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The Geology
of the
Flora Quadrangle

By

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Geology and Ground Water Resources of the Flora Quadrangle

— *by* —

JOHN R. BRANCH

INTRODUCTION

Abstract

An intensive examination of the glacial geology of the Flora quadrangle was made and the features observed were mapped in detail. The glacial features were found to consist of a set of recessional moraines with their respective belts of outwash and ground moraine. The present surface and drainage is the natural consequence of these features. A well census showed the water lies at a level from five feet to twelve feet in shallow wells and at varying depths in deeper wells in the till. With one exception no artesian flow was found. Gravel deposits are, in general, found as terraces on the Sheyenne River and in the glacial drainage system.

Location of the Area

The Flora quadrangle is located between 99 degrees 15 minutes and 99 degrees 30 minutes West longitude and between 47 degrees and 45 minutes and 48 degrees North latitude. It lies chiefly in Benson and Wells Counties although portions of it lie in Eddy County on the southeast. Aurora, West Antelope, and Valhalla Townships are included within the quadrangle while the Townships of North Viking, South Viking, Norway Lake, Hamburg, Bremen, Munster, Grandfield, and Oberon are partially included. The area of the quadrangle comprises approximately 210 square miles.

Purpose of the Survey

Recognizing the importance of ground water to agricultural activities and its dependence on glacial geology in this area, the North Dakota Geological Survey has instituted this investigation as part of a program to supply detailed geologic information concerning areas where this information is of vital concern. Recent attention has been focused on this and adjacent areas because of the proposed development of North Dakota in connection with the program of work on the Missouri River. Cooperative activity by the North Dakota

Geological Survey, the State Water Conservation Commission and the United States Geological Survey is now under way on this program.

Therefore, this investigation was made to provide a detailed map of the geology of the Flora quadrangle, to examine the ground water conditions and their relation to the glacial geology and finally to determine the gravel resources of the area. Geologic mapping was performed using the topographic map of the Flora quadrangle as surveyed by the United States Geological Survey as a base map. A preliminary reconnaissance by car along all section lines was followed by a detailed location of all points and boundaries on foot. Detailed field examination on foot was made of all terraces, and outwash area boundaries were located as definitely as possible by the use of a soil auger. Well data was gathered systematically and recorded on data sheets of the North Dakota Geological Survey which are similar to those used by the United States Geological Survey Ground Water Division. With the exception of a very few permanently covered or deeper drilled wells, all wells were personally measured with steel tape. When this was not possible the word of the occupant of the farm was taken. Records of wells not specifically measured were so marked.

Previous Work in this Area

This area has received attention in the past in a cursory manner in regional studies. It was mentioned by Warren Upham¹ in his report on the Glacial Lake Agassiz. Frank Leverett² in his report also touches upon the geology affecting this area. H. E. Simpson,³ former State Geologist of North Dakota, conducted a survey of ground water conditions of North Dakota and offers certain data on this area that are useful for purposes of comparison. He also treated the general physiography of adjacent areas in his report on Devil's Lake.⁴

From 1937 to 1940, a ground water survey sponsored by the Works Progress Administration was conducted in

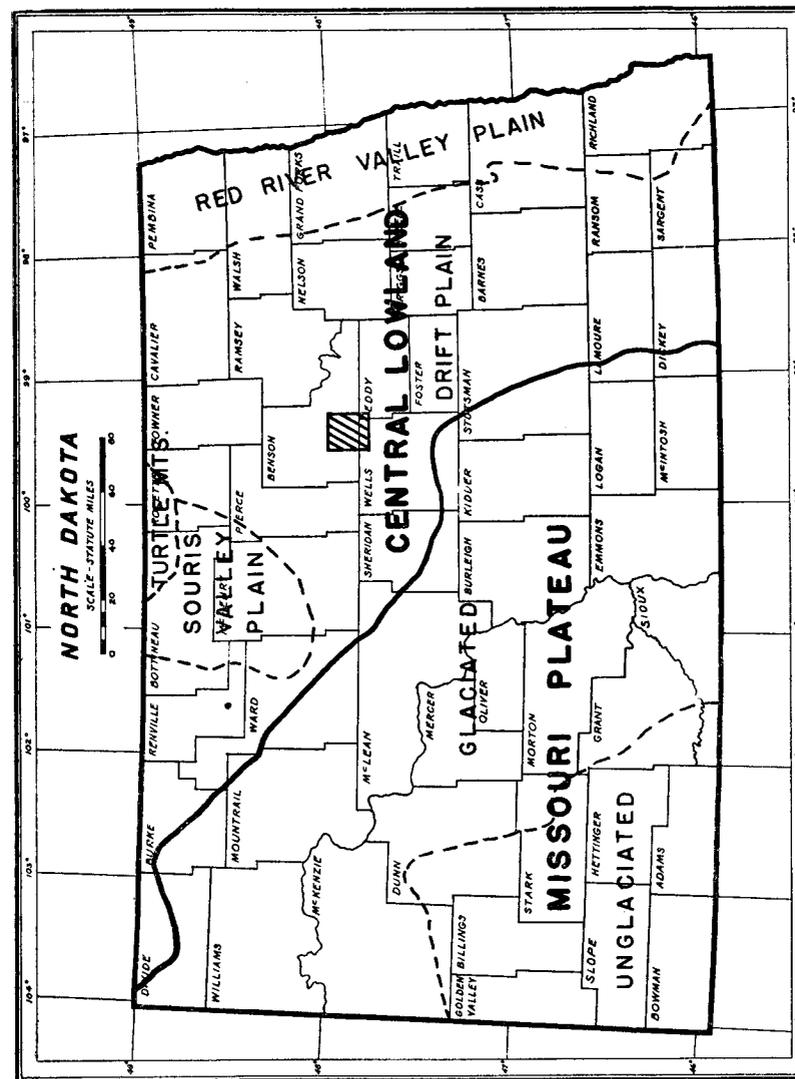


FIGURE 1. Sketch Map showing the location of the Flora Quadrangle.

¹ Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.

² Leverett, Frank, Quaternary Geology of Minnesota and parts of adjacent states; U. S. Geol. Survey Prof. Paper 161, 1932.

³ Simpson, H. E., Geology and ground water resources of North Dakota, U. S. Geol. Survey, Water Supply Paper 598, 1929.

⁴ Simpson, H. E., The Physiography of Devils-Stump Lake Region, N. Dak. Geol. Survey, 6th Bienn. Rept. pp 103-157, 1911.

cooperation with the North Dakota Geological Survey. This project gathered data on approximately 58,000 wells in North Dakota. A summary of this report was published in mimeograph form⁵ and it and the original data are on file in the offices of the North Dakota Geological Survey in Grand Forks, North Dakota.

Acknowledgements

During the course of the field work of this investigation, the writer had frequent occasion to work with members of a field party of the Ground Water Division of the United States Geological Survey under the direction of Mr. P. E. Dennis. The cooperation of this group cannot be too highly emphasized. Residents of the area were without exception very friendly and cooperative and contributed materially with information and assistance. The writer gratefully acknowledges the able and considerable assistance of Dr. Wilson M. Laird, Director of the North Dakota Geological Survey, in supplying data and aiding in the preparation of the manuscript, and the comments and criticism of Mr. P. E. Dennis, United States Geological Survey, on the final manuscript.

GEOGRAPHY OF THE FLORA QUADRANGLE

Physiography

The Flora quadrangle is located within the Western Young Drift Section of the Central Lowland⁶. The surface is one of moderate relief, averaging about 150 feet, between 1400 feet A. T. on the present flood plain of the Sheyenne River and 1700 feet on the summit of the Black Hammer Hill, a drift covered monadnock south of the Sheyenne River (Sec. 8, R. 68 W., T. 150 N.). The present surface is one primarily resulting from the deposition of a series of recessional moraines laid down in Wisconsin time on what was probably a gently rolling surface cut on nearly flat-lying Upper Cretaceous sedimentary rocks (Pierre shale), and finally from the erosional and depositional effects of the Sheyenne River which flows in a southeasterly course across the middle portion of the area.

⁵ Survey of Water Supplies, Parts 1 & 2: N. Dak. Geol. Survey and Works Progress Admin. Grand Forks, N. Dak. July 1940.

⁶ For a complete treatment of the Central Lowland see Fenneman, N. M., Physiography of the Eastern United States, pp. 559-68, New York, McGraw-Hill Book Co., 1938.

FLORA QUADRANGLE

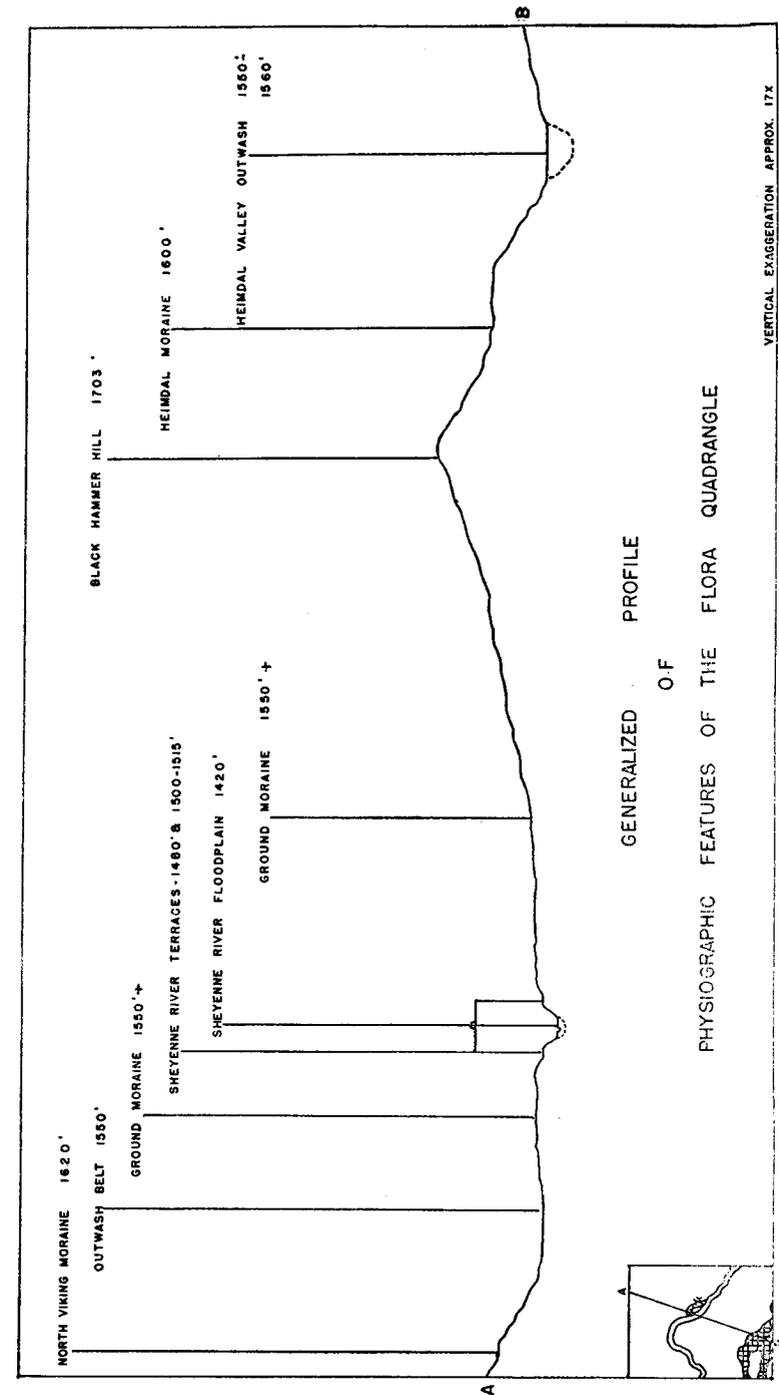


FIGURE 2

In the Flora quadrangle two distinct recessional moraines lie parallel and trend locally northwest-southeast across the area. The northern moraine, designated the North Viking moraine, lies in the northern margin of the area, north of the Sheyenne River, and consists of a well-developed knob and kettle belt about four miles in width with a well-defined front or southern limit. The back slope or northern boundary is gradational into a belt of ground moraine and hence it is difficult to ascertain accurately any line of demarcation between the two. Fairly numerous small lakes and marshes dot the knob and kettle belt.

Portions of the southern moraine, designated the Heimdal moraine, lie in the extreme southern part of the quadrangle and possess topographical characteristics similar to those of the North Viking moraine.

Immediately south of the North Viking moraine lies a belt of outwash material forming a flat about one and one-half miles wide. To the south this belt is directed into a number of channels, now partially or wholly unoccupied by any surface flow, which lead to the Sheyenne River.

Southward of the outwash area a belt of ground moraine, six to eight miles wide, characterized by a gently rolling surface of low relief leads to the Heimdal moraine. The constituent belts of the Heimdal moraine are essentially similar with the exception of a narrower outwash belt lying in what is believed to be a buried preglacial channel in the Heimdal valley. Detailed descriptions of the foregoing features will be given later in the report.

Drainage

Drainage in the northern three-fourths of the area flows south into the Sheyenne River, either through intermittent surface flow or underground through the outwash channels mentioned above. The present drainage system is a sluggish vestige of the former glacial system which was well integrated and copiously supplied locally by melt water from the North Viking moraine. Local exceptions in the recessional moraine are numerous kettles formed in impervious till and now containing small lakes or marshes. Certain lakes, notably Stony Lake and the series directly northeast of it, could possibly be depressions in the bed of a former glacial spillway system

draining areas to the north, running through the drainage system of this area and into the Sheyenne River or they might be merely ice block depressions.

The divide between the present drainage systems of the Sheyenne River and the James River to the south lies along the northwest-southeast axis of the Heimdal recessional moraine. The continental divide between Hudson Bay drainage, i. e., the Sheyenne River which flows to the Red River, and the Gulf drainage i. e., tributaries of the James River which flows into the Mississippi drainage system, runs east-west through the Heimdal recessional moraine. Drainage to the south of this divide flows into the outwash area and then by surface flow and possibly considerable ground water movement, down the Heimdal valley to the James River near New Rockford. As in the North Viking moraine, there is local drainage into kettles. Black Hammer Hill probably is a drift-covered remnant of a preglacial divide existing on the preglacial surface on Pierre shale.⁷

All of the above mentioned drainage is intermittent with the exception of the Sheyenne River which maintains a small year-round surface flow, except in very dry years. Most of this flow is apparently supported by local seepage from springs in the old gravel filled glacial channels leading into the Sheyenne River. The movement of ground water down the Sheyenne valley could not be measured with facilities available at the time the investigation was made. The gradient of the Sheyenne River in the Flora quadrangle is approximately two and one-half feet to the mile.

PRESENT DEVELOPMENT OF THE AREA

Agriculture

The land in the Flora quadrangle is almost entirely devoted to farming. A few areas, chiefly on the flood plain of the Sheyenne River, are used only for grazing due to a concentrated alkali content in the top soil. Certain portions of the recessional moraine are too stony and knobby to be farmed profitably.

⁷ Fenneman, N. M., *Physiography of the Eastern United States*, p. 563, New York, McGraw-Hill Book Co., 1938.

Communications

Two railroads cross this area. The main line of the Great Northern Railroad runs east-west on the outwash surface south of the Heimdal moraine. The Northern Pacific Railroad operates a spur line which runs east-west along the level outwash belt south of the North Viking moraine. Although there are no bituminous surfaced roads in this area, numerous graded and gravel-surfaced county and township roads form an adequate network connecting almost all points. A few of the bridges on township roads crossing the Sheyenne River have been allowed to deteriorate but early in the fall of 1946 these were being repaired.

Resources

The principle resource of this area consists of a fertile soil. This is primarily devoted to raising wheat and some rye.

However, gravel deposits of considerable extent are numerous. These can be divided into two types, namely, the Sheyenne River terrace gravels and the glacial gravels in outwash channels. The former are found at intervals along the Sheyenne River in this area, with the possible exception of the terrace remnant in the extreme eastern portion of this quadrangle, and are of somewhat limited extent. This terrace remnant appears to broaden in the southeast and if this tendency is consistent, a large deposit is indicated. The second classification, the glacial channel gravels, can be found in various parts of the area. Varying degrees of continuity of deposition may be traced by reference to the map (see Plate II). Various small kame deposits containing considerable sand with the gravel have been located but as a rule these deposits are too small to be of value except for very local use on farms or as an immediate source for road material.

Of particular interest is the terrace in the Heimdal valley in the southern part of the quadrangle. This deposit (Sec. 5, T. 149 N., R. 68 W.) has considerable areal extent and one-half mile west of the town of Bremen considerable gravel has been excavated from it by the Great Northern Railroad for use as ballast. In this location the gravel has been dug out to a depth of about thirty feet where the ground water table was encountered.

Climate

The Flora quadrangle lies in a belt having a climate known as Humid Microthermal⁸, with a short summer phase. The annual range of temperature is characteristically very great. The growing season averages 110 days over a 16 year period but this short growing period is somewhat offset by the longer duration of daylight in this relatively high latitude⁹. The rainfall is usually less than 25 inches and comes for the most part during the summer months. Consequently the snowfall is usually light, coming in the more arid phase of the climatic cycle. This climate is also known as a spring wheat climate because the wheat crop in this region reaches its best development in the drier parts of the climatic cycle.

While there are no weather stations on the Flora quadrangle data are available from Maddock, North Dakota, one mile to the west of this quadrangle and at Fessenden, Wells County, about thirty miles to the southwest. Precipitation tables are furnished on the following pages. (See Table I). No information is available on temperatures for any point nearer than Devils Lake, North Dakota. Figures for that location may be found by reference to "The Climatic Summary of the United States."¹⁰

GEOLOGY

General

The surface of the Flora quadrangle is made up almost entirely of glacial drift. Bedrock is encountered at only three widely separated points where road cuts have uncovered the Pierre shale in small exposures in the valley walls of coulees or creeks. Although there is no direct evidence of the bedrock underlying the Pierre shale it is reasonable to conclude, on the basis of the general regional structural pattern that has been established from deep well logs in this state,¹¹ that the formations underlying the Pierre shale would follow fairly closely the data obtained from the Glenfield Oil No. 1 deep well and the Prairie Oil and Gas No. 1 deep well.

⁸ Trewartha, G. T., *An Introduction to Weather and Climate*, pp. 313-319, New York, McGraw-Hill Book Co., 1937.

⁹ U. S. Dept. of Agriculture, Weather Bureau, *Climatic Summary of the United States*, Section 35, Eastern North Dakota, 1930.

¹⁰ *op. cit.*

¹¹ Laird, W. M., *Stratigraphy and structure of North Dakota*, N. Dak. Geol. Survey Bull., 18, 1944.

TABLE I — PRECIPITATION TABLES. FESSENDEN, WELLS COUNTY — Elevation 1610 feet.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1912	0.24	T	0.15	2.37	6.80	4.53	3.18	2.83	2.17	0.89	0.02	0.30	23.48
1913	...	T	0.15	1.25	.96	1.90	1.66	2.23	1.41	1.66	.08	.11	12.67
191430	1.10	.91	2.85	6.58	1.46	3.79	1.14	1.06	.36	.54	20.51
191505	.25	1.24	1.88	6.53	2.63	1.25	3.17	.26	.46	.54	18.78
191627	1.93	1.01	1.74	4.00	3.31	1.04	1.04	.43	.22	1.85	17.91
1917	...	1.00	.05	1.54	.08	2.97	2.84	.85	1.96	.45	.17	.95	13.94
191844	1.10	2.4	2.01	2.58	3.14	5.93	.13	.57	1.71	1.35	21.10
191925	.95	.70	2.97	3.52	.72	2.02	.88	.80	1.50	.90	16.51
1920	...	1.15	.15	.86	.82	3.02	2.12	2.36	1.09	T	.75	.55	13.52
192143	.40	.91	3.13	4.90	3.41	1.46	4.17	1.70	1.40	1.04	24.70
192240	1.06	.74	3.54	4.43	1.64	3.28	2.01	.67	2.45	1.37	22.54
192345	1.40	.53	.82	1.32	2.65	1.38	2.31	1.18	.78	.29	14.19
192441	.45	.25	4.18	4.75	.61	.92	3.36	1.96	.15	.37	18.10
192507	.44	.55	1.89	1.16	.84	1.42	2.75	.75	T	.49	15.79
192645	.45	.50	2.24	1.84	2.72	2.38	2.21	1.08	.66	.34	15.84
192746	.40	1.30	1.74	6.27	2.83	2.12	3.71	.42	.66	.33	22.08
192821	.08	1.06	1.19	2.43	3.03	2.42	.63	.00	.48	.38	19.57
192942	.28	.89	1.13	2.00	1.10	.94	2.06	1.56	1.60	.97	14.11
193027	2.04	.18	.88	2.99	.96	1.07	1.14	1.90	.98	.08	15.19
193125	.14	.70	.75	1.75	3.52	3.71	2.22	1.74	.74	.00	17.17
193245	.69	.79	1.98	2.70	1.61	3.20	.89	2.47	.78	.07	20.86
193392	.41	.77	2.04	3.31	2.03	.39	.59	.84	1.13	1.58	15.38
193435	.04	.46	.35	1.12	1.83	1.22	1.22	1.37	.16	.35	9.25
193553	.25	1.11	2.27	2.84	7.26	2.43	.44	.26	1.38	1.02	20.90
193678	1.34	.88	.09	.92	.95	2.62	2.04	.29	.25	.35	10.55
193791	.81	.19	.84	4.91	3.19	.59	.82	.91	.49	.86	16.80
193841	.74	.61	1.20	2.08	4.66	.89	.12	.66	.89	.37	14.52
193930	.66	.35	1.03	1.76	2.01	1.79	.30	.72	.02	.42	14.72
194013	.56	.68	3.08	2.12	7.13	.79	.51	2.34	.79	.28	19.85
194170	.28	.93	2.30	4.91	2.58	4.16	3.66	1.80	.89	.22	25.18
194208	.90	1.86	2.58	3.77	2.63	2.71	1.37	.25	.09	1.03	21.40
194360	.41	1.01	2.27	3.33	2.10	1.24	.45	.40	.24	.12	13.64
194402	.32	.57	.40	4.37	1.64	3.48	.86	.00	2.29	.27	19.44
194539	.02	1.38	.53	.92	3.71	1.33	2.19	.43	.80	1.04	16.61
194651	.72	1.59	.24	2.62	1.56	1.86	2.30	1.95	1.03	1.04	18.92

MADDOCK, BENSON COUNTY — Elevation, 1604 feet

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1915	0.04	0.00	T	0.98	2.41	5.35	0.67	1.45	2.88	1.50	0.44	0.17	15.89
191617	.86	.74	1.17	5.94	5.60	3.47	.77	.51	.08	.59	18.26
191715	.18	2.57	T	1.85	2.55	.44	2.17	.60	.13	.51	11.81
191830	.40	1.47	3.62	1.73	3.00	3.31	.17	.00	2.01	.36	16.37
191936	.94	1.25	2.95	2.02	.92	2.06	1.49	.31	.75	.32	13.70
1920	...	1.33	.21	.55	.93	3.26	1.60	3.70	.98	.00	.47	.23	13.49
1921	...	T	.90	2.41	1.47	5.76	5.63	2.27	4.84	1.78	.26	.22	26.24
192219	1.12	.45	.13	4.23	1.44	2.34	3.61	.42	2.11	.34	21.16
192321	.95	.27	.99	2.54	3.32	1.31	2.23	.84	.41	.19	14.48
192416	.15	.08	3.14	.95	1.68	1.83	3.42	1.90	.13	.25	16.51
192504	.17	.47	1.67	5.28	1.52	.64	3.74	.66	.22	.15	15.82
192614	.14	.27	.37	2.01	1.45	2.91	1.89	1.05	.19	.10	12.69
192711	.18	.37	1.61	1.95	1.98	3.78	.25	2.18	.19	.05	18.53
192806	T	.34	.97	6.32	5.43	4.12	.31	.08	.16	.17	19.03
192980	.62	.53	1.82	2.16	.67	.93	2.29	1.30	.84	.44	13.17
193007	1.16	T	.65	2.74	1.01	.82	1.42	1.75	.27	.08	14.25
193107	1.03	.75	.33	.93	3.85	4.23	2.90	1.22	.08	T	16.03
193255	.31	.36	1.87	2.42	3.56	.75	1.65	2.56	.42	.05	18.08
193356	.22	.33	.13	3.61	1.63	.20	.62	.22	.29	.60	10.68
193418	.04	.14	.23	.61	1.95	.58	.89	.61	.10	.16	9.34
193525	.16	.41	1.62	2.90	5.89	5.61	.51	.15	.55	.33	20.07
193685	.98	.30	.38	.09	.86	1.85	.65	.22	.15	.34	11.10
1937	...	1.05	.34	.03	1.14	2.01	2.65	1.12	1.24	1.18	.21	.33	16.44
193829	.68	.55	1.75	2.14	6.73	.46	T	.23	.41	.21	15.74
193921	.47	.54	.91	1.21	5.08	1.51	1.62	.29	.48	T	13.37
194009	.47	.52	1.33	1.91	4.38	1.93	4.49	1.11	.30	.24	14.14
194163	.33	1.06	2.28	4.60	1.29	2.26	5.79	1.43	.39	.11	22.31
194209	.18	1.58	.86	2.48	3.56	1.72	.82	.36	.06	.38	15.60
194320	.31	.94	1.78	2.45	1.69	.74	.50	.24	.14	.12	10.40
194411	.19	.63	.27	4.76	.68	4.59	1.47	.00	2.34	T	18.92
194533	.15	1.53	.61	1.50	3.62	1.73	2.00	.51	1.03	1.04	16.61
194668	.61	1.50	.18	4.06	5.28	1.68	2.53	2.00	1.03	1.04	18.92

The following is a generalized table of geologic formations for the Flora quadrangle:

Cenozoic

Pleistocene system

Eldoran series

Wisconsin stage

Mankato substage

Glacial till and outwash

Mesozoic

Cretaceous system

Upper Cretaceous series

Montana group

Pierre formation

Colorado group

Niobrara formation

Dakota formation

Benton formation

Paleozoic

Ordovician system

Red River formation

Winnipeg formation

Cryptozoic

Granite¹²

Pierre Shale

In the few shallow surface exposures of the Pierre shale in this quadrangle, it appeared as a blue-green, poorly indurated shale showing a pronounced rectangular cleavage causing it to weather into small blocks or sheets. Along the partings caused by this cleavage weathering frequently produces a limonitic stain and a certain degree of induration as well. Small deposits of gypsum in the form of rosettes and small crystals are encountered. Near the surface, in addition to being discolored by limonitic stains, the shale tends to fade to a gray color. No occurrences of sandy phases of this formation, characteristic in other areas, were found. This formation is further distinguished by being impervious to ground water and the upper boundary of the formation customarily terminates water drilling activities in this area.

¹² For a detailed discussion of these formations and summary of current information see Laird, W. M., *op. cit.*

Pleistocene system

Name and definition¹³

Charles Lyell¹⁴ originally referred strata which contained more than 70% of recent species of shells to the newer Pleistocene or Pleistocene. This original definition included beds now regarded as older than Pleistocene. The definition of the Pleistocene as now used includes all beds deposited during the Great Ice Age and contemporaneous marine, fluvial, lacustrine, and volcanic beds. This is essentially the redefinition of the term Pleistocene as it was proposed by Forbes¹⁵ and agreed to by Lyell.

Deposits belonging to the Recent are not included in the Pleistocene by the United States Geological Survey¹⁶ although G. F. Kay and M. M. Leighton¹⁷ 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 G. F. Kay¹⁸ to include the Wisconsin glacial, the Peorian interglacial, and the Iowan glacial stages of the Pleistocene epoch. As can be seen the original definition did not include the Recent but Kay and Leighton¹⁹ later included the Recent in the Eldoran series

¹³ See Laird, W. M., *Geology and ground water resources of the Emarado Quadrangle, North Dakota Geological Survey Bull. No. 17, 1944.*

¹⁴ Lyell, C., *Elements of Geology, French translation, appendix pp. 616-621, Paris, 1939.* Reference from Wilmarth, Grace, *The geologic time classification of the United States Geological Survey compared with other classifications: U. S. Geol. Survey Bull. 769, p. 47, 1925.*

¹⁵ 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, pp. 402-403, 1846.* Reference from Wilmarth, Grace, *op. cit.* p. 48.

¹⁶ See Wilmarth, Grace, *Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, p. 1781, 1938.*

¹⁷ Kay, G. F. and Leighton, M. M., *Eldoran epoch of the Pleistocene period: Geol. Soc. America Bull. vol. 44, pp. 669-674, 1933.*

¹⁸ Kay, G. F., *Classification and duration of the Pleistocene period: Geol. Soc. America Bull. vol. 42, pp. 425-466, 1931.*

¹⁹ Kay and Leighton, *op. cit.*

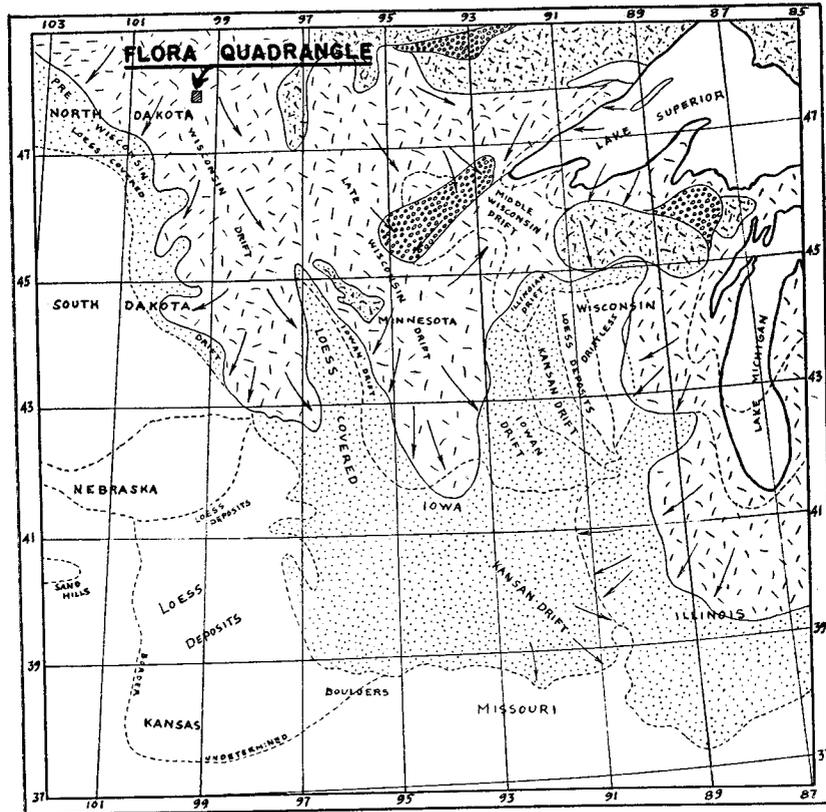


FIGURE 3

Extent of Wisconsin Glaciation in the North Central United States

making classification for the Mississippi Valley as follows:

Pleistocene or Glacial period (system)

Eldoran epoch (series)

Recent age (stage)

Wisconsin age (stage)

Mankato substage (Late Wisconsin)

Cary substage (Middle Wisconsin)

Tazewell substage (Early Wisconsin)

Iowan substage

The Wisconsin Stage

Name and definition

The term "Wisconsin" will be used as originally proposed by T. C. Chamberlin²⁰ and later expanded by M. M. Leighton²¹. Deposits in form of recessional moraines and related outwash are considered to be of the Mankato substage laid down as the Keewatin glacial ice retreated to the north in the declining phases of that substage²². Any correlation of these moraines with other similar features on a statewide basis must await further study of this portion of North Dakota and a comprehensive geologic mapping leading to an overall regional determination of glacial patterns. This has been accomplished in the eastern part of the state by Leverett²³ and Upham²⁴ and in part of the western part of the state by Andrews²⁵. At the present time the North Dakota Geological Survey is adding to the regional knowledge by intensive study on key areas.

Mankato substage

Name and definition²⁶

This term for the latest Wisconsin substage was proposed by M. M. Leighton²⁷ and named for the excellent exposures in the vicinity of Mankato, Minnesota. In this report the glacial till will be considered to have been deposited during the phases of the Jamestown lobe of Keewatin ice of Mankato or Late Wisconsin age.

Description of Members of the Mankato Substage

Till

The till covers approximately seven-eighths of the surface of this quadrangle and undoubtedly underlies the remaining area whose surface is covered with outwash deposits. It varies in thickness from zero where the Pierre shale is now exposed (See map Plate II) to determined depths of approximately

²⁰ Chamberlin, T. C., in Geikie, J., *The Great Ice Age*, 3rd ed. pp 240-775, London, Edward Stanford Ltd., 1894.

²¹ Leighton, M. M., *The Naming of the subdivisions of the Wisconsin glacial stage*, *Science*, new ser., vol. 77, p. 168, 1933.

²² See Figure 3.

²³ Leverett, F., *Quaternary Geology of Minnesota and Adjacent States*, U. S. Geol. Survey Prof. Paper 161, 1932.

²⁴ Upham, W., *The Glacial Lake Agassiz*, U. S. Geol. Survey, Mon. 25, 1895.

²⁵ Andrews, D. A., *Geology and coal resources of the Minot Region, North Dakota*: U. S. Geol. Survey, Bull. 906-B, 1939.

²⁶ See Laird, W. M., *op. cit.* p. 18.

²⁷ Leighton, M. M., *The naming of the subdivisions of the Wisconsin glacial age*: *Science*, new ser., vol. 77, p. 168, 1933.

165 feet in drilled wells. (Well of Paul Paulson, S. E. $\frac{1}{4}$ Sec. 29, Twp. 151 N., R. 68 W.). In this case, however, at the recorded depth till was still encountered and for that reason this data does not represent a maximum. However, numerous other well logs show penetration to similar depths before encountering shale and taken together tend to indicate a varying depth of till in disconformable contact with a surface of mild relief on the Pierre shale.

The till is composed of a blue to gray sandy clay containing many pebbles of varying sizes, angularities, and compositions. The color of the till varies from place to place but only in the degree of blue or gray color. In places it is so sandy that a semi-fluid condition of transport is suggested. The rocks contained in the till vary from pebbles of less than one inch in diameter to slabs of limestone and dolomite ten feet long and from three to five feet in thickness but the greater proportion by far, is composed of smaller pebbles. The percentage composition of pebble samples taken in the recessional moraines averaged about 47 per cent of limestones and dolomites and 44 per cent of granites and granite-gneisses. The remaining fraction is composed of schists, shale, basic felsites, quartzites, and others in about equal quantities. One notable exception was encountered in Sec. 8, T. 152 N., R. 67 W. on the north side of road, 200 yards west of school house where 44 per cent is shale in fragments or weak boulders, 35 per cent is limestone and dolomites and the remainder of equal minor proportions of the constituents mentioned above. Apparently the contact between the Pierre shale and the till is close to the surface at this location. Occurring near the edge of the glacial spillway (See map Plate II) it is conceivable that the till is filled with fragments from the shale comprising the old preglacial valley wall which was eroded when the initial advance of the ice sheared off some of the relief features then existing.

The nature of the pink dolomite and the dense buff colored limestone points to a probable origin in Canada, possibly the Red River formation of Ordovician age and the Stonewall formation of Silurian age as exposed near Winnipeg, Canada.

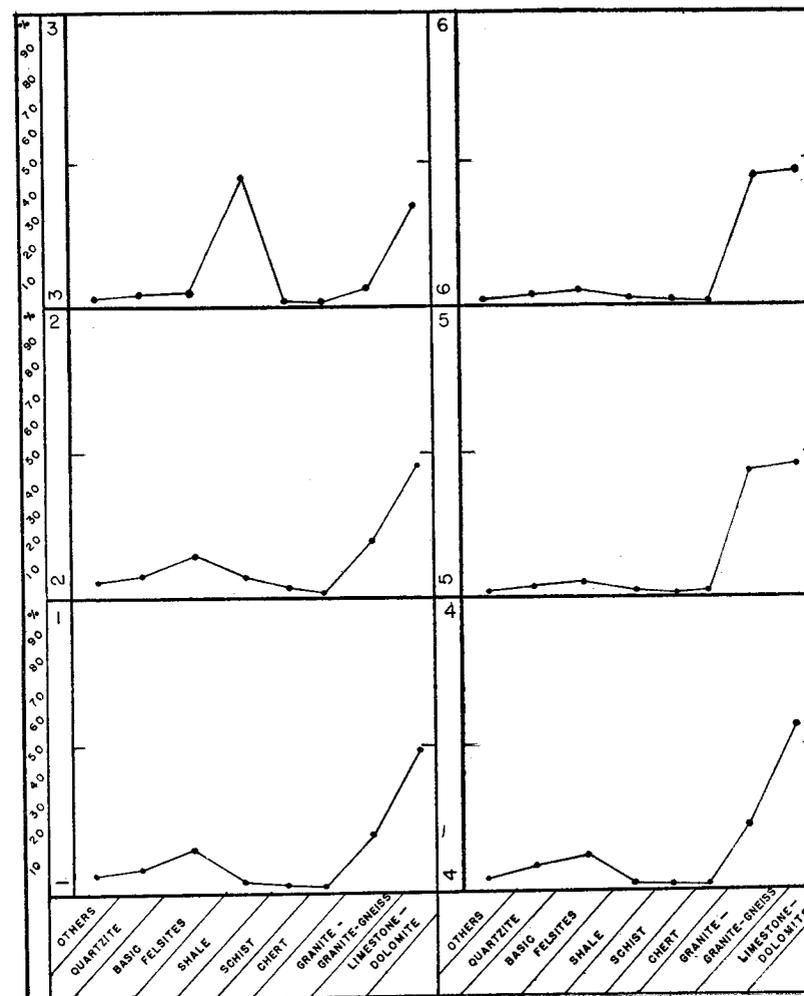


FIGURE 4
PEBBLE COUNTS IN THE RECESSIONAL MORAINES
(SEE PLATE II FOR LOCALITIES)

The main body of the till is relatively little weathered, unleached to any considerable depth, and loose to moderately consolidated although the degree of consolidation varies considerably within the area and in general is found to be less where the till is of a more sandy character. This of course represents no departure from the established behavior of

clayey matrices in contrast to those of a sandy base. At no place was any surface exposure observed that might positively indicate the presence of an older, distinct till which might be assigned to an earlier glacial stage or substage. However, the writer does not imply that such a till might not exist beneath the present till covering. Sufficient evidence for any differentiation of tills in the Flora quadrangle is not at the present time available.

The weathered surface of the till has undergone a change from blue to light gray and this change has usually taken place to a depth of less than two feet. Few of the pebbles in the till, with the notable exception of the granite-gneisses and the shale, show any marked effect of weathering after transportation and deposition by the glacier. Obviously they were subjected to considerable abrasion while enroute from their original location.

In places the till is highly impervious and forms an effective retainer for kettle lakes and swamps. However, as observed in surface exposures and noted in well logs, the till varies from a pronounced sandy content to actual lenses of sand and gravel of considerable depth and areal extent. These lenses act as local aquifers and reservoirs when of sufficient size and when the infiltration of meteoric waters is not prevented by complete envelopment by impervious deposits. Numerous wells have been sunk into what are probably lenses of this type but well records show that the water supply from sources of this kind is sometimes rather limited and apt to be unreliable in dry years. In a number of instances, small and scattered deposits of gypsum were found in the till as crevice or fracture fillings.

An unstratified layer of fine sandy material, usually from one to three feet in thickness in observed exposures, commonly exhibiting a pseudo-columnar structure, is found on the ground moraine belts immediately south of the outwash areas. This deposit thins out to the south away from the outwash belt, and is found only to a minor extent in the recessional moraine as pockets or small areal deposits. No evidence of a deposit of this nature was found on the surface of the outwash belts. This material is considered by the writer

to be loess of local origin blown from the surface of the outwash belt during the winter or dry season when the glacial meltwater streams are frozen and the surface of the outwash belt is dry. In this area the glacial anticyclone blew to the south, outward from the high pressure, cold center of the glacial area over the dry outwash area and transported the fine sandy material to windward of the outwash belt to a point where the growth of a soil mantle inhibited further transportation. (See Figure 5). Some of this material in times of greatest wind was transported as far as the southern moraine area.²⁸

Glacial Outwash

While representing only a minor fraction of the drift cover, the outwash sediments are a major factor in the ground water resources and gravel deposits in this quadrangle. Along the continuous east-west belt directly south of the North Viking recessional moraine the ground water level is within one foot to four feet of the surface. This area contains wells whose water supply is the most reliable even in driest years. As previously mentioned, the outwash surface is that of a nearly level flat, sloping very gently southward from the front of the moraine, averaging from one to one and one-half miles in width and dividing in the south into a number of tributary channels flowing into the Sheyenne River. Near the surface this belt is composed of fine to coarse sand. Where the outwash channels join with the Sheyenne River they merge with the present surface of the Sheyenne River terrace.

From data obtained by drilling and augering it was found that the fine sand commonly gives way to very coarse sand and small pebbles at depths of less than six feet near the axes of the outwash drainage. However, observations made in a sand pit one-half mile northwest of Oberon, on the south side of the Northern Pacific Railroad spur line to Maddock, and other sand pits in glacial channels indicate that the fine sand, in places, reaches depths of at least twenty feet. Undoubtedly, the stratification within the outwash will reflect the varying conditions of sedimentation commonly associated with a retreating glacial front. Rotary drilling on the outwash belt indicates

²⁸ Hobbs, W. H., The Glacial anticyclone and the continental glaciers of North America, Proc. of Am. Phil. Soc., vol. 86, No. 3, 1943.

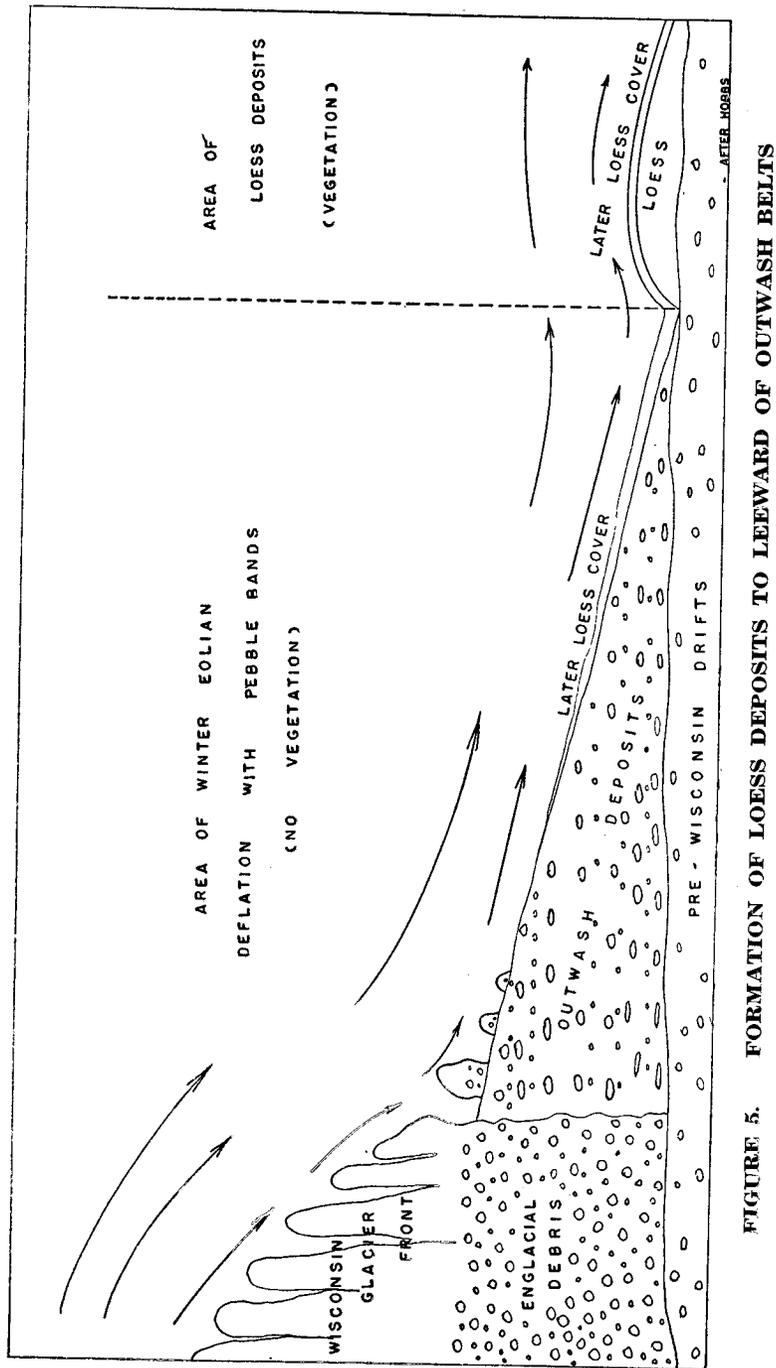


FIGURE 5. FORMATION OF LOESS DEPOSITS TO LEEWARD OF OUTWASH BELTS

that below ten feet of fine to coarse sand, up to thirty additional feet of gravel of varying sizes rests on the till. Shale is encountered at 90 to 105 feet in two of the above mentioned holes, and at 60 to 80 feet in the others. To the east and closer to the front of the North Viking moraine an increasing proportion of shale pebbles was noted in the outwash.

In general the southern fringe of the North Viking outwash belt ends abruptly against the ground moraine which at this boundary frequently has a slight slope to the north. As indicated on the map (Plate II) outwash deposits continue in relatively narrow channels to the Sheyenne River where they show a tendency to broaden out. This is especially noticeable in the section of the quadrangle north and east of the intersection of the county lines of Benson, Wells, and Eddy counties, where the outwash channel appears to be very broad and well developed as it approaches junction with the Sheyenne River. It seems probable that some of this effect is due to braiding of the south-flowing outwash channels in response to a loss in gradient as they approached the Sheyenne terrace. This latter terrace was probably the local base level directly controlling the outwash gradient and competency.²⁰

A number of the coulees at present leading into the Sheyenne River from the north contain considerable deposits of fine, well sorted sand and gravel in their upper reaches. A good example of this can be seen in S. E. $\frac{1}{4}$, Sec. 35, T. 152 N., R. 69 W., and in the Peterson coulee, N. E. $\frac{1}{4}$, Sec. 16, T. 151 N., R. 68 W. In the latter case the deposit is at the same level as the present upper surface of the Sheyenne terrace gravel and is considered by the writer to form the single instance of correlation of the present upper surface of the Sheyenne terrace with the outwash in its final stage. It seems likely that these coulees, notably those specifically located above, may have been outlets for the outwash material from the front of the North Viking moraine. However, as indicated on the map (Plate II) the outwash could not be traced to a positive contact on the north with the outwash belt. Hence, for a number of coulees this connection with the outwash belt is deductive except on occasion, as mapped, where the contact was

²⁰ Tetrick, Roderick, Geology and ground water resources of the Oberon Quadrangle, North Dakota Geol. Survey Bulletin in preparation.

capable of being traced. The possibility that contact with the outwash belt of the northern heads of those coulees whose contact is uncertain, is actually present but that this contact is covered with till seems unlikely when it is considered that no case of outwash underlying till was noted elsewhere in this area. However, the possibility that the channel heads are masked by a mantle of loess from the outwash belt itself is a subject that might be investigated by drilling.

From surface observation and examination of excavated pits, the general size gradation of the material in the outwash channels and the outwash belt appears to be in sizes considerably smaller than the material found in the terrace of the Sheyenne, and the sources of sand of economic value are hence more numerous in the former.

The outwash belt to the south of the Heimdal moraine possesses, in this quadrangle, a somewhat different aspect. The recessional moraine front ends somewhat abruptly in the south and the till of the ground moraine on the southern limit of this outwash belt begins with a considerable slope only about one-half mile to the south. (See Physiographic Cross Section Figure 2). This has resulted in a rather constricted outwash belt following what was a preglacial valley running northwest-southeast parallel to the present front of the Heimdal moraine. Rotary drilling near the village of Heimdal to the west of this quadrangle indicates that the gravel in the present Heimdal valley extends to a maximum depth of at least 50 feet. This valley can be traced to the northwest to intersect with the present Sheyenne River valley in the Mad-dock quadrangle (Sec. 13, T. 150 N., R. 71 W.) and to the southeast where it joins the drainage of the James River near New Rockford. The outwash material was probably deposited largely as a valley filling and now appears in this quadrangle as a terrace with a surface at about 1550 feet. Indications of different levels for this surface point to a possibility of more than one level but the limited occurrence of the Heimdal valley in the Flora quadrangle forbids determination of these levels on local evidence alone. Possibly on the basis of regional study some of the different elevations noted in this study will be found to have correlatives elsewhere along the old water-

course. No statistical grouping of elevations in this quadrangle offers evidence of more than one level. The figure of 1550 feet is rather a median elevation where the range may be over differences of as much as twenty feet.

Augering showed that in some places there is a deposit of fine to coarse sand overlying the main terrace deposit of gravel. The best exposure of this material is in the Great Northern Railroad pit near Bremen. In this quadrangle, the Heimdal valley appears only in the southwest corner and although apparently of small areal size as far as this quadrangle is concerned it is considered a good economic source of gravel, being located near or on the Great Northern Railroad and limited only as far as economic removal is concerned by the occurrence of the ground water table about thirty feet below the upper surface of the gravel terrace.

A remarkable feature of this part of the Heimdal valley is the island or till outlier in the valley around which the outwash was deposited after the northward retreat of the ice. At the present time it may be questioned whether the alluvial deposits on the north side of this island are deposits from the Heimdal valley drainage system laid down when that drainage now represented by the terrace was at its maximum height or are simply outwash from the drainage out of the front of the Heimdal moraine. The writer prefers the former interpretation, while admitting that unquestionably some of the outwash from the moraine merged with the Heimdal gravel and probably during the last stages of active deposition covered the basal gravels with the present mantle of fine silt.

Glacial Outwash Channels in the Recessional Moraine

Of considerable interest in both the North Viking and the Heimdal recessional moraine belts are glacial spillways running through the morainic knobs into their respective outwash belts to the south. These channels are to be distinguished from the outwash channels which run for the most part from the outwash belts south of the North Viking moraine to the south into the Sheyenne River and traverse only the ground moraine. The channels in the recessional moraine run through at least one series of moraines in addition to that from which they originate before joining the regional drainage to the east.

In the North Viking moraine there are two such clearly defined channels. One flowing from the northeast corner of the quadrangle includes in its course the present Stony Lake (Secs. 13 & 24, T. 152 N., R. 68 W) and a series of dry lake beds extending to the northeast. Augering in these dry lake beds (N. W. $\frac{1}{4}$ Sec. 18, T. 152 N., R. 68 W) shows fine clay to a depth of two feet and fine sand from two feet to six feet. Recent gastropods and pelecypods were found in the boring. The present barriers between Stony Lake and the dry bed to the north is a finely sorted beach sand with no evidence of gravel or coarse sand on the surface or to a depth of six feet. A similar channel, containing no standing water at present, is located in Secs. 11, 12, 14 T. 152 N., R. 69 W., and runs parallel to the Stony Lake channel.

In the Heimdal moraine a long and well defined channel runs from Sec. 33, T. 151 N., R. 69 W., (see map Plate II) in a southeasterly direction and connects with the Heimdal outwash belt at Sec. 25, T. 150 N., R. 69 W. This channel is marked by sand and gravel deposits along its length and has been traced farther to the west on the Maddock quadrangle. Augering has shown that coarse sand occurs to a depth of six feet along its channel and to a considerable distance laterally from the channel axis.

It is the view of the writer that these channels were glacial spillways through which outwash material was carried, after the ice had retreated a considerable distance to the north and that they were probably flowing at a time somewhat later than that during which the main deposits in their respective terminal outwash belts were laid down. This is most forcefully indicated in the case of the Stony Lake spillway which possesses a valley of considerable width and depth (see map). It is interesting to note that the pebble count showing the high percentage of shale was taken on the east valley top of the Stony Lake spillway (S. E. $\frac{1}{4}$, Sec. 8, T. 152 N., R. 67 W.) and that rotary drilling in the outwash just south of the mouth of the spillway in the outwash belt shows a high count of shale pebbles. This might indicate the presence of the Pierre shale close to the surface and possibly the existence of a pre-glacial north-south valley now occupied by a chain of lakes or dried lake beds. On the examination of areas to the east

of this quadrangle, similar physiographic features appear and indicate that the chain of lakes is a recurring regional phenomenon.³⁰ As further study is done in this general region, in all probability these drainage patterns can be correlated and be made part of a larger physiographic pattern.

Kame deposits

In this discussion the term "kame" is used in a broad sense as recommended by R. F. Flint to describe isolated fluvioglacial deposits in the recessional moraine or in the ground moraine.³¹ These are, however, distinct from the deposits of the outwash belt as a unit and are considered to have been formed within or below the body of the glacier.

Numerous deposits of this nature are located in the recessional moraine and occur in some cases as ellipsoidal hills or knobs of up to seventy-five feet high or as smaller deposits on the sides of morainic hills. The latter are considered to have been formed in a manner similar to that of kame terraces, i. e., in a wedge-shaped opening between the ice and a hillside in a recessional or melting stage of glaciation when the fluvial processes were active. In most cases the sorting is fair to fine, with a wide range of sizes. Most of these deposits are of limited extent and in places show an appreciable amount of shale particles and pebbles. Examples of this type of deposit can be found well developed at N. E. & N. W. $\frac{1}{4}$'s, Secs. 17 & 18, T. 152 N., R. 68 W. respectively, and at other places noted on the map.

Gravel Terraces of the Sheyenne River and the Heimdal Valley

While positive and detailed correlation of the age of the Sheyenne terrace awaits regional study, it is the belief of the writer, that this terrace was formed in this area soon after the retreat of the ice front to the north, possibly at a time when the present Sheyenne valley was part of one or more of the successive drainage outlets of the glacial Lake Souris.

From a study of the Maddock, Selz, and Aylmer quadrangles to the west it appears possible that southeast drainage from glacial Lake Souris might have flowed over a number of successive courses, now represented by chains of lakes and

³⁰ Tetrick, *op. cit.*

³¹ Flint, R. F., Personal communication, August 10, 1946.

low areas, until the drainage found its present course at the lowest level.

At the present time sufficient detailed work has not been completed, with the exception of the area some distance to the west which has been mapped by Andrews³², to establish the succession and continuity of these old drainage patterns as they affect areas to the east.

In this quadrangle, the Sheyenne River terrace appears as remnants in the present valley or as an abandoned channel filling at approximately the same level. The altitude of the terrace varies considerably from place to place between 1480 feet A. T. (Sec. 22, T. 151 N., R. 69 W.; Secs. 21, 22, 26, 27 T. 151 N., R. 68 W.) and 1515 feet A. T. (Secs. 22, 23, T. 151 N., R. 69 W.; Sec. 7, T. 150 N., R. 67 W.) but exhibits no particular trend or downstream descent. It is entirely likely that erosion has altered the terrace locally since its formation. In the abandoned channel (Secs. 21, 22, 27, T. 151 N., R. 68 W.) where it seems reasonable that dissection of the terrace would be at a minimum, the level is at an average of 1500 feet although it falls to 1480 at the downstream end of the old channel.

In several cases the preservation of the terrace remnants seems to be due to the presence upstream of a protecting spur of till (S. E. $\frac{1}{4}$ Sec. 22, T. 151 N., R. 69 W.; Secs. 23, 24, T. 151 N., R. 69 W.). In these instances it is apparent that the protecting spur has served to deflect the course of the river across the valley in a wide meander. However, in other cases, the preservation of the remnants is due to other causes. From field observation not supplemented by drill data, the writer believes that the Sheyenne River at present is for the most part flowing on till, and although it is possible that the river may be on bedrock no instance of this was encountered in this quadrangle. Evidence that the Sheyenne terrace is at least in part laid down in till is available at the Peterson coulee (N. E. $\frac{1}{4}$ Sec. 16, T. 151 N., R. 68 W.) where a dam cut shows three to four feet of gravel at 1470 feet elevation in sharp contact on a till base. One hundred yards to the north, the deposit is present on the surface as a shallow gravel pit but the contact with the till cannot be observed. It is the belief of the

³² Andrews, D. A., *op. cit.*

writer that this remnant is the homologue of the Sheyenne terrace found in the valley of the Sheyenne River proper. The terrace at the present time is covered by a durable growth of short grass and the river side maintains a somewhat high angle of repose (35 to 40 degrees) toward the axis of the river. At the present time the erosion of the terrace by gully-ing or by direct dissection by streams tributary to the Sheyenne is not active, although evidence of this in the past is present where the remnants are partially isolated from the valley walls by gullying.

In most instances where the remnant has a considerable areal extent the flat top surface is constructed on gravel, or cobbles of size from one to four inches in diameter (Secs. 7, 8, 17, 18, T. 150 N., R. 67 W.). However, there are remnants where some fine gravel and coarse sand form the top surface (N. E. $\frac{1}{4}$, Sec. 2, T. 150 N., R. 68 W.). The latter is the exceptional case in this quadrangle. It is quite possible that former silt coverings have been removed by winnowing action of wind and slope wash over the surface of the terrace.

In the eastern end of the Sheyenne River in this quadrangle in Secs. 17 and 18, T. 150 N., R. 67 W., a distinct level at 1480 feet is developed on both sides of the river. This secondary bench on the main terrace is about 100 yards wide and about 20 feet below the general terrace level. While clearly evident at this location, no other occurrence was encountered where two levels appeared in this relation. It is suggested, however, that there may be two distinct levels or terrace surfaces and the disparity of altitudes farther upstream may be partially explained by assignment as correlatives with either the 1480 foot level or the 1500 foot level with certain allowances for erosion and stream gradient. However, the validity of any such correlation is obviously subject to further proof on a regional basis.

The Floodplain of the Sheyenne River

The Sheyenne River is now flowing in a trench varying from fifteen to fifty feet wide cut, on an average, about fifteen feet into its floodplain. The present floodplain ranges from between one-third of a mile to one-half mile in width and is covered with alluvium to an undetermined depth. This deposit consists of well sorted, fine sand and silt of a medium-

gray color due probably to the fact that much of the silt originally came from the Pierre shale. The coloring near the surface is probably additionally darkened by the presence of organic content from the sod. Well data available on the floodplain shows quicksand with water reached at depths of from four to twelve feet below the surface of the ground. Fertility of the floodplain varies. In some areas it is made to bear paying crops of grain while a short distance up or down river from this point it may be so alkaline that it is suitable only for grazing.

Drainage Changes in the Flora Quadrangle

In the light of the foregoing physiographic information some very interesting inferences may be drawn. It seems probable that in pre-Wisconsin time an erosional surface of mild relief possibly of less magnitude than that of the present surface, existed on the Pierre shale. In the Flora quadrangle the Sheyenne River flowed on the floor of a valley probably somewhat deeper than the present valley. With the advent of the glacial ice in this region, some of the original relief was destroyed by planation and filling under the ice. The ice overrode this region and pushed to the south in the James River lobe.

At the close of the glacial cycle, the ice retreated in stages, forming successive fronts as it paused in its recession to the north. These fronts remained stationary for periods of time, during which the deposits known as recessional moraines were formed at the southern limits of the ice sheet. The periods of recessional moraine formation represent times of accumulation of ice sufficient to bring southward ice and debris which maintained the front but which was not in sufficient quantity to extend the front. In this area the Heimdal and the North Viking moraines were formed in the order mentioned. Apparently the retreat of the ice front from the Heimdal to the North Viking moraine position was accomplished in a relatively short time, with no intermediate pauses with their accompanying deposits. During the halt of the ice at each of these fronts, outwash belts were built up during the summer or warmer seasons when the meltwater was active. During the winter the formation of thin loess cover to the south of the outwash probably took place on a small scale under conditions outlined previously.

Recent drilling conducted cooperatively by the United States Geological Survey and the North Dakota Water Conservation Commission in this area suggests that the pre-glacial Heimdal valley or a low bedrock area of other origin was partly filled with outwash (?) gravels in front of the advancing ice. From 70 to 200 feet of till was deposited on this gravel and after the retreat of the ice the present Heimdal valley was cut and partly filled with gravel more or less parallel to, but north of the pre-glacial valley cut in the bedrock.³⁸

Drainage flowed to the James River system, thence to the Mississippi. When the ice retreated to the North Viking moraine position apparently a new outlet, the somewhat altered pre-glacial Sheyenne valley, became available at a considerably lower level. At this time the regional drainage along the front of the ice, from the northwest to the James River at New Rockford gradually began to be diverted into the Sheyenne valley. Geologic evidence of this diversion may be found to the west in the Maddock quadrangle where the Sheyenne makes a sharp turn to the north away from the axis of the Heimdal valley, into which the drainage would have gone if the turn had not been made, and runs for several miles before turning sharply east again in its present course parallel to the morainic system.

However, the tremendous load of sediment from the melting glacier to the west and north soon built up the floor of the Sheyenne River to the level of the main terrace, at about 1510 feet. Further recession of the ice to the north with a decrease in the amount of sediment caused the Sheyenne to cut down through its gravel filling, stopping for a time at 1480 feet, until it had cleaned out its valley to its present condition. The Sheyenne River is now very inactive as far as cutting is concerned due largely to lack of copious rainfall along its course. Determination of the source of the water and the sediment in the period immediately following the northward retreat of the glacial front awaits a broader regional study, although it is reasonably apparent that the Sheyenne River was part of some phase of the spillway drainage system of glacial Lake Souris.

³⁸ Personal communication from Mr. P. E. Dennis.

GROUND WATER RESOURCES⁴⁴**General Statement**

The occurrence of ground water in the Flora quadrangle may be classified into three types of occurrence, namely: (1) occurrence in the till; (2) occurrence in the outwash belts or channels; (3) and artesian flows. For the purpose of this report ground water is treated as "that water which occurs in the pore spaces of the consolidated and unconsolidated materials below the surface of the earth. Rocks near the surface of the earth, while they may appear solid, contain innumerable small pore spaces and crevices. Water that fills these open spaces is spoken of as ground water and may be made available at or near the surface of the earth by means of wells."⁴⁵

It can readily be seen that beds or lenses of gravel or sand, because of their relatively high degree of porosity and their ability to allow water to travel through their volume (permeability) constitute effective means of storage and transmission of ground water. In most regions, permeable rocks contain water up to a certain level. This level is called the water table and can be determined by noting the altitude at which water occurs in wells and lakes in a given region. This level generally fluctuates throughout the year as the wet and dry seasons occur and it is generally observed that over a given area at any given time the ground water table occurs at different altitudes above sea level, implying that this water table has a surface of some relief, due to differences in supply and the nature of the topographical surface and the underlying rocks in which the water is stored.

Ground Water in the Till

As previously mentioned, approximately seven-eighths of the rock material covering the Flora quadrangle is made up of till which probably varies in thickness up to 200 feet. The till in this area is composed, for the most part, of fine-grained rock particles varying in size from rock flour to fine sand

with boulders scattered throughout, and it possesses varying degrees of induration. This is a relatively impervious material, serving as a poor agent for storing or transmitting ground water. Virtually no water can be obtained in the till unless a gravel or sand lens is encountered in drilling. However, a notable characteristic of the till in this area is the presence of many of these lenses of gravel and sand, laid down and covered in the till as it was formed. Accordingly, if their size is considerable and water can penetrate to them from a surface exposure or through underground percolation of some kind, they become local water reservoirs of some importance. It is this glacial geologic phenomenon which furnishes the water for the wells in the till in this area. These wells penetrate to various depths and show varying degrees of constancy of supply. Depths vary in this area from twelve feet to one hundred and fifty feet (Paulson well, see p. 16) and there is no evidence of any occurrence at uniform depths suggesting a continuous aquifer. For the most part the water in these wells is hard but suitable for domestic purposes. The volume and year-round constancy of yield varies from very poor to very good, but the average of wells in the till is rather poor in both respects. Location of adequate subsurface gravel lenses is at the present time difficult and a matter of chance. While this type of well is frequently adequate for either domestic and stock purposes for farms in normal years, seldom, if ever, do these wells possess sufficient quantities of water for dependable year-round municipal or industrial supply. The wells in the knobby surface of the recessional moraine represent the poorest variety while in the ground moraine, this type of well tends to be at its best.

As much of the good agricultural land of this quadrangle lies in the ground moraine belt, this type of well is very common and represents probably the only readily available source of water at this time for a great proportion of the residents. A summary of wells sunk in the till shows a wide range of quality and perennial yield. In most cases, where information is positive, the aquifer is a sand or gravel lens. Some of these lenses give excellent quality of water, according to reports of the residents, and sufficient flow for farm use even during the dry years although during the dry years the drop in level

⁴⁴ For a generalized summary of principles of ground water behaviour in this region see: Laird, W. M., Geology and ground water resources of the Emerald Quadrangle: N. Dak. Geol. Survey Bull. No. 17, pp. 29-32, 1944.
For a complete, detailed discussion and explanation of ground water see: Meinzer, O. E., The Occurrence of ground water in the United States: U. S. Geol. Survey, Water Supply Paper 489, 1923.

⁴⁵ Laird, W. M., op. cit.

is quite noticeable. However, as a group, this class of wells has proved to be much less reliable in both quality and quantity of flow than the wells in the outwash belt or those near an outwash channel or spillway. Of the total wells recorded in the till area (thirty-four), fifteen were definitely unreliable or dry during the dry seasons of even normal years. The quality of water in wells in the till showed that of thirty-four wells, sixteen were regarded as unfit for human use, usually because of high mineral content causing excessive hardness and alkaline taste, and were used only for stock.

Ground Water in the Outwash Belts

While the principles governing ground water supply apply with equal validity in the outwash areas, certain basic differences in the nature and surroundings of the material forming the reservoirs give rise to a different and more favorable ground water situation.

In this case, the reservoir, of unconsolidated gravel and/or sands, covers a relatively large area and in some cases possesses depths of up to sixty-five feet. Thus the total volume of the reservoir is large and the porosity relatively good and constant over considerable areas. Furthermore, these deposits have ample surface exposure for the entrance of precipitation and being located in natural drainage channels surface flow is more likely to enter and fill the reservoir. Although a relatively large number of cubic feet of water is probably lost from the surface of the gravel reservoir, chiefly by evaporation but to some degree by transpiration, it is believed that this loss constitutes a small fraction of the total water content of the gravel body.

This relation contrasts with that of the morainic belt where, with the exception of ground water in scattered lenses in the till, the only rainfall retained after runoff is a relatively small percentage which is held in the upper soil zone. Evaporation and transpiration probably accounts for the loss of a large percentage of the soil water although the actual amount lost is relatively small.

Consequently, the outwash deposits provide a reservoir for water 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. Reference to the tables II and III will afford specific examples of the tendencies of the wells in this type of material. In general, the major intake in this area lies in the outwash belts just to the south of the moraine fronts. At the time of this investigation the water table in the intake area lay just below the surface, from two to four feet.

Water in these gravels, in general, has a tendency to flow following the natural gradient of the drainage channel in which the gravels are deposited. This flow, of course, is much slower than surface flow. Water entering through the surface of the outwash belt thus flows slowly, following the outwash channels (see map Plate II) and gradually empties into the Sheyenne River in the case of the belt associated with the North Viking moraine and into the Heimdal valley in the southern part of the quadrangle. Evidence of this may be seen on the north side of the Sheyenne River (S. E. $\frac{1}{4}$, Sec. 27, T. 151 N., R. 68 W.) where springs or seeps flow from the sides of the gravel terraces into the Sheyenne River. These terraces merge to the north with an outwash channel. During the driest part of the year when no rain had fallen for two months and wells and lakes in the till in this area were at an unusually low level, the writer traced this outwash channel from the northern part of the quadrangle to the site of the seeps. Although there was no surface flow, augering showed water at a depth of about two feet near the axis of the channel throughout its length.

There was no surface flow and wells and lakes in the till in this area were reported to be at an abnormally low level. The presence of a series of ponds at the lower end of the tributary of the Sheyenne into which the seepage flows, built by the erection of dams by beavers or some other animal of similar habit further attests to the probable permanency of this supply. According to testimony of residents possessing wells near the axis of the outwash belts or channels these wells have been a source of excellent quality and sufficient perennial supply, even in dry years, although at that time the water level did drop to some extent in the wells. There was no record of any well in this belt having been dried up in even the driest years.

TABLE II

DEPTHS OF WELLS IN THE FLORA QUADRANGLE

LOCATION	FEET							
	0-10	11-20	21-40	41-60	61-80	81-100	101-150	over 150
Outwash areas	14	9	0	0	0	0	1	1*
Ground moraine	4	9	4	1	1	1	1	1
Recessional moraine	0	5	2	0	0	0	0	0

NOTE: This information covers only those wells which were personally measured. Seven wells could not be measured and no reliable information was available on them.

* Artesian flow located on edge of outwash belt. It is believed that this penetrates a thin outwash cover and taps a gravel lens deep in the till.

TABLE III

ANALYSIS OF WELLS IN THE FLORA QUADRANGLE
ACCORDING TO ADEQUACY AND QUALITY

LOCATION	ADEQUACY			QUALITY		
	Good	Fair	Poor	Good	Fair	Poor
Outwash areas	20	0	0	10	15	0
Ground moraine	11	14	5	8	14	1
Recessional moraine	5	4	1	3	7	0

NOTE: Criteria for terms above:

Adequacy: Good—Adequate for year round and in dry years; Fair—adequate for year round but not in dry years; Poor—Adequate only during wet season of good years.

Quality: Good—Suitable for domestic and stock uses; Fair—Suitable for stock use only; Poor—Unfit for consumption by human or stock.

Note: With but one or two possible exceptions the well water is hard water.

Information on a number of wells in regard to adequacy and quality was unavailable or unreliable.

Artesian Wells

A single instance of artesian flow in this area is to be found on the farm of Mr. W. J. Maddock, on the county road about two and one-half miles due east of the town of Maddock. This well was drilled in the fall of 1907 to a depth of 155 feet. When no appreciable water was obtained it was shot with dynamite at about 140 feet and an artesian flow resulted which caused the water to rise about five feet above the ground and to flow in large quantities. Since that time no effort has been made to control the flow and at present it is flowing at the rate of 1.7 gal. per minute. The flow has been steady but constantly diminishing since the time of drilling.

While this well is located in the outwash belt, this alone cannot account for the flow. It is the belief of the writer that the casing penetrates below the depth of the outwash and taps a lens of gravel in the till below which might derive its hydrostatic head from the North Viking moraine to the north. Possibly ground water might enter along the spillway to the north (Secs. 11 & 12, T. 152 N., R. 69 W.) and follow a lens connecting with the gravel body tapped. It is a possibility that the well is in the sandy basal portion of the till. However, more positive evidence by drilling must be obtained before the origin of this artesian flow can be known with certainty.

NORTH DAKOTA GEOLOGICAL SURVEY

Plate I — Bulletin 22

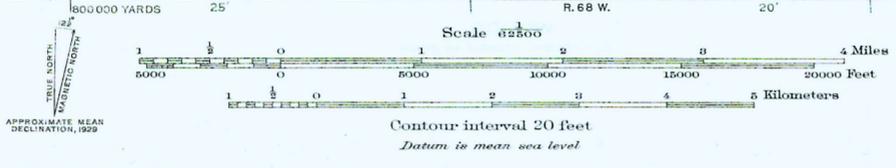
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

STATE OF NORTH DAKOTA
ROBERT E. KENNEDY
STATE ENGINEER

NORTH DAKOTA
FLORA QUADRANGLE



Topography by C.L. Sadler, Daniel Kennedy,
and M.J. Harden
Control by U.S. Geological Survey
Surveyed in 1929



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

HARD IMPERVIOUSLY SURFACED ROADS
OTHER MAIN TRAVELED ROADS
1931

FLORA, N. DAK.
Edition of 1932

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a standard topographic atlas of the United States. This work has been in progress since 1882, and its results consist of published maps of more than 42 per cent of the country, exclusive of outlying possessions.

This topographic atlas is published in the form of maps on sheets measuring 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, they represent areas of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, and miles. 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 similar 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 for the United States proper and the resulting maps have for many years been divided into 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 accuracy to be used in the publication of maps on a scale of $\frac{1}{31,250}$ (1 inch = one-half mile), with a contour interval of 1, 5, or 10 feet.

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 accuracy 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 25 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, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles), with a contour interval of 25 to 100 feet.

A topographic survey of Alaska has been in progress since 1898, and nearly 43 per cent of its area has now been mapped. About 10 per cent of the Territory has been covered by reconnaissance maps on a scale of $\frac{1}{62,500}$, or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of $\frac{1}{31,250}$, but about 4,000 square miles has been mapped on a scale of $\frac{1}{62,500}$ or larger.

The Hawaiian Islands, with the exception of the small islands at the western end of the group, have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

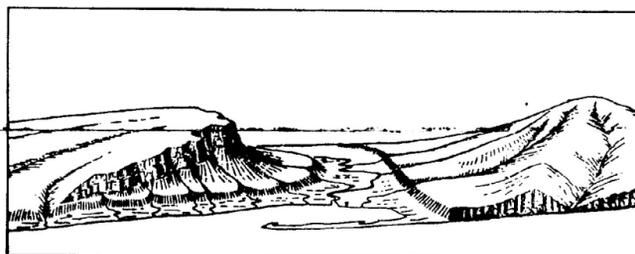
The features shown on these maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture

(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, the lakes, and the sea 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 some 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 line of the seacoast itself is a contour, the datum or zero of altitude being mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet. 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 inclosed 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

ing 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 table-land 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. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road corners, summits, surfaces of lakes, and bench marks—are also given on the map in figures, which show altitudes to the nearest foot only. More exact altitudes—those of bench marks—as well as the geodetic coordinates of triangulation stations, are published in bulletins issued by the Geological Survey.

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. Good motor or public roads are shown by fine double lines, poor motor or private roads by dashed double lines, trails by dashed single lines.

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. Over 3,300 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.

The topographic map is the base on which the geology and mineral resources of a quadrangle are represented, and the maps showing these features are bound together with a descriptive text to form a folio of the Geologic Atlas of the United States. More than 220 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 per cent is allowed on an order for maps amounting to \$5 or more at the retail price. 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.

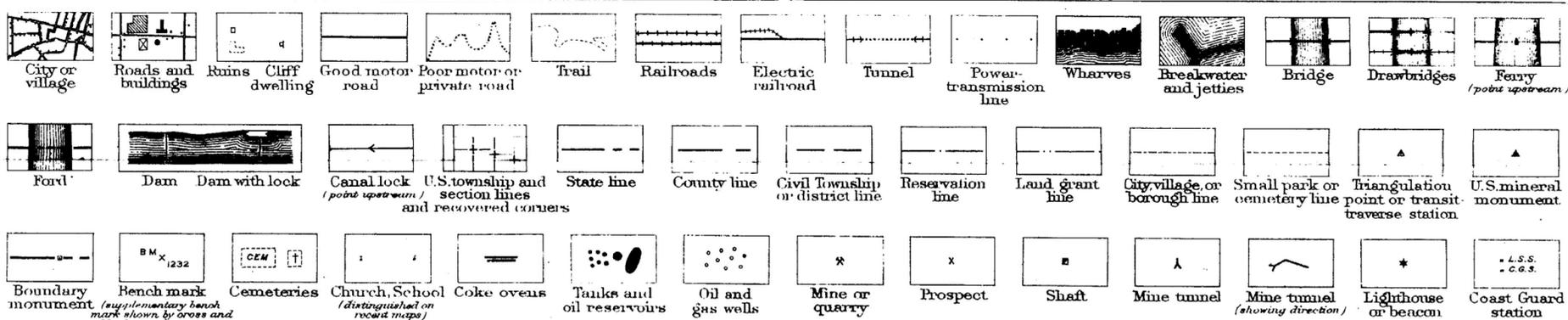
Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

THE DIRECTOR,
United States Geological Survey,
Washington, D. C.

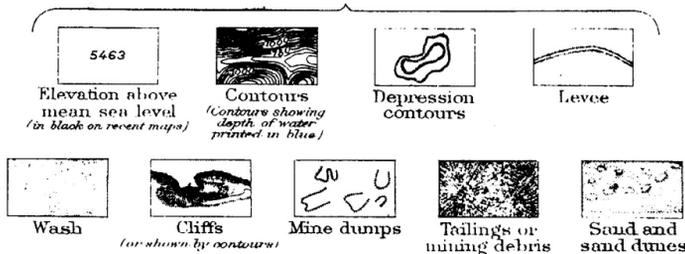
September, 1928.

STANDARD SYMBOLS

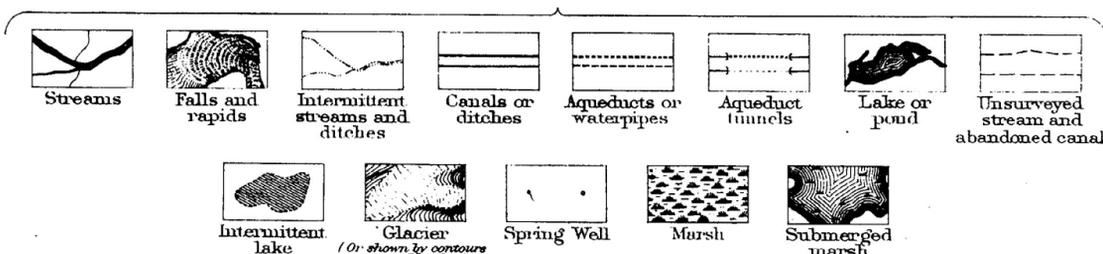
CULTURE (printed in black)



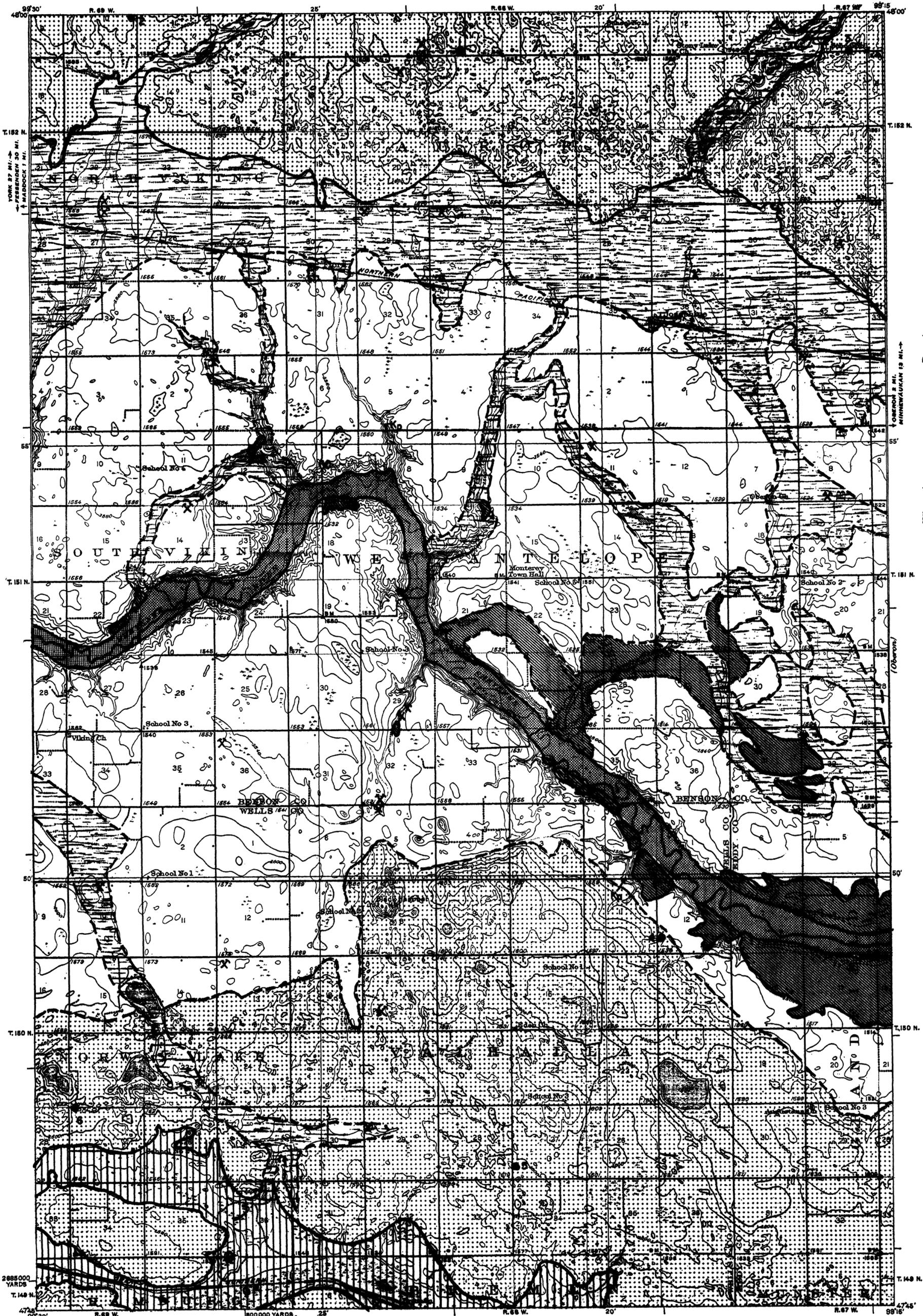
RELIEF (printed in brown)



WATER (printed in blue)



WOODS (when shown, printed in green)

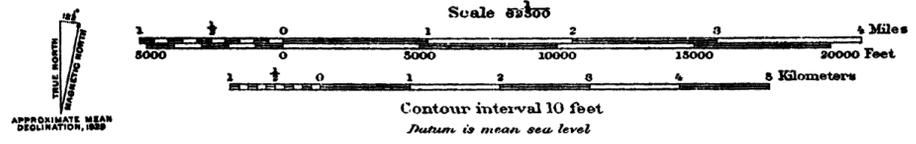


LEGEND

- Recent
 - Alluvium
 - Terrace along Sheyenne River
 - Terrace along Heimdal Valley
- Wisconsin
 - Outwash and Distributary Channels
 - Till—Recessional Moraine
 - Till—Ground Moraine
- Gravel Pit
- Pebble Count Locality
- Pierre Shale Outcrop

GEOLOGY OF THE FLORA QUADRANGLE

Topographic base surveyed by
 U. S. Geological Survey,
 1929



Geology by
 J. R. Branch
 1946