DESCRIPTION OF THE HERMAN, BARRETT, CHOKIO, AND MORRIS QUADRANGLES.

By Frederick W. Sardesoiu.

INTRODUCTION.

GENERAL RELATIONS.

The area described lies between parallels 46° 30' and 46° 45' north latitude, and meridians 95° 45' and 96° 15' west longitude, and includes the Herman, Barrett, Chokio, and Morris quadrangles, comprising 504.88 square miles. It is in western Minnesota and includes the greater part of Grant and Stevens counties and small adjacent parts of Douglas, Pope, and Big Stone counties. (See fig. 1.) The western boundary of the quadrangle of that name is the principal town in the area.

In its geographic and geologic relations the area forms a part of the geologic province known as the Glaciated Plains, which lie between the Laurentian Upland on the north and northeast, the Appalachian province on the east and southeast, the Ozark province on the southwest, and the Great Plains on the west. The quadrangle lies near the middle of this part of the Glaciated Plains, only a few miles from the southwestern limit of that part of the Laurentian Upland that is commonly known as the Lake Superior Uplands by some as simply The Ranges. The bedrock beneath the quadrangles contains largely, if not wholly, of rocks of the same kind as those of The Ranges, but inasmuch as it is thickly overlain by glacial drift and the topographic features are wholly of glacial origin and not at all affected by the bedrock, the boundary is as drawn to include those quadrangles wholly in the Glaciated Plains.

OUTLINE OF THE GEOGRAPHY AND GEOLOGY OF THE REGION.

RELATIONS.

The general region in which the quadrangles are situated lies in the upper region of the Great Plains or prairie district, and is rather deep depression, and nearly all the land surface of the region is swampy or marshy. Parts of the area are so flat that comparatively low accumulations of drift have caused flooding of considerable areas, and in the district along and south of the international boundary there is a network of irregularly shaped lakes that are joined by streams which are virtually parts of the lakes themselves.

GEOLOGY.

The hard rocks of the region range in age from pre-Cambrian to Cretaceous and include both sedimentary and igneous rocks, some of them highly metamorphosed and others virtually unaltered. All the igneous and all the greatly metamorphosed rocks are pre-Cambrian in age. Their distribution in the district is shown in figure 3 (p. 2).

The Laurentian Upland within the region is underlain almost entirely by pre-Cambrian rocks representing both the Archean and the Algizian systems and all the series into which these systems have been divided, so that the region abutting Lake Superior has been recognized as one of the best in North America for the study of pre-Cambrian rocks and is the one in which they have been studied in greatest detail. The igneous rocks include both intrusive and volcanic types and the highly metamorphosed sedimentary rocks include some of the richest deposits of iron ore on the continent. Beneath the drift, in a part of the Glaciated Plains, the pre-Cambrian rocks, which are exposed in places by the Mississippi River and in several areas in southwestern Minnesota and eastern South Dakota. Unusually rich in the same age underlie the entire region at great depth, but elsewhere they are covered by younger stratified rocks.

In southeastern Minnesota and southwestern Wisconsin, in the adjacent parts of Iowa and Illinois, and in the lower part of the Red River Valley, chiefly in Canada, the Glaciated Plains within the region are underlain by stratified rocks of Paleozoic age, ranging in age from Cambrian to Carboniferous.
The remainder of the Glacial Plains within the region and all that part of the Great Plains which is included in the areas shown in figure 2 are underlain by stratified rocks of Cretaceous and Tertiary age.

The whole region, except parts of South Dakota and Nebraska and the Driftless Area, was covered by ice at one time or another during the Pleistocene epoch and received deposits of glacial drift. These deposits consist in part of till—a heterogeneous mixture of rock waste transported by the ice and remaining practically as the melting ice left it—and in part of stratified drift or outwash—sheets of gravel, sand, and silt laid down by streams that flowed from the melting ice or in lakes that were formed for a time at the margin of the glacier while it was melting. The greater part of Red River Valley is occupied by deposits laid down in the bed of such a vanished lake.

The Pleistocene glacial era was of great duration, and the great part of the country was covered by ice and the drift that accumulated around it. The Pleistocene drift is essentially the deposit of the Wisconsin glaciation; it overlies many drifts and the bedrock. The extent of Wisconsin drift in Minnesota is shown by the heavy lines in figure 4. The ice retreated from the northeastern part of the region during the last of the glacial epoch, and during the interval between the first and last invasion of it, the surface of the land was lowered by the melting of the ice. The Wisconsin drift is characterized by the fact that it covers a large part of the land area of the region. It is essentially the deposit of the Wisconsin ice age, which has been described as the last great glaciation of the earth. The climate was colder and the precipitation was heavier during the glacial epoch than it is now, and the winds were generally from the north or northwest.

The climate is very much affected by the amount of precipitation and by the temperature, which is influenced by the amount of snowfall. The temperature varies greatly from day to day, and the winds are variable. The climate is influenced most by the westerly winds. On many days the skies are clear and the sunshine is bright. The average annual rainfall is about 25 inches. A few snow falls during the winter and early in the spring.

The land in the quadrangles having the same features as the land in the quadrangle shown in figure 1 is characterized by the fact that it covers a large part of the land area of the region. The land in the quadrangle shown in figure 1 is characterized by the fact that it covers a large part of the land area of the region. The land in the quadrangle shown in figure 1 is characterized by the fact that it covers a large part of the land area of the region.
The general character.—The area is in greater part the northern extension of the prairie region of the Minnesota Valley, but its northeastern corner is crossed by the western border of the Leif Erikson Quad and thence across the eastern end of the area.
The bed of Lake Hattie is said to have been dry in September, 1886. Some of the lakes have been artificially drained. A large, irregular lake called Moon Island Lake, which has been mapped by Warren Upham, is lying 2 miles southeast of Donnelly in 1888, has now disappeared, but its shores remain as an encompassing area surrounded by fields and meadows. Its general outline is indicated by the 1,100-foot contour on the topographic map, which also shows the divides by which the lake was drained. A lake that once extended from a point 1 mile west to another 2 miles south of Chokio and another lake in see on Logan Township, have also been drained. Pullman Lake, near Herman, has been drained for the topographic map was made.

Nowadays, these numbers, both large and small, are abundant in the area. Some occupy the beds of naturally or artificially drained sloughs or lakes, and many little ones that are distributed over the till plain occur. Many, almost all of which are small and shallow but may hold water for some time, for the clay of the plain is too impervious to allow the water to sink away quickly. As not much past grows in the area, the marshes are simply interspersed in character between the prairie on the one hand and the sloughs on the other. Artificial drainage has already converted much marsh to prairie or field. In the gravelly tracts, marshes are found only in basins that are as low as the level at which ground water stands under the plain. Along the Chippewa and Pomme de Terre Valleys the marshes are many at practically all river levels. The lake plain west of the Herman town contains few marshes, having been artificially drained by ditches.

The early explorers and traders who penetrated the area crossed it in various river valleys. The railroad followed the building of the railroads and began after 1870. The river called the Pomme de Terre by the French traders who had been known as the Pimme by the Indians, on account of the abundance along it of the prairie tump and tripshen (Pomme oceano Praha).

DESCRIPTIVE GEOLOGY.

General Character of the Rocks.

The exposed rocks of the area are all bedrock deposits of Quaternary age and comprise unconsolidated till, gravel, sand, and silt, in part glacial and lacustrine deposits of Pleistocene age and in part alluvial deposits of Recent age. The bedrock beneath the surficial deposits consists everywhere, for as far as known, of crystalline rocks of pre-Cambrian age, chiefly Archean granite. Bedrock is not exposed anywhere in the area but has been reached in several wells bored at depths ranging from 40 to 400 feet. Some of these records are included in the accompanying table.

Rocks beneath the drift.

The drift, so far as it is known in this area, is like the Archean rock that outcrops along Minnesota River near Onalaska, about 18 miles southeast of the town of Onalaska. In the area records it is called granite. At the northern end of the town of Onalaska, 18 miles southeast of this locality, the granite forms a bedrock surface at least 350 feet in thickness. In the southeastern part of the area the bedrock surface is at least 300 feet thick. Nowhere does the bedrock surface form a plain, nor parallel with the present surface of the ground. (See figs. 5, 6, and 7.) The accompanying table shows the depths of the bedrock surface at various places in the area. The bedrock surface is highest at a place north of Herman, although the elevation of this surface is not so high as at Herman. The deep well at Elbow Lake indicates conditions similar to those at Herman, although the elevations of the surface is somewhat higher. Three neighboring wells near Herman show a descent of 90 feet at the bedrock surface where the present surface has a descent of only 6 feet.

The bedrock, so far as it is known in this area, is like the Archean rock that outcrops along Minnesota River near Onalaska, about 18 miles southeast of the town of Onalaska. In the area records it is called granite. At the northern end of the town of Onalaska, 18 miles southeast of this locality, the granite forms a bedrock surface at least 350 feet in thickness. In the southeastern part of the area the bedrock surface is at least 300 feet thick. Nowhere does the bedrock surface form a plain, nor parallel with the present surface of the ground. (See figs. 5, 6, and 7.) The accompanying table shows the depths of the bedrock surface at various places in the area. The bedrock surface is highest at a place north of Herman, although the elevation of this surface is not so high as at Herman. The deep well at Elbow Lake indicates conditions similar to those at Herman, although the elevations of the surface is somewhat higher. Three neighboring wells near Herman show a descent of 90 feet at the bedrock surface where the present surface has a descent of only 6 feet.

The bedrock, so far as it is known in this area, is like the Archean rock that outcrops along Minnesota River near Onalaska, about 18 miles southeast of the town of Onalaska. In the area records it is called granite. At the northern end of the town of Onalaska, 18 miles southeast of this locality, the granite forms a bedrock surface at least 350 feet in thickness. In the southeastern part of the area the bedrock surface is at least 300 feet thick. Nowhere does the bedrock surface form a plain, nor parallel with the present surface of the ground. (See figs. 5, 6, and 7.) The accompanying table shows the depths of the bedrock surface at various places in the area. The bedrock surface is highest at a place north of Herman, although the elevation of this surface is not so high as at Herman. The deep well at Elbow Lake indicates conditions similar to those at Herman, although the elevations of the surface is somewhat higher. Three neighboring wells near Herman show a descent of 90 feet at the bedrock surface where the present surface has a descent of only 6 feet.

The bedrock, so far as it is known in this area, is like the Archean rock that outcrops along Minnesota River near Onalaska, about 18 miles southeast of the town of Onalaska. In the area records it is called granite. At the northern end of the town of Onalaska, 18 miles southeast of this locality, the granite forms a bedrock surface at least 350 feet in thickness. In the southeastern part of the area the bedrock surface is at least 300 feet thick. Nowhere does the bedrock surface form a plain, nor parallel with the present surface of the ground. (See figs. 5, 6, and 7.) The accompanying table shows the depths of the bedrock surface at various places in the area. The bedrock surface is highest at a place north of Herman, although the elevation of this surface is not so high as at Herman. The deep well at Elbow Lake indicates conditions similar to those at Herman, although the elevations of the surface is somewhat higher. Three neighboring wells near Herman show a descent of 90 feet at the bedrock surface where the present surface has a descent of only 6 feet.

The bedrock, so far as it is known in this area, is like the Archean rock that outcrops along Minnesota River near Onalaska, about 18 miles southeast of the town of Onalaska. In the area records it is called granite. At the northern end of the town of Onalaska, 18 miles southeast of this locality, the granite forms a bedrock surface at least 350 feet in thickness. In the southeastern part of the area the bedrock surface is at least 300 feet thick. Nowhere does the bedrock surface form a plain, nor parallel with the present surface of the ground. (See figs. 5, 6, and 7.) The accompanying table shows the depths of the bedrock surface at various places in the area. The bedrock surface is highest at a place north of Herman, although the elevation of this surface is not so high as at Herman. The deep well at Elbow Lake indicates conditions similar to those at Herman, although the elevations of the surface is somewhat higher. Three neighboring wells near Herman show a descent of 90 feet at the bedrock surface where the present surface has a descent of only 6 feet.
The pre-Kansan drift is widely distributed in the region but only as remnants, for it had been greatly eroded before the next drift sheet was deposited. It is not known to exist in those counties where, in its present location, the pre-Kansan drift is at present parallel and some distance from the Wisconsin drift, but it is a distinct sheet, and is in general more than 300 feet thick. The drift is such as would be formed by the washing and shifting out of pebbles and boulders on the Wisconsin drift. South of Fond du Lac the ridge is another, then it is north of the creek.

The beach forms either a single ridge or in places two, three, or four more or less distinct ridges, of which the outer or outermost one is highest. West of Herman, on the south side of sec. 15, Logan Township, the beach has two ridges. The lower one is of gravel about 10 feet deep and the higher is chiefly about 15 feet deep. On the north line of secs. 15 and 14, Logan Township, the beach is a single ridge 16 feet high on the west side and 8 feet high on the east side and has a maximum thickness of 15 feet of gravel. Where the ridge is cut through by the Great Northern Railway, near Herman, it consists of 6 feet of gravel resting on a low ridge of till.

The beach forms either a single ridge or in places two, three, or four more or less distinct ridges, of which the outer or outermost one is highest. West of Herman, on the south side of sec. 15, Logan Township, the beach has two ridges. The lower one is of gravel about 10 feet deep and the higher is chiefly about 15 feet deep. On the north line of secs. 15 and 14, Logan Township, the beach is a single ridge 16 feet high on the west side and 8 feet high on the east side and has a maximum thickness of 15 feet of gravel. Where the ridge is cut through by the Great Northern Railway, near Herman, it consists of 6 feet of gravel resting on a low ridge of till. (See fig. 8.) The beach is there 300 feet wide.
Algonkian rocks of Minnesota indicate that they probably once covered this area. In the region on the northland, south of the area occupied by Lake Superior, great sheets of lava were poured out on the old land surface. The lava did not extend far westward into Minnesota, but the igneous rock seems to have extended to the general region in which the area lies, and some of the dikes of dark volcanic rock exposed in the Minnesota Valley were probably intruded at that time. Dikes of the same age presumably cut the granite rocks underlying the area. At the close of Pre-Cambrian time the region seems once more to have been dry land and undergoing subaerial denudation.

PALEOZOIC ERA.

The area here considered appears to have been land during a large part of the whole of the Paleozoic era, as is shown in the accompanying table, which gives the relative age of the existing formations and of those that were perhaps once present but that have been removed by erosion if they were present, thus indicating the submergence and emergence of the area. Mantle sedimentary formations of Upper Cambrian, Ordovician, Silurian, and Devonian age are found in southeastern Minnesota or in adjacent States and also north of the region, in Canada, but none are found in central and southwestern Minnesota, a region which appears to have been a peninsula extending into the Paleozoic sea. Whether the Pennsylvania was at any time submersed and strata were deposited over it can not now be determined.

Quaternary.


Deposited but not overlaid.

Quaternary period.

Sedimentary formations.

Tertiary period.

Deposited but overlaid.

Algal deposits.

Devonian period.

Mazon Creek fauna.

Devonian period.

Silurian period.

Trenton period.

Upper Carboniferous.

Lower Carboniferous.

Pennsylvanian.

Lower Paleozoic.

Mesozoic era.

Devonian period.

Silurian period.

Ordovician period.

Algonkian period.

Paleozoic era.

Carboniferous period.

Silurian period.

Ordovician period.

Pre-Cambrian time.

Carboniferous period.

Ordovician period.

Devonian period.

Trenton period.

Trenton period.

Carboniferous period.

Silurian period.

Devonian period.

Pennsylvanian.

Pre-Cambrian time.

Carboniferous period.

Silurian period.

Devonian period.

Ordovician period.

Algonkian period.

Deposited but overlaid.

Carboniferous period.

Deposited but overlaid.

Algal deposits.

Pennsylvanian.

Archean period.

Formation still existing.

In late Cambrian time the sea on the south extended as far north as Taylors Falls, Rush City, Monticello, and Cambria, as is shown by the occurrence near those places of beds of limestone 7 or 8 feet thick was encountered before the granite was reached. 1 During the Carboniferous period the slow subsidence again allowed the sea to encroach on southeastern Minnesota. During the Carboniferous period the slow rise of the land drove the sea southward more, and at this time. The exact location of the bedrock surface in the quadrangles were formed chiefly of the base of the Cretaceous strata. Where the granite rocks underlying the area here considered, though patches of them may exist beneath the drift sheet in places where the basalt has not been eroded away, is believed to have faced east rather than south and to have retreated westward. Such a north to south trend of the ice margin is suggested by the uneven thicknesses of the Kansan drift and by the direction of the interglacial valleys.

The position of a Kansan terminal moraine may be inferred from the trend of a prominent elevation coinciding with the nearly straight line of the old streams across the area considered. This line can be traced across the area by means of the old courses of the streams of the Minnesota region. The river valleys then flowed not from east to west but rather in the general direction of the drift. At and near their margins the Kansan ice sheet probably once stood. Clay deposits were probably also deposited in the area during the Upper Cretaceous stage. The Kansan drift was deposited on the clay deposits, which were probably still undrained at that time. Dikes of the same age presumably cut the granite rocks underlying the area. At the close of Pre-Cambrian time the region seems once more to have been dry land and undergoing subaerial denudation.

QUATERNARY PERIOD.

The history of the earliest Pleistocene glacial stage in the area is obscure, as whatever record of it may exist is buried deep under younger deposits. The pre-Kansan drift, where observed in Iowa and southern Minnesota, has, however, the calcarious nature and other general characters of the gray drift deposits of the Midwest, and they may be relatively early in age. The pre-Kansan ice sheet is believed to have been entirely melted away from the area, so that an interglacial stage—the Algonkian—preceded the advance of the Kansan glaciation. During the Algonkian stage, as well as during the Kansan glaciation, the record of the pre-Kansan glaciation was exposed to destructive agencies and largely or wholly removed by later erosion.

KANSAK STAGE.

Advance of the glacier.—As neither the Kansan or old drift nor the bedrock on which it rests is exposed in these quadrangles, the Kansan Ice sheet advanced and the length of time during which it remained

Benton shale. Some fresh-water sediments were deposited in lagoons and estuaries. At and near their margins the Upper Cretaceous deposits were probably rather irregular both in thickness and in plan. No such strata have been encountered in wells in the area here considered, though patches of them may exist beneath the drift in places where the basalt has not been eroded away. The drift here consists chiefly of a well-sorted and well-rounded glacial drift, consisting of fragments of rocks of various ages and sizes, from the base of the Kansan formation to the pre-Cambrian rocks underlying the area. The drift here consists of a well-sorted and well-rounded glacial drift, consisting of fragments of rocks of various ages and sizes, from the base of the Kansan formation to the pre-Cambrian rocks underlying the area. At the close of Pre-Cambrian time the region seems once more to have been dry land and undergoing subaerial denudation.
Erosion and weathering.—Although the whole surface of the Kansan drift in the Barrett quadrangle is covered with a thick loess, its original thickness may have been appreciably modified before the end of interglacial time. The thickness of the material removed east of Mud Creek, where the bedrock now appears to have been swept bare, possibly because the Kansan drift on it was originally thin. North of Herman, as shown in the table on page 7, the drift is from the very greatest amount at that place probably because no Kansan drift remained at that place when the Wisconsin stream began to ascend the valley. Now, therefore, just above where the Wisconsin stream begins to ascend the valley, it is possible that the surface has been reduced by the same process by which the surface of the Wisconsin drift has been reduced north of the table on page 4, the bedrock is only 42 feet from the surface. Below this point, where the Wisconsin ice sheet reached northward, the surface is still somewhat below the Wisconsin ice sheet level southward, and where the Wisconsin drift lies, the surface is only 44 feet above sea level.

The beginning of the last glacial invasion was in early Wisconsin time and its end was in late Wisconsin time. The work of this ice sheet is best shown by the eskers developed during its retreat, but there may have been considerable deposition during its advance, also. Eskers are deposits made by certain features of the Wisconsin ice sheet have been described in the area. The eskers are a chain of lakes extending northwest toward Herman from the lower land on the west to the higher land on the east. The margin of the glacier ascended gradually from the lower land on the west to the higher land on the east. The area covered by the Kansan drift may have been dissected by erosion and its original thickness may have been appreciably modified before the end of interglacial time. The Wisconsin ice sheet reached northward, the surface is still somewhat below the Wisconsin ice sheet level southward, and where the Wisconsin drift lies, the surface is only 44 feet above sea level.

The drainage from the melting ice did not flood the whole valley, but the glacial river followed a narrow course, in places less than 200 feet wide, along the line of the stream. In the early postglacial period, the drainage was confined to the valley south of the Pine River, and the drainage from the melting ice did not flood the whole valley, but the glacial river followed a narrow course, in places less than 200 feet wide, along the line of the stream.
but later it passed westward along the margin of the ice. During the early part of this stage streams from the ice deposited first the outwash that forms the plains southeast and northeast of Niemak Lakes, then the outwash along the Mustin Valley, only four small remnants of which remain, and finally the larger area, north of herman and one or two miles north of Chokio. Much greater streams flowed at the same time from the ice north of this area to the Pomme de Terre Valley.

The interglacial valley of the Mustin had not been obliterated by the deposits from the Wisconsin ice, and as the ice margin receded the valley reappeared. It received very little drainage until the ice margin north of this area had retreated from the head of the Pomme de Terre Valley to the place where the head of the Mustin Valley intercepted Otter Tail River. Then, while the ice there still blocked the course of drainage towards the west, water from the ice and from other Tails and Polkian rivers swelled southward through the Mustin Valley, which was distinctly eroded and termed, especially in the northern part of the Herman quadrangle, where the stream occupied the entire width of the valley. There it left its bottom stream with large boulders, showing that its current was swift.

The Norcross beach was 3 miles south of the Wisconsin ice during the last interglacial stage of Lake Agassiz at the time the ice border stood at Norcross, as shown by dashed line D. Earlier positions of the ice border during the last interglacial stage of Lake Agassiz are shown by lines A, B, C, and D. At time that intervened between the formation of the Herman and the Norcross beaches therefore appears to have been short.

Eighty-five per cent of the total drainage of the lake was to the south, although two short, low sandy ridges were built and the sandy flat extended southeastward for 3 miles, the shore line was the north-northeastward. This uplift took place after the waves formed by the prevailing northwest winds extended beyond the lake and the sandy flat extended southeastward for 3 miles, the shore line was the north-northeastward. This uplift took place after the December of Lake Agassiz at the time the ice margin stood during the last interglacial stage of the lake. Because of the presence of a shallow moraine ridge, which appears to be crossed by the lake as the north-northeastward. The depth of Lake Agassiz at the time the ice margin stood during the last interglacial stage of the lake.
interglacial valley. Only the glacial channel of that valley has been deeply eroded and filled with drift, or perhaps in the case of the Mustinka, to the nearness of the water table. Pomme de Terre River has likewise eroded a channel about 6 feet in depth within the limits of the channel of a glacial river, and outside of that channel the erosion has been very limited. The Recent stream has had no effect on the glacial interglacial valley in which it flows, but on the other hand, it has made slight though somewhat unequal reduction along its course. The deepening of these valleys by Recent erosion is small compared to that effected by glacial and interglacial streams.

Mud Creek has an erosion valley 100 feet wide and 15 feet deep in places, on the line between sec. 22 and 25, Darnen Township. This contrast with the interglacial valley in which it flows, its own valley is small. Perhaps less than 5 feet of the depth of this valley has been lost since recent times. Fireflies, in Logan Township, and Tawondale Township, in Eldorado Township, have small erosion valleys from 1 to 15 feet deep. The probability is that some of these valleys are those along Mustinka River, near Sylvan Lake, north of this region, and thus far they have been stripped and a thickness of gravel measuring 10 to 20 feet has been exposed. The Great Northern Railway, on the east side of Pomme de Terre River near Morris are owned and worked by the town. Another dam, about 6 feet high, near Morris, in the NW. 1-4-7, Darnen Township, is also not now used, the flour mill which the ground water will rise in wells. For example, the well at farmhouses along the Chippewa Valley likewise penetrates the ancient shore gravels of the Herman beach also contain water near their base and supply several shallow wells dug near houses on the beach. Practically all the hill in the till till drawn water from irregular and discontinuous bodies of gravel, sand, or silt that are interbedded with till. The glacial outwash gravels that lie at the surface in this region draw water from beds of gravel, sand, or silt in the glacial layers or to the dried-out till around them. As the water descends or flows from one gravel bed to another, some shallow wells that penetrate water-bearing beds that are continuously replenished may be practically inexhaustible. A few wells are supplied from flowing underground streams. For example, a well at a house in the NE. 1-7, Eldorado Township, which is 45 feet deep and contains 2 feet of water, is supplied by a stream that flows near the bottom of the well.

Because of the conditions described some wells fail to yield water because of dry seasons, or the water is not equal to the demand. Some such wells, however, are still in use. In many shallow wells there is liability to contamination of the water, and some of these are used only for small purposes. Distinction must be made between shallow wells in gravel and those in till. The glacial outwash gravel beds that lie at the surface in the Pomme de Terre Valley are filled with water to a level controlled by the river, and wells sunk into them find an adequate supply of water. As the ground is porous and shallow, the water table is everywhere near the surface, and all the water near the surface is free from contamination; especially from areas that lie upstream. Besides the wells at the farmhouses on the glacial outwash deposits that are shown on the maps, the wells at Barrett and those at the Monitor windmills draw their supply from gravel beds in the Pomme de Terre Valley. Wells at farmhouses along the Chippewa Valley likewise penetrate glacial outwash gravel beds that are saturated below the level of Pomme de Terre River and which yield abundantly.

The ancient shore gravels of the Mustinka River also contain water near their base and supply several shallow wells dug near houses on the beach.
water can not generally be predicted. The bedrock is nearly everywhere too impervious to be water bearing, but in some places it may have open joints, which serve the same purpose as a bed of gravel in carrying water or collecting it from the surface. In a well in the SW sec. 5, Everglade Township, water was found only after the drill had passed 8 feet into the granitic rock under the drift.

More than half the deep wells now in use get water from beds of gravel or coarse sand that yield freely, but many wells are stopped in beds of fine sand or silt, either to save the cost of sinking them deeper or because they have struck bedrock without finding gravel. A screen is commonly attached to the casing of such wells to prevent the silt or sand from entering with the water. These screens may become coated with calcareous deposits and in a few years may thus become entirely clogged.

When an old well is sunk deeper and reaches a water-bearing bed at or below the ground-water table, the head of water generally falls nearly to the lower water level, even if the water from the higher bed is admitted to the well. If the deep water-bearing bed is relatively weak the height to which the water rises in the well may fluctuate greatly with alternation of wet and dry periods.

There is reason to believe that good wells are more commonly obtained in high than in low places, for the height of a tract may be due to some extent to underlying lenticular beds of gravel and sand, which bear water, as shown in figure 12.

Municipal supplies.—All the towns of the area have deep wells except Morris and Barnett, where the wells are shallow. A well 400 feet deep supplies the entire town of Elbow Lake, yielding 40,000 gallons a day without notable lowering of its head. Hermann is supplied in the same way by wells 140 feet deep, and Donaldson by one well 125 feet deep. The one well 75 feet deep at Hoffman yields 40,000 gallons a day without notable lowering of its head. The well at Chokio is 150 feet in depth, and that at Norcross 150 feet. The waterworks at Hancock is supplied by a well that is sunk to a depth of 480 feet but yielding 40,000 gallons a day without notable lowering of its head.

Flowing wells.—Wells flow because the surface of the land on which they are sunk stands below the plane of artesian head, or below the height to which water rises in wells from the pervious beds within the till. The water which is derived from Michigan is not the ordinary height of water tables is high to where it is lower, its flow being most rapid through the pervious beds, to which it is in large part confined by the nearly impervious beds of till. The water thus flows horizontally under certain surface depressions, although it has an artesian head enough to overflow the top of a well sunk to the water-bearing beds.

Where the bottom of the Mustinka Valley enters the Herman quadrangle it is a little below the level to which the artesian water rises, the water in the only deep well in the valley there standing 1,100 feet above sea level, or 10 feet above the level of the water in the river. The same condition occurs on the Mustinka east of the Hermann beach, where the water in a deep well stands 1,075 feet above sea level, or 25 feet above the river. There are no deep wells in the Pomme de Terre Valley, but flowing wells could perhaps be obtained in some parts of it. A flowing well that has a head of 1,095 feet above sea level was drilled on the south side of sec. 20, Elbow Lake Township.

In certain districts in the northwestern part of the Hermann quadrangle all the deep wells overflow. One of these districts is north of Mustinka River, in Gorton and North Ottawa townships, and extends several miles north of the Herman quadrangle. In the northern district there are more than 20 flowing wells, which range in depth from 20 to 105 feet and have 1 to 10 feet head above the ground; in the southern district there are 8 flowing wells, which range in depth from 100 to 150 feet and have 1 to 3 feet head. The head of the flowing wells in the two districts ranges from 1,012 to 1,042 feet above sea level. The best wells have a flow of about 10 gallons a minute. Some of them have been flowing without restrain for 10 to 20 years, but the rate of flow is said to have decreased somewhat in that time. A few wells that barely overflowed at first have lost head, and the water level in them is now 1 to 4 feet below the surface.

Soils

General character.—The soil of the region is derived wholly from material of glacial origin. The differences in the soil are caused by the greater or lesser degree of weathering and decomposition of the surface of the drift and from subsequent drainage. The chief differences are in the proportion of clay and sand, the amount of humus, the surface drainage, the underground drainage, the thickness of the subsoil, and incidentally the presence of alkali.

The underlying drift is a like source of future soil. At many places the water table is high to where it is lower, its flow being most rapid through the pervious beds, to which it is in large part confined by the nearly impervious beds of till. The water thus flows horizontally under certain surface depressions, although it has an artesian head enough to overflow the top of a well sunk to the water-bearing beds. Where the bottom of the Mustinka Valley enters the Herman quadrangle it is a little below the level to which the artesian water rises, the water in the only deep well in the valley there standing 1,100 feet above sea level, or 10 feet above the level of the water in the river. The same condition occurs on the Mustinka east of the Hermann beach, where the water in a deep well stands 1,075 feet above sea level, or 25 feet above the river. There are no deep wells in the Pomme de Terre Valley, but flowing wells could perhaps be obtained in some parts of it. A flowing well that has a head of 1,095 feet above sea level was drilled on the south side of sec. 20, Elbow Lake Township.

In certain districts in the northwestern part of the Hermann quadrangle all the deep wells overflow. One of these districts is north of Mustinka River, in Gorton and North Ottawa townships, and extends several miles north of the Herman quadrangle. In this northern district there are more than 20 flowing wells, which range in depth from 20 to 105 feet and have 1 to 10 feet head above the ground; in the southern district there are 8 flowing wells, which range in depth from 100 to 150 feet and have 1 to 3 feet head. The head of the flowing wells in the two districts ranges from 1,012 to 1,042 feet above sea level. The best wells have a flow of about 10 gallons a minute. Some of them have been flowing without restraint for 10 to 20 years, but the rate of flow is said to have decreased somewhat in that time. A few wells that barely overflowed at first have lost head, and the water level in them is now 1 to 4 feet below the surface.

Soils

General character.—The soil of the region is derived wholly from material of glacial origin. The differences in the soil are caused by the greater or lesser degree of weathering and decomposition of the surface of the drift and from subsequent drainage. The chief differences are in the proportion of clay and sand, the amount of humus, the surface drainage, the underground drainage, the thickness of the subsoil, and incidentally the presence of alkali.

The underlying drift is a like source of future soil. At many places the water table is high to where it is lower, its flow being most rapid through the pervious beds, to which it is in large part confined by the nearly impervious beds of till. Although the bottoms of most of the sloughs and lakes are stopped in beds of fine sand or silt, either to save the cost of sinking them deeper, or because they have struck bedrock without finding gravel, a screen is commonly attached to the casing of such wells to prevent the silt or sand from entering with the water. These screens may become coated with calcareous deposits and in a few years may thus become entirely clogged.

When an old well is sunk deeper and reaches a water-bearing bed at or below the ground-water table, the head of water generally falls nearly to the lower water level, even if the water from the higher bed is admitted to the well. If the deep water-bearing bed is relatively weak, the height to which the water rises in the well may fluctuate greatly with alternation of wet and dry periods.

There is reason to believe that good wells are more commonly obtained in high than in low places, for the height of a tract may be due to some extent to underlying lenticular beds of gravel and sand, which bear water, as shown in figure 12.

Municipal supplies.—All the towns of the area have deep wells except Morris and Barnett, where the wells are shallow. A well 400 feet deep supplies the entire town of Elbow Lake, yielding 40,000 gallons a day without notable lowering of its head. Hermann is supplied in the same way by wells 140 feet deep, and Donaldson by one well 125 feet deep. The one well 75 feet deep at Hoffman yields 40,000 gallons a day without notable lowering of its head.

Flowing wells.—Wells flow because the surface of the land on which they are sunk stands below the plane of artesian head, or below the height to which water rises in wells from the pervious beds within the till. The water which is derived from Michigan is not the ordinary height of water tables is high to where it is lower, its flow being most rapid through the pervious beds, to which it is in large part confined by the nearly impervious beds of till. The water thus flows horizontally under certain surface depressions, although it has an artesian head enough to overflow the top of a well sunk to the water-bearing beds. Where the bottom of the Mustinka Valley enters the Herman quadrangle it is a little below the level to which the artesian water rises, the water in the only deep well in the valley there standing 1,100 feet above sea level, or 10 feet above the level of the water in the river. The same condition occurs on the Mustinka east of the Hermann beach, where the water in a deep well stands 1,075 feet above sea level, or 25 feet above the river. There are no deep wells in the Pomme de Terre Valley, but flowing wells could perhaps be obtained in some parts of it. A flowing well that has a head of 1,095 feet above sea level was drilled on the south side of sec. 20, Elbow Lake Township.

In certain districts in the northwestern part of the Hermann quadrangle all the deep wells overflow. One of these districts is north of Mustinka River, in Gorton and North Ottawa townships, and extends several miles north of the Herman quadrangle. In this northern district there are more than 20 flowing wells, which range in depth from 20 to 105 feet and have 1 to 10 feet head above the ground; in the southern district there are 8 flowing wells, which range in depth from 100 to 150 feet and have 1 to 3 feet head. The head of the flowing wells in the two districts ranges from 1,012 to 1,042 feet above sea level. The best wells have a flow of about 10 gallons a minute. Some of them have been flowing without restraint for 10 to 20 years, but the rate of flow is said to have decreased somewhat in that time. A few wells that barely overflowed at first have lost head, and the water level in them is now 1 to 4 feet below the surface.