NORTH DAKOTA GEOLOGICAL SURVEY

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Geology of the Lower Pipestem Creek Area North Dakota

by

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INTRODUCTION

Abstract

East-central Stutsman County, North Dakota, the area of the lower Pipestem Creek, is in the border zone between the Missouri Plateau to the west and the Drift Prairie to the east. Pleistocene drift deposits mantle this area which topographically is influenced by a Tertiary erosion surface on upper Cretaceous shale.

Buff to brown, calcareous, clay till, derived from the underlying shale bedrock, is the main constituent of the extensive areas of gently rolling ground moraine, recessional moraine and terminal moraine. Kames are of greater prominence in terminal and recessional moraine, but eskers are sparsely situated in ground moraine throughout the area. Glacial melt water deposits assume the form of outwash deltas in the Pipestem Creek and Minneapolis Flats Creek channels.

Joint systems in the Cretaceous Pierre shale appear to control the trend of the eastern boundary of the Missouri Plateau, influence the southern orientation of the main spillway systems in the area, and provide avenues for ground water movement. This ground water in the shale, at the shale-drift contact, and in restricted lenses of sand and gravel in the till provides an adequate supply of water for the local farm needs.

Three main spillway systems with parallel north-south orientation drain the area. These streams are the pre-glacial James River, Pipestem Creek and the glacial and post-glacial Minneapolis Flats creek.

Location of the Area

The lower Pipestem Creek area is defined by 99° 00′ and 98° 45′ west longitude and 46° 52′ 30″ and 47° 07′ 30″ north latitude, in east central Stutsman County, North Dakota (Fig. 1). Hidden and Eldridge townships are included within the area while the townships of Jim River Valley, Plainview, Buchanan, Midway, Woodbury, Lippert, Roundtop, Deer Lake, Windsor, and Moon Lake are partly included. U. S. Highway 10 crosses the southern half of the area. The area included in this report is approximately 197 square miles.

Purpose of the Survey

Sand and gravel and ground water have long been recognized in North Dakota as being among the state's most valuable mineral resources. The exploration of these deposits and their geological mode of occurrence is best accomplished through detailed geological mapping. This investigation was conducted in order to provide more detailed information on the sand and gravel deposits and the ground water resources of the lower Pipestem Creek area.

Methods of Investigation

The lower Pipestem Creek area consists of the following United States Geological Survey quadrangles: Pingree SW, Buchanan, Eldridge NW, and Eldridge (Fig. 1). These topographic maps were used as base maps. preliminary reconnaissance of the four quadrangles was done by car. Further detailed mapping, establishing the limits of outwash areas was done by soil auger tests. The detailed mapping of terrace levels was accomplished on foot.

Water well information was obtained and recorded on North Dakota Geological Survey well data sheets. Wherever possible, actual depth measurements of these wells were made, and where permanently covered wells were encountered, the word of the occupant of the farm was accepted. Samples were collected from major outwash zones and a size and composition analysis of them was made in the laboratory (Tables IV and V). Attitudes of joint systems were taken in order to determine the local and regional influence of Pierre shale bedrock on the drift covered area.

The mapping of the Pingree SW and Eldridge quadrangles was accomplished in the latter part of the summer of 1954. In the summer of 1955, the geology of the Buchanan and Eldridge NW quadrangles was mapped. Well data surveys of the four quadrangles were also completed at this time.

Previous Work in the Area

On a regional basis Upham and Todd in their work on the terminal moraines of the Drift Prairie and Missouri Plateau mentioned the general geology of the area. Willard, on a less regional basis, discussed the geology of the southern portion of this area in his report on the Jamestown, Eckelson, and Tower quadrangles.

Acknowledgements

The writer wishes to express his appreciation to Dr. Wilson M. Laird, State Geologist of North Dakota, for the opportunity of studying and mapping this area. Ray Huot was especially helpful as an assistant in the field in the summer of 1954. Suggestions in the ground water geology and in the preparation of the piezometric map of the area were obligingly offered by Mr. Joseph Brookhart, United States Geological Survey. Thanks are also due to Edward Flewitt, George Green, Jay Garske, and Richard Monroe, field associates in the summer of 1955. The writer is especially indebted to Dr. Gordon L. Bell, Department of Geology, University of North Dakota, for his frequent consultations and numerous helpful suggestions in the field as well as for his invaluable assistance in the preparation of this report.

PHYSIOGRAPHY OF THE AREA

Regional Physiography

Physiographically, the area lies in the zone of contact between the *Coteau du Missouri* (Missouri Plateau) on the southwest and the *Coteau des Prairies* (Drift Prairie) on the northeast (Fig. 1). The Drift Prairie province, chiefly a region of gently undulating ground moraine plain, is delimited on the west by a series of ridges (Pierre shale bedrock escarpments) which increase in altitude to the west and collectively become a part of the Missouri Plateau. The eastern boundary of this plateau consists of a knob and kettle topography typical of the several terminal moraines as mapped by Todd. The westernmost or Altamont moraine and the Gary moraine form the eastern limit of this plateau.

The surficial deposits of this area are chiefly those formed by ablation in the last several recessions of the Pleistocene ice sheet and the topographic expression of the terminal moraines is notable.

Minneapolis Flats Creek drains the Eldridge NW quadrangle. This stream flows north and enters the Pipestem Creek in the central portion of the area. The Pingree SW and Eldridge quadrangles are drained by the south and east-flowing Pipestem Creek and the Buchanan quadrangle is drained by the south-extending James River. Although the James is the master stream in the area today, there is evidence to show that in the Pleistocene epoch it was the Pipestem that did the most constructional and destructional work in the area. In this area the gradient of the James River is 1.2 feet per mile while that of Pipestem Creek is 3.2 feet per mile.

Local Physiography

Three main topographic divisions are recognized in this area. The highest level, coincident with the eastern boundary of the Missouri Plateau, ranges from 1650 feet above sea level in the extreme northwest corner of the area to 1750 feet above sea level in the extreme southwest corner of the area. This level consists of terminal moraine which is characterized by typical knob and kettle topography.

The second topographic division includes those areas of gently rolling ground moraine, recessional moraine, and outwash. The range in altitude above sea level of this division is from 1500 feet to 1650 feet.

The third division includes the floodplains of the James River, Pipestem Creek, and Minneapolis Flats Creek, as well as those lower levels occupied by the main spillways of the area.

PRESENT DEVELOPMENT OF THE AREA

Agriculture

The major portion of the area, including portions of the floodplain of the Pipestem Creek, is under cultivation and is utilized for farming. The more prominent crops include wheat, barley, and winter rye. Cattle raising is also quite important and such areas as those along the James River, Minneapolis Flats Creek, and portions of the Pipestem Creek floodplains, the bouldery terminal moraine land, and the poorly drained ground moraine are used for grazing and hayland. Less important projects in the area include dairying and sheep raising.

Communications

Two branches of the Northern Pacific Railroad serve the area. The main line parallels U.S. Highway 10 which is in the southern portion of the area. A branch line extends northwest parallel to U.S. Highways 52 and 281 in the Northeast portion. U.S. Highway 10 trends west through the southern portion of the area and U.S. Highway 52 and 281 extends northwest through the northeast section of the area. These transportation routes, combined with a moderately well developed system of county roads, gravelled township roads, and graded section roads, provide a satisfactory means of traversing the area.

Resources

The principal resource in the area is the fertile soil which is used primarily for farming. Ground water ranks second in importance and provides an adequate supply suitable for both human consumption and stock. Deposits of gravel and sand are used locally for road metal and minor construction work.

Climate

East-central North Dakota is in an area of Humid Microthermal, continental, cool summer climate. Summer is the season of maximum precipitation and warm to hot summers with cold winters account for the large annual temperature ranges in this type of climate.

There are no weather stations in the lower Pipestem Creek area; however, precipitation data are available from the nearby weather station at Jamestown, North Dakota. These data are shown in Table I.

Table I

Annual Precipitation in Inches for the Years 1930-1951 Inclusive for Jamestown, North Dakota.

* Indicates Greatest and Least Amounts.

1930	14.13	1938	18.44	1945	13.76
1931	19.70	1939	17.54	1946	19.71
1932	19.69	1940	20.95	1947	18.24
1933	15.90	1941	22.44*	1948	14.23
1934	14.01	1942	21.32	1949	18.50
1935	21.63	1943	18.41	1950	18.34
1936	6.91*	1944	17.12	1951	16.69
1937	18.44			Mean	19.54

GEOLOGY

General Geology

Bedrock exposures are rather limited in this area. Pierre shale crops out at many places in the James River valley and is present at several locations (sections 3, 4, and 5, T. 140 N., R. 65 W.) in the lower Pipestem Creek valley. In the greater portion of this area, a thin mantle of glacial drift overlies the Pierre shale bedrock and at numerous places in the James River valley the contact between bedrock and drift can be readily determined by the location of springs.

From the surface and subsurface data it is reasonable to assume that the bedrock underlying the Pierre shale is the Niobrara formation. The field evidence included several bentonite beds which, according to Leonard, are very persistent and cover a large area. They form the lower portion of the Pierre and rest directly upon the Niobrara.

The following is a generalized outline of the geologic formations of the lower Pipestem Creek area.

Table II

Generalized Outline of the Geologic Formations of the Lower Pipestem Creek Area

Cenozoic
- Tertiary System
  - Pleistocene series
    - Wisconsin stage
      - Mankato substage
      - Pre-Mankato substages

Mesozoic
- Cretaceous System
  - Upper Cretaceous series
    - Montana group
      - Fox Hills sandstone
      - Pierre shale
    - Colorado group
      - Niobrara formation

Cretaceous System

Upper Cretaceous Series

Colorado Group

Niobrara Formation. — Although the Niobrara is not exposed in this area, it is known to crop out 39 miles east in the Valley City, North Dakota area. The Niobrara is a gray, calcareous, fossiliferous shale possessing a speckled appearance in the calcareous beds. Because the contact between the Niobrara and the Pierre is so nearly exposed in portions of this area as is proven the existence of the bentonite beds, it is expected that Niobrara underlies much of the drift to the east of the area.

Montana Group

Pierre shale. — Pierre shale is the only bedrock exposed at the surface in this area. When unweathered, this shale is bluish-black to greenish-black and is non-calcareous. It has a prounounced rectangular joint system causing it to weather into small blocks and silvery thin flakes approximately one millimeter thick. Numerous limonite and hematite concretions within the shale account for the orange-brown to brown zonal coloration of the shale numerous places. Ground water percolation through the joint systems of this shale accounts for the coloration along the joints. A discussion of these joint systems will be covered in the section on structural geology.

Near the base of the Pierre near its contact with the Niobrara formations are several beds of bentonite (NE¼ SW¼ section 35, T. 142 N., R. 64 W.). The bentonite beds numbered five and range in thickness from 0.5 to 5.0 inches.

In the same location of the bentonite beds mentioned above, is a zone of Pierre shale which underlies the thickest bentonite bed and contains in major joints within the shale a paper thin, metallic deposit of a mineral similar to the manganese mineral manganite—MnO (OH). The Odonah beds (Pierre shale) of the Riding Mountains, Manitoba, Canada, contain manganiferous concretions and it is the opinion of the writer that the limonite and hematite concretions of the Pierre shale in this area resemble the Odonah concretions. This material was probably concentrated by ground water action in the joint systems of the shale rather than by cold water action as it was in the rancieite manganese deposits of the Turtle Mountains, North Dakota.

Fox Hills sandstone. — Fox Hills sandstone outcrops are not present in this area; however, it is thought that this sandstone at one time was present in this area, or for that matter still exists in an area to the north—the Grasshopper Hills of T. 143 N., R. 64 W. in Jim Lake quadrangle to the north of Buchanan quadrangle. Evidences of the existence of Fox Hills sandstone (present nearby in the area previous to Pleistocene glaciation if not now) are as follows:

1. The presence of glacially striated angular Fox Hills sandstone boulders prevalent along the main spillways—James River, Pipestem Creek, and Minneapolis Flats Creek channels (Fig. 2). These sandstone boulders, if carried under or in the ice for any apreciable distance, would not retain the glacial striations due to the relative lack of resistance of this type of sandstone.

2. The occurrence of zones of sandy till interbedded with and also independent from the Pierre shale derived clay till. This was noted especially in NW¼ SW¼ section 35, T. 142 N., R. 64W. near the James River valley.

3. The presence of sandstone pebbles and cobbles (many of which contain fossil wood fragments—probably upper Fox Hills) in till and outwash in numerous places throughout the area. This was especially noted in the number 3 terrace gravel of east section 16, T. 140 N., R. 64 W.

FIGURE 2. Fox Hills sandstone with glacial striations. Pipestem Creek channel NW¼ NW¼ section 10, T. 141 N., R. 65 W.

Tertiary System

Pleistocene Series

Definition

The terms newer Pliocene or Pleistocene were first proposed by Lyell in 1839 to include those strata which contained 70 or more percent of recent species of shells. Forbes, in 1873, with Lyell's agreement, re-defined the term Pleistocene to include the deposits of the Great Ice Age and contemporaneous marine, fluviatile, lacustrine, and volcanic rocks. Pleistocene, then is a term that is synonymous with post-Pliocene.

As recognized by the United States Geological Survey, the Pleistocene includes all deposits that are post Pliocene and pre-Recent. It is the contention of the writer that the term Pleistocene includes all recent deposits as well as those included in the Great Ice Age since a distinct boundary between upper-Pleistocene and Recent deposits has not yet been clearly demonstrated.

General Statement

Because of the relatively small part of the glaciated portion of the state that is geologically mapped in detail, the Pleistocene stratigraphy of the state is as yet largely unknown. The several glacial features in this area have been mapped in detail and will be discussed below. In general, deposits of from 1 foot to over 300 feet of glacial drift blanket the area. Those deposits of the last retreat of the glacier range from clay to boulder size and in general the materials are either a buff or brown, calcareous clay till with a few rock fragments, or outwash sand and gravel.

Erratic boulders in this area are pre-Cambrian granite, granite gneiss, schist, and basic igneous rocks. Of greater prominence than these crystalline rocks, however, is the Ordovician and Silurian limestone and dolomite. Several limestone boulders have been identified by their fossil content as being from the Stony Mountain formation (Ordovician of Manitoba, Canada). The source area of most of these erratics is mainly eastern Manitoba.

Wisconsin Stage

Pre-Mankato substage deposits. — Certain clay tills in the area (especially in NE¼ SW¼ section 23, T. 140 N., R. 66W.) are extremely well indurated and compact when compared with the other poorly indurated clay tills of the area. The materials, color and degree of weathering do not seem to differ from the poorly indurated clay tills; although the toughness in makeup seems to suggest additional compression of the till due to a re-advance of the ice. This overridden, compact till lies unconformably on outwash gravel in the area cited above, and is shown in Figure 3.

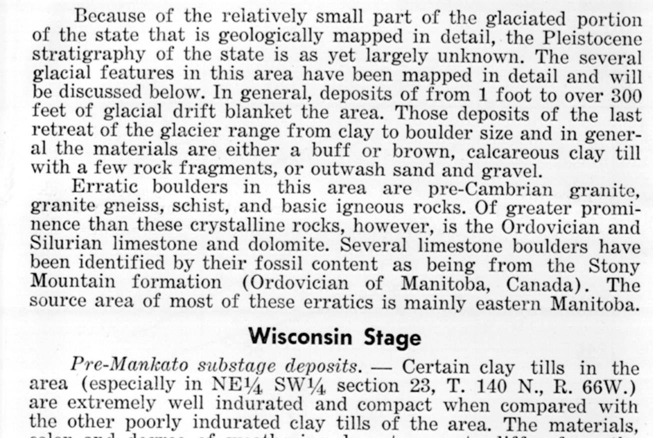


FIGURE 3. Erosional unconformity of outwash gravel overlain by clay till.

A limited profile of buried soil between two outwash zones was observed in Pipestem Creek channel, in SE¼ SW¼ of section 4, T. 140 N., R. 64 W. Possibly the soil was developed during an interglacial age. However, more regional data are required to establish the inference.

Mankato substage deposits. — The deposits of Mankato substage are moderately weathered light brown clay till, some outwash, and ice-contact stratified drift. These deposits are more fully described below under glacial features.

GLACIAL FEATURES

Terminal Moraine

An *end moraine* (also known as a *terminal moraine*) is a ridgelike accumulation of drift along the terminal margin of a valley glacier or the margin of an ice sheet. Reference to terminal moraine in the area was made as early as 1883 by Chamberlain who on a regional basis correlated the Altamont, Gary, and Antelope moraines of South Dakota with those of North Dakota. The terminal moraines named above according to the original work of T. C. Chamberlain are, except the Antelope moraine, tentatively retained since they mark significant advances of the Wisconsin ice sheet and are of historical importance. The genetic classification of these moraines is subject to change as the geologic mapping of the state progresses.

In the area covered in this report, the Gary terminal moraine embraces the extreme western section of the lower Pipestem Creek area and shall be referred to as the Gary terminal moraine. The Gary terminal moraine of this area has an average relief of 75 feet above the ground moraine plain to the east. The Antelope terminal moraine also mapped by Willard extends north through the central portion of the lower Pipestem Creek area and is mapped as a recessional moraine for this report. The Antelope moraine is a discontinuous recessional moraine on a ground moraine plain. The moraine is not named on the map but the segments are clearly aligned northward across the central part of the area. These morainal segments are characterized by low relief, and lack of knob and kettle topography.

The northern three-fourths of the Gary terminal moraine along the western margin of the area is herein termed the Hawk's Nest moraine from the local term Hawk's Nest Hills, the range of hills observed west of U.S. Highway 52 and 281 south of Carrington, North Dakota. The topography of the northern three-fourths of the moraine in this area can best be described from Willard who states that the "Steep and stony hills, close set as if packed together to economize space, deep ponds (kettle lakes) at different levels within short distances, long ridges, and short, steep rounded hills give to the landscape a wild and fascinating aspect in comparison with the long and broad swells and gently undulating contour of the plain to the southwest" (Fig. 4). The southern one-fourth of the moraine illustrates to a lesser degree the extreme knob and kettle topography of that portion of the moraine described above, and might reflect a greater degree of

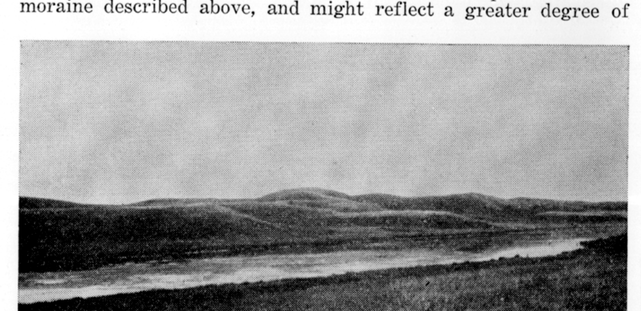


FIGURE 4. Terminal moraine.

modification by glacial meltwater produced by the glacier as it hesitated to the east of this area long enough to deposit this mantle of till on the plateau of Cretaceous bedrock which existed here in Pliocene time.

The materials of this terminal moraine are not unlike the materials of the ground moraine to the east. They consist of a buff to gray-brown, calcareous, clay till with a few limestone, shale, and crystalline rocks of pebble to boulder size. This clay till is derived mainly from the underlying Cretaceous Pierre shale. Several restricted and minor zones of sand and gravel can be found in the clay till of the terminal moraine. In the NE¼ of section 26, T. 140 N., R. 66W. is an exposure of stratified drift underlain conformably by outwash sand and gravel.

The sand and gravel deposits in the terminal moraine are not of commercial value except in places where glacial spillways have developed noteworthy outwash deposits of sand and gravel at or near the ice contact edge of the moraine as in sections 14 and 23, T. 142 N., R. 66 W. The height of this moraine is not due entirely to drift; rather it owes much of its general elevation to the underlying Cretaceous Pierre shale escarpment. Evidence of this underlying shale bedrock was obtained from water well data.

After deposition by the glacier, this moraine remained for some time in a saturated condition and following the removal of the ice from the area, the saturated clay till slumped under the influence of gravity. While the moraine was saturated it contained many large blocks of ice which were derived from the glacier front. These blocks were partly or completely covered by till and when they melted till slumped into the space that they formerly occupied, thus forming kettle lakes and kettle chains.

Kettle chains are the larger more elongated depressions left by the melting of a large fracture block of ice and are usually oriented with their long axes either parallel or perpendicular to the direction of the ice movement (see Gary terminal moraine in western portion of the area). Kettle lakes are the rounded or elliptical, steep-sided lakes, commonly connected by two or more meltwater drainage outlets, and locally are termed potholes or sloughs. The water level of these kettle lakes varies from lake to lake and there is commonly a difference of several feet in the level of these lakes within a relatively short distance (50-100 rods). Boulder lines or concentrations of boulders are typical features found at or above the present water level of these kettle lakes and kettle chains. They are also found in the larger kettle chains in the terminal moraine in the northwest portion of the area.

Recessional Moraine

Recessional moraines are glacial depositional features that stand out as topographic highs on the ground moraine plain and represent a greater amount of deposition in a more restricted area than commonly is deposited in an area of flat lying, gently rolling, ground moraine. These deposits signify a period of hesitation of the ice in which conditions of equilibrium existed and when there was a balance between nourishment and wastage of the glacier.

These moraines are from 20 to 80 feet higher than the surrounding ground moraine plain. Their length ranges from less than a mile to five miles or more. The average recessional moraine in this area is about 1.5 miles long and half a mile wide.

This type of moraine in this quadrangle is commonly connected to terminal moraines. Many recessional moraines have a subdued, relatively insignificant, topographic expression which may have been caused by a re-advance of the ice which modified these moraines to a gentle rolling form.

The recessional moraines of the Pipestem Creek area are oriented with their long axes to the north and are developed about one half to one mile apart. The general pattern of spacing suggests that these moraines are annual deposits of the glacier. The recessional moraine material is a buff to gray-brown, calcareous clay till with a few shale, limestone, and granitic pebbles, cobbles, and boulders.

Recessional moraines in this area are commonly associated with terminal moraines and ground moraine but in the northeast quarter of the area several small recessional moraines are associated with outwash.

Ground Moraine

The most extensive deposit in this area is ground moraine. This relatively thin layer of till tends to reflect the underlying bedrock conditions. Ground moraine in this area is characterized by a gently rolling and undulating surface and has a topographic relief usually less than 20 feet.

In certain areas, especially the northeast corner of the Pingree SW quadrangle, the ground moraine is quite pitted. An abundance of rock fragments from pebble to boulder size so typical on the surface of the terminal moraine is lacking in this ground morainc area. An occasional cobble or boulder will be found on the ground moraine plain, however, and in certain road cuts (especially the south side of the road between section 34, T. 142 N., R. 65 W. and section 3, T. 141 N., R. 65 W.) where the relief is quite pronounced, residual pavements do occur. Where these rock fragments are found they commonly bear glacial striations. This is especially true of limestone cobbles. Crystalline rocks in this area are generally unstriated or at best poorly striated.

Generally speaking, the ground moraine areas are less effectively drained than the areas of terminal moraine. The reason for this is that the supply of meltwater under conditions of terminal moraine deposition was greater than under conditions of ground moraine deposition. The greater supply of glacial meltwater working in an area of greater gradient (rugged terminal moraine topography) accounted for better drainage in terminal moraine areas than in areas of ground moraine.

A constant rate of ablation seems to be the major factor in the deposition of ground moraine. Whenever ablation increased in one specific ground moraine area the deposition of a recessional moraine occurred. This does not necessarily represent a slower rate of retreat of the glacier but may signify a greater amount of materials and meltwater available at that specific time in the area of recessional moraine deposition.

The materials of ground moraine are a buff to brown usually unstratified, calcareous, clay till with an occasional boulder, cobble or pebble. Close observation of this clay till reveals a nearly horizontal flow structure which developed as a result of the plastic flow of this meltwater saturated clay till during and shortly after its deposition by the ice. In NW¼ section 17, T. 141 N., R. 65 W. is a section of ground moraine containing stratified gravel, sand, and silt.

Ice Contact Deposits

Kames. — Typical ice contact deposits, exposed topographically as circular or elliptical hills or knobs, are formed by *moulin* action of surface or englacial waters in cracks and crevasses and are known as kames. These water-worked deposits of sand and gravel are crudely stratified and commonly faulted. This is due to the large amount of slumping after the removal of the ice contact support. Kame gravel in this area consists of Pierre shale fragments, limestone, and crystalline rocks. The sand is made up chiefly of quartz grains. A noticeable amount of limonite and hematite staining is present in this sand and gravel; probably due to ground water action on the included Pierre shale fragments.

The kames in this area are usually associated with recessional moraine and terminal moraine as in SE¼ section 33, T. 140 N., R. 64 W. and NE¼ section 26, T. 142 N., R. 66 W.; although they do occur in ground moraine as in NE¼ section 21, and NW¼ section 22, T. 140 N., R. 64 W.

Kames provide a local source of road metal. The large content of shale particles in kames of this area makes the material unfit for use as concrete aggregate.

Eskers. — Three esker systems are present within the area and are situated in NE¼ section 16, T. 142 N., R. 65 W., sections 29 and 32, T. 141 N., R. 64 W., and SW¼ section 33, T. 141 N., R. 65 W. Eskers are subglacial stream deposits that are formed near the frontal thinning ice area of the glacier. Topographically they stand out as winding, discontinuous ridges. The material of eskers is course-grained gravel and sand alternating with fine-grained, well-sorted, stratified sand which is commonly limonite and hematite stained. The long axes of these eskers are either parallel or normal to the direction of the ice movement. Eskers in this area occur in ground moraine. They are approximately half a mile long, 200 to 450 feet wide, and project 15 to 20 feet above the ground moraine plain.

Special mention will be made of the esker systems in sections 29 and 32, T. 141 N., R. 64 W. in which distinct esker troughs are developed about 35 feet away from either side of the esker. The subglacial stream also developed a delta at its southern terminus. The origin of esker troughs can be explained as that portion of the previously eroded subglacial river channel not heavily loaded with debris, which later became heavily loaded and deposited stratified debris in all but the flanks of its channel. As a typical glacial stream develops deltas at its mouth, so do these subglacial streams form deltaic deposits at the flanks and terminus. These deltaic sediments follow the normal sedimentary processes in grading outward from coarse, to medium, to fine-grained material, according to decreased velocity and consequent inability to transport the mixed load. Topographically these esker deltas are broad low swells where they merge with the ground moraine.

Loess

In the extreme north central portion of section 26, T. 140 N., R. 66 W. are two exposures of loess. The largest exposure is 200 feet long, 30 feet wide, and 9 feet high. The smaller exposure located 300 feet to the south is about 75 feet long, 60 feet wide, and has a vertical section of 6 feet. This decrease in size and thickness to the south would indicate a source area to the north since the surface elevation of the two exposures is the same. In the winter period when the glacial meltwater streams were frozen, the cold dry winds blowing over the terminal end of the glacier had an abundance of material available to transport from the erosional limits of the meltwater and re-deposit it as eolian silt.

This wind-blown silt is light buff when weathered and greenish-gray when unweathered. It is a calcareous, unfossiliferous, faintly and delicately cross-bedded deposit that weathers to nearly vertical cliffs with a semicolumnar structure. The deposits are associated with the terminal moraine in the southwest section of the area. There were no deposits of loess found in the outwash areas.

Outwash

Four specific types of outwash deposits are present in the lower Pipestem Creek area. The origin of these deposits is basically the same. Glacial meltwater streams originating on, within, and under the terminal portion of the ice were charged with millions of cubic yards of rock debris. These overloaded glacial rivers flowing in low gradient, till-covered channels deposited these stratifiedmaterials of gravel, sand, and silt in braided river systems.

In the extreme northwest portion of the area in sections 13, 14, and 24, T. 142 N., R. 66 W. is an outwash deposit which was formed somewhat differently from those deposits described above. Meltwater from the accumulated ice blocks in the terminal moraine dscharged down the ice contact side of the moraine concentrating the coarse material from the clay till. The surface of this outwash zone is a bouldery gravel pavement with no apparent soil profile.

The second type of outwash deposit which is situated in the northeast portion of the area (T. 142 N., R. 64 W.) covers an area of more than seven square miles. A gravel pit in this outwash zone (NE¼ section 18, T. 142 N., R. 64 W.) revealed from the top downward a one foot black soil profile, two feet of cross-bedded pebble gravel and sand underlain by two feet of fine quartz sand, thinly laminated but not cross-bedded, one and a half feet of cross-bedded pebble gravel and sand, and four feet of fine-grained, thinly laminated, quartz sand underlain by a light-brown gumbo clay of unknown depth. About 40 percent of the gravel in this pit is composed of Pierre shale fragments. Soil auger tests were used to outline the limits of this outwash area. The topographic change between relatively flat-lying outwash and gently rolling ground moraine gave additional proof of the outwash boundaries.

The third type of outwash concerns two deltaic deposits. The first is situated in sections 32 and 33, T. 141 N., R. 64 W. and NW¼ section 6, T. 140 N., R. 64 W. at the flanks and terminus of an esker. The second deposit is situated in the Pipestem Creek channel in sections 4 and 9, T. 140 N., R. 64 W. and is also thought to have been an esker delta although no evidences of this esker exist today. The materials of these deltaic deposits are cross-bedded sands and gravels.

Cross-bedded sand and gravel of the major spillway systems comprises the fourth type of outwash deposit in this area. The James River channel does not contain any gravel deposits in this area but the Minneapolis Flats Creek and Pipestem Creek contain abundant deposits of sand and gravel in their channels. Four terraces are well developed along Pipestem Creek where glacial and post-glacial drainage has cut the gravel and till fill in the pre-glacial channel. The terraces are numbered upward from No. 1, the present stream. Fill terrace number three in the Pipestem Creek channel is composed of alternating beds of cross-bedded sand and gravel. All field evidence indicates that the Minneapolis Flats Creek channel contains extremely large amounts of sand and gravel. See tables IV and V for size and composition analysis of these outwash materials.

Table III

Locations of Samples Analyzed for Size and Composition

Sample no. 1: NE¼ sec. 18, T. 142 N., R. 64 W. Two foot vertical channel of medium-grained, thinly laminated, light brown, outwash sand.

Sample no. 2: Bluff in NW¼ sec. 26, T. 140 N., R. 66 W. Eight foot vertical channel of medium-grained silt, finely cross-laminated, weathered buff, loess.

Sample no. 3: NE¼ sec. 18, T. 142 N., R. 64 W. Four foot vertical channel of medium brown outwash gravel.

Sample no. 4: North central portion of sec. 33, T. 142 N., R. 64 W. Seven foot vertical channel of medium brown outwash gravel.

Sample no. 5: Number three terrace level in Pipestem Creek channel. NE¼ sec. 16, T. 140 N., R. 64 W. Ten foot vertical channel of medium brown outwash gravel, limonite stained.

Sample no. 6: Number three terrace level in Pipestem Creek channel. SW¼ sec. 4, T. 140 N., R. 64 W. Ten foot vertical channel of medium brown, limonite stained, outwash gravel.

Sample no 7: Number three terrace level in Pipestem Creek channel. NW¼ sec. 25, T. 141 N., R. 65 W. Three foot vertical channel of medium brown outwash gravel.

Sample no. 8: Number three terrace level in Pipestem Creek channel. Basal channel of medium-grained, brown, outwash sand underlying outwash gravel. NE¼ sec. 16, T. 140 N., R. 64 W.

Sample no. 9: Outwash gravel near ice-contact side of terminal moraine. Five foot vertical channel. SW¼ sec. 14, T. 142 N., R. 66 W.

Pipestem Creek and Minneapolis Flats Creek channels contain an abundance of outwash sand and gravel of commercial quantity. The large percentage of shale fragments in the gravel probably limits its use to road metal rather than for construction-al purposes.

In general, the materials of these outwash deposits are quite similar. The rock fragments do not bear glacial striations, limonite staining is present on freshly exposed gravel surfaces and abrupt changes in grain sizes occur in these sediments. Black lenses of peat-like material are commonly found inter-bedded with the sand and gravel which are lacking in the terminal moraine outwash and the deltaic outwash. This organic material in the other types of outwash in the area suggests an intergiacial interval.

GLACIAL DRAINAGE

General Statement

The following brief discussion will include a description of the three main spillways in the area—James River, Pipestem Creek, and Minneapolis Flats Creek channels and the development or absence of terraces in these channels as well as a possible indication of the history of each stream.

James River Spillway

The erosion and deposition by the James River spillway in this area were subordinate to the amount of work the Pipestem Creek spillway did during and immediately following the last retreat of the glacier. In this particular area, above the point where the Pipestem Creek joins the James River, spillway gravel and distinct terrace development are lacking. South of this point, however, the terraces are developed and spillway gravel occurs in abundance. When Pipestem Creek was engaged in active erosion and deposition, the ice-blocked James River was in a dormant state.

The James River channel is half a mile wide, 60 to 80 feet deep and was quite well established before glacial time; the meltwater debris that entered its channel in this area during and after glaciation was removed with little or no deposition occuring.

The deposition of the till in the James River channel occurred after the spillway gravel in the Pipestem Creek channel was deposited and is probably comparable in age with the till overlying the spillway gravel of SW¼ section 23, T. 140 N., R. 66 W. in the southwest portion of the area.

Pipestem Creek Spillway

This stream, in glacial time, did more work than the James River. The pre-glacial channel 40 to 60 feet deep, half a mile wide relieved the area of most of the glacial meltwater following the final recession of the great ice sheet. The erosion of the till-choked Pipestem Creek valley by these glacial meltwaters produced a series of well developed terraces (Fig. 5).

FIGURE 5. Terraces of the Pipestem Creek channel.

The till in the upper portions of its channel has been eroded to form terrace level number 4. The number 4 terrace is from 15 to 50 feet higher than the number 3 terrace. In the northern portion of the area the number 4 terrace is broad and poorly developed where it is cut in the till of the general upland surface. The erosion of the till in the development of these terraces has resulted in the residual boulder concentrations along the lip of the Pipestem Creek channel. The number 3 terrace of the Pipestem consists of cross-bedded outwash sand and gravel. This terrace is quite discontinuous along the Pipestem and is from 20 to 45 feet higher than the number 2 terrace.

Number 2 terrace consists of stratified sand and silt. This terrace is the most extensive level in the channel and is from 5 to 25 feet higher than the number 1 terrace. Several species of Pleistocene gastropods and pelecypods (described below) were collected from this terrace level.

The present stream channel is the number 1 terrace. It also is a cut terrace. The stream in most places cuts the number 2 terrace silt but in the NE¼ section 5, T. 140 N., R. 65 W. and sections 3, 4, 9, and 10, T. 140 N., R. 64 W. the stream cuts and is controlled by Pierre shale bedrock.

In the SE¼ section 4, T. 140 N., R. 64 W. is a 400 foot wide and 25 foot deep water gap. This gap was formed by the Pleistocene glacial stream (section 34, T. 140 N., R. 64 W. and the northern portion of section 4, T. 140 N., R. 64 W.) which deposited the delta at this place and at one time extended east through this water gap into Pipestem Creek.

Minneapolis Flats Creek Spillway

The Minneapolis Flats Creek is of glacial origin. Its shallow gently-rounded channel with very poor terrace development was carved by glacial meltwaters. This channel, 20 to 30 feet deep and 2000 feet wide, contains much sand and gravel. Boulder concentrations are present at the high levels of the channel. The meanders of this present stream are more restricted in lateral extent than the wide meanders of the James River and the Pipestem Creek. In the central portion of the area where this stream enters the Pipestem Creek, a depositional terrace at the number 2 level is developed. At this place (SW¼ section 26, T. 141 N., R. 65 W.) within the channel of the Minneapolis Flats Creek is a large slump block 800 feet long and 200 feet wide.

It should be noticed in the southwest portion of the lower Pipestem Creek area that all of the Minneapolis Flats Creek Tributary drainage is from the west and at right angles to the north trending main spillway channel. This condition is attributed to the fact that when the ice lobe receded just to the east of the Minneapolis Flats Creek channel, after depositing the Gary terminal moraine, glacial meltwaters pouring off the terminal moraine initiated the east flowing streams on the eastern flank of the Missouri Plateau.

STRUCTURAL GEOLOGY

In a homogenous rock such as shale, removal of the overlying bedrock accounts for a release in overburden pressure and the consequent development of joint sets — collectively termed joint systems. Undoubtedly these joint systems are more prominent near the surface and become less common at depth where the confining pressure increases. The greater percentage of the joint sets measured in the Pierre shale bedrock of this area strike N 5° E and another set strikes S 85° E. The dip of the joints averages 81°. The strike of these joints may be the major controlling factor in the trend of the principle drainage systems of the area. This trend is generally to the north with a slight trend to the northwest.

These joint systems form good avenues for migration of ground water which carries in solution the limonite derived from the ironstone concretions in the Pierre shale.

In the SW¼NE¼ section 5, T. 140 N., R. 64 W. is a 100 foot long zone of Pleistocene conglomerate and sandstone. The number 3 terrace gravel has become cemented with limonite and hematite apparently carried by ground water through the joint systems in the underlying Cretaceous Pierre shale. The process of cementation is still going on in this 5 to 10 foot thick gravel zone which directly overlies the Pierre shale.

PALEONTOLOGY

Pleistocene Fauna

Pleistocene paleontology is a very useful aid in the correlation of the glacial time intervals (ages and subages). Such correlation is not possible at this time because of the small amount of attention paid to the Pleistocene fauna of North Dakota.

Representative Pleistocene gastropods and pelecypods of the lower Pipestem Creek area have been collected and identified. They include from the Class Gastropoda in the Phylum Molusca specimens of: *Amnicola limosa* Say, *Gyraulus* sp., *Physella sayii* Tappan, and *Helisoma antrosa* Conrad. Representatives of the Class Pelecypoda include: *Sphaerium* sp. and *Sphaerium simile* Say (Plate III). Possibly the original species were more wide spread at a time when the stream systems of the region were more continuous than at present.

The only Pleistocene vertebrate fossils found in the area were the vertebrae of a fossil snake, *Thamnophis sp.* Dr. B. H. Brattstrom, California Institute of Technology, Pasadena, California, kindly identified this fossil snake material.

ECONOMIC GEOLOGY

Bentonite

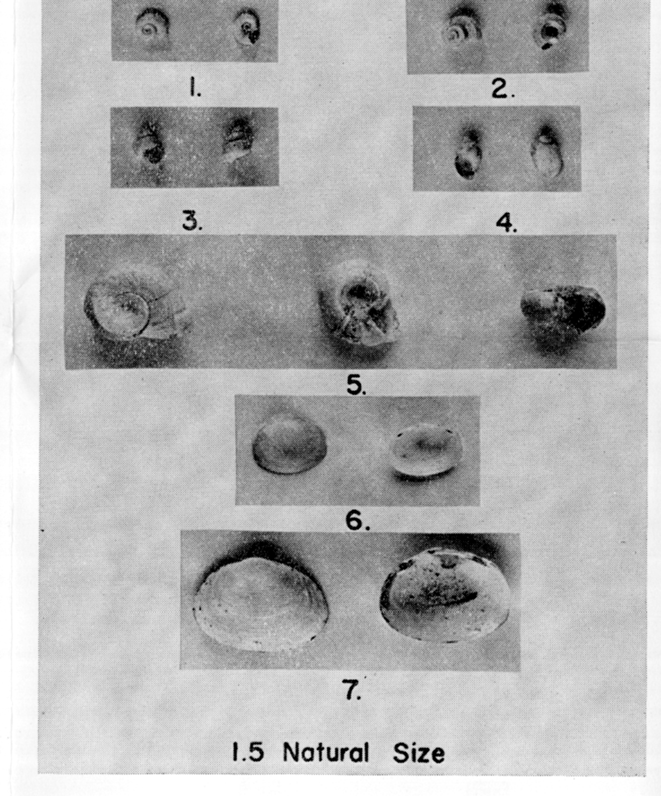
The bentonite of this area occurs in the lower Pierre shale in beds from 0.5 to 5.0 inches thick. A total of five bentonite beds are present in this area. In the James River channel SW¼ section 35, T. 142 N., R. 64 W. eleven feet of shale caps the uppermost bentonite bed and from this location the shale and till overburden progressively thickens westward.

Gravel and Sand

The best commercial deposits of gravel and sand occur in the valleys of the Pipestem and Minneapolis Flats Creeks. These outwash deposits although fit for use as road metal and railroad track ballast, are not used for construction purposes because of the large percentage of shale. Lenses of gravel and sand are good aquifers and thus provide excellent locations for water wells.

Explanation of Plate III

Representative Pleistocene gastropods and pelecypods in the lower Pipestem Creek area, North Dakota.



Class Gastropoda

Figure 1. *Gyraulus* sp.
2. *Valvata bicarinata* Lea.
3. *Amnicola limosa* Say.
4. *Physella sayii* Tappan.
5. *Helimosa antrosa* Conrad.

Class Pelecypoda

Figure 6. *Sphaerium simile* Say.
7. *Sphaerium* sp.

Ground Water

General Statement

That water which exists below the surface of the solid earth is called subsurface water in order to distinguish it from atmospheric or surface water. Soil and rock contain numerous pore spaces or interstices which provide storage spaces for the water which percolates into the ground from precipitation and surface runoff. That part of the subsurface water which is in the zone of saturation is called ground water or phreatic water. The upper surface of this zone of saturation in ordinary permeable soil or rock is the water table. Subsurface water in the zone of aeration above the water table is called suspended subsurface water or vadose water. A rock formation or stratum that will yield water in sufficient suantity to be a source of supply is called an aquifer.

Description and Occurrence of Ground Water

The lower Pipestem Creek area is situated in the Dakota Drift-Cretaceous ground water province. Glacial drift (outwash gravel and clay till) overlies Cretaceous shale and three major types of water wells are present in the area. The most prominent type is the shallow, dug well which pierces outwash sand and gravel or local sand and gravel lenses within the clay till. The wells, including drilled wells, are from 10 to 120 feet deep and yield a grade of water which is suitable for domestic use as well as for livestock. The majority of those wells produce from the main zone of saturation but some, especially those in the terminal moraine of the western portion of the area, yield from perched zones of saturation in sand and gravel lenses within the impermeable clay till. This perched water table is sometimes marked by the water level of some of the kettle lakes and kettle chains in the area.

The second type of well includes those wells which produce from the sand and gravel zone at the glacial drift-shale contact. These wells are generally from 120 to 300 feet deep and also yield a grade of water that is suitable for both domestic and stock uses.

The third type of well yields a grade of water usually acceptable only for stock and produces from sand lenses within the Cretaceous shale. These wells are from 130 to 450 feet deep.

The major portion of the water table wells in this area are situated in the deposits of ground moraine and recessional moraine. They include the shallow and deep wells in the sand and gravel lenses within the till. Wells situated in outwash areas and spillway channels are generally shallow and also yield ground water from sand and gravel aquifers. In the rugged terminal moraine area the wells are generally deep — usually from 130 to 450 feet and produce from the sand zones within the shale bedrock. The quality of this water is unsatisfactory for domestic use because of the relatively high saline content. Chemical analysis of the water in this area were not made but from interviews with the occupants of the farms it was found that most wells contain water with a high iron and calcium content.

Only two artesian wells are known in the area and are used both domestically and for stock. A number of springs are present in the northeast portion of the area at the till-shale contact in the James River valley. The flow of these springs is very small, however some supply enough water for livestock.

See tables VI, VII, and VIII for records and data of wells in this area. Plate II illustrates the water table in the area contoured at a 50 foot interval. In general it may be noted that this water table reflects the topography of the area.

Well Numbering System

The well numbering system used in this report (Table VI) is in agreement with that system used by the United States Geological Survey in their North Dakota Ground-Water Studies. "The first number is that of the township north of the base line which extends laterally across the middle of Arkansas. The second number is that of the range west of the fifth principal meridian. The third number is that of the section within the designated township. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections, depending on their position in the well number." Thus well 140-64-31 acd is in the SE¼ SW¼ NE¼ section 31, T. 140 N., R. 64 W.

GEOLOGIC HISTORY OF THE AREA

Sequence of Events

At the start of the Laramide Revolution in upper Cretaceous time, deposits of clay accumulated in the Cretaceous seas and were later indurated to form the Cretaceous shale deposits. Vulcanism in western United States accompanied by epeirogenic uplift accounted for the deposition of volcanic ash during the accumulation of the first few beds of the Pierre shale. As the Cretaceous seas regressed to the northwest and southwest, near-shore deposition of sand, which later developed into the Fox Hills sandstone, signified the final deposition of marine sediments in the last major marine inundation of the area. The deposition of the continental Hell Creek beds closed the Cretaceous period.

In this semi-arid area in which epeirogenic uplift was taking place, erosional processes were at work in sculpturing the shale and sandstone into a badland topography in early Tertiary time. Development of the Pipestem Creek and James River channels was in its early youth at this time. By late Pliocene time the weathered shale and sandstone surface awaited the advance of the first or Nebraskan ice sheet. This sheet and the Kansan and Illinoian which followed, reworked the surface of this mature topography and transformed some weathered materials into sand and clay tills.

As conditions for wastage of the glacier became more exaggerated, the front of the ice sheet receded to the east and paused a few miles west of the James River channel. At this time, glacial meltwaters poured out millions of cubic yards of outwash to the west of the ice front plugging the wide pre-glacial Pipestem Creek channel. Contemporaneous with this deposition, meltwaters from the saturated clay till mass of the Gary terminal moraine were flowing to the east of the moraine, thus forming a glacial stream —the Minneapolis Flats Creek spillway and resulting outwash deposits. The ice lobe again re-advanced upon the area eroding in places the crudely stratified outwash materials and then upon recession, blanketed the eroded outwash unconformably with a thin mantle of clay till.

Constant retreat by ablation was due to decreased amounts of precipitation and increased solar radiation. Glacial meltwaters, rushing in torrents from the ice front, found the path of least resistance in the outwash choked channel of the Pipestem and by exhuming the channel, constructed the delicate system of terraces now present in that channel.

TABLE VI

Records of Wells in the Lower Pipestem Creek Area.

Location Number	Owner or Name	Depth of Well (feet)	Depth to water level feet below land surface	Use of Water D. = domestic S. = stock	Aquifer
139-64					
4bba	Wallace Pendroy	18	10	D. S.	Sand
6bbc	D. Lawrence	36	25	D. S.	Clay
9aaa	Ray Sahr	90	30	D. S.	Sand
139-65					
2aba	Ed Rosnav	37	30	D. S.	Sand and Gravel
2baa	Wm. Wahl	100	60	D. S.	——
4daa	Art Schutt	22	10	D. S.	——
7aaa	Lompkins	310	30	D. S.	Shale
10aaa	Herman Wagenke	321	40	D. S.	——
10bbb	R. J. Lippert	118	40	D. S.	Gravel
11baa	Richard Baldwin	250	175	D. S.	Sand
139-66					
1aaa	R. Wanzk	300	45	D. S.	——
2acd	F. Sikel	285	20	D. S.	Gravel
2bca	——	180	50	——	——
2cac	J. Stroh	290	60	D. S.	Sand
10aaa	J. Schroeder	280	60	D. S.	Sand
11aaa	Carl Kunze	285	80	D. S.	Shale
140-64					
5aac	G. Hartvikson	200	100	D.	Shale
7cdd	——	30	26	——	——
8bbc	Fred Bortcher	105	90	D. S.	Sand
9dda	Ade Roeszler	14	10	D.	Sand
9dda	Ade Roeszler	8	4	S.	Sand
17ddd	Joe Crimes	140	130	D. S.	Shale
18aad	Art Perleberg	165	85	D.	Sand
18dda	Art Reile	33	28	S.	Sand
19ddd	Ed Kehl	91	30	D. S.	Sand
20ddd	Art Reile	29	23	D.	Sand and Gravel
21cdd	Mrs. Con Jensvold	35	20	D. S.	——
21cdd	Mrs. Con Jensvold	24	14	D.	——
21dcd	Chris Trautman	175	140	D. S.	Sand
21dcd	Chris Trautman	30	24	S.	——
28bad	Frank Flecther	34	26	——	Gravel
28bad	Frank Flecther	34	30	D. S.	Sand
29cdd	D. H. Devitch	35	22	D.	Gravel
29cdd	D. H. Devitch	32	22	D. S.	Gravel
31aad	B. L. Sagaser	120	115	D. S.	——
33dcd	Odin Aus	26	13	D. S.	Sand
140-65					
2bdb	Vern Wahl	160	80	D.	Shale
2bdb	Vern Wahl	130	123	S.	Sand
2dad	John H. Winberg	25	20	D. S.	——
3abd	Bernard Wagner	167	80	D. S.	Shale
3daa	W. C. Fairfield	160	80	D. S.	Shale
140-65					
4bbd	Mrs. W. Lange Sr.	45	13	D. S.	——
6add	Bill Bennett	133	40	D. S.	Shale
6ccc	August Robyt	160	70	D. S.	Sand
8aac	Ed Schnuhl	45	10	D. S.	Gravel
9dca	Walter Schutt	198	30	D. S.	Shale
10add	Aaron Sorisen	80	70	S.	Sand
12aac	——	29	29	——	——
12ccb	Walter Perleberg	48	35	D. S.	Sand
13ccc	Ernest Schutt	70	48	D. S.	Shale
15dad	Ed Tone	180	160	D. S.	Sand
16dcd	W. F. Schutt	235	30	D. S.	Shale
20dcd	Walt Miller	80	25	D. S.	Gravel
21dcc	R. Clemens	15	13	S.	Sand
22bab	John Retzer	25	16	S.	Sand
22daa	George Hoffman	160	130	D. S.	Gravel
24dcd	John Mammen	180	30	D. S.	Sand
25ccc	Art Wolf	150	50	D. S.	——
26cdd	John Fairfield	180	30	D. S.	Shale
27daa	William Foesch	170	30	D. S.	Shale
28dcd	Richard Olgabee	17	14	D. S.	Gravel
30cdd	Ben Job	244	150	D. S.	——
34aaa	Anna Bawer	180	30	D. S.	——
36cbd	J. Miller	40	15	D. S.	Sand
36ddc	Charles Lawrence	32	20	S.	Clay
140-66					
1cdd	——	28	22	——	——
10dcc	John Zimmer	280	180	D. S.	Gravel
11acc	Walter Pharr	232	212	D. S.	Shale
140-66					
11ddb	Alvin Pharr	185	155	D. S.	Shale
12cad	Alfred Pharr	180	80	D. S.	Shale
22adc	——	280	80	D. S.	Shale
24adc	Erwin Meuller	40	15	——	Gravel
24bbc	J. C. Anderson	220	100	D. S.	Shale
24ccd	Carl Kunze	285	80	D. S.	Shale
35dcd	R. Woddell	450	25	D. S.	Shale
141-64					
4abc	Ard Rugarson	34	32	D. S.	Gravel
4abc	Ard Rugarson	130	60	S.	Shale
6daa	Schaff Brothers	50	40	S.	Gravel
6daa	Schaff Brothers	215	120	D.	Shale
6daa	Schaff Brothers	254	120	S.	Shale
8baa	Wilson Brothers	205	125	D. S.	——
9bbc	Sorenson	160	70	D.	——
17ccc	Samettarr	245	90	D.	Shale
18bad	H. Holzworth	40	30	D. S.	——
18bad	H. Holzworth	160	60	D. S.	Sand
19ddd	J. H. Knobel	246	65	S.	Shale
19ddd	J. H. Knobel	200	60	D.	Shale
20bcb	F. Hadersite	300	100	S.	——
21adc	Hennings	135	40	D. S.	——
21bab	R. McKeen	150	110	D. S.	Shale
22ddb	T. Telken	180	80	D. S.	Shale
23bdc	Dunphy	212	70	D.	Shale
27bda	R. Jeske	185	125	D. S.	Shale
27bda	R. Jeske	160	120	D. S.	Shale
28ada	Harry Sabinash	134	22	D. S.	——
30aad	G. H. Knobel	275	65	D.	Shale
141-64					
32ccc	Walter Maas	18	16	D.	Sand
32ccc	Walter Maas	20	10	S.	Sand
141-65					
2bcc	Elsie Brausch	36	21	S.	——
2caa	Anna Limesand	30	16	S.	Sand
2caa	Anna Limesand	185	160	S.	Shale
3ccc	Art A. Miller	125	65	D. S.	Shale
4aab	Robert Leslie	30	25	D. S.	Gravel
6cdd	Floyd Frederick	330	150	D. S.	Shale
7acd	Floyd Frederick	195	145	D.	Sand
8bab	Carl Smith	152	92	D. S.	Sand
12dbb	C. C. Russell	25	20	S.	Shale
14ada	E. Ova	125	115	——	Sand
14ada	E. Ova	65	30	D. S.	Sand
17bbc	Donald Bear	190	150	D. S.	Sand
21cdd	Hans Anderson	13	7	S.	——
22cca	Martin Kruger	18	5	S.	Sand
22cca	Martin Kruger	28	24	D.	Sand
24ada	R. Pfaff	180	90	D.	——
25adc	——	183	85	——	Sand
26acd	Marvin Limesand	180	20	D. S.	——
26bbb	School No. 1	29	9	D.	——
27adb	Herman Prahl	29	11	D.	Gravel
27bdb	Rudy Perleberg	26	19	D. S.	——
28dcd	——	10	6	S.	——
29add	Alva Perleberg	185	15	D. S.	Sand
30bad	John Aaby	5	0	D.	——
33cdd	Bill Bennett	125	40	D. S.	Sand
34dcd	Fred Lange	42	13	D. S.	——
35ccd	H. M. Wagner	150	25	D. S.	Shale
141-66					
1aaa	Henry Boyle	210	180	D. S.	Shale
12aab	Phil Nagel	285	185	S.	——
12aab	Phil Nagel	30	25	——	——
24acb	Ervan Purcell	225	150	D.	Shale
26aaa	A. G. Walsh	300	240	D. S.	——
142-64					
12cdc	Mike Plenski	8	5	D. S.	Shale
18ccc	Rosenbaun	140	120	D.	Shale
18ccc	Rosenbaun	150	100	S.	Shale
18ddd	Neys	18	9	D.	Gravel
18ddd	Neys	400	90	S.	——
19aaa	Louis Neys	133	83	S.	Shale
22abd	J. L. Kurtz	45	22	S.	Shale
22abd	J. L. Kurtz	65	22	D.	Shale
23acc	Rudnick	153	70	D.	Shale
23acc	Rudnick	19	10	S.	Gravel
28ccd	T. M. Pitts	137	30	D.	Shale
30cdd	John Leimer	160	130	D. S.	Shale
32add	A. Rutkerson	130	70	S.	Shale
32add	A. Rutkerson	180	65	D.	Shale
32bcc	E. Campbell	180	60	D. S.	Shale
33cda	W. Bitterman	130	30	D. S.	Shale
33cda	W. Bitterman	30	12	D. S.	Gravel
34bca	Thomas H. Falck	180	50	D.	Shale
34cac	C. Schuler	150	36	D. S.	Shale
142-65					
15dac	Floyd Barthell	23	16	D. S.	——
16dad	Mrs. Bertha Noh-lemberg	130	120	D.	——
17aaa	John Kulink	18	15	D. S.	Gravel
20baa	N. Oster	20	13	S.	——
22cdd	Harold Andres	70	45	D. S.	Shale
24daa	S. Blaskowski	39	29	D.	Sand
25ddd	C. C. Russell	150	75	D. S.	Sand
25ddd	C. C. Russell	25	20	S.	Shale
32dad	Ida Jokumsen	150	100	D. S.	——
35cda	Elsie Bransch	220	100	D.	Sand
36daa	Johnson	220	75	D. S.	Shale
142-66					
13cbc	Ben Divine	30	20	D. S.	Sand
24dab	Tom Foster	180	100	S.	Sand
26aab	Arnold Krapp	9	1	D. S.	——

TABLE VII

Depth of Wells in the Lower Pipestem Creek Area

Depth to bottom of well	Number of Wells In— Ground Moraine	Recessional Moraine	Terminal Moraine	Spillways	Outwash
0′- 20′	7	0	1	8	1
21′- 40′	19	9	1	7	1
41′- 60′	3	2	0	1	0
61′- 80′	1	3	0	2	0
81′-100′	0	3	0	0	0
101′-150′	15	6	0	0	4
151′-200′	22	12	3	1	0
201′-250′	6	6	2		0
251′-300′	2	5	7		0
300′	2		1		1
TOTALS	77	46	15	19	7

TABLE VIII

Depth to Water Table of Wells in the Lower Pipestem Creek Area

Depth to Water Table	Number of Wells In— Ground Moraine	Recessional Moraine	Terminal Moraine	Spillways	Outwash
0′- 20′	18	6	1	12	2
21′- 40′	30	11	2	5	1
41′- 60′	5	4	3	1	0
61′- 80′	9	8	3	0	0
81′-100′	7	5	0	0	3
101′-150′	6	11	2	1	1
151′-200′	2	1	2		
201′-250′			2		
251′-300′					
300′					
TOTALS	77	46	15	19	7

BIBLIOGRAPHY

Bell, G. L., Unpublished report, 1954.

Brattstrom, B. H., Correspondence, October 7, 1955.

Chamberlain, T. C., Preliminary paper on the terminal moraine of the second glacial epoch: U. S. Geol. Survey 3rd Ann. Rept., 1883.

Flint, Richard Foster, Glacial geology and the Pleistocene epoch: John Wiley and Sons, Inc., New York, p. 127, 1953.

Forbes, Edward, On the connexion between the distribution of the existing fauna and flora of the British Isles, and the geological changes which have affected their area, especially during the epoch of the Northern Drift: Great Britain Geol. Survey Mem., vol. 1, 1846.

Hendricks, T. A. and Laird, W. M., The manganese deposits of the Turtle Mountains, North Dakota: N. D. Geol. Survey Bull. 15, Reprinted from Economic Geology, vol. XXXVIII, no. 7, November, 1943.

Kresl, R. J., Geology of the Eldridge quadrangle, North Dakota: The Compass of Sigma Gamma Epsilon, vol. 32, no. 2, January 1955.

Laird, W. M., Stratigraphy and structure of North Dakota: N. Dak. Geol. Survey Bull. 18, 1944.

Leonard, A. G., Stratigraphy of North Dakota clays: N. Dak. Geol. Survey 4th Bienn. Rept., 1906.

Lyell, Charles, Elements of geology, French translation, appendix, Paris, 1939.

Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water Supply Paper 489, 1923.

Paulson, Q. F., Geology and occurrence of ground water in the Streeter area, Stutsman, Logan, and Kidder Counties, North Dakota: N. Dak. Ground-Water Studies No. 20, 1952.

Spector, I. H., Manganese deposits of the Riding Mountain area, Manitoba: The Pre-Cambrian, July 1941.

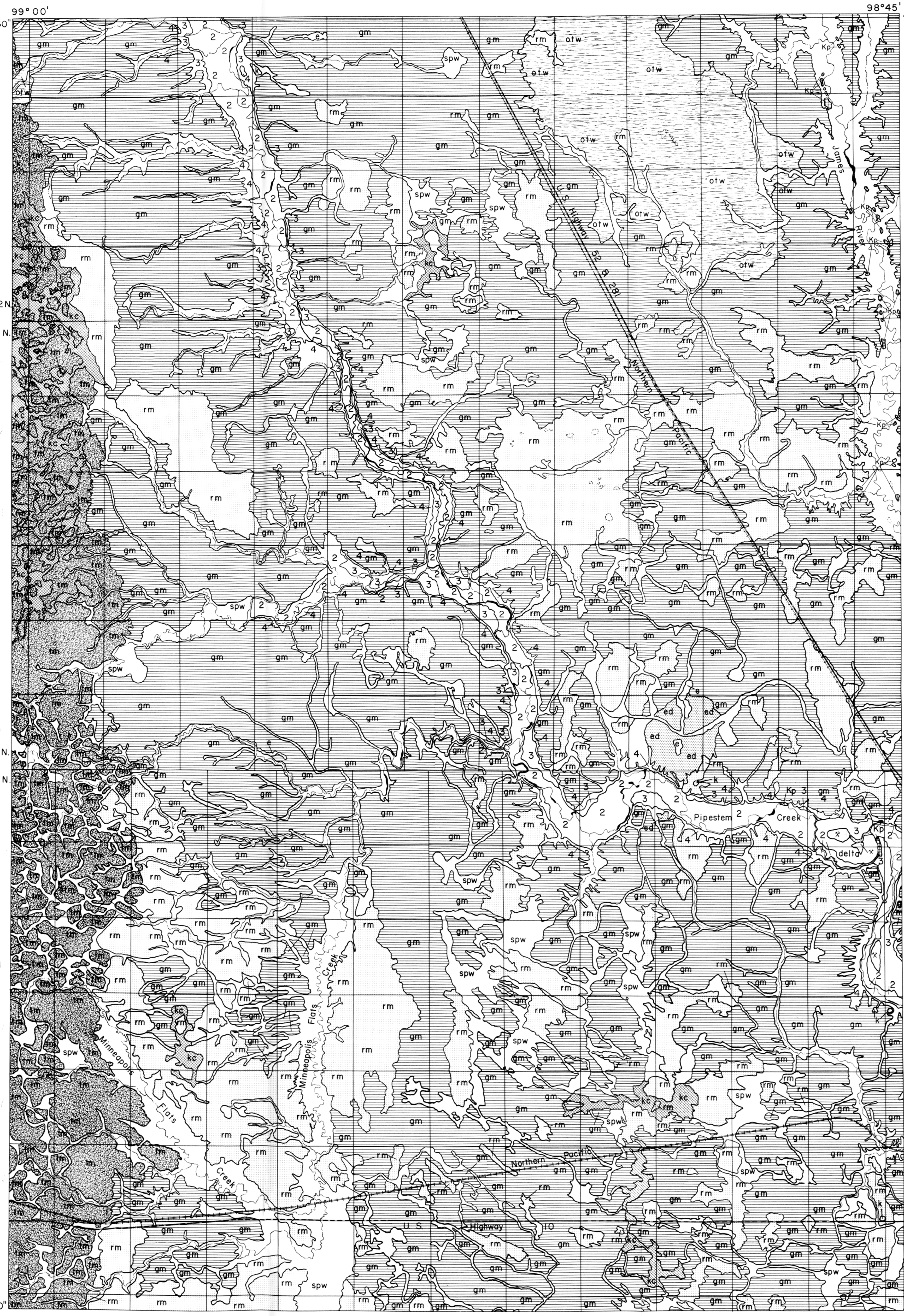
Todd, J. E., The moraines of the Missouri Coteau and their attendant deposits: U. S. Geol. Survey Bull. 144, 1896.

Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1895.

Willard, D. E., U. S. Geol. Survey Atlas, Jamestown-Tower folio (no.168), 1909.

Wilmarth, M. G., The geologic time classification of the United States Geological Survey compared with other classifications: U. S. Geol. Survey Bull. 769, 1925.

PLATE I



99°00' R.66 W. R.65 W. R.65 W. R.64 W. 98°45'

Base map from U.S.G.S. quadrangles
Ronald J. Kresl

SCALE 1 1/2 0 1 mile

NORTH DAKOTA
Area location

Geology by Ronald J. Kresl, Ray Huot, Edward Flewitt, George A. Green, and Jay Garske.

Field seasons 1954 & 1955.

EXPLANATION

Alluvium — Sediments along present streams. (Recent)

2 — Terrace number 2 — Cut terrace in stratified sand and silt

3 — Terrace number 3 — Cut terrace in cross-bedded sand and gravel

4 — Terrace number 4 — Cut terrace in glacial till.

Delta deposits — Cross-bedded sand and gravel at the terminus of the esker.

(TERTIARY; Wisconsin, Pleistocene)

k — Kame deposits — Mounds of stratified sand and gravel.

e — Esker deposits — Glacial stream deposits of stratified gravel, sand, and silt.

spw — Spillway — Glacial drainage channels.

kc — Kettle chain — Depressions, elongated and subangular.

tm — Terminal moraine

(TERTIARY; Wisconsin, Pleistocene)

rm — Recessional moraine

gm — Ground moraine

otw — Outwash — Glacial stream deposits of stratified and cross-stratified gravel and sand.

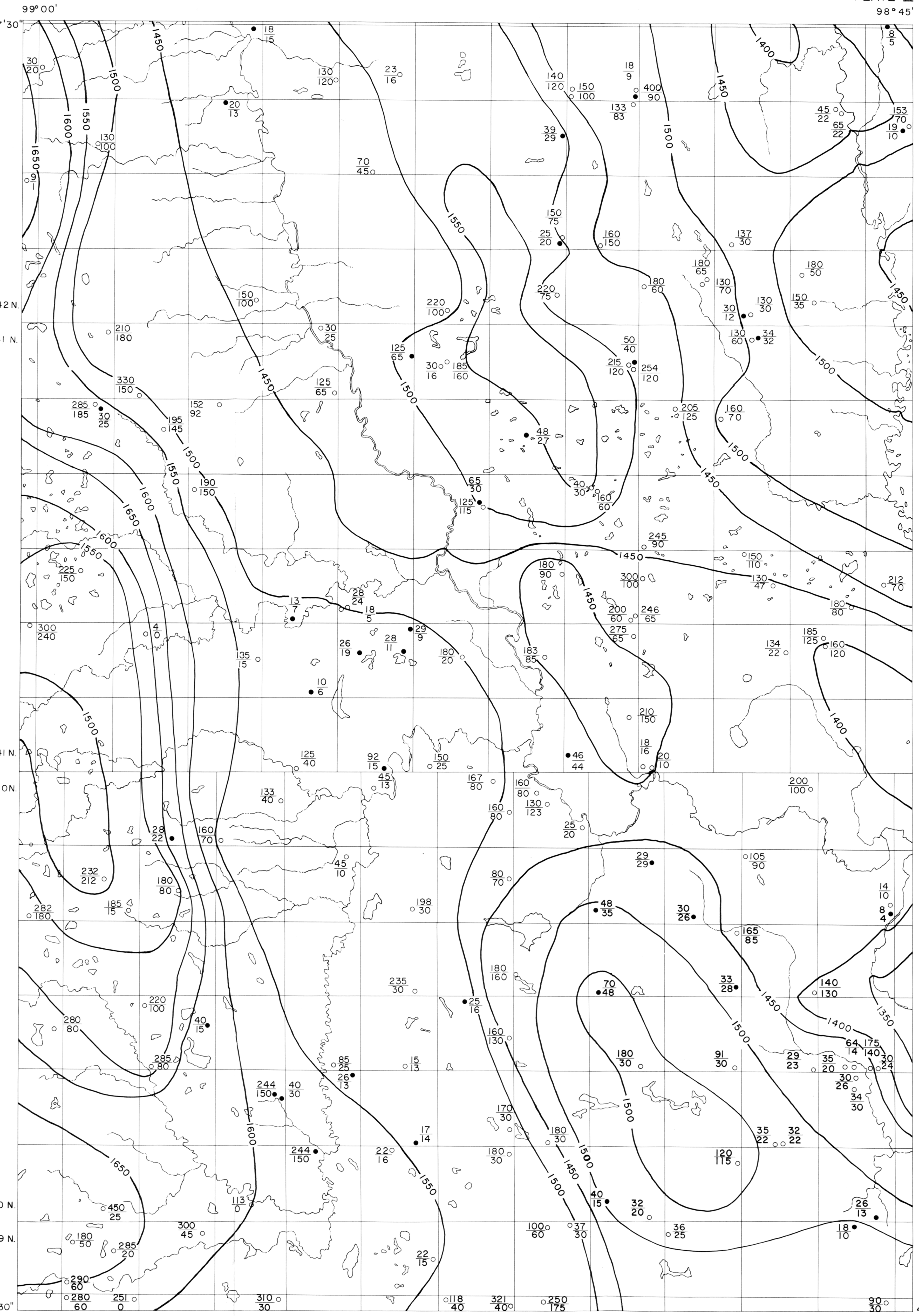
(TERTIARY; Wisconsin, Pleistocene)

Kp — Pierre shale — Shale, gray to blue-black, thin bedded with some interbedded sandstone. (CRETACEOUS)

Gravel pit

GEOLOGIC MAP OF THE LOWER PIPESTEM CREEK AREA, NORTH DAKOTA

PLATE II



99°00' R.66 W. R.65 W. R.65 W. R.64 W. 98°45'

Ronald J. Kresl
1955

0 1 2 Miles

EXPLANATION

● 244/150

Upper number (244) indicates depth of well. Lower number (150) indicates depth to water. Darkened circle (●) signifies a measured well. Open circle (○) signifies reported data.
Contour interval 50 feet. Datum sea level.
Contours are drawn on the ground water table.

PIEZOMETRIC MAP OF THE LOWER PIPESTEM CREEK AREA, NORTH DAKOTA

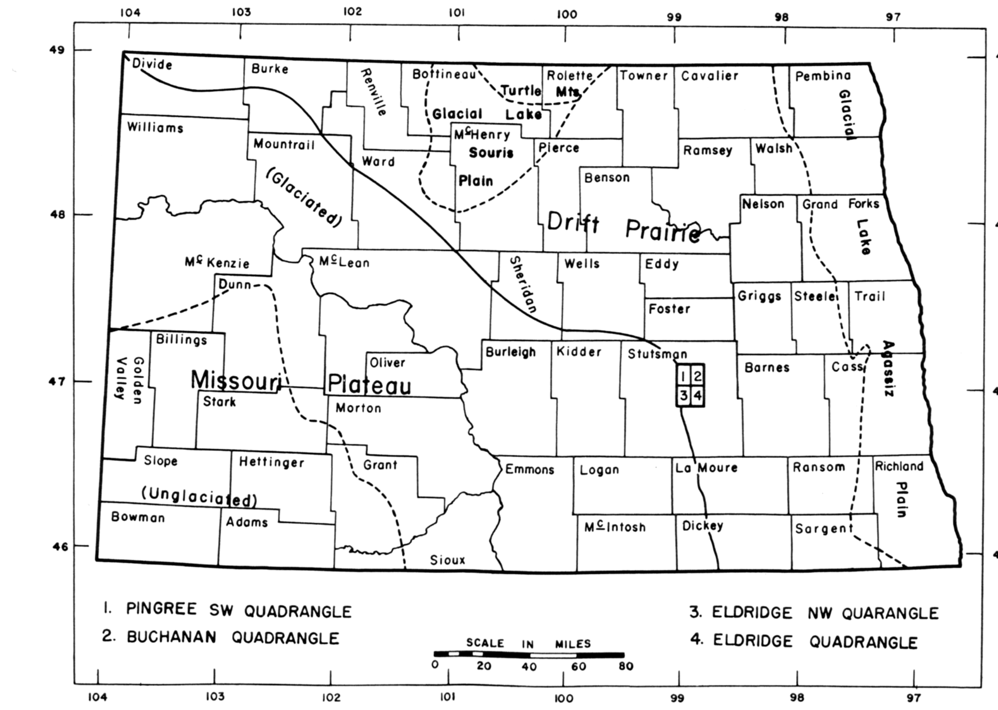


FIGURE 1 LOCATION OF LOWER PIPESTEM CREEK AREA

TABLE IV

Size analyses histograms of fluvial and eolian deposits in the lower Pipestem Creek area.

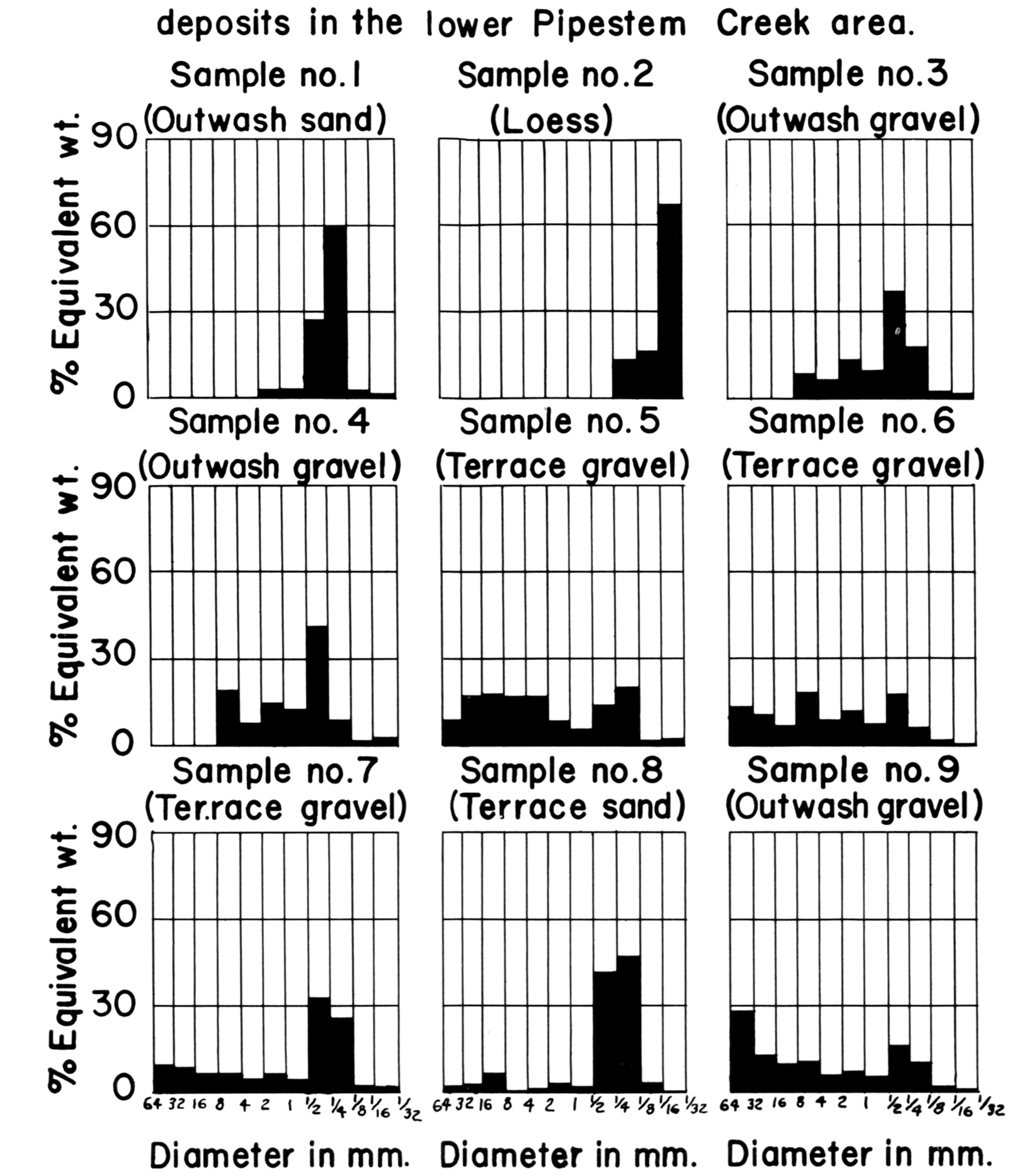


TABLE V

Composition analyses histograms of outwash gravel in the lower Pipestem Creek area.
(Includes all particles greater than 8 mm. in diameter)