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Glacial Geology

of the

Oberon Quadrangle

By

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Glacial Geology of the Oberon Quadrangle, North Dakota

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INTRODUCTION

Abstract

The Oberon quadrangle was buried under 50 to over 200 feet of drift deposited by the latest Wisconsin ice sheet. Three-fourths of the quadrangle is covered by two distinct recessional moraines. Outwash plains generally fan out to the south from the recessional moraines. Patches of ground moraine cover most of the balance of the area. The Sheyenne River in its early post-glacial history cut a large valley across the quadrangle. Extensive terrace deposits containing gravel and sand of commercial value are present in the river valley. Other deposits of gravel and sand, but of secondary importance, occur in the form of kame terraces, eskers, and outwash. Most of the inhabitants of the quadrangle depend upon water obtained from wells in the glacial drift. Deeper wells are either too expensive or the water is too saline. The only reliable sources of water from the shallow wells are in the outwash plains or terraces.

Location of the Area

The Oberon quadrangle is located in the central part of northeast North Dakota between 99°00' and 99°15' west longitude and 47°45' and 48°00' north latutude. (Figure 1). The quadrangle includes parts of Eddy and Benson counties. The Northern Pacific Railroad enters the southern boundary of the quadrangle and continues northward through Sheyenne and Oberon, the only two towns in the quadrangle. State Highway No. 57 comes into the northeast corner of the quadrangle near Fort Totten and continues across the northern edge. Highway No. 4 runs north and south through the center of the quadrangle. The city of Devils Lake lies to the north and east.

Purpose of the Survey

In the summer of 1946, the glacial geology of the Oberon quadrangle was mapped by the writer for the North Dakota

Geological Survey. The same summer the next two quadrangles to the west, Maddock and Fora, were mapped by Dr. John R. Ball and by Mr. John R. Branch, respectively. The purpose of the work was to prepare a comprehensive report upon the glacial geology and to obtain pertinent data concerning the gravel deposits and ground water supply—two of the most important natural resources of the area.

Investigation of these quadrangles represents another step of a program by the North Dakota Geological Survey to map the glacial geology of the state. This is desirable for a more complete understanding of the glacial phenomena and the resulting conditions which affect the present-day developments of the state, particularly since the two most important non-agricultural resources—ground water, and sand and gravel—are closely dependent on the glacial geology. The average rainfall in this part of the state is about 17 inches (Table II) and, since most of the ground water depends upon this relatively small amount of rainfall, the supply is none too abundant. Consequently, all features and conditions pertaining to the supply of ground water were noted and the conclusions drawn are here recorded. Also, since the scarcity of timber makes the sand and gravel of the state important for use in construction and for extensive use as road surfacing, all commercial deposits were mapped and mechanical analyses were made.

Method of Investigation

Most of the section-line roads in the Oberon quadrangle can be traversed by car in dry weather, thereby greatly facilitating the field work. A quick reconnaissance of the quadrangle was first made. A system of symbols devised by Thwaites[1] and slightly revised for adaption to the immediate needs was used to indicate on the map rolling and flat topography, knobs and kettles, and other obvious features of glaciation.

With the above information as a guide, boundaries of the recessional moraines, outwash, and ground moraines were mapped. The difference in appearance between the ground moraine and outwash is slight, and only after several soil

[1] Thwaites, F. T., Outline of glacial geology: Lithoprinted, Edwards Brothers, Inc., 1946.

auger test holes was it possible to delimit the boundaries—and then only within approximate imits. The different types of glacial deposits were studied in the field to determine the kind of material, orientation, and relative significance. Where there was doubt as to the material, samples were taken for laboratory examination. Samples from all of the major gravel deposits were collected for mechanical analyses.

Some scattered pebble counts were made and an orientation study of the pebbles was attempted. This was abandoned because of insufficient exposures within the ground moraine. Since only highly diversified results coud be expected within the recessional morainic areas, it was concluded that orientation studies were impractical for determining direction of ice movement. No striae could be found on bedrock. The pattern of the morainic belts, therefore, was the chief indicator of the direction of ice movement within the quadrangle.

Well data were collected during the latter part of the summer, By means of a steel tape, the depths of the wells and depths to the top of the water were recorded in all the accessible wells. Elevation of the ground adjacent to each well was approximated from the topographic sheet or was determined by use of a hand level. These elevations are believed to be generally correct to the nearest five feet. This degree of accuracy is deemed satisfactory, as only general information on the fluctuations and altitude of the water table was requested.

Acknowledgements

The author is greatly indebted to Dr. Wilson M. Laird of the North Dakota Geological Survey for the opportunity to study and map this area. Also, his supervision and suggestions have been very helpful. The frequent consultations with and numerous suggestions by Drs. John L. Rich and Gordon Rittenhouse of the Geoogy Department of the University of Cincinnati have been invaluable in writing this report. Drs. George Barbour, O. C. vonSchlichten, and A. T. Cross of the same department have aided materially by their technical advice. Mr. P. E. Dennis of the U. S. Geological Survey has made available information secured by that agency.

TOPOGRAPHY

Regional Topography

According to Fenneman[2] three physiographic divisions are represented within North Dakota. They are bounded by distinct escarpments, and each is well marked as to physiographic form, origin, and relief. They are, from east to west, the Red River Valley, the Drift Prairie Plain, and the Great Plains Plateau. (Figure 1). The Red River Valley and the Drift Prairie Plains are part of the larger Central Lowland province.

The Oberon quadrangle is located in the Drift Prairie Plain, which rises 300 to 500 feet above the Red River Valley (the basin of old Glacial Lake Agassiz). This plain varies in width from 200 miles at the north to 100 miles at the south and has a general elevation of 1,500 to 1,800 feet above sea level. The topography of the Drift Prairie Plain varies from undulating through rolling to hilly. The present forms are due almost entirely to the original disposition of the glacial drift which has been but little modified. As the underlying bedrock is soft Pierre shale, it has contributed little to the relief of the region. Leonard[3] maintains that Crow Hill, Sullys Hill, and the Blue Hills to the south and east of Devils Lake are low, shale hills covered with glacial material. They are exceptional features within the area.

The most conspicuous topographic features within this province are the numerous recessional moraines which appear as meandering ridges extending in a general northwest-southeast direction. In places these moraines are well marked; in others they are only slight remnants. In most cases hummocky knobs, undrained depressions, and small lakes mark the morainic areas.

Except for the few abnormally deep valleys, such as those of the Sheyenne and James Rivers, the glacial drift has been only slightly eroded. At the present rate of erosion it has been computed that only one inch is being eroded every 3,900 years, which is the lowest rate in any area in the United States.[4] The waters of the Sheyenne River flow into the Red River and

[2] Fenneman, N. F., Physiography of western United States, New York, McGraw-Hill, 1931.
[3] Leonard, A. G., North Dakota Geol. Survey, 6th Bienn. Rept., 1909-1910.
[4] Data from National Conservation Commission, reprinted in Geology principles and processes, Emmons, Thiel, Stauffer and Allison, McGraw-Hill, 1939.

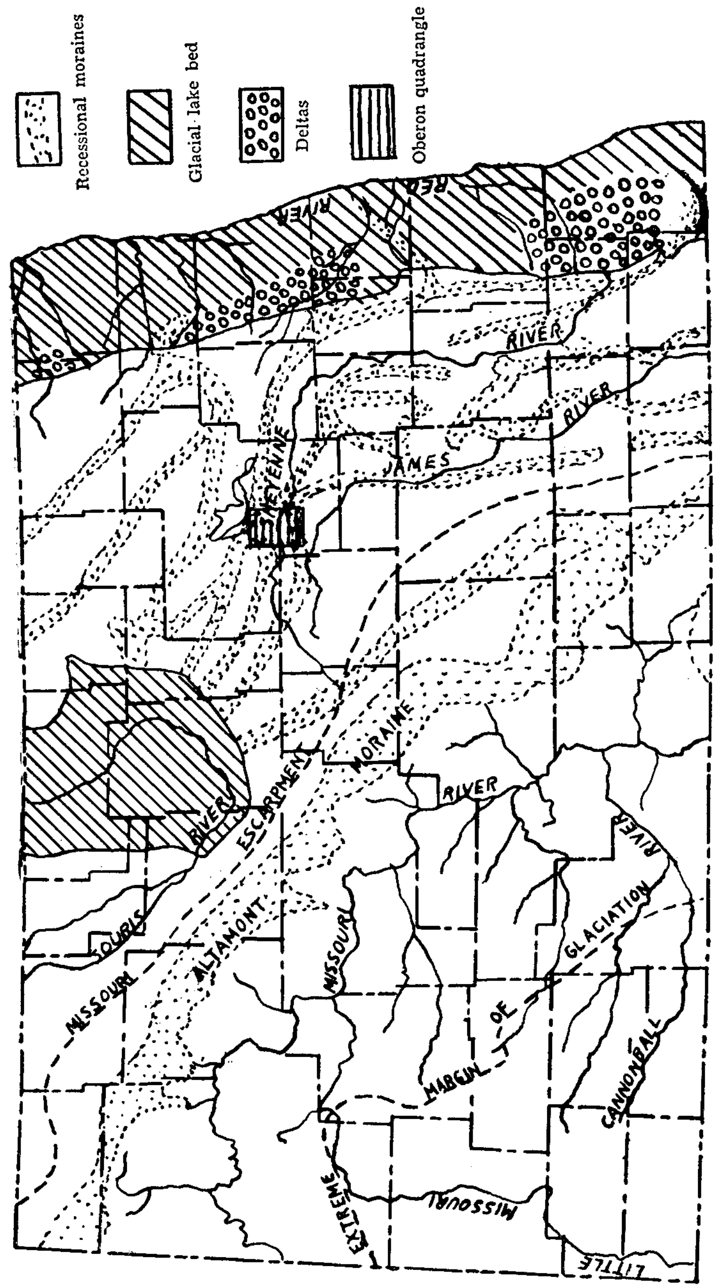


Figure 1. Map of North Dakota showing the Pleistocene geology and the physiographic divisions.

thence north into Hudson Bay. Evidence of the Sheyenne's original large capacity is offered by its enormous delta which extends far into the Red River Valley. The James River compares closely to the Sheyenne in its history, but, with the final recession of ice, the James River was diverted so as to empty its waters into the Missouri River. As a result of the glaciation and slope to the south of this entire province, the Continental Divide lies between the drainage basins of the Sheyenne and the James Rivers.

Local Topography

Three major topographic divisions are recognizable within the Oberon quadrangle. (Plate II). The most conspicuous of these is that made by the recessional moraines. These moraines, consisting of knobs and kettles, cover approximately three-fourths of the quadrangle. The morainic topography includes two separate recessional moraines, roughly parallel to each other in their east-west elongations. At the very eastern side of the quadrangle they are separated only by the valley of Sheyenne River.

The second topographic division consists of outwash plains. With but few exceptions, the southern sides of the moraines are bordered by glaciofluvial deposits which were laid down over the ground moraine contemporaneous with the melting of the glacier and the forming of the recessional moraines. This activity has left a featureless plain virtually without boulders and consisting of stratified gravel and sand. These outwash plains extend beyond the moraines to the line where they abut against ground moraine or earlier recessional moraines.

The third division is ground moraine. It is usually a gently-rolling, featureless plain with occasional boulders which have been exposed by cultivation or freezing and thawing.

Erosion contemporary with and immediately after the recession of the ice sheet has wrought several modifications in the area. The Sheyenne River Valley, in places over two miles wide and 100 to 200 feet deep, clearly depicts the large stream which once flowed within the valley. Its age is post glacial, as is shown by the fact that for at least one-half its depth the valley walls consist of the latest drift deposits and

for the remainder they are of the local bedrock, Pierre shale. Most of the coulees, or tributaries, are shallow, short, and contain intermittent streams. Erosion in recent times has contributed little to the present topography, as shown by the poorly developed coulees and the undrained depressions or kettles within the recessional moraines.

At the north-central edge of the quadrangle lies a small dry segment of Devils Lake. The lacustrine soil is highly alkaline, and consequently there is little vegetation except marsh grass. Devils Lake lies in the center of a basin of interior drainage. The rapid lowering of the lake and its increase in salinity in the past few decades show that evaporation far exceeds replenishment by run-off waters. This general trend seems to typify conditions over the major part of the state.

STRATIGRAPHY

Regional Stratigraphy

The Keewatin ice sheet, which covered the Oberon quadrangle during the Wisconsin glacial period, had its center west of Hudson Bay. In moving south and southwest from this center, the ice sheet moved across Ordovician, Silurian, and Devonian rocks near Hudson Bay; over Pre-Cambrian granites and gneisses further south in Canada; and across more Ordovician, Silurian, and Devonian rocks southwest of Lake Winnipeg. In North Dakota the ice passed over shales and sandstones of Cretaceous age. A small amount of Pre-Cambrian granite and Paleozoic limestones and dolomites may have derived from the Red River Valley, where well logs indicate that these formations directly underlie the glacial and lacustrine deposits. Composition analyses of the pebbles in the drift from two selected areas give proof of this source. (Figure 5).

In the Oberon quadrangle the glacial deposits contain much shale. This is readily explained by the glacial erosion of the broad exposures of the Pierre shale in the eastern portion of North Dakota and in southern Canada. Much of the clay of the drift is believed to have been derived from this underlying shale.

Subsurface geology of the state is not completely known, and therefore only a general outline is presented in this report.

Ballard's[5] structural map, contoured on the top of the Dakota sandstone, shows these rocks dipping to the west to within 70 miles of the western border of the state. Further west the dip is to the east. This broad syncline has been referred to as the Dakota basin and as the Williston basin. The dip in the eastern part of the state is reported[6] to be about 8 feet per mile. Apparently it increases somewhat toward the trough of the basin.

Within the Red River Valley most of the sedimentary beds have been pinched out or eroded so that only Cretaceous and a few of the Paleozoic limestones and dolomites remain buried beneath the lacustrine and drift deposits. From the vicinity of Big Stone Lake in southeastern North Dakota to Grafton in the northeastern part of the state, Archean granite is found and it increases in depth from outcrops on the surface to 903 feet. Well data indicate that Silurian limestone increases in thickness from one foot near Grand Forks to 317 feet at Grafton.[7]

Local Stratigraphy

The Pierre shale is the only formation outcropping within the Oberon quadrangle. It was observed at several points along the Sheyenne River. Outcrops have been reported[8] in the Tokio quadrangle near Fort Totten and in the Sullys Hill area. Also, Crow Hill may have a shale core, but no exposures are visible. Well data[9] indicate that the Pierre is approximately 600 feet thick in this part of the state.

Investigation of the ground water supply in adjacent quadrangles by the U. S. Geological Survey in 1946 yielded information on the pre-glacial topography of the Pierre shale. In some parts of the drift-covered area the pre-glacial relief is as much as 300 feet.[10] Drilling to shale near Minnewaukan, ten miles north of Oberon, show a relief of approximately 280 feet within a distance of 6 miles. In the Oberon quadrangle, however, scattered wells indicate that the surface of

[5] Ballard, Norval, Regional geology of the Dakota Basin: Am. Assoc. of Petroleum Geologists Bull., vol. 26, p. 1568, 1942.
[6] Leonard, A. G., The geology of North Dakota: Jour. of Geol., vol. 27, 1919.
[7] Leonard, A. G., op. cit.
[8] Leonard, A. G., op. cit.
[9] Laird, W. M., Selected deep well records: North Dakota Geol. Survey Bull. 12, 1941.
[10] Dennis, P. E., U. S. Geol. Survey, Grand Forks, North Dakota, Personal correspondence.

the shale is relatively level except for the Crow Hill sector and possibly the chain of akes through the center of the North iking moraine.

The Pierre is uniformly a fine-textured, bluish-gray, argillaceous, marine shale. Fossils from this shale have been reported, but none were found during the recent investigation. Where exposed and weathered, the Pierre shale appears as a medium-gray clay characterized by polygonal mud-crack forms.

GLACIAL FEATURES

North Viking Moraine

The moraine to the south of Devils Lake in the northern part of the Oberon quadrangle must be considered as a combination of the Waconia, Elysian, Dovre, Fergus Falls, and Leaf Hills moraines defined in Upham's report.[11]

However, the northern moraine in the Oberon quadrangle is referred to in this report as the North Viking moraine. It is by far the most important of the five which converge to the southeast, and it has been mapped as extending across Minnesota and through North Dakota to Glacial Lake Souris. The Fergus Falls and other moraines merge, as in the Oberon quadrangle, and diverge throughout this distance. Without doubt local variations in pre-glacial topography have contributed to this divergence.

The North Viking moraine is clearly bounded at the southern terminus for most of the distance across the quadrangle. It rises abruptly 30 to 60 feet above the outwash plains to the south and shows the distince knob and kettle topography of recessional moraines. Only on the eastern side of the quadrangle south of the Crow Hills area is the margin blurred, and even there the unmistakable hummocky topography is evident. (Figure 2).

Upham's report states that the moraines separate in the northwestern part of the Oberon quadrangle; no separation could be made by the writer.[12] Northward from the edge of the moraine at Oberon, one passes through approximately two

[11] Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1895.
[12] According to Mr. Saul Aronow of the U. S. Geol. Survey, an examination of aerial photographs, which were not available at the time this investigation was made, does suggest a separation of the moraines in the area north of Oberon.

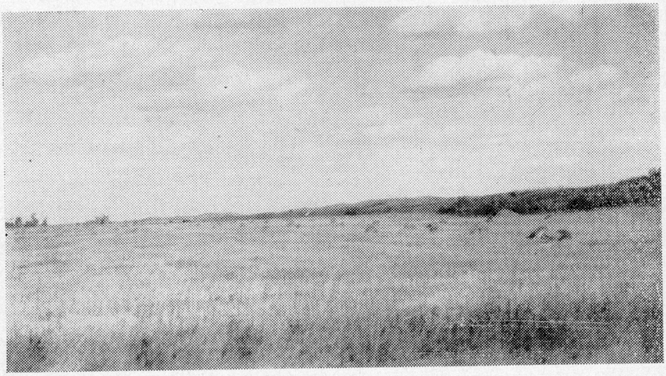


Figure 2. Typical junction of outwash with recessional moraine.

miles of prominent morainic topography, about two miles of very subdued morainic topography with knobs and kettles and much swamp land, and then into stronger morainic topography which extends to the western part of the bed of Devils Lake. This most northern area is more ridge-like and does not contain an abundance of knobs and kettles. Throughout the entire distance from Oberon to Minnewaukan there are deposits of the recessional morainic type. These features differ in intensity rather than method of disposition. Perhaps a division of these moraines can be made to the northwest of the Oberon quadrangle, but no investigations were made in that direction.

Knobs and kettles predominate through the southern half of the North Viking moraine. Some of the knobs are kames which rise 20 to 60 feet above the surrounding drift. Such kames are well developed in the northwest corner of Section 8 and the south-center of Section 6, T. 151 N., R. 66 W. Kettles are generally associated with the kames and knobs.

Near Lallie, in the northwest corner of the quadrangle, the strongly hummocky topography disappears. Instead, subdued knobs prevail within a generally swampy lowland. To the east are short ridges of drift aligned in a general northwest-southeast direction. Some knobs and kettles are still present. The ridges to the northeast are consecutively more and more subdued until the bed of Devils Lake is reached.

The less pronounced features, the transformation from knobs to ridges, and the general association of these changes with the direction of ice recession suggest an increase in the rate or ice retreat in this area. Northeast of Crow Hills the same subdued topography is present, furthering the idea that the ice retreat accelerated in this area. In addition, high level lake waters may have contributed to the modification of some of the glacial features.

Chain of Lakes

A chain of lakes extends southward through the North Viking moraine from the bay of Devils Lake which juts into the north center of the quadrangle. Within the moraine these lakes lie in a broad trough up to three miles in width. They are confined to a valley 60 to 80 feet deep and in most places not over one-half mile wide. This valley from Devils Lake to the Sheyenne River is known as the Crow Hill Coulee.[13] The distinctive valley form disappears a short distance north of the horseshoe lake in Section 28, T. 152 N., R. 66 W.

A network of eskers winds through the valley from Devils Lake to the southern edge of the moraine. The horseshoe-form of the above mentioned lake is due to the extension of one of the eskers into its center. The eskers contain very poorly sorted fluvial material that is remarkable for its high shale content. For an analysis of the material see histogram, page 28.

Kame terraces border the western side of the valley from Section 33, T. 152 N., R. 66 W., through Section 4 and into Section 9, T. 151 N., R. 66 W. Some of the bedding is still preserved, but most areas show slumping due to melting away of the retaining ice. These kame terraces rest upon the till or morainic drift that was found bordering the valley throughout its length. Field observations indicated that the kames contain a much smaller percent of shale pebbles than the nearby eskers.

The marked difference in shale content suggests how the eskers and kames differ in mode of deposition. The eskers contain a tremendous quantity of poorly sorted shale, some granite, gneiss and limestone; whereas the kame terraces have little shale and a much greater percentage of other materials.

[13] Leonard, A. G., North Dakota Geol. Survey, 6th Bienn. Rept., 1909-1910.

When it is considered that the material constituting the kame terraces was derived from the upper part of the glacier, and that of the eskers from the bottom part, this difference in composition becomes logical. The accumulated evidence indicates that the gouging out of the Pierre shale bedrock to form the basin of Devils Lake would have contributed more shale to the lower than to the upper part of the ice sheet.

As these eskers within the relatively large Crow Hill Coulee have not been removed, conclusive proof is afforded that no large volume of water flowed from Devils Lake through this coulee to the Sheyenne since the time of the glacier. The erosion of the lower portion of the coulee, where a distinct channel form can be traced from the moraine boundary to Sheyenne River, must have been done largely while the ice was still present. Presumably a large stream, probably fed by the streams which formed the eskers, issued from the ice at this front and cut the present channel.

A short distance south of the North Viking moraine Crow Hill Coulee has a channel elevation of about 1485 feet. From this point north all of the drainage flows into the Devils Lake basin, and from this point south it flows into the Sheyenne River. The highest water mark for Devils Lake is approximately 1475 feet, as evidenced by wave-cut morainic knobs surrounding the part of Devils Lake in Oberon quadrangle. The highest remaining beach level is about 1460 feet. As the high point in the coulee is ten feet above any evidence of high water level observed for Devils Lake, it is improbable that much, if any, water ever drained from the lake through the coulee.

Devils Lake and Stump Lake may have been formed within the general limits of a pre-glacial stream valley. The northwest-southeast alignment of these lakes gives the major clue for this belief. Coulees, such as the Seven Mile which extends from the bay near Sullys Hill to the Sheyenne River in the Tokio quadrangle, and the previously mentioned Crow Hill Coulee add to the physiographic evidence. They appear as tributary valleys to the pre-glacial stream valley suggested for the location of Devils and Stump Lakes. The broad depression occupied by the Crow Hill Coulee (Sections 14 and 24, T. 151 N., R. 65 W.) substantiates the argument that a pre-glacial

valley existed there. Also, the eskers and kame terraces are evidence that most of the drainage contemporary with the ice in this sector was through this depression.

The supposition of a pre-glacial drainage pattern as suggested would give the necessary toe-hold for subsequent gouging by the glacier to form the basins and troughs for the lakes and coulees. Gravels within the eskers and outwash along the North Viking moraine show a high percentage of shale which is indicative of the gouging and removal of the shale locally. Well data from the Minnewaukan area[14] give additional proof of the pre-glacial drainage pattern. A series of nine test holes drilled by the U. S. Geological Survey on a line due east from Minnewaukan to Grahams Island, a distance of six miles, shows a valley in the shale approximately 250 feet deep. The deepest point is near the center of this dessicated basin of Devils Lake. Whether this buried valley extends eastward to the other basin or through the Crow Hill Coulee has not been determined, but the existence of a pre-glacial drainage system for the location of these features seems to be securely established.

Crow Hills Area and its Eskers

One of the most outstanding features of the North Viking moraine is the range of hills in the northeast corner of the quadrangle. These hills protrude above the general moraine level 100 to 200 feet. The main hill is called Crow Hill, but for sake of clarity the entire group will be called Crow Hills in this report.

No wells have been drilled in Crow Hill itself, but its general outline and the fact that shale has been found to exist in the hills around Fort Totten and in Sullys Hill suggest a core of Pierre shale.

A 177-foot well[15] drilled in the SW¼, Section 24, T. 152 N., R. 66W., struck shale between 130 and 140 feet, indicating that the group of hills to the northwest of Crow Hill does not have a shale core. This range, although almost as high as Crow Hill, appears more elongate in form and is crested by several braiding and crooked ridges trending roughly northwest-southeast. In most cases these ridges consist of

[14] Dennis, P. E., op. cit.
[15] Morsea, C. R., Plant operator and maintenance engineer, Fort Totten Indian Agency, Personal correspondence.

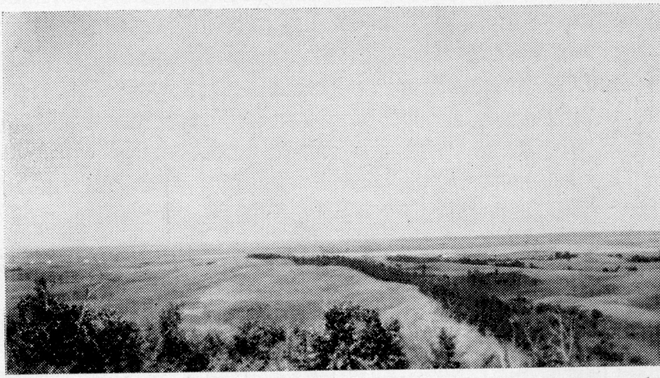


Figure 3. Esker atop Crow Hills, facing northwest. Note how esker disappears to the northwest.

fluvial material. The composition and serpentine form of the ridges indicates that they are eskers (Figure 3). To call them eskers introduces the problem of explaining why they are limited to a range of hills about 3 miles long in the highest part of the quadrangle. Some of the ridges appear to consist entirely of till, whereas the others consist entirely of vaguely stratified material comparable to that found in the eskers in the Crow Hill Coulee. A few of the ridges show till overlapping the waterborne material. To the southeast these eskers turn to the east and northeast where they become much less pronounced and difficult to recognize as eskers. Numerous large kettles are present in the area between the eskers. The lake in Section 25, T. 152 N., R. 66 W. appears to have been formed by morainic damming which left a large block of ice to form the basin. Most of the lakes and kettles in the moraines were probably formed in the same manner.

Explanation of the eskers atop Crow Hills is complicated by several factors. Their orientation, which is generally parallel to that of the moraine, is contrary to the normal trend of eskers. The only escape for the melt waters within the ice is at the edge of the ice sheet; therefore in almost all instances the resulting eskers are approximately normal to the front of the recessional moraine. It is not uncommon to find eskers at relatively higher elevations than the surrounding drift, but to find them restricted to the highest point is exceptional. Another complicating factor is the overlapping of the drift on the eskers in the manner found here. In one place the drift overlaps the gravel and in another the gravel overlaps the till, both within a distance of 100 yards of each other.

It seems highly improbable that these eskers were formed when the ice front was at the edge of the present North iking moraine. If they had been, in all probability they would have been destroyed by continued movement of the ice in building up the moraine from the present boundary back to the vicinity of the eskers. More likely is the supposition that they were formed when the ice front was impounded agains Crow Hill and only the northeastern corner of the quadrangle was covered by ice. With Crow Hill blocking the flow of melt water to the south and southwest, the under-ice streams would have been diverted to either or both sides in the direction of the existing eskers. Slight advances of the glacier could have easily caused the overlapping of the till and present disconformaable conditions.

Crevasse Fillings

In Sections 5 and 8, T. 151 N., R. 65 W. there are three flat-topped, short, straight ridges. Cuts showed water-borne material as in the eskers discussed. These short, single ridges comply with Thwaite's description of crevasse fillings and consequently they were mapped as such.

Morainic Remnants

A small unmistakably morainic accumulation of drift is to be found in Sections 26 and 27, T. 151 N., R. 67 W. No extensive continuation of this suggested moraine can be found to the northwest; however, the alignment of this morainic patch with the ridge of subdued appearance southwest of Sheyenne seems to prove a temporary stay of the front of the ice sheet in this location. Upham has mapped a moraine in this area and continues it to the northwest beyond the limits here indicated. The insignificance of this moraine and the small changes which it has brought about in the topogrophy merit only mention as to its existence.

Heimdal Moraine

South of the Sheyenne River lies another moraine fully as distinctive as the North Viking but not more than five miles wide in Oberon quadrangle. The name Heimdal moraine is used in this report. The crest of this moraine for at least part of its extent in the quadrangle forms the divide between the drainage of the Sheyenne and the James Rivers. Here again knobs and kettles predominate within the morainic belt especially on the east side of the quadrangle. As in the North Viking, erratics of granite, gneiss, greenstone, and limestone up to 14 feet long abound.

Along the distal edge the Heimdal moraine compares favorably with the North Viking. The moraine rises sharply above the flat plain to the south, creating a sharp boundary. West of the Northern Pacific Railroad, along the southern edge, two isolated morainic remnants interrupt the solid front displayed by the moraine farther east. The morainic area west of the railroad appears to be divided into three distince ridge-like accumulations orientated in a northwest-southeast direction. They indicate that the ice here retreated in three stages. While the ice on the west side of the quadrangle was retreating, the ice on the east side was relatively static. The valleys between the ridges represent intervals of rapid retreat of the ice; however morainic material was still deposited.

The location of the valley between the ridges of the second and third stages indicates that the Sheyenne River may have at one time occupied it. Three factors militate against such a conclusion. First, the valley walls do not give evidence of corrasion by a large stream. Second, morainic knobs are present within the valley, indicating that the erosional activity was not great and that morainic material very likely underlies the fluvial material at shallow depths. Third, most of the fluvial material consists of very fine silt and clay, indicating ponded waters. Conditions promoting ponded waters are much more probable as a result of morainic damming than from diversion of the Sheyenne. In fact, diversion of the Sheyenne River from this valley to its present channel should have accelerated drainage and prevented any deposition of lake clays.

All of the ridges as well as the moraine in the eastern half of the quadrangle along the proximal side, adjacent to the Sheyenne River, show the erosional effects of the early post-glacial river. Most of the knobs are subdued or entirely destroyed and but few of the kettles remain undrained. The ridge has been so modified that it could be considered as ground moraine were it not for its association with the Heimdal moraine and the morainic remnants to the northwest.

Kames

Several moulin-type kame deposits exist in Sections 23, 27, and 34, T. 150 N., R. 66 W. They are scattered over these sections along with typical knobs of unstratified drift. Several other kames are located along the front of the moraine in Sections 3 and 4, T. 149 N., R. 66 W. This latter group contains a relatively high grade of gravel and sand for kames. Most peculiar about these kames is their location at the very border of the moraine with the outwash plain spreading out from the base. Except for this location they could be considered as normal moulin-type kames. Undoubtedly they did form in much the same manner, but their appearance in this one particular area in the quadrangle merits an explanation. Dr. John L. Rich has offered a very plausible explanation for their formation. The area in which they are found is a small lobe extending southeast from the main mass of the Heimdal moraine. This lobe suggests a local bulging of the ice at this point due, for example, to a pre-glacial valley extending in this direction. Longitudinal crevasses might then be expected to form along the lobe. The melt-waters flowing off the surface of the ice into these crevasses and depositing their load would therefore result in the formation of the kames. Consequent recession of the ice would then leave outwash overlapping the base of the kames and moraine developed to the sides and to the rear.

Morainic Remnants

Across the northern edge of Section 25, T. 150 N., R. 66 W., and Sections 30 and 29, T. 150 N., R. 65 W. is a discontinuous string of boulder-matted ridges extending eastward into the Tokio quadrangle. The westernmost ridge is sharply defined and somewhat serpentine in form and resembles an esker. Gravel is found in a cut across the ridge toward the western end. However, most of the ridge appears to consist of unstratified drift with associated pebbles and boulders. Examination of the area to the east revealed that a small poorly developed moraine exists in line with the ridges in the Oberon quadrangle. This association necessitates classifying these ridges as morainic; another temporary stand of the ice in its recessional history.

A triangular morainic remnant is peculiarly surrounded by terrace gravels east of Sheyenne. It has an irregular morainic surface and is abundantly strewn with erratics. Apparently it was formed in conjunction with the Heimdal moraine, but why it was not modified by erosion so as to be unrecognizable as morainic cannot be satisfactorily explained.

Local Control of Glaciation

In the northwest corner of the Tokio quadrangle a group of hills including Sullys Hill has apparently controlled the glaciation and deglaciation of the Oberon quadrangle. The North Viking and Heimdal moraines coalesce in the west center of the Tokio quadrangle. From there they extend to the north around Sullys Hill where they turn south again and extend to the southeast across the Tokio quadrangle. Across the southern part of the Tokio quadrangle only a trace of morainic development can be found. The scarcity of morainic material in the wedge extending up to Sullys Hill from the south is readily explained when the mechanics of morainic deposition are considered. In the later stages of deglaciation the moraines are built up by continually forward-moving ice with melting of the advanced section so as to retain an apparently stationary front. If the movement is impeded, as would be the case in the latter stages with such an obstruction as Sullys Hill, then the actual melting back would overtake the forward movement until it reached the buttress. There a more concentrated moraine would be developed. A cursory examination of this area indicated this to be true. Also, this disposition of the ice and the presence of the buttress might possibly explain the swinging recessional movement from the Heimdal to the North Viking moraine. (Figure 4).

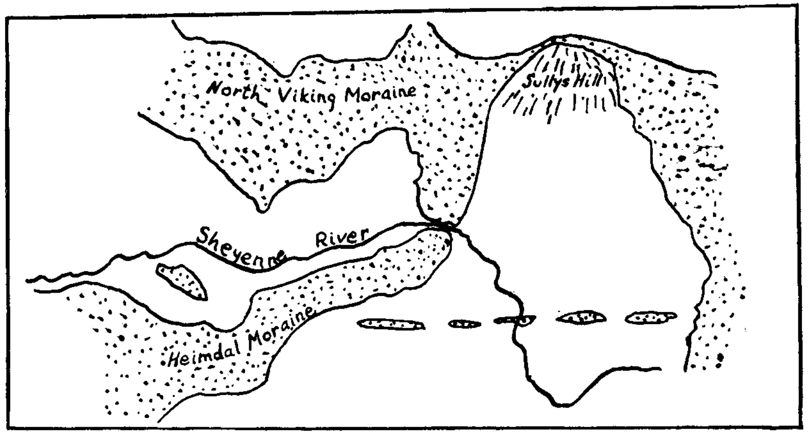


Figure 4. Sketch showing blocking of ice by Sullys Hill area and consequent coalescing of Heimdal and North Viking Moraines.

Numerous examples of coalescing moraines are cited by Alden,[16] but no explaantions are offered. No doubt several factors might be introduced to aid in explaining these movements. In this case the obstruction explains: why the Heimdal moraine does not extend across to the south; the voluminnous morainic deposition along the boundary of the Tokio and Oberon quadrangles; and the coalescing of the moraines.

Ground Moraine

Although the most extensive deposits commonly encountered from the Pleistocene glaciation are ground moraine, only a small part of the area within the Oberon quadrangle can be mapped as such. Recessional moraine deposits and outwash gravels have obscured most of the original till plain which was plastered down during the forward movement of the Keewatin lobe of the Wisconsin ice sheet in this area.

Areas mapped (Plate II) as ground moraine are rarely adjacent to the recessional moraines. Usually outwash deposits intervene, covering the ground moraine for several miles. A few patches of ground moraine were observed completely surrounded by outwash.

16 Alden, W. C., Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey Prof. Paper 106, 1918.

The ground moraine shows little relief and is often difficult to distinguish from the bordering outwash plains. It was necessary to make several auger holes in order to determine the boundary. A few scattered knobs, evidently morainic deposits left by the recession of the ice, remain within the tract of the ground moraine. Boulders like those in the recessional moraine were frequently found within the ground moraine; whereas they were rarely observed in the outwash areas.

Very few exposures were found in areas of the ground moraine. Those that were observed and the samples from the auger holes revealed a fine-grained, compact clay containing scattered grains of quartz, particles of silt, and angular pebbles, cobbles, and boulders of various lithologic character. Some stratified material is present but not as abundantly as within the recessional moraines.

Information from well logs and observation of a few uncased wells showed a tannish-yellow clay in the upper part of the till changing rather suddenly to a dark bluish-gray. The blue-gray color has been attributed to the lack of oxidation in the clay below the level of the water table. Comparable conditions were noted in the outwash and recessional moraines. According to all the data available, the depth of oxidation varies from 5 to 30 feet. The blue-gray clay resembles the underlying Pierre shale in color. Willard[17] believes that more than 90 per cent of the clay of both the ground moraine and the terminal moraine tracts has been derived from the nearby shale.

The top layer of the till, and also of the outwash, has been heavily enriched by organic material so that it appears as a rich black loam. The thickness is generally greater in the low places and becomes less at the crests of the gently rolling hills. This same condition, though far less pronounced, was noted in the recessional moraines. Sheetwash and wind denudation of the uplands and the enrichment by organic material of the low spots have all been jointly responsible for this condition. Regardless of its origin, where the black loam does occur, rich grain crops can be raised during favorable seasons.

[17] Willard, D. E., Description of Jamestown-Tower district, North Dakota: Geologic Atlas of U. S., Jamestown-Tower Folio, 1909.

Loess

In the northeast corner of Section 4, T. 151 N., R. 67 W., in the south-center of Section 28, T. 151 N., R. 66 W., and atop the knob along the southern edge of Section 19, T. 151 N., R. 65 W. material closely resembling loess was found. Later laboratory examination and comparison with samples of known loess deposits bore out the field conclusions to the satisfaction of the author. No material directly overlying outwash was identified as loess. Admittedly, loess might be present there, but several auger holes failed to show it.

The failure to find loess in the outwash area leads to the conclusion that it must have been deposited when the outwash was being laid down contemporaneous with the melting of the glacier, while it was forming North Viking moraine. Studies of existing glaciers and of other glaciated areas show that this is highly plausible. The cold dry winds blowing over the ice during winter seasons would have had plenty of material available to pick up, and deposits of the material could be expected beyond in areas of free ice.

The third location of loess deposits cited best fulfills the requirements for eolian deposition and indicates that the material came from the ice. Two holes were augered, one on the northeast side of the knob, and the other on the southwest side. In the first, nothing but a very fine yellow silt with only two pebbles was found after 6 feet of augering. In the second, loess was found to a depth of only 4 feet where gravelly clay was contacted. Both holes were started at approximately the same surface elevation. The distribution of this very fine-grained, pebble-free material on the side toward the moraine further confirms that it is loess and indicates that it was derived from winds blowing off the ice sheet retreating to the northeast.

Outwash

Plate II shows the general distribution of the outwash plains in the quadrangle. Along most of the length of the recessional moraines the outwash abruptly fans out to the south in a broad smooth apron. There is a noticeable slope to the outwash near the moraines, but a few hundred feet beyond it lies essentially flat. Occasionally knobs of morainic origin protrude above the plain as in T. 151 N., R. 65 W. A few widely scattered boulders can be found. Overlying the alluvial material of the outwash is a layer of black loam comparable to that found in the ground moraine.

The outwash plains where adequately drained are areas of relatively fertile farmlands. The areas which are poorly drained often are quite alkaline or too swampy for use except as pastureland. Areas in the southeast corner of the quadrangle furnish good examples of this latter condition. As important as the fertility is the good drinking water obtainable in the outwash areas. Shallow wells, usually not over 30 feet deep, are practically assured of a water supply; whereas, in the recessional moraines and ground moraines water is difficult or impossible to find. Consideration of the water supply has prompted a special section in this report.

The size of the material constituting the outwash plains varies considerably both within each outwash area and among the different outwash areas. In the area near Oberon most of the material is below the four millimeter size, ranging to very fine sand. The gravel is very impure here, containing about 25 per cent shale, which is a high percentage in respect to the outwash on the south side of the Heimdal moraine. Most of the shale is concentrated in alternate laminae from ½ to 3 inches thick. The intervening laminae consist predominently of limestone, dolomite, quartz, and granite.

Melting activity comparable to that described in the chain of lokes for ascribing the difference of material in the kame terraces and eskers might also be applied to explaining these deposits. Exposures up to twenty feet thick consistently show alternation of the dark and light bands of gravel and sand. The resemblance to varved clays suggests that these alternating bands may be due to seasonal changes. Melting during the winter seasons could be expected only near the bottom of the glacier as pressures developed by the overlying ice would be great enough to cause melting there throughout the year. Melt waters pouring from under the ice in this area should have a high percentage of shale. The dark bands conform to the deposits which might be expected during the winter seasons. On the other hand, during the summer seasons surface melting might easily be expected to augment the deposits being continually furnished from the melting under the ice.

Surface melting, as explained for the kame terraces, should supply material having much less shale. The addition of this material from the surface of the ice would greatly lighten the color of the resulting fluvial deposits so that a definite contrast might be seen. No marked increase in thickness of the light layers over the dark ones was noted as a suggestion that more material was being supplied during the summer intervals. It is possible that the increased volume of water with its increased capacity carried most of its load further out than the winter flow. Also the increased capacity would be more likely to carry the lighter shale pebbles and fragments than the material of higher specific gravity found in the light bands.

As illustrated by the boundaries, there is a tendency for the outwash to be confined to broad, poorly-defined channels. The outwash plain beyond Oberon swings along the front of the moraine to Section 23, T. 151 N., R. 67 W., where it becomes confined to the coulee of the intermittent stream shown on the map. Outwash gravel and sand are traceable for the length of this coulee. The broad shallow terraces along the stream channel are traceable to the outwash area. Field observations indicate a tremendous decrease in size grade of the alluvium towards the lower end of the coulee.

The outwash in Sections 24 and 25, T. 151 N., R. 67 W., and Sections 30, 31, and 32 of T. 151 N., R. 66 W. is separated from the outwash to the west by a narrow strip of ground moraine. This second area consists of coarse sand and has a much lower percentage of shale than the outwash near Oberon.

Coarser material is found west of the Crow Hill Coulee than in any of the other outwash plains. Several morainic knobs are present over this last area.

Outwash deposits along the south side of Sheyenne River Valley are at the same level as those on the north side. Apparently the composition also remains the same. The outwash plain must have continued across the valley at one time indicating that the outwash of the North Viking moraine or outwash from the ice as it melted back to the North Viking moraine was deposited prior to the establishment of the Sheyenne River in its present course.

In the southeast corner of the quadrangle lies an outwash plain extending some distance beyond the boundary of the

Oberon quadrangle. This plain is broken by the string of morainic ridges to the north and by the patches of ground moraine as shown on the map. Over a large part of the area the outwash is so shallow that it is of little value for wells. To the east, along the front of the Heimdal moraine, the outwash is confined to channels between the morainic remnants. The outwash plain lies to the south beyond the quadrangle.

The present stream is only a few feet wide except in flood stage. Even then it rarely overflows its shallow banks. The floodplain is generally about one-third of a mile wide, increasing to about three-fourths of a mile in a few places. The original valley form, as measured across the top, is generally a mile wide and at Sheyenne is two miles wide and vividly illustrates the difference in size between the early Sheyenne River and the present stream.

Sheyenne River and Terraces

Two well-formed and distinct terraces are present within the wide valley of the Sheyenne River. The present floodplain level of the Sheyenne is approximately 1420 feet. The terraces are at the approximate elevations of 1460 and 1480 feet. They are referred to as No. 1 (the latter) and No. 2 (the former) terraces, respectively, in this report.

The present stream is only a few feet wide except in flood stage. Even then it rarely overflows its shallow banks. The floodplain is generally about one-third of a mile wide, increasing to about three-fourths of a mile in a few places. The original valley form, as measured across the top, is generally a mile wide and at Sheyenne is two miles wide and vividly illustrates the difference in size between the early Sheyenne River and the present stream.

It is believed the Sheyenne River established itself in its present channel contemporaneous with or soon after the retreat of the ice from the Heimdal moraine to the North Viking. The outwash found on both sides of the valley must have been deposited during the retreat. Eary escape of the waters to the east was blocked by the continued contact of the ice with the Heimdal moraine on the east side of the quadrangle, thereby preventing the development of Sheyenne River and prmitting the outwash deposits to be laid down in the ponded waters between the ice front and the proximal side of the Heimdal

moraine. However, an early formation of the Sheyenne must be hypothecated, otherwise the channel of the Crow Hill Coulee could not have been eroded. In other words, the Sheyenne had to cut through the moraine, drain the ponded waters, and lower the base level before the greater volume of water from the melting ice in the North Viking area flowed through the coulee channel.

Subsequent erosion of the Sheyenne cut a valley through 50 to 70 feet of drift and an undetermined thickness of shale. Diversion of the waters of Glacial Lake Souris, in the north-central part of the state, from the James River to the Sheyenne, as suggested by Upham,[18] undoubtedly swelled the Sheyenne to its greatest magnitude, and accompanying outwash gravels filled the valley up to the No. 2 terrace level. Drainage of the Sheyenne at that time was into Glacial Lake Agassiz, as testified by the 800 square miles of Sheyenne delta deposits which still remain. Recession of Lake Agassiz lowered the base level for the Sheyenne and permitted downcutting in the stages recorded by the terraces and present flood plain. The two terrace levels are matched on both sides of the river, indicating devlopment in stages rather than a gradual decline in base level. The exact relationship of these stages with the history of Lake Agassiz has not been attempted for this report.

Along the south side of the river outcrops of the Pierre shale are found below the No. 2 terrace. The outcrops are located as follows: northwest corner of Section 11, T. 150 N. R. 67 W.; southwest corner of Section 9, T. 750 N., R. 66 W.; and south center of east side of Section 31, T. 151 N., R. 65 W. The No. 2 terrace gravels which overlie the shales in thickness from on foot at the eastern outcrop to approximately twenty feet at the other two. Evidently, in cutting down, the river swung against the Heimdal moraine, occasionally eroding the drift down to the shale. All the remnants of the No. 1 terrace show gravel down to at least the floodplain level.

The material of the terraces varies widely in size. The vertical distribution of these assorted sizes is relatively uniform in any section. Composition and grain size analyses are shown in the section on gravel and sand.

[18] Upham, Warren, op. cit.

GRAVEL AND SAND

Frequent references have already been made to the different types of gravel and sand deposits found in the Oberon quadrangle. Further description of these deposits is believed to be unnecessary except in consideration of the composition and size. Results of analyses[19] of samples from representative types of deposits are shown below.

It is not to be inferred from these analyses that they perfectly represent their particlar type of deposit. Samples have been chosen which were deemed most illustrative of the character of the various types of deposits to be used as a key by those interested in locating construction material within the broad limits of composition and size established in this report.

TABLE I
Location of Samples and Type of Deposits

Sample No.	Location	Type Deposit
		(Figs. 5 and 6)
120	SW¼ NW¼ Sec. 4, T. 150 N., R. 66 W.	River Terrace (No. 1)
37	NE¼ SW¼ Sec. 4, T. 150 N., R. 66 W.	River Terrace (No. 2)
86	NC Sec. 4, T. 149 N., R. 66 W.	Kame
7	NW¼ SW¼ Sec. 2, T. 151 N., R. 67 W.	Outwash
25	NE¼ SW¼ Sec. 17, T. 152 N., R. 66 W.	Beach
14	NW¼ Sec. 10, T. 151 N., R. 66 W.	Esker
		(Fig. 5)
146	NC Sec. 12, T. 151 N., R. 67 W.	Till
29	SC Sec. 24, T. 152 N., R. 66 W.	Till

River Terraces

The terraces along Sheyenne River offer the best and most extensive gravels found in the quadrangle. (Figures 5 and 6). The shale content is relatively low, and no chert was

[19] Standard Tyler screens up through the 2 mm. size were used. Screens used for the coarser gravels were not of the same standard Wentworth grade scale as the Tyler screens. In order to plot the data, the results obtained from all the sieves were plotted on a cumulative curve and the sizes shown above 2 mm. conforming to the Wentworth scale were interpolated from the curve for plotting the histograms.

found. Most objectionable is the wide range of size grades, but screening would yield a rather high grade product of uniform sizes. The Northern Pacific Railroad has used large quantities of this material for ballast, and the State Highway Department uses it for local roads. The writer estimates that there are rouhgly 85,000,000 cu. yds. of this material comprising the terraces in the Oberon quadrangle.

Kames

Second most important for commercial use are the kame deposits located along the south side of the Heimdal moraine. Their particularly high quality has already been mentioned. There is rather close similarity between the material in these kames and the river terraces. The State Highway Department also uses these deposits for local roads.

Other kame deposits scattered over the morainic areas are of such small extent, and consist of such poorly sorted material along with considerable shale, that they are believed to be impractical for any large scale commercial use. Some of these kames have been excavated for aggregate in foundations or nearby buildings.

Beach Deposits

The fluvial deposits comprising the early beach of Devils Lake are relatively well sorted when compared to most of the other deposits in the quadrangle. The beach here has a relief between 4 and 8 feet and a width of approximately 30 feet. Some excavations along the beach indicated an average thickness of about 10 feet. Considering the areal extent of Devils Lake, an enormous volume of this material should be available surrounding the lake.

Outwash

Except for the outwash area east of Crow Hill Coulee, most of the outwash is less than 4 mm. in size. In the southeastern corner of the quadrangle and in the area just northwest of Sheyenne the material is fine enough that a sandpoint can be used for obtaining water. The material in the outwash plain extending beyond Oberon is somewhat coarser than these two areas but is still below 4 mm. Extensive use has been made of this material for foundations of local buildings and for highways. The shale content (Figure 5) is believed to be too high for any more extensive uses.

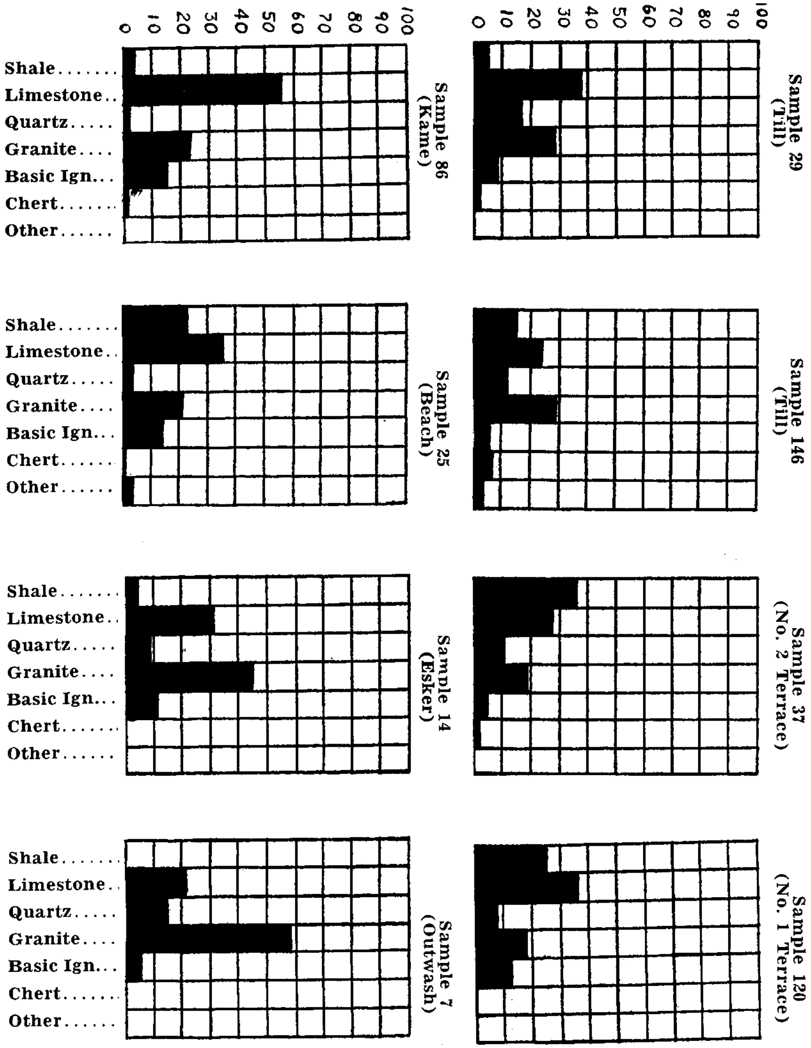


Figure 5. Composition analyses of gravels in Oberon Quadrangle.

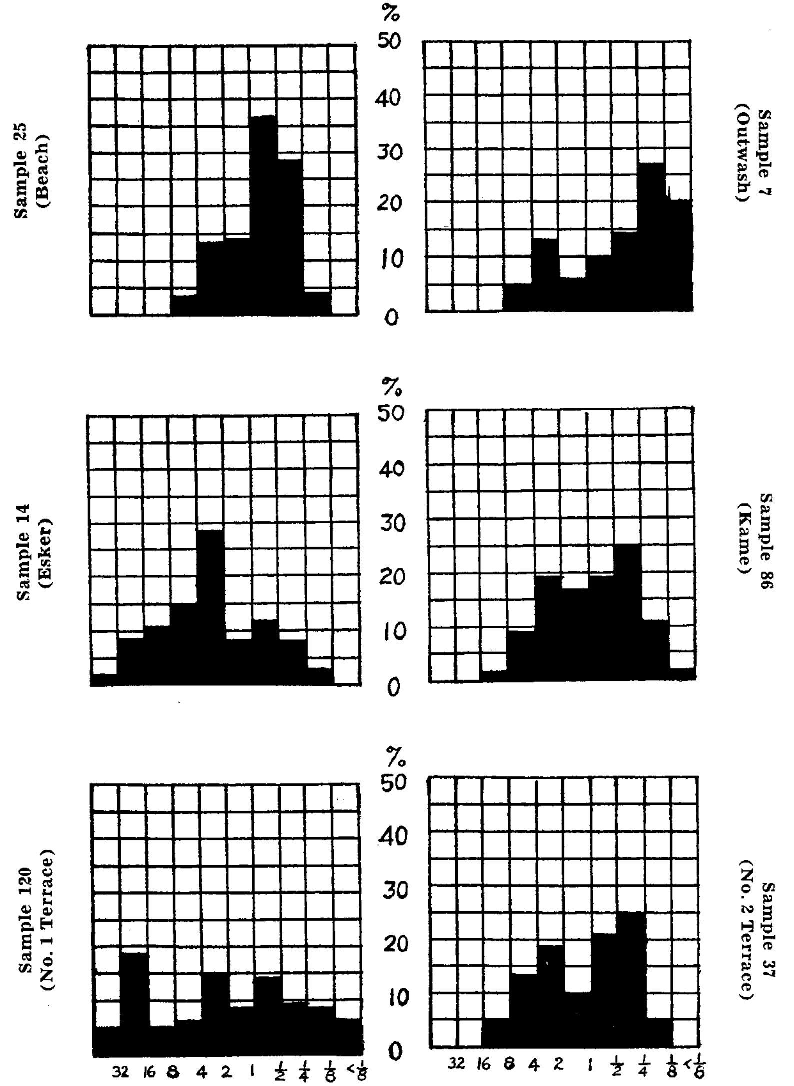


Figure 6. Size analyses of selected gravel and sand deposits in the Oberon Quadrangle.

GROUND WATER RESOURCES

Supply

The influence of glaciation on the distribution of ground water within this quadrangle and adjacent areas is of critical importance. Because of this relationship and because the ground water is a significant economic factor within the area, this section discussing its mode of occurence and relative abundance is included.

Several factors contribute to the limited supply of ground water in this part of North Dakota. Foremost is the amount of rainfall. Reference to Table II shows that the two areas adjacent to Oberon quadrangle have an average rainfall of about 17 inches. Approximately 77 per cent[20] of the rainfall occurs during the growing season. As replenishment of the ground water supply here depends entirely upon the amount of rainfall, an abundant supply of water cannot be expected. Further decrease in supply is brought about by surface runoff, high rate of evaporation, and the ever-increasing consumption by the inhabitants.

Simpson[21] found that in the 20 years preceding 1934, the ground water level was lowered by 15-20 feet in an area including the Oberon quadrangle. His estimates cannot be considered as giving a true picture, for most of his final data was collected towards the close of the worst drought experienced in North Dakota in recent times. It is obvious, however, that without adequate rainfall the ground water supply cannot be maintained.

Artesian Wells

Several non-flowing artesian wells have been drilled in the area. Apparently the aquifier supplying these wells is at the contact of the drift and the Pierre shale. The scant information concerning them makes accurate conclusions impossible; therefore only general information can be presented. Information from several owners of these wells indicates that the depths vary from 90 to over 200 feet, which is believed to be the approximate range of the depth of drift over the area. The water is too saline for human consumption. Consequently, although they do furnish adequate quantites of water, these wells are valuable to the rural population only for livestock which have become accustomed to it.

[20] Climate and Man, U. S. Department of Agriculture, 1941.
[21] Simpson, H. E., Changes in ground water levels in North Dakota, North Dakota Geol. Survey Bull. 10, 1934.

TABLE II

Annual Precipation for the Years 1915-1945, Inclusive, for Maddock and Fessenden.

Maddock, Benson County Elevation, 1604 feet		Fessenden, Wells County Elevation, 1610 feet	
1915	15.89	1915	18.78
1916	18.26	1916	17.91
1917	11.81	1917	13.94
1918	16.37	1918	21.10
1919	13.70	1919	16.51
1920	13.49	1920	13.52
1921	26.24	1921	24.70
1922	21.16	1922	22.54
1923	14.48	1923	14.19
1924	16.51	1924	18.10
1925	15.82	1925	15.79
1926	12.69	1926	15.84
1927	18.53	1927	22.08
1928	19.03	1928	19.57
1929	13.17	1929	14.11
1930	14.25	1930	15.19
1931	16.03	1931	17.17
1932	18.08	1932	20.86
1933	10.68	1933	15.38
1934	9.34	1934	9.25
1935	20.07	1935	20.90
1936	11.10	1936	10.55
1937	16.44	1937	16.80
1938	15.74	1938	14.52
1939	13.37	1939	14.72
1940	14.14	1940	19.85
1941	22.31	1941	25.18
1942	15.60	1942	21.40
1943	10.40	1943	13.64
1944	18.92	1944	19.44
1945	16.61	1945	13.77

Artesian wells to the Dakota sandstone must be drilled to depths of about 1300 feet in this part of the state, as proved by the deep well at Devils Lake which struck the aquifer at 1320 feet.[22] This depth makes drilling for the Dakota sandstone

[22] Laird, W. M., op. cit.

impractical for the individual farmers. It is objectionable even for the small towns such as Oberon and Sheyenne since the taste is undesirable and the water contains a high percntage of salts. As a result the shallow wells deriving their supply of water from aquifers in the drift and near the water table are by far the most important in the quadrangle.

Shallow Wells

Reliable information concerning the depth to the bottom of the well and the depth to the water level was secured from 78 shallow wells scattered over the quadrangle. Table III tabulates the wells as to total depth, depth to top of water table, and type of glacial deposit in which they were dug. A study of Table III clearly shows a marked variation of the ground water level in the recessional moraines. The hummocky, irregular surface is the principal explanation. The number of wells in the morainic areas for which data are quoted mught suggest that a strong flowing supply of water is easy to find here, but experience has proved the contrary. All wells with an adequate supply have struck gravel streaks occurring within the impervious clayey drift. Although much glacio-fluvial material exists on the surface of these moraines, gravel beds of suitable dimensions below the water table level are relatively rare. Several farmers have dug as many as 15 wells on their farms in an attempt to locate an adequate supply. Most of the wells that have been located are inadequate during droughts.

It is even more difficult to locate water in areas of ground moraine than in the recessional moraines. This is understandable in view of the fact that fewer gravel streaks could be expected in deposition of ground moraine than in the building up of recessional moraine. The depth to water is more consistent, due only to the more level surface.

The outwash areas and the river terraces furnish the only reliable sources of water in the quadrangle. Undoubtedly the availability of water from the outwash gravels has determined the location of Oberon, as the availability of water from the river terrace has probably done for Sheyenne. In recent years, according to local inhabitants, the supply has been sufficient for both these towns. No large industrial use is

TABLE III

Shallow Wells in Oberon Quadrangle.

Depth to Bottom of Well	Outwash	Terrace	Ground Moraine	Recessional Moraine
10−	3	2	—	—
10+	10	6	4	4
20+	8	—	2	11
30+	—	—	2	11
40+	—	—	—	2
50+	—	—	—	7
60+	—	—	—	3
70+	—	—	—	—
80+	—	—	—	—
90+	—	—	—	3
Totals	21	8	8	41
Depth to Water Level				
10−	10	3	2	4
10+	8	5	6	13
20+	3	—	—	8
30+	—	—	—	4
40+	—	—	—	8
50+	—	—	—	2
60+	—	—	—	1
70+	—	—	—	—
80+	—	—	—	—
90+	—	—	—	1
Totals	21	8	8	41

made of the water. However, it is stated that in the extremely dry year of 1934 it was necessary to deepen most of the wells. This again indicates the direct dependence of these gravel reservoirs upon the amount of rainfall for their replenishment. The aquifers supplying both of these towns collect drainage from very small areas.

All the other outwash areas, as marked in Plate II, furnish water. However, in low places and where the outwash is thin, the water is alkaline and unfit for domestic use. Some wells within the recessional moraines and ground moraine were also found to contain alkaline water. Evidently this is due to local conditions such as poor surface drainage.

One interesting point to be noticed is that three different watersheds are present within the quadrangle. Most of the North Viking moraine drains into Devils Lake which, as previously stated, is an interior drainage basin. The distal side of the North Viking, the outwash to the south, and the proximal side of the Heimdal moraine drain into Sheyenne River whose waters eventually enter Hudson Bay. The distal side of the Heimdal moraine and the outwash beyond drain into James River whose waters eventually reach the Gulf of Mexico. No effect of these different watersheds upon the ground water level could be found. Instead, the different glacial deposits have determined the reservoirs and many other factors, primarily rainfall, determine the supply.

Conclusions

Although a general lowering of the water table has evidently occurred, it seems reasonable to believe that with normal rainfall and conservative use by the inhabitants, an adequate supply of water can continue to be obtained in most of the outwash areas, in the terraces, and in the moraines where large gravel beds can be located. The effects of cultivation of the land, large crop yields, and transpiration loss through the plants have not been determined. However, the water table within the Oberon quadrangle has apparently risen since 1934. The shallow lakes were dry during the severe drought. Now they contain from 3 to 10 feet of water. At the same time, data on Devils Lake indicate that there has been a steady decrease in depth from 26.75 feet[23] in 1867 to 7.00 feet[24] in 1946. Leonard contends that subsidence of the water table as a result of increased cultivation of the prairie is the best explanation for the lowering of Devils Lake. This is undoubtedly occurring within the Oberon quadrangle also, even though the results have not been as severe. A careful seasonal study of the water table fluctuations should be highly desirable in this area. More information is needed in order to draw accurate conclusions as to the cause for the lowering water table and as to methods for preserving the present supply.

[23] Leonard, A. G., North Dakota Geol. Survey, 6th Bienn. Rept., 1909-1910.
[24] Morsea, C. R., op. cit.

Future investigations for any considerable volume of water in the quadrangle should be more likely to succeed in the Crow Hill Coulee and in the floodplain of Sheyenne River than elsewhere. If the deductions in this report have been correct, a buried valley should exist in the general area of the coulee. Consequently, thick gravel might be expected which would yield a large flow of water. No information concerning the material underlying the floodplain alluvium has been discovered. There is a strong possibility that material similar to that in the terraces may extend downward several feet. If this should prove true, an important supply of water would be available. The valley south and west of Sheyenne is not believed to contain any deep gravels; therefore it probably has no heretofore untapped supply of water.

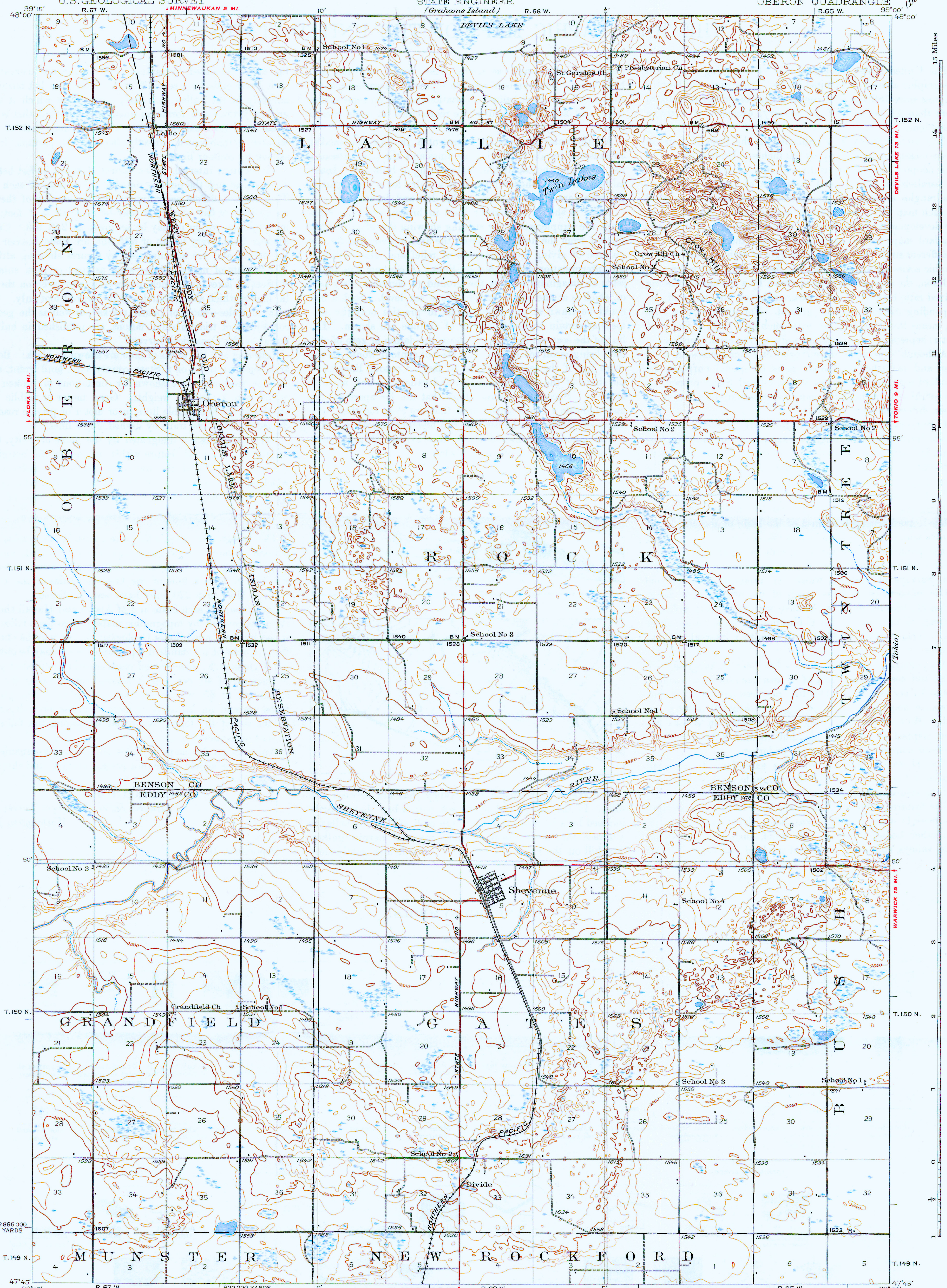
NORTH DAKOTA GEOLOGICAL SURVEY

Plate I — Bulletin 23

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

STATE OF NORTH DAKOTA
ROBERT E. KENNEDY
STATE ENGINEER

NORTH DAKOTA
OBERON QUADRANGLE



Topography by Daniel Kennedy and H.S. Milsted
Control by U.S. Geological Survey
Surveyed in 1928

Scale $\frac{1}{62500}$

Contour interval 20 feet
Datum is mean sea level

APPROXIMATE MEAN DECLINATION, 1928

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

HARD IMPERVIOUSLY SURFACED ROADS
OTHER MAIN TRAVELED ROADS
1930

OBERON, N. DAK.
Edition of 1931.

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 $\frac{1}{31,680}$ (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 $\frac{1}{625,000}$, or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of $\frac{1}{250,000}$, but about 4,000 square miles has been mapped on a scale of $\frac{1}{62,500}$ or larger.

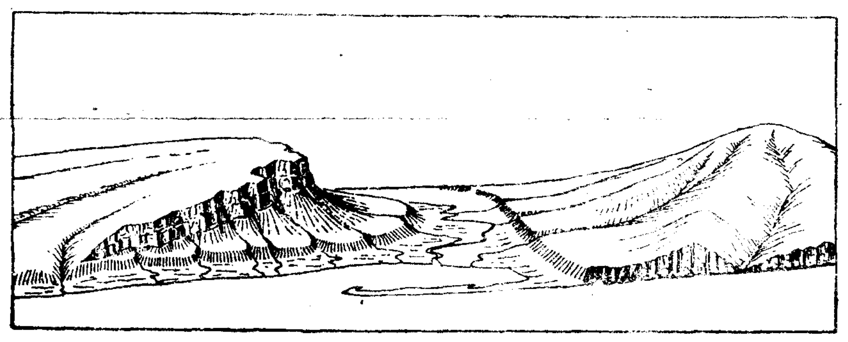
The Hawaiian Islands, with the exception of the small islands at the western end of the group, have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

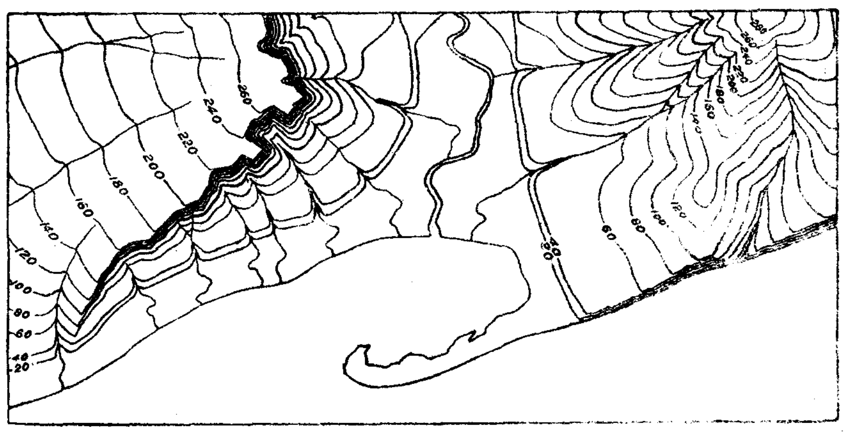
The features shown on these maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads,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

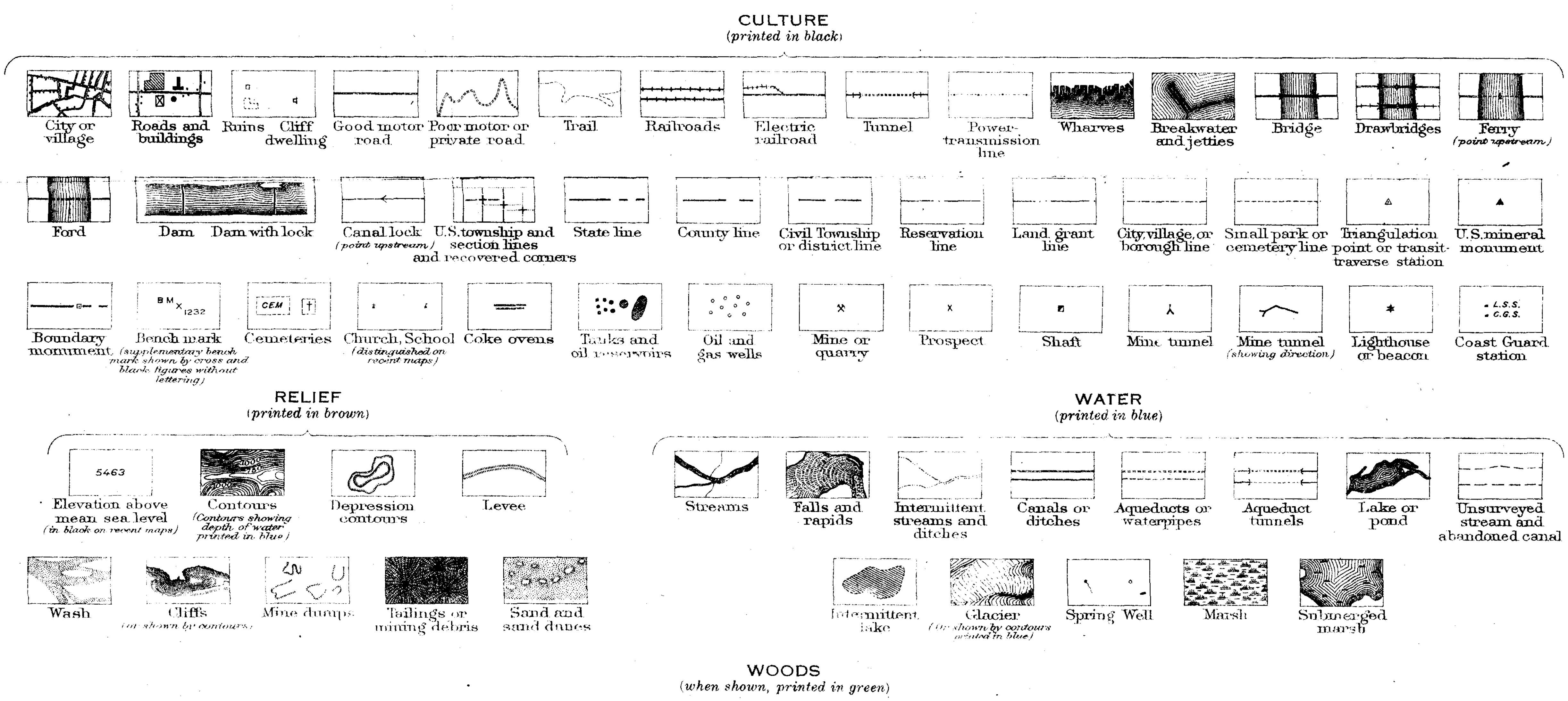
Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different 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.

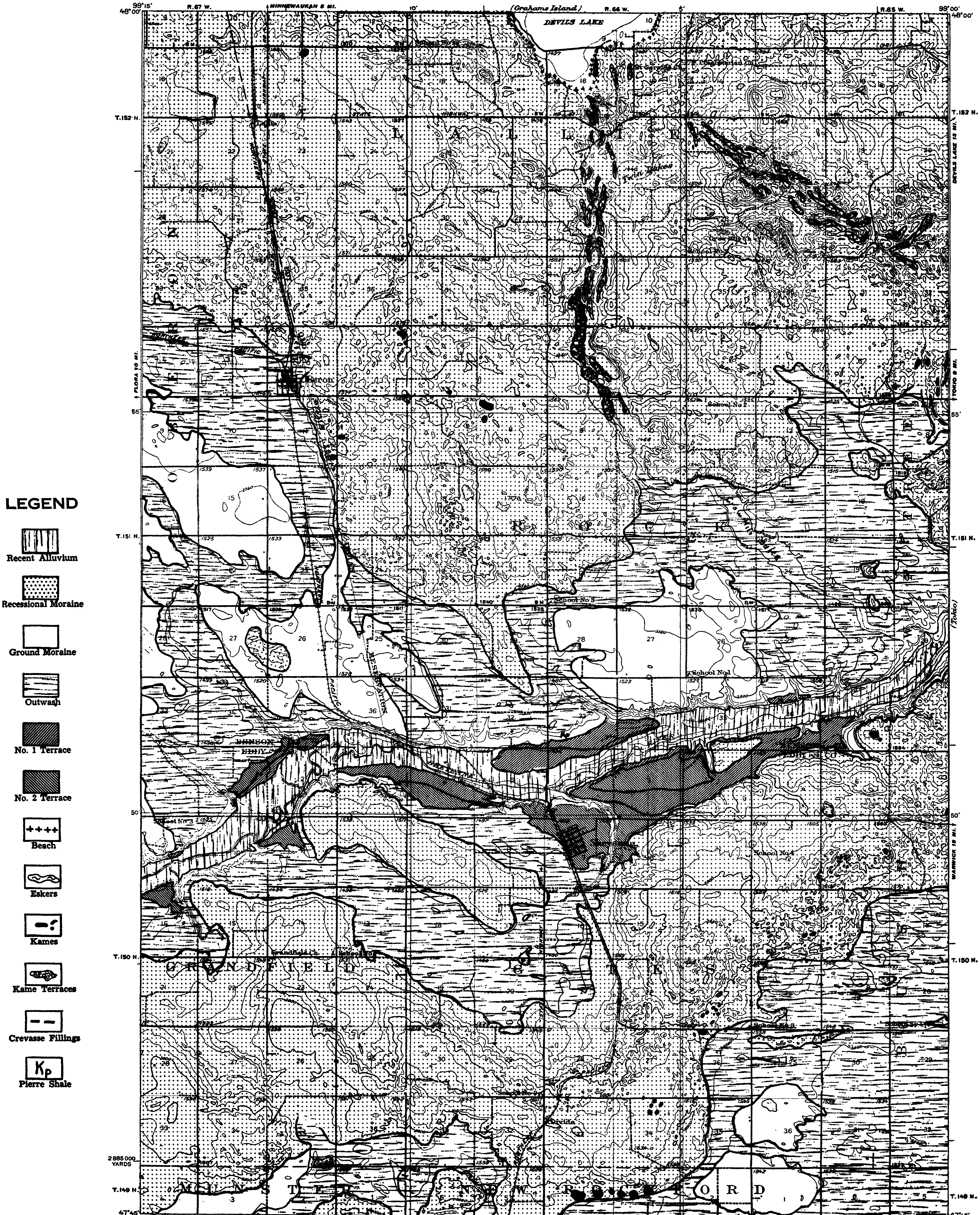
Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

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

September, 1928.

STANDARD SYMBOLS





Topographic base surveyed by U. S. Geological Survey 1928

Geology by P. R. Tetrick 1946

GEOLOGY OF THE OBERON QUADRANGLE