further suggesting that downcutting by the river preceded the glacial damming of the river.

As the glacier retreated, numerous pre-existing valleys were uncovered and acted as outlets for the lake. One of these outlets, in the southeast corner of the study area, is a broad channel associated with the northeast-southwest trending Charbonneau low and comparable in width to narrow parts of the Missouri River trench. Within this channel, sand and gravel of unit A underlie glacial sediment of units F and E. It is not known whether this sediment was redeposited as the lake drained through the outlet channel after deposition of pebble-loam of unit B or if pebble-loam of unit B was removed by erosion and the channel was eroded into pre-existing sediment deposited by the Yellowstone River prior to the glacial damming.

After the glacier retreated and the lake drained, the Yellowstone River drainage was re-established. Tributaries of the Yellowstone deposited gravel of unit D on top of silt and clay of unit C in the Charbonneau Creek valley. The gravel consists predominantly of siltstone, limonitic concretions, and "scoria," all locally derived from the Fort Union Group. This tributary flowed westward because the base of the gravel of unit D slopes toward the west.

The re-established drainage of the Yellowstone River was interrupted by two additional glacial advances. The pebble-loam deposited by these advances (unit E and F) are very similar, suggesting that much of the pebble-loam of unit E was incorporated into the pebble-loam of unit F. The scarcity of fragments of lignite, siltstone, limonitic concretions, and "scoria" from the Fort Union
Group and fragments of shale from the Pierre Formation suggest that bedrock was not extensively exposed to glacial erosion at the time of these advances.

No directional indicators associated with the deposition of unit E were found, but it is reasonable to assume that this glacier advanced from the north or northeast. The glacier which deposited pebble-loam of unit F advanced from the northeast. The orientation of washboard moraines composed of sediment of unit F and striations on a boulder lag occurring beneath pebble-loam of unit F suggest an advance from the northeast.

As the last glacier retreated, meltwater eroded channels and deposited gravel of unit G on the upland area north of Charbonneau Creek. These north-south trending channels slope toward the south and were eroded into the pebble-loam of unit F. Two of these channels are very well preserved (Fig. 3). The base of the eastern channel has an elevation of about 730 meters near its southern end. The base of the western channel has an elevation of about 713 meters near its northern end. The difference in elevation is probably a result of stagnant ice blocking the drainage. The eastern channel formed first and as the ice melted, the western channel was formed. The western channel is deeper than the eastern channel, suggesting that it was used more. Initially the southern part of the western channel trended southeast through sec. 9, 15, 16, 22 and 23, T. 151 N., R. 103 W. Its position shifted and the channel trended southwest through sec. 8, 17, 19, and 30, T. 151 N., R 103. The meltwater deposited gravel of unit G that underlies a surface about 13 meters above the present flood plain of Charbonneau Creek. The surface, underlain by gravel of unit G, is found only on the north side of the creek.

As the drainage of the Yellowstone was again re-established, the river deposited gravel of unit G. The upper surface of this gravel forms a terrace about 13 meters above the present flood plain of the Yellowstone River and is the lowest well-developed terrace (Howard, 1960, p. 21) along the river. This terrace appears to be graded to the level of the surface which was formed by
Figure 3. Meltwater channels in northwestern McKenzie County, North Dakota
meltwater about 13 meters above the present flood plain of Charbonneau Creek. This suggests that the lowest well-developed terrace along the Yellowstone River developed as the last glacier in the area retreated.

During Holocene time, the climate became warmer and drier. Eolian activity occurred. Wind-blown silt of unit H was deposited on the uplands and lowlands of the study area. The silt was probably derived from glacial outwash plains. Sand dunes occur in sec. 26, 35, and 36, T. 152 N., R. 102 W. These dunes are now inactive and covered with vegetation. Many of the large valleys in the study area are now occupied by small intermittent streams such as Camp Creek, which occurs in the large valley in the southeast corner of the study area. Renewed downcutting during the Holocene, established the present flood plains of the Yellowstone and Missouri Rivers and their tributaries about 13 meters below their lowest well-developed terraces.

SUMMARY

During late Pliocene or early Pleistocene time, the Yellowstone River deposited gravel of unit A containing chert and volcanic and plutonic rocks. The upper surface of this gravel is about 90 meters above the present flood plains of the Yellowstone and Missouri Rivers. Subsequent downcutting was interrupted by a glacial advance that deposited sediment of unit B. This sediment is correlated with the "early Wisconsinan drift" described by Howard (1962, p. 27). This sediment is not the surface sediment over the study area as indicated by Howard (1960, pl. 1). The glacier dammed the Yellowstone River, forming a lake in which evenly bedded silt and clay of unit C were deposited. As the glacier retreated, a series of outlet channels drained the lake. Yellowstone drainage was re-established and the gravel of unit D, locally derived from the Fort Union Group, was deposited by tributaries of the Yellowstone River. Drainage was again disrupted by two additional glacial advances that deposited sediment of units E and F. This sediment is correlated with the
"middle Wisconsinan drift" described by Howard (1960, p. 36) and occurs south of the "middle Wisconsinan drift" boundary indicated by Howard (1960, pl. 1). As the last glacier retreated, gravel of unit G was deposited along the Yellowstone River and in a series of meltwater channels. Contrary to Howard (1960, p. 23), this gravel overlies all the glacial sediment in the area. The upper surface of the gravel deposited by meltwater is graded to the level of the lowest, well-developed terrace along the Yellowstone River, suggesting that this terrace was developed as the last glacier in the area retreated. During the Holocene, the climate became warmer and drier. Wind-blown silt of unit H was deposited in the study area and sand dunes were formed. Renewed downcutting established the present flood plains of the Yellowstone and Missouri Rivers and their tributaries.
ACKNOWLEDGMENTS

The North Dakota Geological Survey funded this project and assisted in the preparation of the figures. I wish to thank Dr. Stephen R. Moran, Dr. Lee Clayton, and Dr. Walter L. Moore for advising this project and reviewing the manuscript. I would especially like to thank Mrs. Gyda Swenson and her family for adopting me during the summer while I did my field work.
BIBLIOGRAPHY


### Appendix A. Sample Locations

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<th>Sample No.</th>
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</table>

* G (pebble-loam or pebble-loam and gravel samples)
  GG (gravel samples)
Appendix B. Section Descriptions

G-1 NE\_\_\_\_NW\_\_\_\_, sec. 29, T152N, R104W  Cut along west side of canal

<table>
<thead>
<tr>
<th>Section</th>
<th>Unit</th>
<th>Depth from surface (ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1 (a)</td>
<td>I</td>
<td>0 - 3</td>
<td>Sandy silt, poorly sorted with some shell fragments</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>3 - 3.5</td>
<td>Black layer with abundant organic debris</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>3.5 - 5</td>
<td>Silt, medium to coarse grained, no pebbles, yellow</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>5 - 9</td>
<td>Pebble-loam, coarse sand (61-36-3), few pebbles: Cb_Cr_Sh, granular texture, gray brown</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>9 - 17</td>
<td>Pebble-loam, coarse sand (58-24-8), abundant pebbles: Lig + Lim &gt; Cb + Cr, poor jointing, yellow brown</td>
</tr>
<tr>
<td>G-1 (b)</td>
<td>I</td>
<td>0 - 2</td>
<td>Same as above</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>2 - 6</td>
<td>Pebble-loam, coarse sand (73-27-0), few pebbles: Cb_Cr_Sh, fine columnar jointing, gray brown</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>6 - 6.1</td>
<td>Boulder lag, Cr + Cb boulders, striations trend NE - SW</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>6.1 - 11</td>
<td>Same as above</td>
</tr>
<tr>
<td></td>
<td>D?</td>
<td>11 - 12</td>
<td>Clay, laminated, brown</td>
</tr>
<tr>
<td></td>
<td>D?</td>
<td>12 - 15</td>
<td>Silt and sandy clay, laminated, lignite fragments and iron staining common along bedding planes</td>
</tr>
<tr>
<td></td>
<td>D?</td>
<td>15 - 16</td>
<td>Gravel, poorly sorted, siltstone, shale, and sandstone pebbles</td>
</tr>
</tbody>
</table>
Section | Unit | Depth from surface (ft) | Description
--- | --- | --- | ---
G-3 (a) | F | 0 - 10 | Pebble-loam, coarse sand (70-23-7), crumbly, few pebbles: Cr\(\rightarrow\)Cb\(\rightarrow\)Sh
gray brown
F | 10 - 10.2 | Boulder lag, Cb, Cr, + sandstone boulders, striations trend NE - SW
E | 10.2 - 15 | Pebble-loam, coarse sand (57-35-8), crumbly, few pebbles: Cr\(\rightarrow\)Cb\(\rightarrow\)Sh, gray brown

G-8 SE\(\frac{1}{4}\)SE\(\frac{1}{2}\)NE\(\frac{1}{4}\), sec. 13, T151N, R104W Cut on north side of road

Section | Unit | Depth from surface (ft) | Description
--- | --- | --- | ---
G-8 (a) | H | 0 - 3 | Silt, coarse grained, few pebbles associated with burrows, vertical joints
F | 3 - 3.5 | Pebble-loam, crumbly, white streaks, grunty zone
F | 3.5 - 11 | Pebble-loam, coarse sand (60-34-6), compact, pebbles: Cb\(\rightarrow\)Cr\(\rightarrow\)Sh\(\rightarrow\)Vol + chert, gets sandier downward
A | 11 - 12 | Sand, fine to medium grained, moderately sorted, planar bedding, fragments: quartz\(\rightarrow\)lithic
A | 12 - 26 | Gravel, sandy, iron stained, well rounded, pebbles: Chert\(\rightarrow\)Vol\(\rightarrow\)Plu\(\rightarrow\)Qtz
A | 26 - 31 | Sand, medium grained, moderately sorted, fragments: quartz\(\rightarrow\)lithic
G-14 NW\NW, sec. 31, T151N, R103W
Cut on east side of road

<table>
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<th>Section</th>
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<th>Description</th>
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<tr>
<td>G-14 (a)</td>
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<td>0 - 3</td>
<td>Gravel, sandy, coarse-grained sand, pebbles: Chert&gt;Vol&gt;Plu&gt;Cb</td>
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<td>E</td>
<td>3 - 8</td>
<td>Pebble-loam, coarse sand (64-30-6), hard, angular chunks, pebbles: Cb&gt;Cr, yellow brown</td>
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<td></td>
<td>E</td>
<td>8 - 11</td>
<td>Silt and sand, poorly sorted, yellow</td>
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<td>E</td>
<td>11 - 41</td>
<td>Pebble-loam, coarse sand (64-31-5), few pebbles, Cb&gt;Cr&gt;Sh, compact, brown gets gray downward</td>
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<td>D</td>
<td>41 - 42</td>
<td>Sand, poorly sorted, fragments: quartz&gt;lithic</td>
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<td>D</td>
<td>42 - 45</td>
<td>Gravel, sandy, iron and manganese staining, some lens of organic debris, pebbles: Chert&gt;Sed=Lim&gt;Plu&gt;Scoria</td>
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<td>D</td>
<td>45 - 46</td>
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G-16 NW\SW, sec. 31, T151N, R103W
Cut on south side of creek

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<td>D</td>
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<td>Silt, sand, and clay, evenly bedded</td>
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<td>D</td>
<td>20 - 25</td>
<td>Sand, gravel, interbedded, pebbles: Lim&gt;Chert&gt;Sed=Vol=Plu</td>
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<td>C</td>
<td>25 - 50</td>
<td>Silt, sand, clay, laminated, some contorted bedding, lignite fragments and iron staining along bedding planes</td>
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G-20 SE 1/4 SE 1/4, sec. 2 T151N, R103W. Cut on north side of road

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<td>Pebble-loam, coarse sand (86-14-0), few pebbles: Cb&gt;Cr, granular texture, gray brown</td>
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<td>E</td>
<td>3 - 5</td>
<td>Pebble-loam, coarse sand (63-36-1), few pebbles: Cb&gt;Cr, granular texture, gray brown</td>
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<td>B</td>
<td>5 - 12</td>
<td>Pebble-loam, coarse sand (54-25-21), pebbles: Cb&gt;Lig&gt;Lim&gt;Sh, poorly jointed, yellow brown</td>
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<td>12 - 18</td>
<td>Sand, fine to medium grained, poorly sorted, fragments: quartz&gt;lithic</td>
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G-26 NW 1/4 NE 1/4, sec. 27, T152N, R103W. Gravel pit on west side of road

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<td>Silt, coarse grained, massive, no pebbles, brown</td>
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<td>E</td>
<td>3 - 9</td>
<td>Pebble-loam, coarse sand (63-37-0), few pebbles: Cb&gt;Cr, granular texture, gray brown</td>
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<tr>
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<td>A</td>
<td>9 - 25</td>
<td>Gravel, well rounded, iron stained, Chert&gt;Plub&gt;Vol, pebbles imbricated, dipping south</td>
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<td>A</td>
<td>25 - 30</td>
<td>Sand, fine to medium grained, planar bedding, gently dipping west, lens of organic debris</td>
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<td>A</td>
<td>30 - 40</td>
<td>Gravel, same as above</td>
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### Section G-29

**Location:** NWSE, sec. 28, T151N, R103W  
**Description:** Cut on north side of creek

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<th>Depth from surface (ft.)</th>
<th>Description</th>
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<tr>
<td>0 - 1</td>
<td>Silt, poorly sorted, few pebbles, brown, contains black layer of abundant organic debris</td>
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<td>1 - 1.5</td>
<td>Gravel, poorly sorted, pebbles: Cb&gt;Lim, heavy CaCO₃ coating</td>
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<tr>
<td>1.5 - 3</td>
<td>Silt and clay, poorly bedded</td>
</tr>
<tr>
<td>3 - 18</td>
<td>Pebble-loam, coarse sand (65-32-3), pebbles: Cb&gt;Lim=Lig, granular texture</td>
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<tr>
<td>18 - 20</td>
<td>Silt and silty clay, poorly bedded, lens of organic debris</td>
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<tr>
<td>20 - 23</td>
<td>Sand, poorly sorted, peaty layers, some iron-stained layers</td>
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<tr>
<td>23 - 26</td>
<td>Gravel, poorly sorted, pebbles: Lim&gt;Sed&gt;Scoria</td>
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### Section G-31

**Location:** SWNE, sec. 31, T151N, R102W  
**Description:** Cut on east side of creek

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<td>Silt, coarse grained, yellow brown, contains black layer of organic debris</td>
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<td>Pebble-loam, coarse sand (63-31-6), pebbles: Cb&gt;Cr, compact, fine columnar joints, gray brown</td>
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<tr>
<td>12 - 24</td>
<td>Sand, silt, clay, and gravel, heavy iron staining and CaCO₃ coating, pebbles: Cb&gt;Chert&gt;Plu</td>
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### Southern end of cut on east side of creek

**Section**

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<td>Silt and clay, lenses of organic debris, poorly bedded</td>
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<td>G</td>
<td>10 - 16</td>
<td>Sand, moderately sorted, fragments: quartz, lithic; Gravel, sandy, pebbles: Chert, Vol, Cb; and Silt</td>
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<td>F</td>
<td>16 - 24</td>
<td>Pebble-loam, coarse sand (80-16-4), few pebbles: Cb, Cr, Sh, granular texture, fine columnar jointing, gray brown</td>
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<tr>
<td></td>
<td>E</td>
<td>24 - 36</td>
<td>Pebble-loam, coarse sand (60-31-8), few pebbles: Cb, Cr, Sh, granular texture, gray brown, coarse columnar jointing</td>
</tr>
<tr>
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<td>D</td>
<td>36 - 41</td>
<td>Gravel, sandy, pebbles: Lim, Sed, Scoria, poorly sorted</td>
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### Cut on south side of hiway

**Section**

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<td>Gravel, sandy, pebbles: Cb, Chert, poorly sorted, heavy CaCO$_3$ coating</td>
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<tr>
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<td>E</td>
<td>7 - 15</td>
<td>Pebble-loam, pebbles: Cb, Cr, Sh, compact, gray brown</td>
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</table>

* Pebble-loam: coarse and (Cr-Cb-Sh)$_2$, Cr (crystalline), Cb (carbonate), Sh (shale)
Gravel: Lim (limonitic), Plu (plutonic), Vol (volcanic), Sed (sedimentary)
## Appendix C. Grain Size and Coarse Sand Lithology of Pebble-loam

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>*Grain Size % (Sd-St-C1)</th>
<th>**Coarse Sand Lithology % (Cr-Cb-Sh)</th>
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* Sd (sand), St (silt), Cy (clay)
** Cr (crystalline), Cb (carbonate), Sh (shale)
Appendix D. Lithology of Gravel

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*Qtz. (quartzite), Plu. (plutonic), Vol. (volcanic), Cb. (carbonate), Sed. (sedimentary), Lim. (limonitic)*
ISOPACH MAP OF UNIT A

Plate 4

ROADS
- PAVED
- GRAVEL
- DIRT

1" = 1 MILE

Outer extent of Unit A

Data points

Contour Interval 10 feet

Salomon, N. (1979)

R. 104 W.
R. 103 W.
R. 102 W.
# Geologic Map of Northwestern McKenzie County, North Dakota

## Explanation

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<th>Description of Lithostratigraphic Units</th>
<th>Topography</th>
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<td>Clay and silty clay containing organic debris and interbedded with silt; sand, fine to medium grained, fragments: quartz, lithic; and small amounts of gravel containing chert, quartzite, and carbonate, volcanic, plutonic, and limonitic pebbles</td>
<td>Flat (0%-2%)</td>
</tr>
<tr>
<td>I</td>
<td>Silt containing organic debris and interbedded with clay; sand, poorly sorted, fragments: quartz, lithic; and gravel containing chert, quartzite, and carbonate, volcanic, plutonic, and limonitic pebbles coated with calcium carbonate</td>
<td>Undulating (2%-8%)</td>
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<td>I</td>
<td>Clay, sandy, silty, dark gray, massive</td>
<td>Rolling (8%-20%)</td>
</tr>
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<td>G</td>
<td>Gravel, sandy, poor to moderate sorting, coated with calcium carbonate, pebbles: chert, carbonate, plutonic, volcanic, quartzite, limonitic</td>
<td>Flat (0%-2%)</td>
</tr>
<tr>
<td>G</td>
<td>Sand, poor to moderate sorting, fragments: quartz, lithic, interbedded with silt and gravel</td>
<td>Undulating (2%-8%)</td>
</tr>
<tr>
<td>E-F</td>
<td>Pebble-loam, gray brown, fragments: crystalline, carbonate, shale, granular texture, fine columnar jointing, generally 1 meter of silt (Unit H) overlies the pebble-loam</td>
<td>Rolling (8%-20%)</td>
</tr>
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<td>A</td>
<td>Gravel, sandy, moderately sorted, iron stained, pebbles: chert, volcanic, quartzite</td>
<td>Flat (0%-2%)</td>
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<tr>
<td>A</td>
<td>Sand, medium grained, moderately sorted, fragments: quartz, lithic</td>
<td>Undulating (2%-8%)</td>
</tr>
<tr>
<td>Sentinel Butte Formation</td>
<td>Mudstone, siltstone, sandstone, poorly consolidated gray, minor beds of lignite and scoria</td>
<td>Rolling (8%-20%)</td>
</tr>
<tr>
<td>Tongue River Formation</td>
<td>Sandstone, siltstone, mudstone, poorly consolidated yellow, minor beds of lignite and scoria</td>
<td>Hilly (over 20%)</td>
</tr>
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</table>

Sorenson, N. 1979