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The Geology

of the

Tokio Quadrangle

By

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Geology of the Tokio Quadrangle

by

DAVID G. EASKER

INTRODUCTION

Abstract

An extensive examination of the glacial geology of the Tokio quadrangle was made and the features observed were mapped in detail. The glacial features consist of a set of recessional moraines and their respective belts of outwash. Other glacial deposits present are ground moraine, eskers, crevasse fillings, kames and lake deposits. The gravel resources of the area were determined and are indicated on the geologic map. Ground water conditions were studied and their relations to the glacial geology of the area are cited.

Location of the Area

The Tokio quadrangle is located between 98° 45′ and 98° 00′ north latitude. (Fig. 1). It is situated, for the most part, in Benson and Eddy counties with only very small areas in the northwest and northeast corners located in Ramsey County. (Plate I). The shore of Devils Lake forms the Benson-Ramsey county line, and only those portions of the lake known as Fort Totten Bay, in the northwest corner, and Black Tiger Bay, in the northeast corner, are included in Ramsey county. Mission Bay, which is no longer a part of Devils Lake, is in Benson County. Hillsdale and Wood Lake townships are included within the quadrangle, and the townships of Eddy, Warwick, Lohnes, Bush and Twin Tree are partly included. The quadrangle is approximately 14 miles in an east-west direction by 17½ miles in a north-south direction, embracing an area of approximately 205 square miles.

Purpose of the Survey

During the past few years the North Dakota Geological Survey has organized investigations as a part of a program to obtain geologic information on certain important areas. Recent attention has been focused on the Tokio quadrangle and adjacent areas because of their significance in the present Missouri River development program. The Bureau of Reclamation has recently re-surveyed the Sheyenne River Valley and has proposed a dam at some point on the river within the boundaries of the quadrangle. Investigations have been completed and others are now under way by the Survey to obtain as much information as possible concerning these vital areas.[1]

This investigation was made to provide a detailed map of the geology of the Tokio quadrangle, to examine ground water conditions and their relation to glacial geology, and to determine the gravel resources of the area. A topographic map of the quadrangle, as surveyed by the United States Geological Survey, was used as a base map. The topography is shown on this map by 20-foot contour lines so that most of the minor topographic features are well represented. A general reconnaissance of the area by car was followed by detailed mapping of all geologic features on foot. (Plate II). A detailed study was made of all types of glacial deposits and boundaries. The contacts, where not visible on the surface, were determined by the use of a soil auger equipped with a three foot extension which made it possible for soil samples to be taken to a depth of eight feet. All well data were recorded on special well schedule sheets supplied by the Ground Water Division of the United States Geological Survey. All of the wells were measured personally as to total depth and water level except in cases where they were permanently covered, were too deep to be measured, or were impossible to measure as in the case of sand point or driven wells. In such cases the word of the farmer was taken and was so indicated on the data sheet.

Previous Work in the Area

In the past this area has received attention only in a very superficial manner. Most of the studies made have been regional. Of all previous work, that of Howard E. Simpson,[2] former State Geologist of North Dakota, ranks first. Simpson's report deals with the general physical features in the immediate vicinity of Devils and Stump Lakes and explains

[1] Branch, John R., Geology of the Flora quadrangle, North Dakota Geol. Survey Bull. 22, 1947.
Tetrick, P. R., Glacial geology of the Oberon quadrangle: North Dakota Geol. Survey Bull. 23, 1949.

[2] Simpson, H. E., Physiography of the Devils-Stump Lake region: North Dakota Geol. Survey 6th Bienn. Rept., pp. 101-147, 1912.

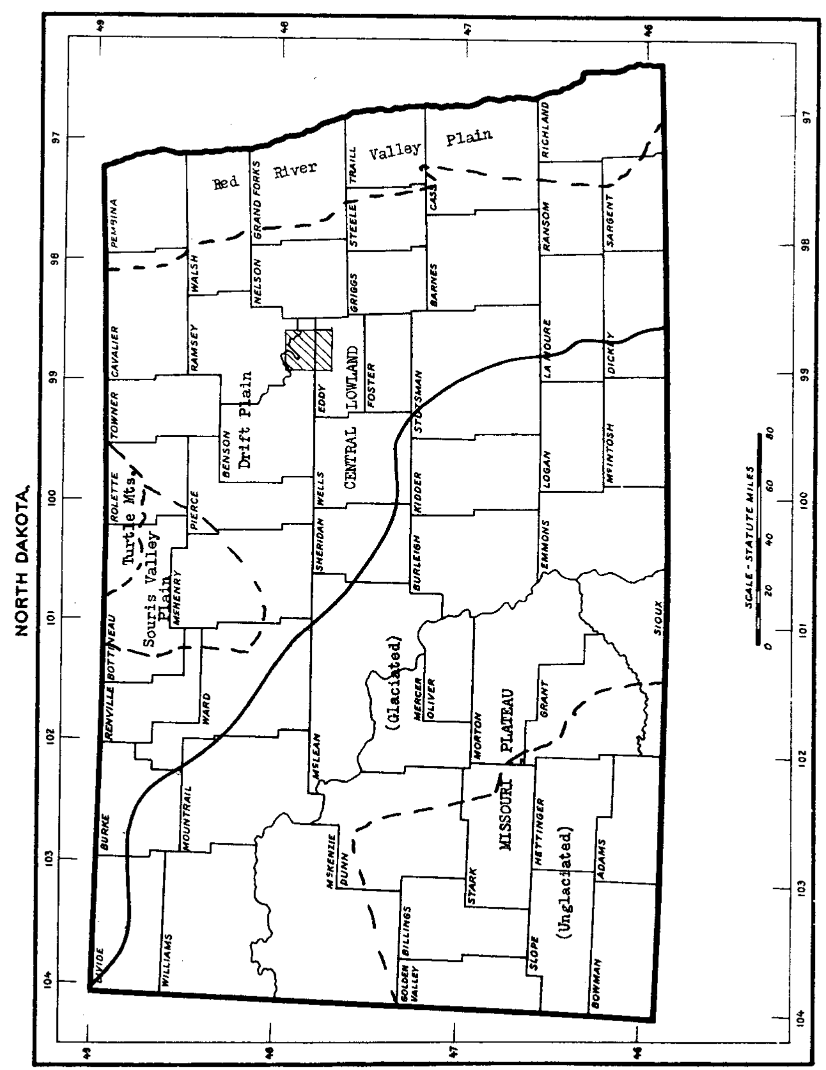

Figure 1. Sketch map showing location of the Tokio Quadrangle.

their origin and geographic relations. He has also compiled considerable information on the ground water conditions in this area for the Ground Water Division of the United States Geological Survey.[3]

Warren Upham[4] in his Monograph on Glacial Lake Agassiz mentions briefly some of the more prominent geological features in the area. Upham also refers to early workers and explorers who passed through this area and published their findings.

E. J. Babcock,[5] formerly Chief Chemist for the North Dakota Geological Survey, gathered considerable information on the surface and shallow water supplies of the "Devils Lake Drainage Basin."

Recently John R. Branch and P. R. Tetrick have completed detailed studies on the Flora and Oberon quadrangles which are immediately adjacent to the Tokio quadrangle to the west.[6]

Acknowledgements

The writer wishes to express his appreciation to Dr. A. C. Trowbridge for his helpful advice and criticism in preparing this paper. Dr. Wilson M. Laird, State Geologist of North Dakota, suggested the area and also extended many courtesies such as maps, field equipment, and valuable information in the field.

GEOGRAPHY

Regional Topography

The Tokio quadrangle lies within the limits of the Western Young Drift Section of the Central Lowland.[7] (Fig. 1). The region is generally one of moderate relief. Its distinguishing features are those of young glacial drift, mainly moraines, lakes, and lacustrine plains. The youthful glacial drift overlies, in most places, a glacially-eroded bedrock surface.

[3] Simpson, H. E., Geology and ground water resources of North Dakota: U. S. Geol. Survey Water Supply Paper 598, pp. 71-76, 127-129, 1929.
[4] Upham, Warren, Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, pp. 157-173, 1896.
[5] Babcock, E. J., Water resources of Devils Lake region: North Dakota Geol. Survey, 2nd Bienn. Rept., pp. 206-250, 1902.
[6] Branch, op. cit.
Tetrick, op. cit.
[7] Fenneman, N. M., Physiography of Eastern United States: pp. 559-568, New York, McGraw-Hill Book Co., 1938.

Local Topography

The area ranges from 1740 feet above sea level at Sullys Hill (Section 14, T. 152 N., R. 65 W.) to less than 1400 feet on the present flood plain of the Sheyenne River (Section 30, T. 150 N., R. 63 W.) (Plate I). The average relief is approximately 150 feet. The present topography is the result of deposition of a series of recessional moraines during Wisconsin time on what was probably a gently rolling erosion surface carved in nearly hotizontal Upper Cretaceous rocks. Subsequent erosion and deposition by the Sheyenne River and its many tributaries have since modified the original glacial features by developing a valley in the drift plain to an average depth of 135 feet.

Within the area are two distinct recessional moraines which are joined in the vicinity of Horseshoe Lake. (Plate II). Both are eastward extensions of Branch's North Viking and Heimdal moraines.[8] The North Viking moraine on the north and the Heimdal moraine on the south consist of typical knob and sag topography containing numerous small lakes and marshes.

Directly south of the North Viking moraine is an extensive belt of outwash material from 9 to 12 miles long and from 2 to 6 miles wide. This belt is definitely of the pitted outwash type, and contains an extinct glacial spillway called Seven Mile Coulee. The coulee extends from the base of Sullys Hill, in the northwest corner of the quadrangle, southward to the Sheyenne Rive a distance of approximately 7 miles.

The outwash belt of the Heimdal moraine, a portion of which is located in the southwest corner of the quadrangle, is topographically unlike the outwash belt described above. This belt is approximately 6 miles wide and extends beyond the southern boundary of the area. It is conspicuously flat with little or no relief.

Scattered ground moraine deposits are located in various places within the area and are characterized by very gently rolling surfaces of low relief. The main concentration of ground moraine is located in the northeast corner of the quad-

[8] Branch, John R., op. cit., page 6.

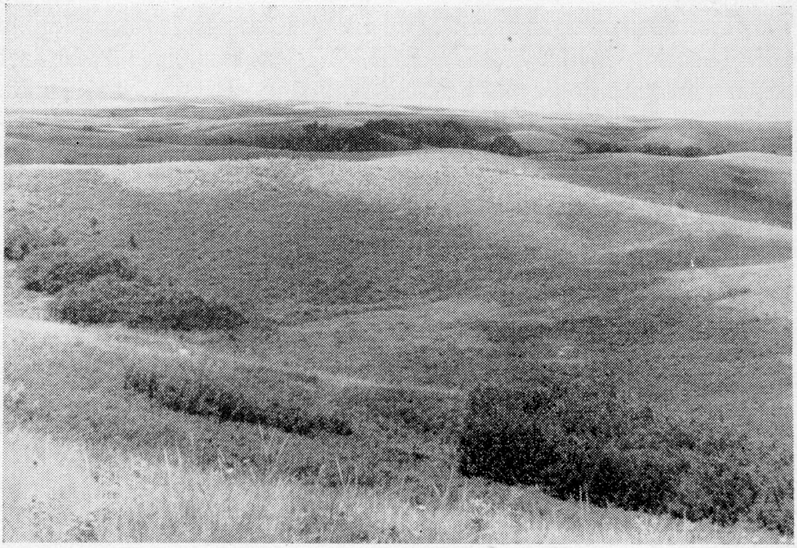

Figure 2. Knob and Sag Topography.
Section 4, T. 151 N., R. 65 W.

rangle. Here the swell-and-swale topography is slightly modified by the lacustrine clays, silts, and beach gravels of Glacial Lake Minnewaukon.[9]

Drainage

The Tokio quadrangle drains for the most part into the Sheyenne River either by intermittent surface flow or by underground seepage through the outwash gravels and till. The drainage of today is only a minute remnant of the drainage system which existed here during Wisconsin time. The great depth of the Sheyenne River Valley and its tributaries indicates that large quantities of melt water were discharged from the glacier when it stood along the North Viking moraine. At present the Sheyenne River maintains a year-round surface flow, except in extremely dry years. Most of this flow is supported by seepage springs from the gravel-filled glacial channels leading to the river. The source of the Sheyenne River is at Jones Lake in east-central Sheridan County, North

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[9] Simpson, H. E., Physiography of the Devils-Stump Lake region: North Dakota Geol. Survey 6th Bienn. Rept., page 110, 1912.

Dakota. The stream flows eastward passing about 10 miles south of and parallel to Devils and Stump Lakes after which it flows southward for 100 miles and enters the Lake Agassiz basin. From here it turns northeastward and enters the Red River approximately 10 miles north of Fargo.

Approximately 10 miles south of the Sheyenne River, and roughly parallel to it, is the James River which is part of the Mississippi River drainage system. Between the James and Sheyenne rivers the Heimdal moraine is the continental divide separating the Hudson Bay drainage from the Gulf of Mexico drainage.

Numerous kettle hole lakes in the recessional moraine areas receive the run-off from the land immediately adjacent. Comparatively little water enters the lakes in this way because the subsoil of glacial till is relatively porous and therefore favors absorption rather than run-off.

Devils Lake has been receding continuously for a long period of time. The water is probably disappearing by evaporation, and in times of normal rainfall the evaporation exceeds precipitation.

PRESENT DEVELOPMENT OF THE AREA

Agriculture

The area included in this quadrangle is almost entirely devoted to agriculture, either crop farming or grazing. Crop farming is most general over the whole area except for the more rugged portions of the recessional moraine and the flood plain of the Sheyenne River which are suitable only for the grazing of cattle and sheep. Much of the land in the quadrangle lies idle and is grown up in sage brush and prairie grass.

Communications

The Great Northern Railroad serves the area with a branch line which runs northwest-southeast across the northeast quarter of the quadrangle. State Highways 20 and 57 made access to the area from Devils Lake city relatively easy. Thus a combination of the State Highways, county roads, and numerous graded and gravel-surfaced township and section roads form an adequate network connecting all points of the area.

Resources

The principal resource of the area consists of the fertile soil which is devoted primarily to raising wheat, rye, and some flax.

Gravel deposits are abundant within the quadrangle and may conveniently be divided into three types on the basis of origin, namely outwash gravels, gravels of eskers and crevasse fillings, and kame gravels. All pits that have produced are marked on the geologic map.

Ground water in the Tokio quadrangle may be classified into three types, (1) occurrence in till, (2) occurrence in outwash belts, and (3) occurrence in seepage springs.

Climate

This area is part of the region having what is known as a Humid Microthermal climate with a short summer phase.[10] This is sometimes known as the "spring wheat country" because the wheat crop reaches its best development during the more arid phase of the climatic cycle. There is a relatively short growing season, varying from three to five months, but this is offset by the long duration of daylight which is always present in high latitudes. Precipitation is generally less than 25 inches, most of it falling as rain in the early part of the summer.

There is no weather station in the Tokio quadrangle. However, statistics on precipation are available for Devils Lake and McHenry, short distances north and southeast of the area.[11] For precipitation data reference should be made to Tables I and II which are self explanatory. The asterick designates the highest and lowest annual precipitation of the overall period.

Although these climatic data are not strictly applicable to the Tokio quadrangle, it is believed that these two stations are geographically near enough to be significant.

[10] Trewartha, G. T., An introduction to weather and climate: New York, McGraw-Hill Book Co., pp. 313-319, 1937.

[11] All climatic data in this report were derived from the publications of the United States Weather Bureau, kindly sent to the author by F. J. Bavendick, Meteorologist at Bismarck, North Dakota.

TABLE I

Annual Precipitation for the Years 1905-1945 Inclusive for Devils Lake, North Dakota.

* Indicates Greatest and Least Amounts.

1905	18.50	1919	17.67	1933	10.91
1906	15.49	1920	19.03	1934	11.78
1907	14.97	1921	25.39*	1935	19.52
1908	14.59	1922	17.21	1936	10.29*
1909	18.78	1923	14.75	1937	14.79
1910	13.33	1924	22.17	1938	15.55
1911	22.41	1925	19.93	1939	14.66
1912	22.74	1926	13.28	1940	23.17
1913	13.13	1927	19.51	1941	25.37
1914	17.34	1928	18.45	1942	18.30
1915	14.90	1929	21.72	1943	13.43
1916	18.26	1930	15.37	1944	25.26
1917	10.47	1931	18.51	1945	19.57
1918	17.71	1932	20.02	Mean	17.52

TABLE II

Annual Precipitation for the Years 1910-1941 Inclusive for McHenry, North Dakota.

* Indicates Greatest and Least Amounts.

1910	7.55*	1921		1932	
1911	20.54	1922	21.61	1933	
1912	21.55	1923	22.79	1934	
1913	14.29	1924	22.90	1935	
1914	18.57	1925		1936	
1915	19.25	1926		1937	16.59
1916	29.74*	1927		1938	14.78
1917	14.32	1928		1939	11.08
1918	23.97	1929		1940	18.59
1919	24.69	1930		1941	26.63
1920	18.78	1931		Mean	18.64

GEOLOGY

General

The Tokio quadrangle contains only a very limited number of bedrock exposures, the majority of the area being covered with glacial drift. The Pierre shale bedrock outcrops in five localities all of which are studied in the Sheyenne River Valley. These exposures are generally thin but may be traced as much as a mile laterally. There is no direct evidence as to the type of bedrock which underlies the Pierre shale, but it is reasonable to assume, on the basis of regional structure which has been established from well logs in this state[12] that the subsurface geology of this area would correlate very closely with the data obtained from the Devils Lake Deep Well of Ramsey County.

The following is a generalized table of the geologic formations, both surface and subsurface, for the Tokio quadrangle:

TABLE III

- Cenozoic
  - Pleistocene system
    - Eldoran series
      - Wisconsin stage
        - Mankato substage
          - Glacial drift
- Mesozoic
  - Cretaceous system
    - Upper Cretaceous series
      - Montana group
        - Pierre formation
      - Colorado group
        - Niobrara formation
        - Benton formation
        - Dakota formation
        - Fuson formation
        - Lakota formation[13]

[12] Laird, W. M., Selected deep well records: North Dakota Geol. Survey Bull. 12, 1941.
[13] For complete discussion of formations see Laird, W. M., Stratigraphy and structure of North Dakota: North Dakota Geol. Survey Bull. 18, 1944.

Pierre Shale

The Pierre shale is one of the most widespread geologic formations in North Dakota and would be exposed at the surface in most of the eastern half of the state were it not for the mantle of glacial drift. Only where streams have cut through the drift cover does the shale appear.

The thickest single outcrop in this quadrangle is located in a meander scar of the Sheyenne River. (NE¼, NW¼, Section 18, T. 150 N., R. 64 W.). This exposure is 24 feet thick and parallels the river for approximately a quarter of a mile. The shale is gray to blue-black in color and weathers into characteristic rectangular blocks or pencil-like fragments. The very thin bedding planes and the numerous joints account for the rectangular fragments. Along the partings caused by the cleavage weathering produces limonite which stains the surface a bright yellowish-brown.

According to Laird,[14] the Pierre shale is thinnest in the eastern part of North Dakota and gradually thickens to the west. The well record of the Devils Lake Deep Well in Ramsey County indicates 560 feet of Pierre shale capped by 50 feet of glacial drift. A road cut in the NW¼, NE¼, Section 12, T. 150 N., R. 65 W., shows the drift-shale contact. Here the drift mantle is 36 feet thick and 5 feet of shale is exposed at its base.

Pleistocene System

Name and Definition[15]

Charles Lyell[16] originally referred strata which contained more than 70 per cent of recent species of shells to the newer Pliocene or Pleistocene. The term Pleistocene as now used included all beds deposited during the Great Ice Age and contemporaneous marine, fluvatile, lacustrine, and volcanic beds. This is essentially the redefinition of the term Pleistocene as it was proposed by Forbes[17] and agreed to by Lyell.

[14] Laird, W. M., Selected deep well records: North Dakota Geol. Survey Bull. 12, 1941.
[15] Laird, W. M., Geology and ground water resources of the Emerado quadrangle: North Dakota Geol. Survey Bull. 17, 1944.
[16] Lyell, C., Elements of geology: French translation ,appendix pp. 616-621, Paris 1939: Reference from Wilmarth, Grace: Geologic time classification of the U. S. Geol. Survey compared with other classifications: U. S. G. S., Bull. 769, p. 47, 1925.
[17] Forbes, Edward, On the connexion between the distribution of the existing fauna and flora of the British Isles, and the geologic changes which have affected their area, especially during the epoch of the Northern Drift: Great Britain Geol. Survey Mem. vol. 1, pp. 402-403, 1846. Reference from Wilmarth, Grace, op. cit. p. 48.

Deposits belonging to the Recent are not included in the Pleistocene by the United States Geological Survey[18] although Kay and Leighton[19] include the Recent in the Pleistocene. Inasmuch as the withdrawal of the ice did not take place everywhere at the same time and as the line of demarcation between the Recent and the Pleistocene deposits is difficult to draw in many areas, it seems logical to include the Recent as part of the Pleistocene period.

Eldoran Series

Name and Definition

The name Eldoran was proposed by Kay[20] to include the Wisconsin glacial, the Peorian interglacial, and the Iowan glacial stages of the Pleistocene system. Kay and Leighton[21] later made the Mississippi Valley classification as follows:

- Pleistocene or glacial period (system)
  - Eldoran epoch (series)
    - Recent age (stage)
    - Wisconsin age (stage)
      - Mankato subage (substage)
      - Cary subage (substage)
      - Cary subage (substage)
      - Tazewell subage (substage)
      - Iowan subage (substage)

Wisconsin Stage

Name and Definition

This term was first proposed by T. C. Chamberlin in the slightly modified form of "East Wisconsin Formation" of glaciation because of the extensive deposits in eastern Wisconsin.[22] Later he changed the name to Wisconsin which is still in use today though in a wider sense.

Leighton[23] in 1931 reclassified the Iowan and Wisconsin drifts by including in the Wisconsin the Peorian loess and the

18 Wilmarth, Grace, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, p. 1781, 1938.
19 Kay, G. F., and Leighton, M. M., Eldoran epoch of the Pleistocene period: Geol. Soc. of America Bull., vol. 44, pp. 669-674, 1933.
20 Kay, G. F., Classification and duration of the Pleistocene period: Geol. Soc. of America Bull., vol. 42, pp. 425-466, 1931.
21 Kay and Leighton, op. cit.
23 Leighton, M. M., The Peorian loess and the classification of the glacial drift sheets of the Mississippi valley: Jour. Geol. vol. 39, pp. 45-53, 1931.
22 Chamberlin, T. C., in Geike, James, Great ice age: 3rd ed., p. 763, 1895.
24 Leighton, M. M., The naming of the subdivisions of the Wisconsin glacial age: Science, new ser., vol. 77, p. 168, 1933.

Iowan drift. He also proposed several substage terms for the Wisconsin which he later retracted in favor of the classification listed on page 12 of this report.[24]

Mankato Substage

Name and Definition

The Mankato, the term for the latest Wisconsin substage was introduced by M. M. Leighton,[25] and was named after the type exposure in the immediate vicinity of Mankato, Minnesota. The glacial till and related outwash described in this report is considered to have been deposited during the latest phases of the Jamestown lobe of the Keewatin ice sheet of Mankato age.

Members of the Mankato Substage

General Statement

Glacial drift may be classified in two different ways: (1) in terms of sediments, (2) in terms of topographic expression. Due to the fact that lithology, thickness, texture, fabric, and shape of the constituent particles as well as the topographic expression must be considered in any attempt to describe glacial drift, both classifications have to be used despite the fact that they are only partly related to each other. In this report the land-form classification is used as an outline, each marignal heading representing a topographic type of glacial feature such as recessional moraine, outwash plain, ground moraine, etc. Any variation in type of sediment within a given land-form will be conveniently included under the single heading.

Recessional Moraine

The North Viking and Heimdal moraines make up the recessional moraine area of the Tokio quadrangle. In studying the geologic map of this area alone there seems to be no evidence of two separate moraines. However, by comparing the geologic maps of the Oberon and Flora quadrangles to the west and the topographic map of the Hamar quadrangle to the east with the Tokio quadrangle, it can readily be seen that there are two sharply defined moraines trending in a general east-west direction.[26] That portion of the recessional moraine

25 Leighton, M. M., op. cit., Science.
26 Branch, op. cit.
Tetrick, op. cit.

between Sections 25 and 26, T. 151 N., R. 64 W., and Sections 7 and 12, T. 150 N., R. 63 and 64 W. (Plate II) is here called the transitional moraine. In the western portion of the quadrangle there is a similar connection of the North Viking and Heimdal moraines. All of the moraine south of the northern boundary of Section 28, T. 151 N., R. 65 W., and southeast of the mouth of Seven Mile Coulee is Heimdal, whereas the small lobe extending southward to the valley flat of the Sheyenne River is North Viking.

Topographically both moraines are similar in that they possess typical knob and sag topography. The average relief is aproximately 40 to 50 feet, ranging from a low of 20 feet in the big bend of the Sheyenne River (Section 27, T. 150 N., R. 64 W.) to a high of 185 feet at Devils Heart (Section 4, T. 151 N., R. 64 W.). Some knobs are almost conical in profile, but generally the summit areas are gently rounded. (Fig. 2). The sags are of two general types; shallow, swampy depressions and permanent kettle-hole lakes. Klemme Lake, located in Section 12, T. 151 N., R. 64 W., is one of the larger, more perfect permanent kettles in the area.

The conspicuous feature of the North Viking moraine is the long line of high hills which extend in a northwest-southeast direction from Sully's Hill (Section 15, T. 152 N., R. 64 W.) to Devils Heart. This linear divide is aproximately eight miles long and includes such prominent high points as Skee Jump Hill (Section 14, T. 152 N., R. 65 W.) and Devils Backbone (NW¼ Section 29, T. 152 N., R. 64 W.). The hills are till-covered remnants of a pre-glacial inter-stream area. They stand 80 to 120 feet above the surrounding moraine. Their flat-topped summits suggest a horizontal bedrock core. Remnants of the horizontal strata may be found in several outcrops along State Highway 57 just outside of the northern boundary of the quadrangle. Here essentially flat-lying beds of Pierre shale have been exposed in deep road cuts along the south side of the road. Lithologically the rock is identical to that found in outcrops in the valley of the Sheyenne River. (See page 11.)

The till making up the recessional moraine is generally a light buff to brown, boulder clay containing pebbles and

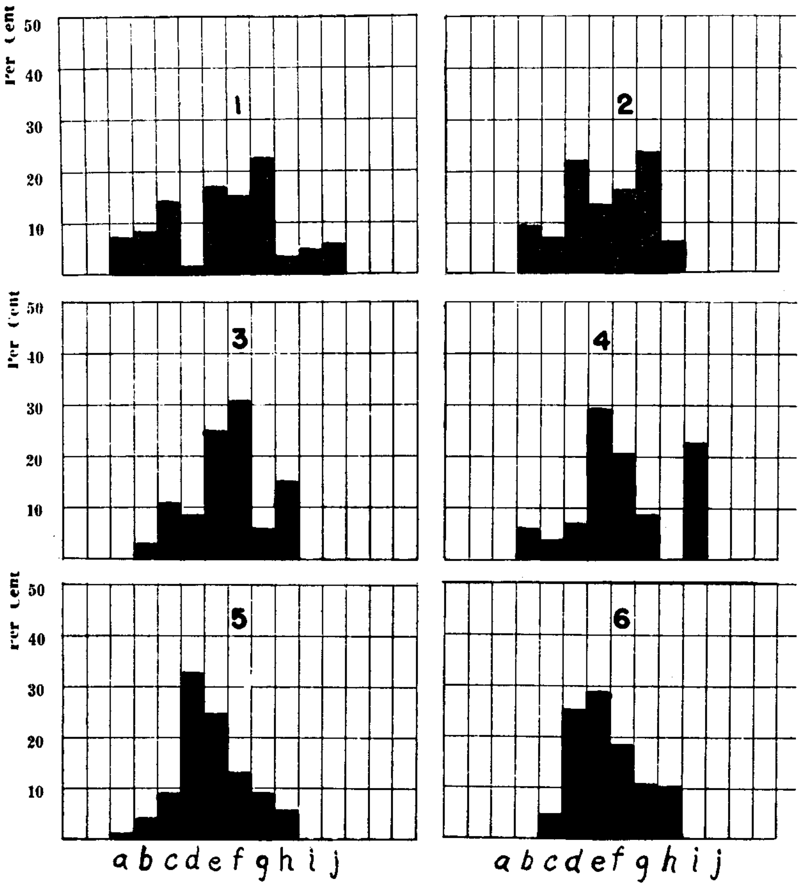
boulders of varying size, shape, and composition. The term boulder clay, though not applicable to the whole range of till deposits, applies very well to those portions primarily composed of clay. The rocks within the till vary from pebbles 4 millimeters in diameter to erratics as large as 15 by 8 feet. Most of these large boulders are feldspathic granites possessing a perthitic or graphic intergrowth of quartz and feldspar. In some localities the large boulders are dominantly huge slabs of white limestone. The erratics are well distributed throughout the quadrangle and commonly lie free on the surface.

Boulder counts were taken at various selected localities to determine the percentage of lithologic types at the surface. Figure 3 shows graphically the results of six boulder counts taken in areas where erratics were especially abundant. The boulders average 22.9 per cent limestone, 19.5 per cent light granite, and 13.5 per cent granite gneiss. The remaining portion is composed of pink dolomite, sandstone, feldspathic granite, and garnetiferus granite. Of the last group, the igneous rocks occur in approximately equal amounts of 6 to 8 per cent, while the dolomites and sandstones are very inconspicuous or entirely lacking.

Percentage compositions of pebble samples taken within the till were also calculated. The samples averaged 47.9 per cent limestone, 29.1 per cent granite and granite gneiss, 8.5 per cent basic igneous rocks (basalt), 7.3 per cent shale, 1.9 per cent sandstone, and 8.5 per cent miscellaneous fragments too small to identify. (Fig. 4). The pebble counts were taken entirely in deep road cuts.

Shale fragments are found in most of the road cuts through till, but rarely occur at the surface. (Fig. 3). This is due primarily to the fact that Pierre shale breaks up rapidly when exposed at the surface and is quickly removed by running water. Where freshly exposed the shale pebbles and cobbles are held together by the relatively solid, impervious clay matrix.

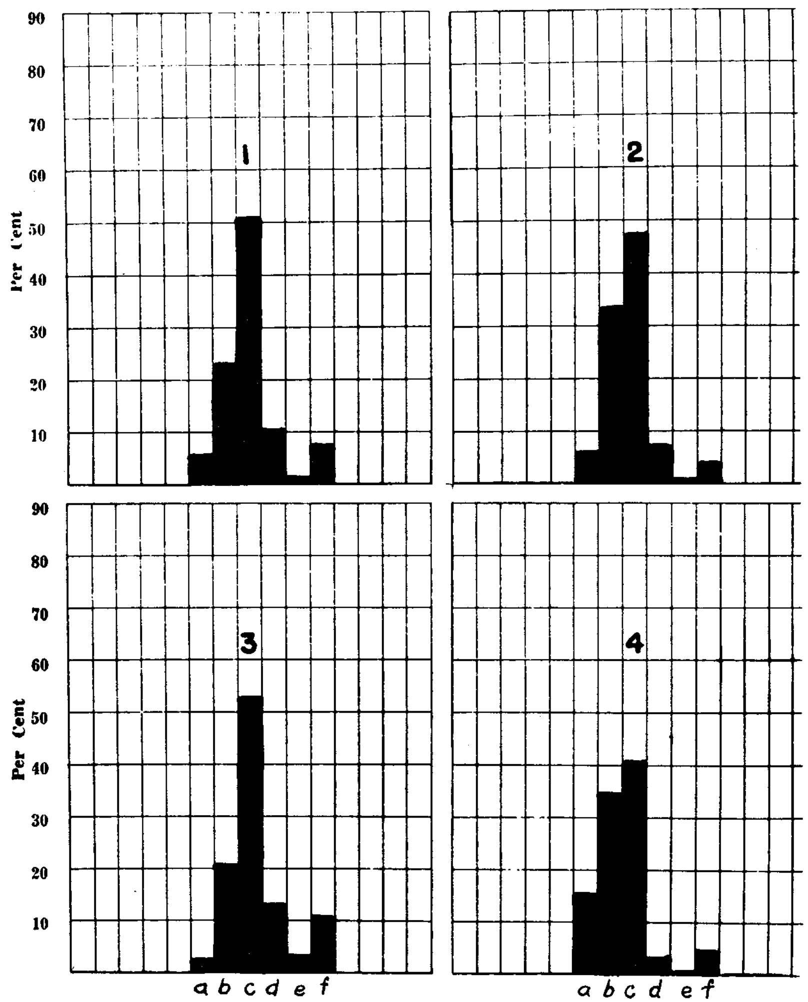
Within Sully's Hill National Game Preserve is a type of till which varies considerably from the common type boulder clay. This till is exposed in a road cut in NE¼, NW¼, Section 15, T. 152 N., R. 65 W. and is composed of 56.5 per cent shale.



KEY—Left to Right

a. Pink dolomite
b. Garnetiferous granite
c. Feldspathic granite
d. Light granite
e. Limestone
f. Hornblende granite
g. Granite gneiss
h. Feldspathic granite pegmatite
i. Basalt
j. Sandstone

Figure 3. Boulder Counts on Recessional Moraine.



KEY—Left to Right

a. Shale
b. Granite
c. Limestone
d. Basalt
e. Sandstone
f. Miscellaneous

Figure 4. Pebble Counts in Recessional Moraine.

The shales occur as fragments, pebbles, or as weak boulders. The fragments, which are the direct result of disintegration of larger pebbles and cobbles, form a characteristic fine talus of paper-thin sheets at the base of each road cut. The pebbles and cobbles form blisters on the surface of the exposures as the surrounding matrix is removed. Apparently the contact between the Pierre shale and the till is very near the surface here which would account for the abundance of shale pebbles, cobbles and boulders. In addition to the predominant shale approximately 32.2 per cent of the fragments are granites of various kinds, and 17.2 per cent are miscellaneous rocks of which limestone and sandstone are dominant. Similar exposures of this shaley till are located on the north side of Highway 57 in the northwest corner of the quadrangle. Here the shale makes up 90 per cent of the fragments within the till.

Another notable deviation from the normal character of the till is found in the big bend region of the Sheyenne River. Here the Heimdal moraine till is sandy and gravelly suggesting melt water as the transportating agent. This area includes Sections 22, 23, and 24, and also the northern halves of 26 and 27, T. 151 N., R. 64 W. The sands and gravels occur as lenses in the boulder clay proper or take the place of the clay till entirely. Auger borings to a depth of 8 feet along the north-south road between Sections 23 and 24 reveal that much of the matrix making up the till is clean sand. Further west, in the gravel pits located in Section 22, the till contains sand and gravel interbedded with clay till. The gravels and sand are very dirty and are of little economic importance because of the abundance of shale pebbles. The presence of numerous eskers and the group of kames in this area also point to a mode of origin involving considerable amounts of melt water. This is probably a deposit of drift let down irregularly from the surface of the glacier due to surface melting or partial stagnation. Repeated slumping and sliding of the drift on slopes of melting ice would afford ample opportunity for washing. Outside of this small restricted area the till in the Heimdal moraine is of the boulder clay type.

The transitional moraine in the vicinity of Horseshoe Lake blends into the till of the North Viking and Heimdal moraines with no change in lithology, fabric or composition.

Thus naming this area on the basis of till type is impossible. Its position relative to the North Viking outwash material, however, places it definitely in the Heimdal. The ice was probably so thick at this point during the Pleistocene that it remained here throughout Heimdal and North Viking time. There is a possibility that this transitional moraine is a continuation of the pre-glacial high divide to the northwest, in which case its altitude would have kept it from being affected by the melt waters from the North Viking moraine.

The main body of the till is relatively little weathered, unleached, and loose to well consolidated. The degree of consolidation varies considerably within the area and in general is found to be loose where the till is of a sandy character. At no place was any surface exposure observed that might indicate the presence of an earlier substage or stage of glaciation. This does not imply, however, that such a till might not exist beneath the Mankato cover.

The few weathered surfaces of till have undergone a small amount of oxidation, mainly the alteration of ferrous iron compounds such as carbonates, silicates, and sulphides. This process has changed the original grays, browns, and tans to reds, yellows, and yellowish browns. Few of the pebbles in the till show weathering after transportation. However, some of the granite gneisses may have been weathered since removal from their original positions.

In most places the till is relatively impervious and forms an effective retainer for the kettle-hole lakes and swamp depressions. Some farmers who have dug-wells in the till areas report lenses of sand and gravel at considerable depths. The lenses serve as local aquifers and reservoirs when of sufficient size, providing the percolation of meteoric waters is not prevented by impervious deposits. The water supply from sources of this kind is often limited and generally fails completely in dry years.

Eskers

Eskers, which are irregular-crested ridges of water sorted drift, are found in various sections of the quadrangle. (Plate II). Their length varies from one-fourth of a mile to five and a half miles. They are from 10 to 25 feet high and 30 to 75

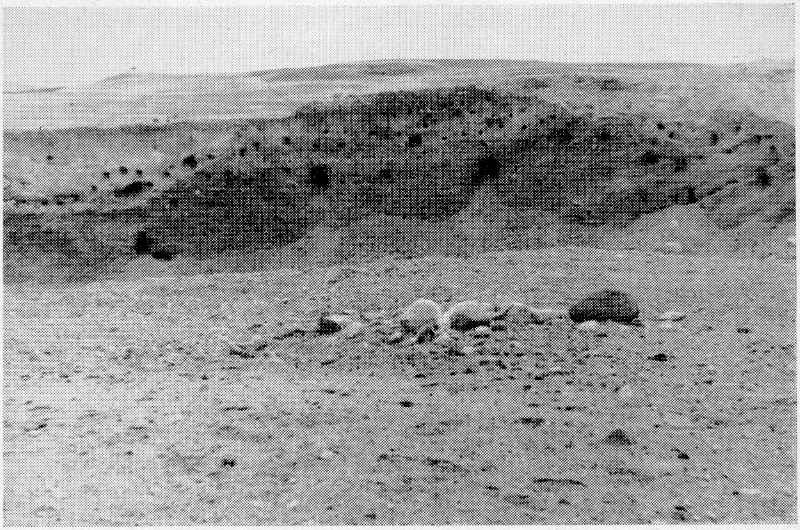


Figure 5. Quarry Pit Through Esker
SE Corner NE¼, Section 32, T. 150 N., R. 64 W.

feet wide, their width depending upon the angle of repose of the sediments making up the deposit. The ground, for a few rods on either or both sides of the esker, is in many cases lower than the ground farther away, forming the "esker trough" of Thwaites.[27] Eskers generally extend in a direction which approximately parallels the direction of ice movement. Assuming that the ice moved from north to south in this area, few of the mapped eskers deviate more than 45° from this direction.

The material making up eskers may best be studied in a gravel pit which is located in SE¼, NE¼, Section 32, T. 150 N., R. 64 W. (Fig. 5). The deposit is chiefly gravels which range in size from sand to pebbles 60 millimeters in diameter. The gravel is everywhere well sorted, containing alternating layers of coarse and fine material. It is evident that the pebbles were not transported a great distance as the fragments are angular to subangular in shape. The gravels consist pri-

[27] Thwaites, F. T., Outlines of glacial geology: Edwards Bros., Inc., Ann Arbor, 1946.

marily of limestone and granite which together make up approximately 60 per cent of the whole. Basalt fragments are next in abundance, making up about 20 per cent. It should be noted that shale is entirely absent in this gravel pit; therefore these gravels are useful as construction material. This is the exception rather than the rule for eskers in this area, as the percentage of shale is generally very high. Ice-rafted stones and boulders are quite common within the quarry, a few of which are shown in Figure 5. The larger depressions in the quarry face undoubtedly held the ice-rafted stones which became loose and fell to the base of the cut.

The angles of repose in the sediments are very high, varying considerably in the coarse and fine grades. The coarse material, from 40 to 60 millimeters in diameter rests at an angle of 20°, while the finer material from 1 to 4 millimeters has an angle repose of 35°. The dip of the beds varies from S. 79° W. 14° to S. 85° W. 31° within the pit proper. From these figures it is quite evident that the velocity of the stream was variable during deposition, and that the direction of flow was in a general southwesterly direction to the Sheyenne River.

The other numerous eskers in the big bend region are similar both topographically and texturally to the one just described. The major differences are in the types of materials making up the deposit, and in the thickness of the beds. The varying percentages of shale is perhaps the most distinct lithologic change.

West of the Sheyenne River, and approximately paralleling the north-south section line between Sections 33 and 34, T. 151 N., R. 65 W., is an esker which has five small distributaries. These distributaries trend eastward in contrast withe parent esker which trends north-south. Excellent cross-bedding may be seen in a gravel pit located in the NE¼, NE¼, Section 33, T. 151 N., R. 65 W. The cross bedding is of the torrential type, which indicates rapid flow of water during deposition.

Origin of Eskers

As Hummel was first to point out, eskers are the deposits of glacial streams confined by walls of ice, and left as elongate ridges when the ice disappeared.[28] Eskers parallel the direction of ice movement and are late deposits having been laid down in the terminal regions of the glacier just before it disappeared from the area. The common mode of origin appears to have been in subglacial tunnels at a very late stage of deglaciation, in which the ice was stagnant or nearly so. It is difficult to be sure that all of the stream course was in a tunnel; portions could very well have been in deep cracks open to the sky. The water was undoubtedly under hydrostatic pressure where enclosed tunnels were present, the source being primarily from surface melt water which worked its way down through cracks and moulins to the main tunnel. The subglacial stream at first eroded a channel into the underlying material and subsequent deposition did not everywhere fill this hollow, thus forming the esker trough.[29] The pebbles composing eskers were derived in the immediate locality and therefore must have been subglacial. Some writers have suggested that the movement of the ice gave rise to the undulations in the esker ridges, but the lack of evidence of shove in the eskers of this area as well as their slightly sinuous form excludes this theory. Subsequent melting of the ice let down till alongside and even on top of some eskers.

There is no structure in the eskers which indicates whether the entire individual was formed at the same time throughout its length, or whether its downstream portion was built first and was gradually added to in an upstream direction as the stagnation and thinning became more widespread. It is evident, however that the esker was protected by enclosing stagnant ice otherwise the structure would have been destroyed.

Crevasse Fillings

According to Thwaites, a crevasse filling is a single nearly flat-topped ridge of water-sorted drift running in almost any direction relative to the ice movement and always in an approximate straight line.[30]

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[28] Hummel, D., Om rullstenbildningar: K. Svenska Vetenskapsakad., Bihang til Handl., vol. 2, no. 11, 36 pp., 1874. Reference from Flint, R. F., Glacial geology and the Pleistocene epoch, John Wiley Sons, Inc., 1947.
[29] Thwaites, op. cit.
[30] Thwaites, op. cit., p. 52.

Figure 6. Group of Three Crevasse Fillings.
SE¼, NE¼, Section 5, T. 151 N., R. 65 W.

Excellent examples are found in the SE¼, NE¼, Section 5, T. 152 N., R. 65 W. A series of three crevasse fillings are found near the western boundary of the area, and extend for some distance southward into the Oberon quadrangle. These crevasse fillings parallel each other, trending in an almost straight north-south direction. (Fig. 6) They are approximately 1 to 1½ miles long, 45 feet wide, and 15 feet high. These single independent ridges merge at their southern end into the adjacent outwash plain. The tops of the crevasse fillings are almost at exactly the same altitude as the outwash or slightly lower. They are even crested except where lowered somewhat by slump of the sides.

The materials making up the central crevasse fillings are exposed in a gravel pit in the SW¼, SE¼, Section 5, T. 152 N., R. 65 W. They range from sand 1 millimeter in diameter to cobbles 13 centimeters in diameter and in all cases are poorly sorted. The gravels are very coarse and irregularly bedded and have abrupt changes in grades. They are poorly rounded and on the whole much more stony than the adjacent outwash deposit. The average size grade is approximately 7 or 8 centimeters. Pierre shale is by far the most dominant rock type, making up 77.1 per cent of the whole. Of the remaining 22.9 per cent, 14.4 per cent is limestone and 8.5 per cent miscellaneous granites and basic igneous rocks. The finer grades, consisting of sand and granules, are oxidized in isolated portions of the exposure giving the affected areas a characteristic reddish-brown color.

A portion of the same crevasse filling is exposed in a road cut within the quadrangle at the north center line, SE¼, Section 5, T. 152 N., R. 65 W. This cut is approximately half a mile northeast of the pit and in this short distance there is a marked change in the size of the gravels. Here they average 1 to 2 centimeters in diameter, a decrease of 11 centimeters in approximately half a mile. Lithologically and otherwise the two exposures are alike.

Origin of Crevasse Fillings

Crevasse fillings and eskers are both deposited by streams within ice walls. Most writers recognize this, but there has been much disagreement as to the position of the streams in respect to the ice and the condition of the ice sheet at the time of deposition. There is no reason why streams in their lower parts might not flow in open channels in the ice. As the crevasse fillings were deposited where the drainage was was concentrated, they would, on the whole, be coarser and less well sorted than the associated outwash. There is, however, no definite break but a gradation into the adjacent outwash. Both eskers and crevasse fillings were deposited in stagnant or nearly stagnant ice.

Kames

The term kame is one of uncertain origin and is believed to have originated in Great Britain.[31] It is used here in a broad sense to describe isolated, fluvioglacial deposits in recessional moraine. Three deposits of this type occur in the Tokio quadrangle.

The group of kames located along the north-south section line between Sections 13 and 14, T. 150 N., R. 64 W., are conspicuous because of their extreme height. They rise ap-

[31] Flint, R. F., Glacial geology and the Pleistocene epoch, New York, John Wiley Sons, 1947.

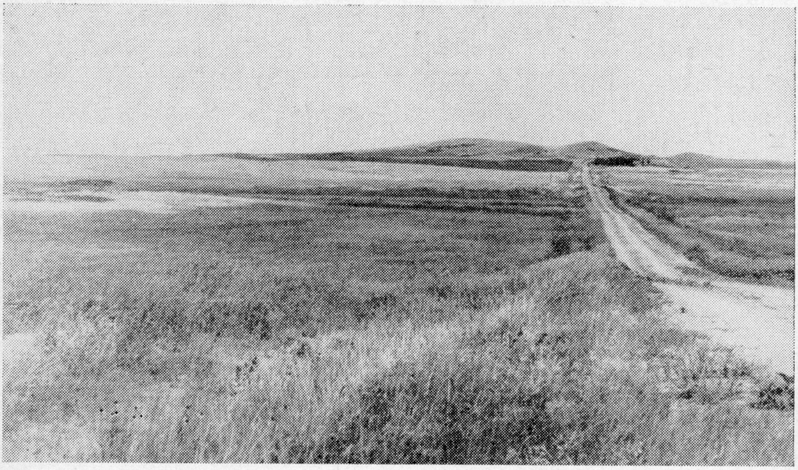


Figure 7. Group of Kames.
Sections 13 and 14, T. 150 N., R. 64 W.

proximately 80 to 100 feet above the surrounding moraine. (Fig. 7). These large conical hills are in sharp contrast to the low steep sided hills which Flint describes as kames.[32]

The material making up these kames is exposed in a road cut in the SW corner, NW¼, SW¼, Section 14, T. 150 N., R. 64 W. The exposure is approximately 15 feet thick and is composed of fine gravel. The size of the constituent materials ranges from sand grains about one-eighth millimeter in diameter to pebbles 60 millimeters in diameter. The deposit is sandy and probably contains the required 50 per cent of pebbles by weight which labels it a gravel. In most cases the sorting is fair to excellent. The deposits contain an appreciable amount of shale pebbles. The sand grains are primarily quartz and feldspar and vary in shape from well rounded to sub-angular.

Warren Upham in his Monograph on Glacial Lake Agassiz, proposed the idea that Devils Heart in Section 33, T. 152 N., R. 64 W. is a kame. There are sandy and gravelly areas on the sides and summit of Devils Heart, but primarily it is

[32] Flint, op. cit., p. 147.

made up of clay till. This prominent hill is a continuation of the drift covered pre-glacial highland of which Sully's Hill and Devils Backbone are a part. The sand and gravels are either lenses within the till or the result of intermittant fluvio-glacial action. Devils Heart is therefore not a true kame.

Origin of Kames

Kames are bodies of sediment in moulins and other openings in or on the surface of nearly stagnant ice which later melted away leaving sediment in the form of isolated or semi-isolated mounds. The sediment in ice-contact features of this sort assume the angle of repose of the constituent materials.

Ground Moraine

The greatest concentration of ground moraine is located in the northeast corner of the quadrangle. Small scattered patches are also present within or on the edges of the outwash deposits. (Plate II). In the ground moraine areas the relief rarely exceeds 20 feet per mile. Swell and swale topography forms a gently undulating drift plain similar to that found in portions of Iowa and Illinois. Only rarely do the depressions contain permanent lakes.

The predominant material in the moraine is clay till though stratified drift is present in places. In shallow road cuts in Sections 24, T. 152 N., R. 63 W. there are layers of silt, sand and even gravels. The till is buff to brown and contains pebbles of many sizes and shapes. The surface is generally free of large boulders which makes the land suitable for farming. In Section 18, T. 152 N. R. 63 W. granite erratics up to 3 feet in diameter are very abundant and quite concentrated. The till is not weathered and is unoxidized and unleached.

The till making up the ground moraine is believed to have accumulated largely by lodgement of material beneath the ice. Some may have been let down from the upper surface of the ice through ablation which would explain the abundant silt, sand and gravel lenses within the till.

Outwash

There are two types of outwash within the quadrangle, the pitted and dissected type which is located immediately south of the North Viking moraine, and the unpitted type associated with the Heimdal moraine.

Along the borders of the North Viking outwash the topography is almost identical to that of the moraine, becoming gradually subdued toward the central portions until finally the surface is essentially flat containing only a few shallow depressions. The marginal areas have an average relief of 20 to 40 feet, although 40 to 60 feet of relief is not uncommon along the northern and eastern edges. Irrespective of the variations in topography, there seems to be a series of even crested summits which have a grade of approximately 8 feet per mile toward the Sheyenne River.

Numerous coulees leading to the Sheyenne River from the north are significant both topographically and historically. At the contact between the North Viking outwash and the Sheyenne River, numerous drainage channels extend headward as much as two miles. The ice evidently remained for a considerable length of time at the North Viking stage to have established such a well marked system of spillways from the North Viking moraine to the Sheyenne River. The largest of the channels is Seven Mile Coulee which originates in the NW¼, NE¼, Section 22, T. 152 N., R. 65 W. and ends in Sheyenne River in the SE corner, Section 22, T. 151 N., R. 65 W. This large glacial drainage channel has a maximum width of three-quarters of a mile and narrows to one-eighth of a mile where it empties into the Sheyenne River. It contains a permanent stream only in its lower portions, where it is fed by seepage springs. In its headward portions Seven mile Coulee is between 20 and 40 feet deep, whereas at its mouth it is between 100 and 120 feet deep. Several tributary valleys feed the coulee in its headward regions, while farther south they are practically non-existant.

The sediments making up the outwash material are of two types, the coarse marginal gravels which occupy a position at the till-outwash contact, and the finer gravels and sand of the central and southern portions of the area. A typical section of coarse outwash is found in a gravel pit in the NW¼, SE¼, Section 15, T. 151 N., R. 65 W. The pit is approximately 30 to 40 feet deep. At first glance the gravel appears to be approximately 100 per cent shale cobbles, but careful examination reveals that limestone is present in considerable quantities. Pebble counts reveal that 74.2 per cent of the material is shale and 22.9 per cent limestone. The remaining 2.9 per cent is principally granite with some basic igneous rocks scattered throughout. The shale pieces range from pebbles 2 centimeters to cobbles 26 centimeters in diameter, and the limestone varies from 2 to 5 centimeters. The deposit is well sorted, and the interstices of the gravels are filled with sand. The material becomes coarser with depth throughout the entire gravel pit.

From data obtained by augering it is found that fine sand commonly gives way to coarse sand and small pebbles at a depth of from 6 to 8 feet in Sections 12, 13, 18 and 19, T. 151 N., R. 64 W. This might indicate that the deposition of outwash material in the central area was relatively uniform. The fine textured gravel extends southward as far as the Sheyenne River.

Seven Mile Coulee contains considerable deposits of fine, well sorted, sand and gravel in its upper reaches. A good example of this may be seen in the NW¼, NE¼, Section 22, T. 152 N., R. 65 W. A few ice-rafted stones ranging from 5 to 8 centimeters in diameter are present within the deposit. Farther southward the gravels are replaced in the valley bottom by gray, fine-grained sand and silt which probably obtained most of its color from the Pierre shale. The coloring near the surface is additionally darkened by the organic content of the sod. Auger borings in this material reveal quicksand with water at depths ranging from 4 to 15 feet. The material which has covered the outwash gravels to an undetermined depth may very well be alluvium. On the other hand it may only be humic material from the soil.

A small portion of the North Viking outwash east of Horseshoe Lake differs both topographically and texturally from that just described. This is a true outwash plain extending eastward 11 miles. The small portion within the quadrangle is flat except for four isolated remnants of till rising from 40 to 45 feet above the plain. Auger borings in the NW corner of Sec. 5, T. 150 N., R. 63 W. show clean, medium to coarse sand made up almost entirely of quartz and feldspar.

The Heimdal outwash which is located south and west of the Sheyenne River is also a true plain, broken only by two local patches of ground moraine and a few isolated shallow depressions in the extreme southern portion of the quadrangle. Excluding the two ground moraine areas the pitted outwash has a relief of less than 20 feet. Numerous auger borings taken throughout the outwash show practically the same sediments. The material is almost entirely made up of medium to coarse sand and small pebbles. The top 2 feet possess a characteristic white color suggesting the presence of rock flour. The pebbles of this top layer average 10 millimeters in diameter and are made up of shale and limestone. The underlying 6 feet of outwash are gray to brown in color and consist of approximately 75 per cent sand and 25 per cent pebbles. Limestone pebbles are entirely lacking in this zone. All pebbles are subspherical to ellipsoidal in shape.

Lake deposits

The glacial lakes which existed during the Pleistocene were so much larger than the present lakes that they were given special names by the early writers. The glacial lake of which Devils Lake is a remnant is generally known as Lake Minnewaukon which is the original Sioux Indian name for this large body of water.[33] Mission Bay, Black Tiger Bay, Spring Lake, and Embryo Lake are also fragments of this old glacial lake. (Plate II). There are two and possibly three distinct levels at which the waters of glacial Lake Minnewaukon stood for considerable lengths of time. These levels take the form of wave-cut cliffs where the relief is strong, and low shelving shores and beach ridges of sand and gravel where the relief is lower.

The water of the first stage stood at approximately 1460 feet above sea level, or 65 feet above the present lake, and is well developed along the northwest shore of Black Tiger Bay.

[33] Simpson, H. E., Physiography of the Devils-Stump Lake region: North Dakota Geol. Survey, 6th Bienn. Rept., pp. 101-157, 1912.

In some places strong wave action during a younger stage has driven the old cliffs and beaches back until they have been completely destroyed or covered. Generally, however, the old lake level may be traced quite easily throughout the area.

The second stage of Lake Minnewaukon stood at an elevation of approximately 1440 feet or 35 feet above the present lake level. This beach can be traced without too much difficulty and is very pronounced in the Embryo-Spring Lakes-Black Tiger Bay district.

A third level is represented by an irregular beach and isolated portions of a beach ridge approximately 10 to 15 feet below the second level. Patches of the beach ridge may be found along the southeast shore of Black Tiger Bay. This third beach is, however, not extensive enough to be mapped.

Beach sands and gravels of the 1440 foot stage occur in the NW¼, SW¼, Section 25, T. 152 N., R. 64 W. Here a portion of the beach ridge is exposed in a very shallow road cut. Primarily the pebbles are from 2 to 6 centimeters in diameter and composed of rocks similar to those found in the glacial till. They are subangular to subspherical in shape, their original shape probably having been modified by wave action. The fact that the beach deposit contains no material coarser than pebbles would indicate that Lake Minnewaukon was quite calm during the formation of this ridge. Associated with the beach gravels are large quantities of sand. In most cases the sand is clean and composed primarily of quartz and feldspar. Sand may fill the interstices between the pebbles but it is usually found in greatest abundance on the lakeward side of the beach ridge.

Lake clays are discovered by augering in most of the areas mapped as lake deposits. Generally these clays are brown in color and contain lenses of granules or pebbles where exposed near old beaches.

Lag boulders of huge dimensions occur along south shore of Devils Lake in the northwest corner of the quadrangle. They seem to be concentrated in front of the headlands and absent in the bay areas. In many instances the boulders are so abundant upon the old lake bed that they almost form a boulder pavement.

Around the borders of the present Devils Lake at approximately 15 feet above the high water mark are found distinct shoreline features. This indicates the lake is continuing to recede at a relatively uniform rate. The lake is now lower than at any time mentioned thus far. Those portions of Devils Lake in the northeast corner of the quadrangle are all intermittant lakes and contain silty and clay-like alkali dust.

Terraces of the Sheyenne River

One distinct river terrace is present in this area. Its altitude varies between 1480 and 1520 feet or 80 to 120 feet above the present stream. The terrace seems to possess no particular trend or down stream grade. It is covered with a heavy growth of prairie grass and the river side maintains a high angle of repose toward the river. At present erosion of the terrace by dissection of streams tributary to the Sheyenne is not strong.

In the NW corner, SW¼, Section 7, T. 150 N., R. 65 W., fine gravel and coarse sand are exposed in a road cut. The pebbles are composed primarily of shale and limestone varying from 15 to 45 millimeters in diameter. Granites and basic igneous rocks are also abundant. The deposit is well sorted with sand lenses between the gravels.

A gravel pit in NE¼, SE¼, Section 2, T. 150 N., R. 65 W. exhibits gravel containing limestone and granite with shale entirely absent. The size range is identical with the terrace gravels found in the road cut.

Numerous auger borings were attempted in the terraces on the south side of the Sheyenne River. The sediment collected from each hole possessed the texture and lithology of glacial till. The terraces result from the fact that gravels and alluvium formerly deposited in the valley were removed by erosion. That is, the terraces resulted from the rejuvenation of the stream which previously was more mature. The rejuvenation was probably brought about by increased gradient or by decrease of the load.

Flood Plain of the Sheyenne River

The Sheyenne River is now flowing in a channel varying from 15 to 60 feet deep. The present flood plain ranges from one-fourth to five-eights of a mile wide and contains some alluvium. The alluvium overlies Pierre shale and consists of well sorted fine sand and silt of medium gray color. The color near the surface is additionally darkened by the organic content of the top soil. The Pierre shale in most places not over ten feet below the surface thus making it accessible with the hand auger. In some places the fertility of the soil is high and crops are quite good. In other localities the flood plain is so alkaline that it is suitable only for grazing. A large portion of the valley flat is so studded with boulders that it is impossible to penetrate the surface with a hand auger.

Historical Summary

In pre-Wisconsin time there was an erosional surface of low relief cut into the Pierre shale. The Sheyenne River flowed on a valley floor which was somewhat deeper than the present valley. With the advance of the glacial ice some of the original relief was destroyed by planation and some by deposition beneath the ice. The ice completely covered this region and extended south in what is known as the James River Lobe.

At the close of the glacial cycle the ice retreated in stages forming successive fronts as it paused in its slow recession northward. These fronts remained stationary for periods of time during which a series of recessional moraines were formed at the southern limit of each new margin. The periods of recessional moraine formation represent times of accumulation of ice sufficient to supply the debris and maintain a front, but not of sufficient magnitude to cause a readvance.

In this quadrangle the Heimdal and North Viking moraines were formed in the order mentioned. The retreat of the ice front from the Heimdal to the North Viking position was probably accomplished in a relatively short time with no intermediate pauses between the two moraines. During the halts of the ice at each of these fronts outwash belts were built up during the warmer seasons when the melting was most active. During the colder seasons the ice was probably in a state of equilibrium in which the rate of melting approximately equaled the rate of advance. The eskers and crevasse fillings were deposited in the terminal region of stagnant or nearly stagnant ice just before its disappearance from the area.

Streams undoubtedly flowed into the James River system and from there to the Mississippi River during Heimdal time. When the ice melted back to the North Viking position, a new outlet, the pre-glacial Sheyenne River valley, became available. The tremendous load of sediment from the melting glacier caused the Sheyenne River to build up its valley floor to the level of the high terrace which is at approximately 1500 feet above sea level. Further recession of the ice caused the Sheyenne to cut through this filled channel until the valley was cleaned out to its present condition. The river is now practically inactive as far as down-cutting is concerned due to the lack of adequate precipitation along its course.

The main spillway from the North Viking moraine to the Sheyenne River was Seven Mile Coulee. It also passed through a period of deposition and subsequent erosion during the time when the ice stood at the North Viking position. Simpson[34] believes that Seven Mile Coulee at one time drained Glacial Lake Minnewaukon, but this appears to be unlikely as the lake was never high enough to cross the divide between the old spillway and the glacial lake. Some melt water undoubtedly flowed northward into Lake Minnewaukon for a short period of time cutting the valley which now remains as a hanging valley at Sully's Hill National Game Preserve.

The dissected character of the North Viking outwash belt is due to the network of glacial channels through which the melt water passed as it poured out from the margin. It is quite evident from the thickness of the outwash gravels and the height of the moraine to the north that the ice stood at this stage for a considerable length of time.

Laird has suggested the possibility of a readvance of the ice to explain the peculiar pattern of the Heimdal till on the northeast bank of the Sheyenne River (T. 151 N., R. 65 W.).[35] The presence of a gravel aquifer in a well 102 feet deep in the NW¼, Section 23, T. 151 N., R. 65 W., was suggested as possibly being contemporaneous with the North Viking outwash. This would place the age of the 102 feet of till overlying the aquifer as post-North Viking. The fact that the lithologies

[34] Simpson, H. E., The Physiography of the Devils-Stump Lake region: North Dakota Geol. Survey, 6th Bienn. Rept., 1912.
[35] Laird, W. M., Field conference, August 28, 1947.

of the isolated till and the Heimdal till to southwest are identical has an important bearing on the problem. It is the opinion of the author that this isolated area of till is Heimdal in age and was merely sufficiently high during North Viking time to escape burial by the outwash. The gravels found at 102 feet are probably only local lenses in the clay till such as are found throughout the entire area.

Ground Water Resources

Ground water in till

The till in the Tokio quadrangle is relatively impervious and serves as a poor agent for storing and transmitting ground water. The water is obtained only from gravel or sand lenses. Fortunately the presence of many lenses of gravel and sand by till is characteristic of this area. Water may percolate into the lenses by surface exposure or through underground seepage.

Well depths range from 9 to 315 feet and there is no evidence of uniform occurrence which would suggest a continuous aquifer. The water is generally hard but suitable for domestic purposes. The volume and yearly constancy varies from poor to good, but the average well in the till is rather poor in both respects. Location of an adequate subsurface gravel lense is difficult and almost entirely a matter of chance. The wells of the knob and sag topography are the poorest while the ground moraine wells are somewhat better.

According to the information supplied by residents, the wells sunk in till have a wide range of quality. Approximately 30 per cent of the wells examined in the till are regarded as unfit for human use, usually because of excessive hardness and an alkaline taste. A few excellent wells are found within the till area, but these are associated with the melt water deposits such as eskers and crevasse fillings. The residents who are fortunate enough to have a well situated in these gravels report a constant supply of excellent water even in the driest years.

Ground water in outwash

In the outwash the water reservoir consists of unconsolidated gravel and/or sand which in some cases extends to a known depth of 40 feet. Thus the total volume of the

reservoir is large and the porosity relatively good and constant over considerable areas. Furthermore these deposits have an ample surface exposure for the entrance of precipitation or run-off and being located in natural drainage channels surface flow is more likely to enter and fill the reservoir. Consequently the outwash deposits provide a reservoir which has a relatively large total volume and a good permeability, factors which in turn afford relatively quick recharge to wells sunk in such material.

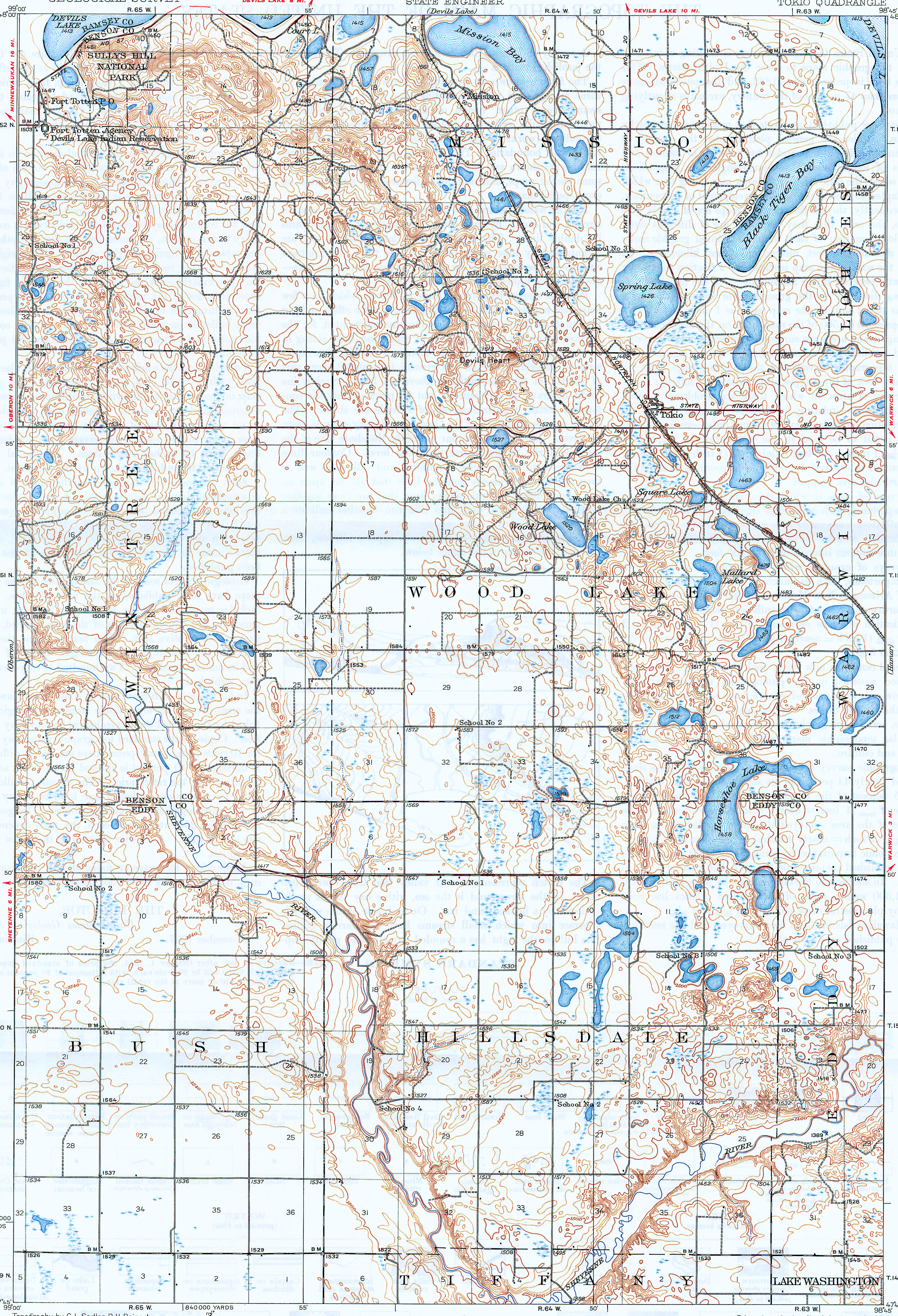
Water entering the surface slowly follows the filled glacial channels and gradually empties into the Sheyenne River in the belt associated with the North Viking moraine and into the James River along the Heimdal moraine. Evidence of this may be seen on the north side of the Sheyenne River in Section 7, T. 150 N., R. 64 W., where springs seep from the sides of the gravel terraces into the river. These terraces merge to the north with outwash channels. During the driest part of the summer when no rain had fallen for a considerable length of time and the wells and lakes were at a low level, augering showed water at depths of three to five feet along the areas of these channels.

According to the testimony of residents possessing wells in outwash belts or channels, the wells have been an excellent source of water both from the standpoint of quality and supply. There is no record of any well having dried up in even the driest years.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NORTH DAKOTA
ROBERT E. KENNEDY
STATE ENGINEER

NORTH DAKOTA
TOKIO QUADRANGLE



Topography by C. L. Sadler, R. H. Reineck, and H. S. Milsted
Control by U. S. Geological Survey
Surveyed in 1927–1928

APPROXIMATE MEAN DECLINATION, 1928

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

5000 0 5000 10000 15000 20000 Feet

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet
Datum is mean sea level

Polyconic projection. North American datum
5000 yard grid based upon U. S. zone system, D

HARD IMPERVIOUSLY SURFACED ROADS
OTHER MAIN TRAVELED ROADS
1930

TOKIO, N. DAK.
Edition of 1931

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a series of standard topographic maps to cover the United States. This work has been in progress since 1882, and the published maps cover more than 47 percent of the country, exclusive of outlying possessions.

The maps are published on sheets that measure about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, the areas that they represent are of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, miles, and kilometers. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 of the same units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys and the resulting maps have for many years been of three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile) or $\frac{1}{24,000}$ (1 inch = 2,000 feet), with a contour interval of 1 to 100 feet, according to the relief of the particular area mapped.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 100 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, and the high mountain area of the northwest, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles) or $\frac{1}{250,000}$ (1 inch = nearly 4 miles), with a contour interval of 20 to 250 feet.

The aerial camera is now being used in mapping. From the information recorded on the photographs, planimetric maps, which show only drainage and culture, have been made for some areas in the United States. By the use of stereoscopic plotting apparatus, aerial photographs are utilized also in the making of the regular topographic maps, which show relief as well as drainage and culture.

A topographic survey of Alaska has been in progress since 1898, and nearly 44 percent of its area has now been mapped. About 15 percent of the Territory has been covered by maps on a scale of $\frac{1}{500,000}$ (1 inch = nearly 8 miles). For most of the remainder of the area surveyed the maps published are on a scale of $\frac{1}{250,000}$ (1 inch = nearly 4 miles). For some areas of particular economic importance, covering about 4,300 square miles, the maps published are on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile) or larger. In addition to the area covered by topographic maps, about 11,300 square miles of southeastern Alaska has been covered by planimetric maps on scales of $\frac{1}{125,000}$ and $\frac{1}{250,000}$.

The Hawaiian Islands have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

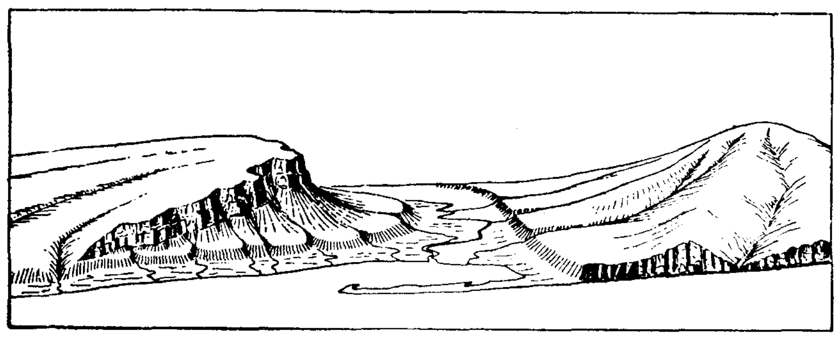
A survey of Puerto Rico is now in progress. The scale of the published maps is $\frac{1}{80,000}$.

The features shown on topographic maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The symbols used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams by double lines. The larger streams, lakes, and the sea are accentuated by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on a few maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The datum or zero of altitude of the Geological Survey maps is mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet above mean sea level. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope, lines that are close together indicate a steep slope, and lines that run together indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.



The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly enclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined tableland that is traversed by a few shallow gullies. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. In order that the contours may be read more easily certain contour lines, every fourth or fifth, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road intersections, summits, surfaces of lakes, and benchmarks—are also given on the map in figures, which show altitudes to the nearest foot only. More precise figures for the altitudes of benchmarks are given in the Geological Survey's bulletins on spirit leveling. The geodetic coordinates of triangulation and transit-traverse stations are also published in bulletins.

Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Public roads suitable for motor travel the greater part of the year are shown by solid double lines; poor public roads and private roads by dashed double lines; trails by dashed single lines. Additional public road classification if available is shown by red overprint.

Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. More than 4,100 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

Geologic maps of some of the areas shown on the topographic maps have been published in the form of folios. Each folio includes maps showing the topography, geology, underground structure, and mineral deposits of the area mapped, and several pages of descriptive text. The text explains the maps and describes the topographic and geologic features of the country and its mineral products. Two hundred twenty-five folios have been published.

Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 percent is allowed on an order amounting to $5 or more at the retail price. The discount is allowed on an order for maps alone, either of one kind or in any assortment, or for maps together with geologic folios. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

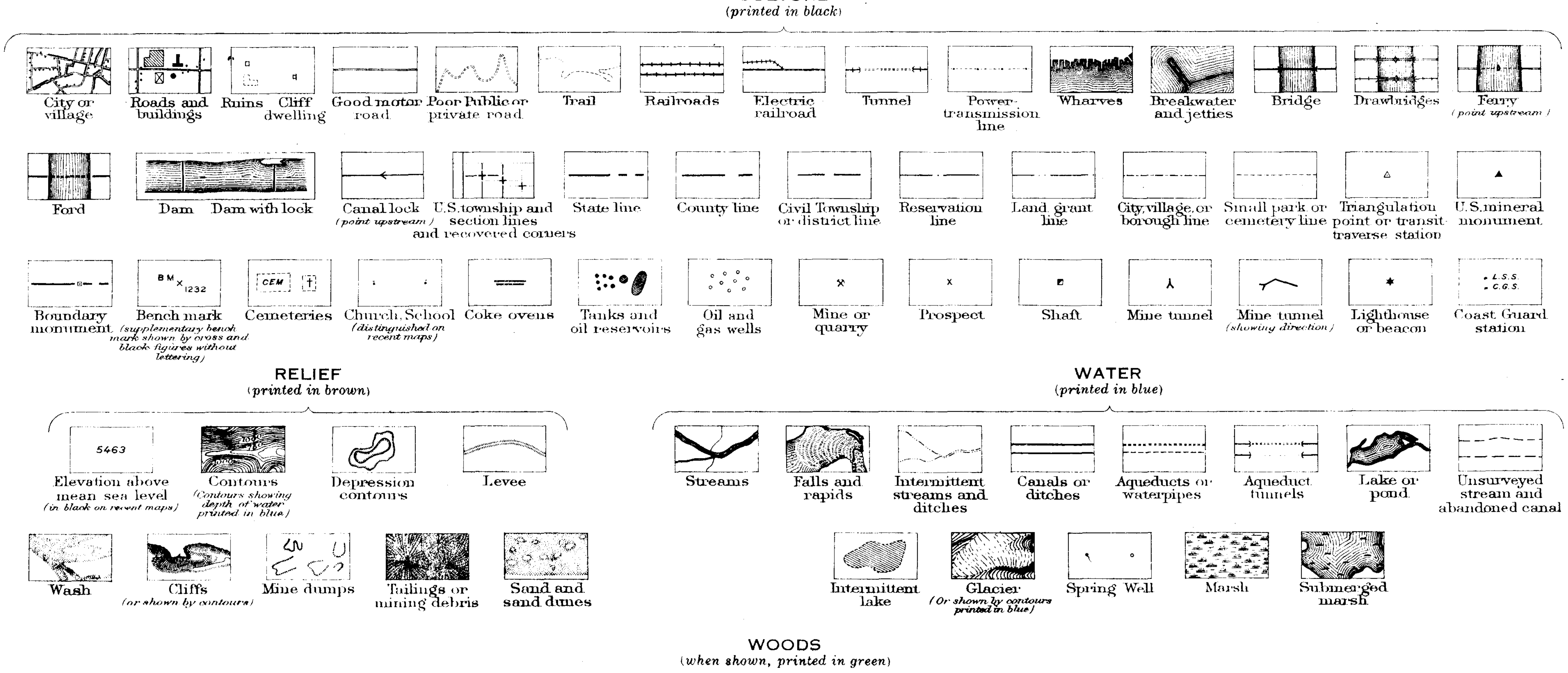
Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

THE DIRECTOR,
United States Geological Survey,
November 1937. *Washington, D. C.*

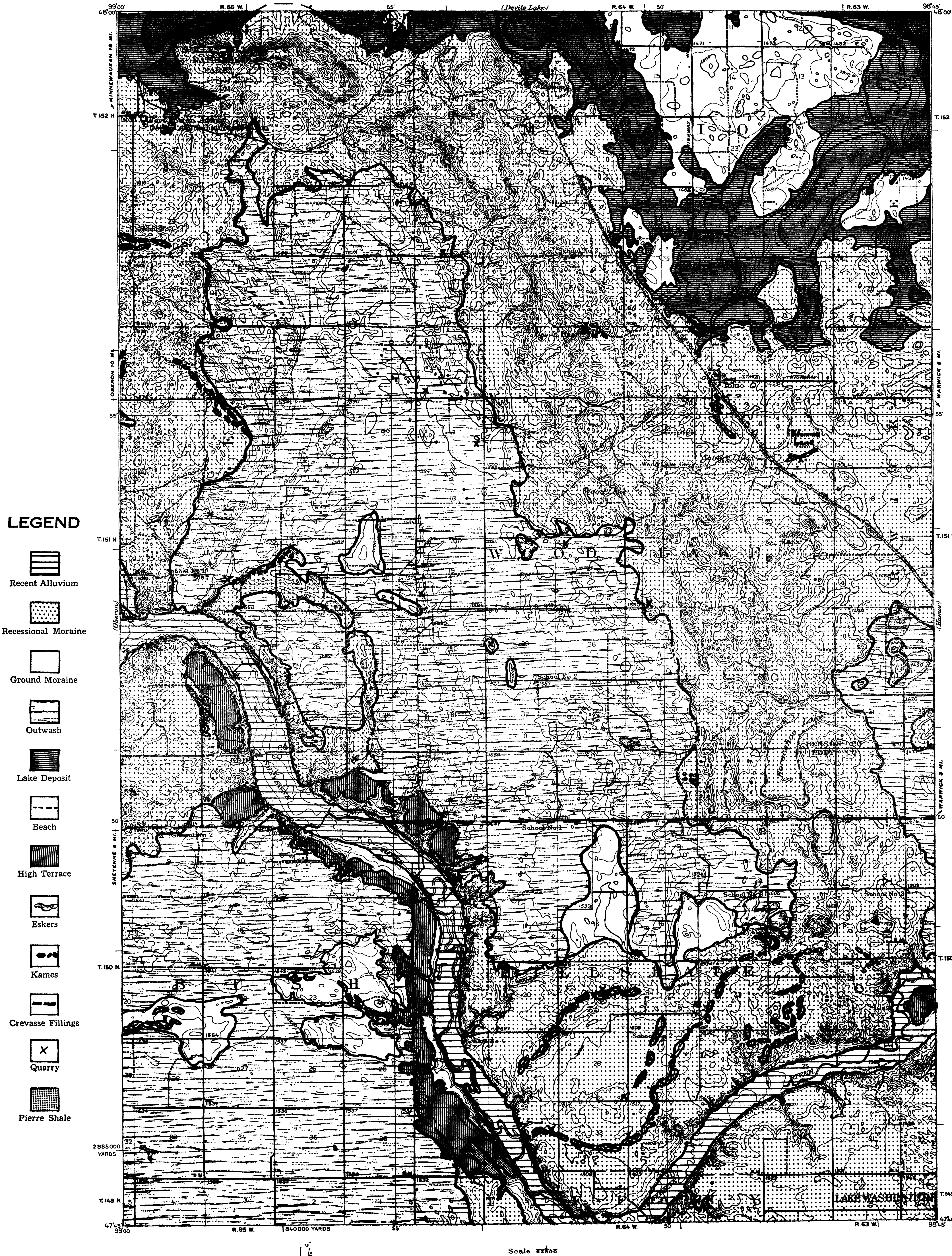
STANDARD SYMBOLS

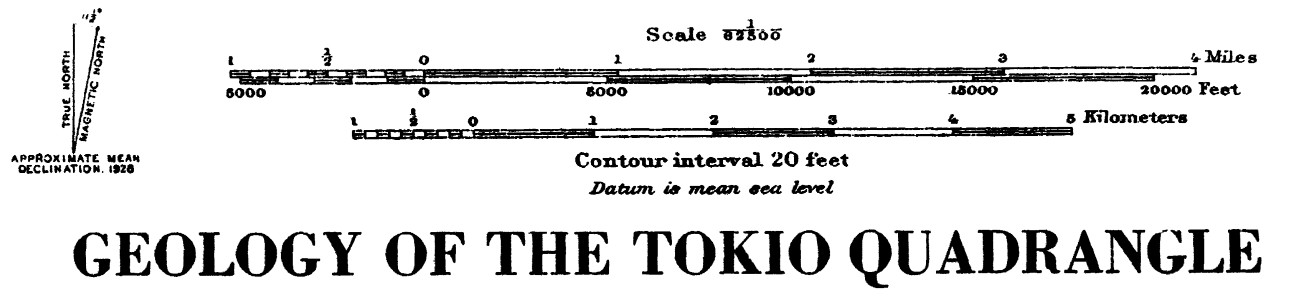
NOTE:—Effective on and after October 1, 1946, the price of standard topographic quadrangle maps will be 20 cents each, with a discount of 20 percent on orders amounting to $10 or more at the retail rate.

CULTURE
(printed in black)



WOODS
(when shown, printed in green)





Topographic base surveyed by
U. S. Geological Survey,
1927-1928

Geology by
D. G. Easker

GEOLOGY OF THE TOKIO QUADRANGLE