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SURFACE GEOLOGY OF THE NORTHERN PENINSULA OF MICHIGAN.

WITH NOTES ON AGRICULTURAL CONDITIONS AND WATER POWER

BY FRANK LEVERETT

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To the Honorable the Board of Geological and Biological Survey of the State of Michigan:

Gov. Chase S. Osborn, President.
Hon. D. M. Ferry, Jr., Vice-President.
Hon. L. L. Wright, Secretary.

Gentlemen—I have the honor to transmit for publication as a part of the report for -1910 of the Board of Geological and Biological Survey, Bulletin No. 7, a contribution to the geological survey of the State.

Very respectfully,
R. C. ALLEN,
Director.

INTRODUCTION.

BY R. C. ALLEN.

The surface geology of the Northern Peninsula has received incidental attention from nearly all of the geologists and explorers who have made investigations of that region. However, the first systematic investigations were those of Prof. I. C. Russell, who in 1904, under the auspices of the Michigan Geological Survey, began a Study of the glacial formations along the north shore of Lakes Huron and Michigan. This study was continued in 1905. The results of Russell's work are published in the annual reports of the Michigan Geological Survey for 1904[1] and 1906.[2]

Prof. C. A. Davis, working partly in collaboration with Prof. Russell, made a reconnaissance of the entire peninsula. Davis made a special study of the peat bogs and their vegetation and also made valuable notes on soils and surface geology, the results of which are presented, in part, in Russell's report for 1906, and in part in a paper in the 9th annual report of the Michigan Academy of Science.[3]

His studies in peat are presented in the annual report for 1906.[4] The studies by Frank Leverett were begun in August, 1905, and continued, with interruptions, down to the autumn of 1910. Leverett was employed by the U. S. Geological Survey, and was assisted throughout much of the investigation by various members of the staff of the Michigan Geological Survey, notably G. E. Tower, W. C. Gordon, L. H. Wood, and I. D. Scott. A. C. Lane, formerly Director of the Michigan Survey, and his successor, R. C. Allen, have each contributed toward the work by field visits and contribution of manuscript material.

The Bureau of Soils of the U. S. Department of Agriculture has mapped a small area lying between Munising and the State Experimental Farm at Chatham.[5] Mr. Leo Geismar, director of the Experimental Farm at

Chatham, has given much attention to the soils in the vicinity of the farm and to the climatic conditions of the adjacent region. A part of the results of his observations has been published in the reports of the Upper Peninsula sub-station, beginning with 1901, appearing as special bulletins of the Michigan Agricultural College.

Publication of this report and the accompanying map was made possible through the courtesy and generosity of the Director of the U. S. Geological Survey who, at my request, granted to the Michigan Geological Survey, free of charge, the services of Prof. Frank Leverett during the time he was engaged in preparing this manuscript.

The publication makes a timely appearance, especially in view of the recently quickened interest in the agricultural development of the Northern Peninsula. This movement has found expression in the organization of the Upper Peninsula Development Bureau organized late in 1910. This organization embraces in its membership many hundreds of Upper Peninsula citizens and has for its purpose the advertising of the latent resources of the peninsula, particularly the agricultural resources, and the dissemination of useful and reliable information regarding them among the citizens of Michigan and other states.

The amount of misinformation and the paucity of reliable information regarding the Northern Peninsula of Michigan, not only among the residents of other states, but among many of our own citizens is as deplorable as it is surprising. The average layman pictures a great metal mining region as one of rugged and mountainous relief, more or less barren and inhospitable. Mining and agriculture are commonly supposed to be each dependent on widely different natural conditions, one set the antithesis of the other, and therefore, not found in the same area. For half a century the Northern Peninsula has been known far and wide as a mining and lumbering region. The over-shadowing importance of the mining and lumbering industries has obscured in a way the agricultural advantages which the peninsula possesses. Its wealth in copper and iron ores and timber has attracted to it from the early 40's of the last century mainly a mining and lumbering population, but the time has come when agriculture in the Northern Peninsula will take rank as a leading industry.

The Northern Peninsula was originally forest covered. Before agriculture became possible it was necessary first to clear the land. Agriculture necessarily follows the lumbering industry in regions of this character. Large areas of the Northern Peninsula are now deforested, particularly those which were pine bearing. A large part of the original hardwood forest is standing. The removal of the forest has made available for agriculture thousands of acres of good agricultural land. These lands await the farmer. It is the main purpose of this volume to publish reliable information regarding Northern Peninsula land. The use of a technical terminology and the discussion of topics interesting only to the student and scientist, so far as possible, have been avoided.

Now a word regarding the proper use of this report and accompanying map. Those who have made even a cursory study of soils understand that it is impossible to show details of soil character and composition on a small scale map. On a single quarter section may be found soils of widely different character. However, it is not less true that certain areas have a great predominance of soils of a particular composition and texture, dependent upon origin of the materials and the manner of the formation of the soils. The determination of the origin of surface or soil formations and their general constitution is a thing which the geologist can best determine. For the Northern Peninsula this has been done and the results appear on the accompanying map. The entire peninsula has been covered by Mr. Leverett and assistants. Some areas have been covered more closely than others because of their greater accessibility or the need of closer work. It is not to be expected that this map is absolutely accurate in all details but its general excellence may be relied upon. To illustrate, it would not be wise for the prospective purchaser of a farm to make his selection of lands entirely on the basis of what is shown on this map. No map, however constructed, can ever take the place of a personal examination on the ground. At the same time the purchaser may rely on the general accuracy and faithfulness to detail in so far as it can be shown on a map of this scale.

It should be stated here, that the fertility of a soil, and hence its value, does not always depend, or in fact usually, upon its mineralogical composition and texture alone. Soil fertility is determined in part by each of a large number of factors, some of which are mineralogical composition, chemical composition, physical composition or texture, character of sub-soil and the property of supporting bacterial life important in plant nourishment, especially of particular kinds of plants. This being true it is not just to say that a well drained lake clay soil is excellent and a light loamy or sandy soil is only fair, unless it is taken into consideration the purposes for which the soil is expected to be utilized, local conditions of temperature and moisture, topography, etc. Any farmer knows that success or failure is very largely dependent on soil management, or in other words the success or failure of a particular kind of soil is very often the difference between good and poor management. The geologist is not necessarily, and in fact usually is not, a scientific agriculturist, and a discussion of matters usually included in the study of soil management forms no part of his work. In our investigations, therefore, we have determined the general physical character and origin of the soil, leaving the determination of the manner in which these soils may be best utilized to those who are better qualified to make such determination. There has been included by Mr. Leverett a discussion of temperature and rainfall, two important factors bearing on agriculture.

The data on water powers have been gathered incidentally during the field mapping of the soil formations. The information is of a general nature and incomplete, but it has some value and interest and is included for what it is worth. At a future time it may be possible to undertake a survey of the power streams of the Peninsula similar to that which has been done by the Wisconsin Geological and Natural History Survey for the State of Wisconsin.

By those who are interested in the subjects treated in this report we believe that much useful information may be obtained by a careful reading of the following pages.

R. C. ALLEN,
Director.

Lansing. Michigan, September 30, 1911.

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[1]A Geological Reconnaissance along the North Shore of Lakes Huron and Michigan. Pp. 33-112.

[2]The Surface Geology of portions of Menominee, Dickinson. and Iron counties. Michigan. Pp. 1-91.

[3]Some interesting Glacial Phenomena in the Marquette Region. Pp. 132-135.

[4]Peat—Essays on its Origin, Uses and Distribution in Michigan. Pp. 94-395.

[5]Soil Survey of the Munising Area, Michigan, by Thos. D. Rice and W. J. Geib.

CHAPTER I. PHYSIOGRAPHY OF THE NORTHERN PENINSULA.

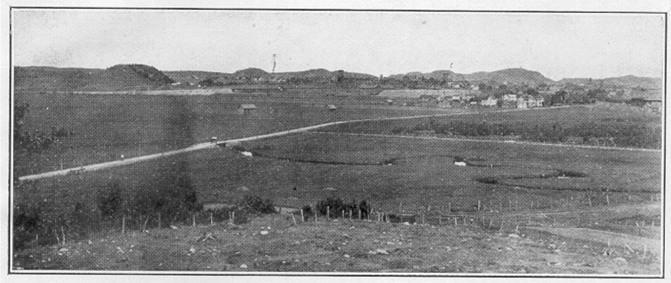
General Geological Features. The geological formations of the Northern Peninsula fall readily into three classes, viz. (1) the crystalline or Pre-Cambrian rocks, (2) the Paleozoic rocks, and (3) the glacial drift. The glacial drift is deposited irregularly over all the hard rock formations of the peninsula, but considering only the indurated rocks, the Northern Peninsula may be divided into two distinct provinces, an eastern and a western province, divided by a meridian passing through Marquette. West of this meridian the rocks are of Pre-Cambrian age, while east of it are the Paleozoic rocks. These two provinces are further differentiated by the lithological character of the rocks. The Pre-Cambrian rocks in the western province contain both sedimentary and igneous types, while those of the eastern province are all of sedimentary origin. Furthermore, the rocks of the western province have been folded and partly or wholly recrystallized. All of them fall into a class known as metamorphic rocks. They embrace many diverse types, such as greenstones, granites, gneisses and schists, and metamorphosed sedimentary rocks, such as quartzite, slate, dolomite, conglomerate, etc. On the other hand, the rocks of the eastern province are relatively unmetamorphosed. They include shale, sandstone and limestone which are in the form of beds or strata, which lie in an almost undisturbed position, dipping gently southward, so that one passes from older to younger formations in going from north to south across the peninsula.

The Pre-Cambrian rocks of the western province differ greatly in hardness, which has resulted in unequal weathering and degradation, forming a surface which is hilly and full of short knobs and ridges wherever the more resistant formations appear at the surface. The whole area, however, is not of a rugged type, because the glacial drift is sufficiently thick over perhaps three fourths of the area to completely conceal the irregularities of the rock surface. The principal areas in which the rocks have a rugged outcrop are found in the Huron Mountain region east of Keweenaw Bay, in the Copper Range along the Keweenaw Peninsula, in the Porcupine Mountains on the border of Lake Superior near the western end of the Peninsula, in the Gogebic Range from Ironwood eastward to Lake Gogebic, and in the region of Iron Mountain on the southern edge of the Peninsula. There is also a small area of rugged country leading from Marquette westward past Ishpeming, another in the vicinity of Crystal Falls, and a very small area in the vicinity of Republic.

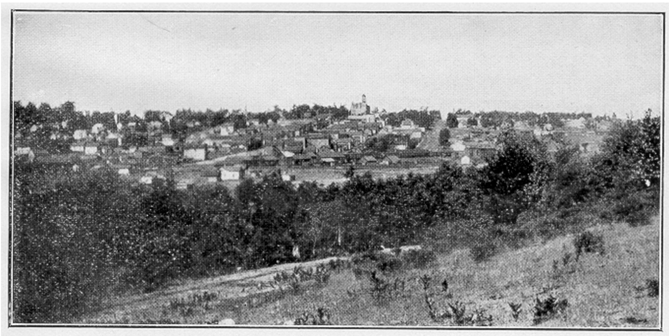
Like the crystalline rocks, the Paleozoic rocks of the eastern province differ in hardness and have weathered unequally. Some of them stand in the form of tablelands, while others occupy the intervening troughs. The Niagara limestone, for example, forms a tableland on the north border of Lake Michigan and Lake Huron, while the shales and softer formations north of it occupy a trough overlooked by the bold outcropping edge of the Niagara formation. Another tableland formed by Cambrian sandstone, is found in eastern Marquette County and Alger County. It abuts either directly on Lake Superior or on the low plain lying between it and the lake shore.

The glacial drift is a mass of boulders, gravel, sand, and clay, differing greatly in constitution from place to place. The drift was brought in by a sheet of ice or continental glacier such as now covers Greenland. It moved from the high lands of Canada to the east, south, and southwest of Hudson Bay, southward across the Great Lakes region into the northeastern part of the United States. The deposit made by the ice has a very irregular thickness; in places it is several hundred feet thick, in others it is very thin or absent, the hard rocks coming quite to the surface. There is evidence that the drift was not made by a single invasion of ice, but by two or more invasions separated by long intervals in which the country was free from ice as it is today.

The oldest invasion into the Northern Peninsula appears to have come from the northwest across the Lake Superior basin, the evidence for this being found in the grooves which bear southeastward, made by the ice on the underlying rock, and also in the presence of rock material which could have been derived by the ice only from the rocks on the northwest border of Lake Superior. The material brought in from the northwest is found at the base of the drift and is therefore known to be the oldest part of it.



A. ISHPEMING FROM THE NORTH.



B. CRYSTAL FALLS FROM THE EAST.

A. CUT IN MORAINE NEAR CHAMPION, MICHIGAN, (PHOTO BY L. H. WOOD, 1909).

B. BOULDER IN MORAINE NORTH OF REPUBLIC, MICHIGAN.

A later invasion of the ice came into the Northern Peninsula from the northeast and brought in from that direction material which is found scattered all over the Peninsula forming the upper part of the drift. The grooves made by the ice during this later invasion bear southwestward or westward in such way as to show that the ice came in from the northeast. On Keweenaw Peninsula at Centennial Hill in the northern part of the city of Calumet, the two sets of grooves made by the ice occur on a single rock ledge, those on the north slope being directed southeastward, while those on the eastern slope and on the upper part of the ledge are directed nearly westward. The earlier set of grooves are preserved only in the lee of the ledge where the later ice movement could not erode them away.

Certain terms have come into common use among geologists to define the various topographic features presented in the drift. Among the most prominent of these features are *moraines*. These are belts of rolling or hummocky surfaced drift in which basins and lakes are enclosed among sharp knolls. Morainic belts may be traced continuously for long distances across the country. These belts were formed at places where the edge of the ice held for a long period nearly a constant position. Their uneven surfaces are probably due to the difference in the dirtiness of the ice, the dirtiest parts when melting giving rise to hills or knolls of drift, the cleanest parts naturally depositing less material, thus leaving corresponding depressions. The glacial map (Pl. I) represents the principal moraines of the Northern Peninsula, and these will be described more fully further on.

While the ice was occupying a given moraine, the water escaping from it would often spread out broad plains of sand on the southern border of the moraine in the district lying just outside the ice. These plains are known as *outwash aprons*. The outwash aprons are shown by symbol on the glacial map. They are most abundant in the eastern half of the Peninsula but are present also on some of the highest portions of the western half. During rapid recession of the ice border from one moraine to another, there is usually deposited with plain surface a somewhat clayey and stony drift known as *boulder clay* or till. Extensive areas of this nature are found in Menominee, Delta, southern Marquette and Western Alger Counties, and also in Iron County. In some cases during such a recession where the ice border is poorly drained, a large amount of sandy material is laid down instead of till or clayey drift. This is the explanation for the occurrence of the sandy plains which occupy broad areas of the Peninsula.

On some of the clayey plains small oval hills are found which present remarkable regularity in their trend, and usually have very smooth slopes. These hills are known as drumlins and are found in great numbers on the clay or till plains of Menominee County and of Iron County. Drumlins occur also on Les Cheneaux Islands in the eastern end of the Peninsula. These peculiar hills are supposed to have been formed by one or both of two processes, either a sculpturing by the movement of the ice across a prominent part of the drift beneath it or by more rapid deposition of the drift at these places than on adjacent lower land. On this latter interpretation, the drumlins bear the same relation to the glacial deposits that sandbars bear to river deposits. The former process resembles that of the formation of islands in the cutting down of a river valley. The structure of the hills usually discloses which of these methods of development will apply. If a section through the hills shows the material to be without any bedding concentric with the surface of the hill, but instead a jumble of stones and clay, the drumlin was probably formed by sculpturing a mass of drift that had been deposited at an earlier time. But if the structure is such as to show definite bedding and evidence of slow building up by the plastering on of one layer of material after another, the drumlin is then likely to have been formed by the second process. These drumlins are formed almost exclusively on plains lying between the moraines, and the trend of their longer axes is in the same direction as the grooves formed by the ice on the underlying rock, and therefore in the direction of the ice movement, whereas the moraines have a trend either oblique to or at a right angle to the ice movement, being formed along the ice border. The relation of the drumlins to the moraines in Menominee County may be clearly seen on the glacial map. Those in Iron County are directed toward a moraine which lies in the northern edge of Wisconsin, while those of Les Cheneaux Islands are directed into Lake Huron and the moraine if present is in the bed of the lake.

In the same situation, on plains between the moraines, there are often found sharp gravel ridges which have a, trend the same as the drumlins, conformable to the direction of the movement of the ice. They are so sharp as to be locally known as "*hogback ridges*," and often bear resemblance to railroad embankments. Their length ranges from a fraction of a mile up to several miles, and they constitute features of much curiosity wherever present. It is a matter of some surprise that a gravel ridge which evidently was formed by water should stand so sharply defined with considerable relief above the border plain. The manner in which such ridges are formed was discovered by Professor Russell by his studies in Alaska. He there found that streams running in or beneath ice through tunnels which ramify through the base of the ice become more or less clogged up with the gravel and sand which they are carrying, so that when the ice melts away and the stream ceases action, these deposits which fill the tunnels are left as ridges of the same dimensions that the tunnels possessed. The material in the tunnels, however, is thickest in the middle portion and thin at the borders and has a level surface while the ice is supporting it, but upon melting of the ice the thin portions along the sides of the tunnel drop down and leave the thicker central portions of the tunnel standing as a ridge. The name *esker* is applied to these sharp gravel ridges, a term which originated in Great Britain where they abound.

ALTITUDE AND RELIEF.

The altitude of the Northern Peninsula ranges from 580 feet. the level of Lake Huron and Michigan, to over 2,000 feet on the highest points in the Porcupine Mountains. The eastern portion of the Peninsula from the meridian of Marquette eastward is generally less than one thousand feet above the level of the sea and less than 400 feet above the bordering lakes. The general elevation is probably not greater than 250 feet above the lakes. From the meridian of Marquette westward, there is a rapid rise to a tableland standing 1,600 to 1,800 feet above the sea, or 1,000 to 1,200 feet above the Great Lakes. From this tableland, the prominent portions of the crystalline rock formations rise only a few hundred feet at the most and constitute hilly rather than mountainous districts (See Pl. 5B), although the term "mountain" has been applied to some of these areas, as for example the Huron Mountains and Porcupine Mountains.

The Porcupine Mountains, which stand near the northwest end of the Peninsula, are the most conspicuous features in this entire area, for they rise on their north slope very abruptly from the shore of Lake Superior to a height of 1,400 or 1,500 feet above the lake. But one can pass southward from these mountains with only a moderate descent to the tableland which lies between them and the Gogebic iron range. In the case of the Huron Mountains, there is an abrupt rise from the shore of Lake Superior of nearly 1.000 feet and a gradual ascent toward the interior to a height of 1,200 or 1,300 feet above the lake. The Huron Mountains have very little relief above the country lying south of them, but differ from that country in being thinly covered with drift. The Copper Range which leads from the Porcupine Mountains east and northeast across the entire length of the Keweenaw Peninsula is also a prominent topographic feature, but its altitude is seldom more than 800 feet above the level of Lake Superior, and portions of it are but 600 to 700 feet. The Gogebic Range rises only 200 to 400 feet above the tableland on its north side, and still less above the tableland on the south, and the variations in its altitude are usually within a range of 100 to 200 feet.

The relief of the limestone tableland which borders the north side of Lake Michigan and Lake Huron is much more abrupt on the north face than on the south, and in places it presents a bluff-like appearance with an altitude of 200 to 300 feet. The usual relief, however, is only about 100 feet above the plain on the north, which has a filling of drift so great as to reduce very materially the original relief which this formation presented. The Cambrian sandstone rises usually 100 to 200 feet above the plain north of it, but it has scarcely any relief above the district on the south. The drainage, however, starts near the north border of the formation and leads southward to Lake Michigan.

In the large portion of the Peninsula which is thickly covered with drift, the reliefs are very moderate, the hills being seldom more than 100 feet above the basins or depressions among them, although in a few cases sharp hills may reach a height of 200 feet above the surrounding country. On the whole, the Peninsula is easy of access for railway lines or highways, the only exception being in the passage from the Lake Superior shore across the ranges which border it.

THE DRAINAGE SYSTEM.

The drainage of the Northern Peninsula discharges to Lake Superior, Lake Michigan and Lake Huron and a few square miles drains into the Wisconsin River. The greater part of the drainage is into Lake Michigan. This includes the broadly branching system of the Manistique River, which forms the outlet of some of the largest lakes in the Northern Peninsula, and which has a drainage area of 1,400 square miles, principally in Schoolcraft County and parts of neighboring counties; the White Fish River with a drain age area of 850 square miles leading into the head of Little Bay de Noc; the Escanaba with a drainage area of about 800 square miles; and the Ford River, with a drainage area of 500 square miles, which discharge into the west side of Little Bay de Noc; and the Menominee River, which forms a large part of the boundary between Wisconsin and Michigan and discharges into Green Bay. This river has a drainage area of about 4,100 square miles of which 1,450 are in Wisconsin. Aside from these there are numerous small streams whose drainage area amounts to from 100 to 300 square miles.

Of the streams draining to Lake Superior the most important is the Ontonagon, which with its widely branching system drains 1,250 square miles, and is the outlet for a large elevated basin lying south of the Copper Range. Next in importance is the Tahquamenon, which drains 300 square miles in the eastern part of the Peninsula into White Fish Bay. The third stream in size is the Sturgeon River with a drainage area of 720 square miles, draining the eastern slope of the southern portion of the Keweenaw Peninsula into Portage Lake. Numerous small streams flow directly into Lake Superior from the Copper Range and the Gogebic Range, as well as from the districts to the east of the Keweenaw Peninsula.

In the drainage to Lake Huron the only important streams heading within the Peninsula, are Pine River and Carp River, which discharge into St. Martin Bay, and each of which has a drainage area of 150 square miles. The St. Mary's River leads from Lake Superior to Lake Huron along the eastern end of the Peninsula and is commercially the most important of all the streams, both for navigation and water power.

The drainage to the Wisconsin River is in the vicinity of Lac Vieux Desert, Gogebic county. The extent of the drainage systems is determined to a large extent by geological features, of which the moraines are perhaps the most conspicuous. The rock formations, although more prominent than the moraines, are more likely to be broken by gaps. For this reason, it is not uncommon to find a drainage system gathering its waters on a district with no exceptional prominence, such as that south of the Copper Range in the case of the Ontonagon River, and then leading through a gap in a prominent rock range.

In considering the drainage of this region it should be borne in mind that swamps still occupy a considerable part of the surface, showing that the drainage lines are not sufficiently developed to carry off the surplus water. The extent of many of the swamps may be materially reduced by a well-planned system of drainage. In many of the swamps there are no miry places, so that they may be safely crossed on foot, and the solid bottoms which they present indicate that if drained they may be profitably cultivated. The lakes of the Northern Peninsula are as a rule very shallow. However, an occasional depth of 60 to 75 feet is reported, but more often a depth of scarcely 10 feet.

CHAPTER II. GLACIAL FEATURES OF THE NORTHERN PENINSULA—

THE MORAINES AND THEIR SIGNIFICANCE.

By reference to the general map (PI. I) it will be seen that the moraines form long narrow belts which are separated from one another by either sand or clay plains, except where these features are disguised by the bolder rock topography. The morainic belts were formed when the ice border was melting back during the last ice invasion. The drift which was deposited at earlier invasions, and even that deposited during the advancing stage of the last ice invasion have been buried beneath the moraines and their intervening plains.

The ice border shrank back in a general way from south to north and formed a succession of moraines at halting places, or perhaps in some cases at the limits of slight readvances of the ice border. In the district west of Green Bay the ice border receded eastward down the slope toward the bay. But from the Bay itself the recession was northward.

That portion of the Northern Peninsula first uncovered seems to have been in southern Iron County in a district where occasional drumlins appear but where moraines are not well defined. On the north border of this district there is a strong moraine which forms the divide between Paint River and the Ontonagon and Sturgeon drainage, and in fact, the divide between Lake Michigan and Lake Superior as far east as Perch River. This strong moraine may be traced westward through southern Gogebic County into Wisconsin. From Perch River eastward it is somewhat disuse in the region drained by the Net, Deer, and Fence rivers, but becomes well defined in eastern Iron County in the vicinity of Michigamme River, and there swings southward along the line of Iron and Dickinson Counties into Wisconsin. The course of the moraine is such as to indicate that the southern half of Iron County was in a great recess in the ice border during the formation of this moraine.

After forming this great moraine the ice border shrank back in a northward direction toward the part of the Superior basin west of Keweenaw Peninsula. The moraines of that portion of the peninsula have a general east to west course, though forming slight loops at some of the valleys or lowlands. The Keweenaw Peninsula being more prominent than the basins on either side, caused a thinning of the ice over its crest and a more rapid recession of the ice border there than occurred in the basin of Keweenaw Bay. As a result the Keweenaw glacial lobe was developed, and the ice, as shown both by the moraines and the glacial striae, moved westward from Keweenaw Bay over the crest of the peninsula. As it shrank toward the bay moraines were formed on the eastern slope which have a nearly north-south trend. To the south of Keweenaw Bay, however, the moraines have a trend from west of south to north of east as far as the Huron Mountains.

Eastward from a line running from Crystal Falls past Lake Michigamme to the northernmost point of the Huron Mountains the ice seems to have shrunk in an eastward direction toward the lower tracts on the borders of the Green Bay basin and the low district to the north of the bay. But from Green Bay and the northern part of Lake Michigan the ice border receded in a northward direction across the low district in the eastern half of the peninsula. The distribution and relations of the moraines are such as to indicate that the portion of the Lake Superior basin east of the Huron Mountains remained completely filled by the ice sheet down to a time when the western part of the basin had become nearly free from ice. As a result of this recession a large lake was formed in the western part of the Superior basin outside the edge of the ice while the eastern part was still occupied by the ice sheet. This lake expanded eastward as the ice melted away until eventually it covered the whole area of Lake Superior and some of the bordering country as is indicated in more detail below.

The kind of material in the moraines throws considerable light upon the direction of ice movement for the moraines vary in their rock constituents to correspond with the changes in the rock formations over which the ice passed. In the district underlain by crystalline rocks to the west of the meridian of Marquette, there is a great preponderance of crystalline material, (See Pl. Ill) while in districts underlain by sandstone and limestone to the east of the meridian of Marquette those rocks are the most plentiful constituents of the drift. A very bowldery moraine north of Republic is shown in Pl. Ill B.

The moraines vary greatly in their topographic expression so that a general description which will adequately set forth their features can scarcely be given. In some cases they are made up of rather steep sided gravelly knolls among which are basins and small lakes with very little inclosed level land. In other cases they are broken up into small strips or clusters of sharp knolls which are separated by level or even swampy tracts. In such cases it becomes somewhat difficult to map the exact position of the ice border during the development of the moraine because of so many gaps or parts only feebly developed. By reference to the general map one may see how fragmentary and disjointed are some of the morainic belts. In general, however, the moranic tracts are characterized by more numerous and sharper knolls than are found on the intervening districts.

THE OUTWASH APRONS.

The outwash aprons as already indicated are plains, of sand and gravel which were formed on the district immediately outside the ice border by water escaping from the ice sheet. The term apron is applied to them because they often have an apron-like relation to the moraines with which they are correlated. Where best developed one passes from the moraine with its sharp knolls, irregular surface, and commingled drift, in which the material is only partly assorted by water, into a nearly level tract of sandy gravel in which complete assortment has taken place. It is such a change as one would look for in passing from a district which lay under the ice to one which lay outside its border. The presence of well defined moraines and the bordering plains of gravel and sand in sharply outlined belts, indicates that the melting away of the ice was not at all regular. Instead, the border must have held a given position for a long time during the development of a moraine and its outwash apron and then made a rapid recession over the district back of the moraine to the next succeeding moraine and outwash apron.

The principal outwash aprons are so clearly shown on the general map that it seems unnecessary to outline their position and extent. They are especially prominent in the district east of the Whitefish and Au Train valleys in the drainage basins of Sturgeon and Manistique rivers. But they are also well developed in Marquette, Dickinson, Baraga, and Houghton counties. They are less extensive on the high tableland of Iron and Gogebic counties, though upon passing into the neighboring portion of Wisconsin they are found in extensive areas.

The outwash aprons are often occupied by pine forests while the moraines are more frequently covered with maple, birch, and other hardwood. Lumbering operations, therefore, which began with the clearing away of pine early resulted in the changing of the outwash aprons to desolate looking tracts of stump land. The moraines and till plains still carry a beautiful covering of hardwood forest.

FEATURES INSIDE THE MORAINES.

The outwash aprons and till plains stand outside the moraines and occupy partially their outer border. Inside of the moraines and often across the entire space between the moraines there is a diversified drift in which the constitution ranges from loose sand to stiff clay and from sharp gravel knolls and ridges to a featureless plain. The knolls and ridges are usually *kames*, *eskers*, or *drumlins*, while the remainder of the districts may be classed as till plains ranging from flat to undulating and from stiff clay to sandy constitution.

The till plains are composed of drift that seems to have been deposited as the ice was melting but without much attendant water-action. The sandy portions, however, in places had water action, and the material is more or less assorted as in the outwash aprons. It seems rather remarkable that in the course of the recession of the ice across the interval between one moraine and its successor there should not have been more water action than seems called for by the constitution of the drift. This condition, however, does not seem so surprising when we consider that the ice border was in a state of nearly constant recession so that the water escaping from it was making frequent shiftings of its course. *The till plains, as indicated in the discussion of soils, are in general well suited for agriculture because of the loamy texture and gently undulating surface.*

DRUMLINS.

The oval or elliptical drift hills, known as drumlins, are found on the till plains but are restricted in the Northern Peninsula to only a few localities. The largest district is in Menominee, western Delta, and southern Marquette counties, there being several townships in which they are present and in which they are so numerous as to be a striking feature of the landscape. Another large district is found in Iron County in the area already referred to as the first to be uncovered by the ice. In this district the drumlins are more scattered than in the Menominee district. A few drumlins occur immediately west of Chatham in western Alger County. There is also a small drumlin district on Les Cheneaux Islands and neighboring parts of the mainland at the northwest end of Lake Huron.

The drumlins are generally composed of a clayey drift thickly set with small stones. Sand or gravel are rarely found in drumlins. They owe their oval or elliptical form to a shaping by the overriding sheet of ice. The ice was moving in the direction of the longer axes of these hills, as might be inferred from their shape and is shown, by the striations on the rock surfaces in the drumlin districts. In the Menominee district there is an interesting shifting of the trend of the drumlins from a nearly due east-west trend in the northern part of the district to a trend about 30° west of south (S. 30° W.) in the southern part of the district, which corresponds to the radiation of the flow of the ice in that region. In the Iron River district the drumlins have a nearly uniform trend about S. 25° W. The drumlins near Chatham trend nearly north-south, those on Les Cheneaux Islands southeastward.

The drumlins range in size from barely detectible ridges 5 to 10 feet high to prominent hills 60 or even 75 feet in height. The larger ones often have a length of nearly a mile and occasionally reach 11/2 miles. Their size is somewhat exaggerated on the map (Pl. I) because on the true scale many of them would have to be represented as mere dots. It should be borne in mind that the number of drumlins is much greater than can be shown on a map of this scale, moreover, full extent of their occurrence is undetermined.

The districts in which the drumlins occur, and the drumlins themselves, are among the choicest agricultural lands in the peninsula. The clayey constitution and the well drained slopes render them productive and easily tillable.

ESKERS.

The eskers are easily distinguished from drumlins though like the drumlins they have a trend in the direction of the flow of the ice. They are composed of gravel and sand with only occasional small deposits of boulder clay. In form they are long narrow ridges but a few feet or yards in width. While their general trend is in the direction of ice movement they have a more or less winding course consistent with their mode of origin, for they appear to have been formed in tunnels in the lower part of the ice sheet. These tunnels would be opened by escape of the water from the under part of the ice along the lines of least resistance which would naturally be more or less devious.

The eskers are of high commercial value as sources of road ballast in places where gravel is otherwise difficult to obtain. But fortunately the Northern Peninsula has an abundance of gravelly road material throughout nearly its entire extent not only in the drift hills and ridges but in the outwash plains and among the rocky knobs.

The eskers are usually so small as to need a large scale map for their proper representation and for that reason very few of them have been represented on the general map. They abound in the Menominee drumlin district, yet they are much less conspicuous than the drumlins for they are usually but 10 to 15 feet high and only a fraction of a mile in length. They are present in many places among the rocky knobs in the region west of Marquette and in the Gogebic Iron range and districts to the south. Indeed these little ridges are apt to occur almost anywhere in the Northern Peninsula outside the outwash aprons and certain plains in which lake clay is of considerable depth.

KAMES.

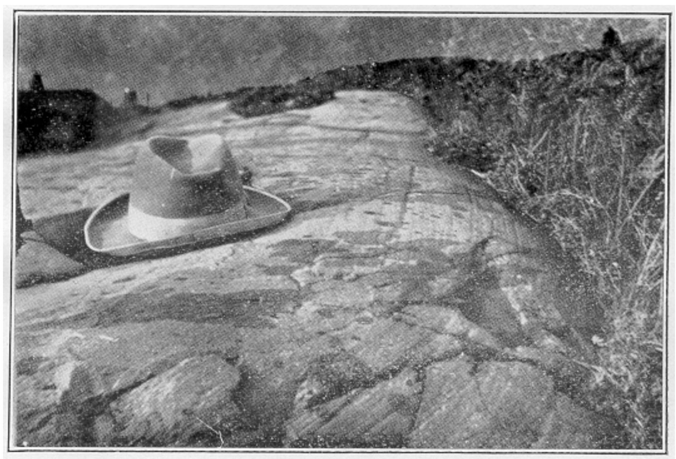
The name *kame* has been applied to sharp gravelly hills which occur either singly or in clusters on till plains and also in the moraines. These hills are thought to have been formed where streams emerging from the edge of the ice dumped their material without spreading it out into a plain. They are often found at the ends of eskers and represent the accumulation of material brought out of the ice during the development of the eskers beneath its margin. Their distribution is general and widespread. They are especially abundant among the rocky knobs of the western half of the peninsula. A kame or a kame cluster usually occupies but a small fraction of a square mile or too small an area to be easily represented on a scale such as that of the general map. (Pl. I). They are also so numerous that no attempt was made to map them in detail. *Like the eskers, kames are of commercial value as road material, wherever there is a demand for it.*

EFFECT OF THE ICE SHEET ON ROCK SURFACES.

In regions which have not been overridden by an ice sheet there is a mantle of dirt and rotten rock several feet deep over the rock ledges, except where slopes are so steep that it is washed away. This mantle represents a long period of weathering and disintegration of the rock surface. In regions that have been glaciated firm rock surfaces are laid bare by the removal of the mantle of dirt and loose rock material. Prominent knobs of rock are sometimes rubbed to almost glassy smoothness, or their surfaces are scored heavily with deep furrows running in the direction of the ice movement. The rock surfaces also often exhibit a multitude of fine lines or striae running in the same direction. In many parts of the elevated western end of the northern peninsula the smooth rock bosses are a striking feature of the landscape. From commanding points one often obtains a view several square miles in extent in which the bare rock surfaces may be seen glistening among the tree tops or rising above the highest of the forest trees. Such a landscape is shown in plate 5B which contains a view taken in the Huron Mountain district north of Champion. These rock bosses are often more heavily glaciated on the side against which the ice advanced than on the opposite or lee side (See Pl. V A) so that one can determine by an examination of a rock knob the main direction of ice movement even where the striae have been removed by weathering. Small inequalities of the surface are also useful in the determination of the direction of ice movement. Thus In Plate VI. A. the slight prominence near the lead pencil is found to have so protected the rock on the lee side that it stands above the surrounding portion of the rock surface. The ice is found to have been very flexible in its movements around some of the rock bosses, the striae being curved to correspond to the surface of the boss, an illustration of which is found in Plate IV. B. In some cases, however, the striae preserve a remarkably direct course in spite of inequalities of the rock surface. (See Pl. IV. A.)

While the effect of glaciation on the whole has been to render the districts over which the ice passed more productive by commingling all sorts of rock material into a fine earthy deposit the effect on rock bosses has frequently been such as to leave them naked and barren. They, however, constitute but a small part of the surface even in the most rugged portions of the peninsula and elsewhere they are so few as to be negligible in amount.

A. STRIATED LEDGE ON HILL IN SOUTHEAST PART OF CHAMPION, MICHIGAN.



B. STRIAE CURVING AROUND A ROCK BOSS NEAR ISHPEMING, MICHIGAN, (PHOTO BY L. H. WOOD, 1909).

On the north border of Lake Michigan and Lake Huron there are extensive tracts in which the limestone is covered by a very thin mantle of drift insufficient to conceal the irregularities of the surface and yet of sufficient depth to support a good forest cover and to give a productive soil for agriculture. These limestone formations present bold bluff-like escarpments on the north over which the ice sheet must have passed without greatly altering the preglacial condition. In places great thicknesses of drift are banked against the north base of the escarpment, but throughout much of Mackinac County it still stands as a bold bluff, rising often 200 feet or more above the lowland on the north. From this it is inferred that the effect of the ice sheet has been sufficient to remove only the rotten surface and to alter slightly the outline of the firm ledges over which it passed. There is no evidence to support the idea that the great lake basins, Superior, Huron and Michigan, were ploughed out by the ice. Instead, Michigan and Huron seem to have been reduced to lowlands in preglacial times by the erosion of soft strata which once underlaid the regions they occupy, while the Superior basin is a structural trough resulting from the folding of the rock formations in and around it. The rock reliefs between the beds of these basins and the uplands which border them were probably as great in preglacial times as at present.

CHAPTER III.

LAKE HISTORY OF THE PENINSULA—ABANDONED SHORELINES—EARLIER INVESTIGATIONS AND DISCUSSIONS.

[Abandoned Shore Lines]

[Earlier Investigations and Discussions]

That the Great Lakes have stood much higher than their present level was noted in the Northern Peninsula as well as in other parts of the Great Lakes region many years ago. The shore lines made by the beating of the waves are so distinct as to be unmistakable even where they are covered with heavy forests and are many miles inland from the present shores of the Great Lakes. Among the earliest notices in print of the abandoned shore lines of the Northern Peninsula are references to them in a paper by Dr. John Bigsby, published in the American Journal of Science in 1821. He made mention of the sand belt along the base of precipices and on the sides of heights and “the belt of rolled masses that gird every slope and often mark the recessive retreats of the lakes."

Henry R. Schoolcraft in his "Narrative Journal of Travels in 1820,” published in 1821, also noted the wide occurrence of the high shore lines and called attention to those on Mackinac Island where several very conspicuous old beaches occur on the tableland immediately back of the fort as well as a very strong beach at the base of the tableland in the village. As a further indication of a former greater extent of the Great Lakes, Schoolcraft also noted the wide occurrence of lake deposits.

During the, progress of the United States Land Survey of the Northern Peninsula, the surveyors came upon these shores and mapped portions of them on the survey plats, one of them being represented a few miles back from the present shore of Lake Superior nearly all the way from Munising to the meridian of Newberry.

Among the earlier students of the Lake Superior region, E. Desor presented the clearest and most interesting discussions of the old shore lines and their lake features. His official papers appear in the Foster-Whitney Reports on the Lake Superior Land District, published in 1850 and 1851, the main discussion being in Chapter 8 of Part 1 and Chapters 14 to 16 of Part 2. Desor inclined to the view that the surface boulders and the surface sand at all altitudes are due to the action of lakes, a view which is now known to be erroneous. It was at first thought that the deposition of the boulders was effected by winter ice rather than by icebergs detached from a glacier, but it now appears that they were deposited by a mass of ice which moved directly over the surface of the land without floating in the water to any marked extent, and are therefore the deposits of glaciers rather than lakes or inland seas.

Louis Agassiz in a paper on "The terraces, ancient river bars, drift boulders and polished surfaces of Lake Superior," published in the American Journal of Science in 1850, and also in his book on Lake Superior of the same date, referred briefly to the old shore lines, whose presence he noted at various altitudes on the Keweenaw Peninsula and elsewhere on the coast of Lake Superior. Agassiz explained the high stages of the 'lake on the assumption that the region has been affected by uplifts which have caused the shores to be carried above their former elevation. In this respect his explanation is in part correct, although the presence of the ice as a barrier in the line of the present discharge of the lakes is the real cause of the high stage of the water, as will be shown more clearly below.

Mr. F. B. Taylor has given more study than any one else to the shore lines of this region, and has published several brief papers between the years 1892 and 1897 giving the results of investigations made at private expense. It is through his investigations that the succession of lakes and the relation of the lakes to different outlets have been clearly interpreted. These matters will be taken up in connection with the discussion of each of the several lakes. The high shore lines were first referred by Taylor to marine occupancy, but reference to his later papers published in and after 1895 shows that this view was discarded, and the ice sheet was assumed to have held the waters of the earlier lakes at their high altitude.

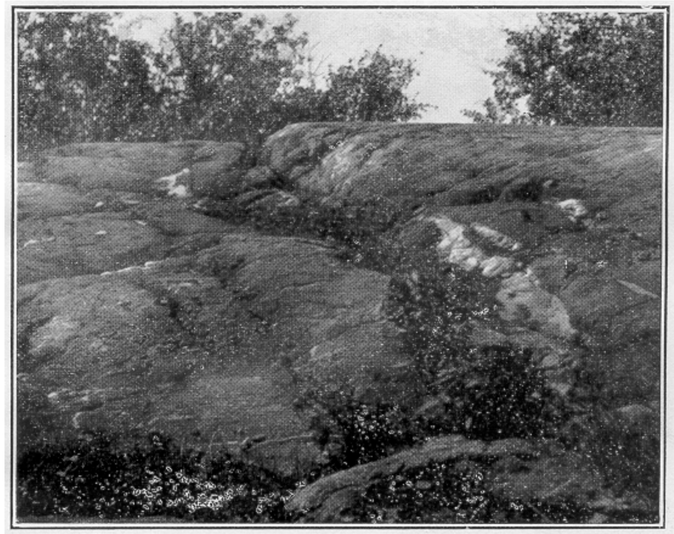
Very little precise levelling has been done on the shore lines of the Northern Peninsula. Lines of levels have, however, been run to the highest ones on Mackinac Island and to neighboring parts of the mainland by F. B. Taylor and J. W. Goldthwait, and to points in the vicinity of the head of Green Bay by Professor W. H. Hobbs. The results of Professor Hobbs' work are presented in a paper published by the Michigan Geological Survey.[6] The results of the leveling by Taylor and Goldthwait are now published only in part, but will appear later in a monograph .published by the United States Geological Survey (now in press).

[6]Publication 5. Geological Series 3.

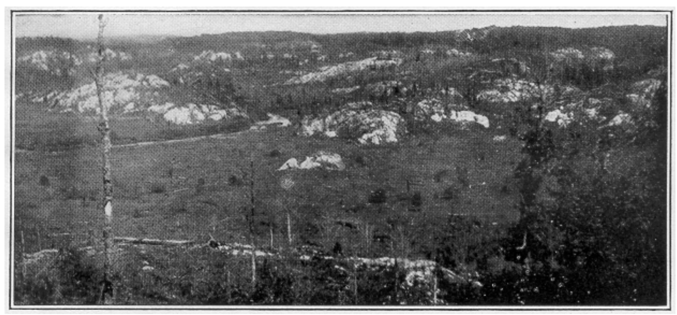
NATURE OF THE PRESENT INVESTIGATIONS.

Inasmuch as the writer attempted only a reconnoissance of the region and restricted his routes chiefly to the roads and trails, the shore lines have received less attention than is required for a full mapping or complete correlation or connection. An endeavor was made to ascertain the upper limits of lake action, but the highest shore line was not in all cases continuously traced. The study, however, was carried far enough to warrant the representation on the map of the approximate extent of the lakes. The altitudes of the old shore lines have been accurately determined only where they lie near railway stations, or in some cases by hand level from points on the shores of the present lakes. Enough has been determined, however, to show that the shore lines are not in the horizontal position in which they were originally formed, but that through an upheaval of the region they have been tilted perceptibly, the altitude of a given shore line becoming, northward, progressively higher. On this account it is difficult to connect shore lines across wide intervals wherein they are undeveloped or obliterated. It cannot be assumed that a shore line of a given altitude in one district will connect with one of the same altitude in another district, for the reason that the uplift which the region has experienced was made great changes in the original levels. In the course of the discussion below a few data are given which will illustrate this feature.

In the course of the advance of the ice sheet into the region around Lake Superior, the drainage was shifted from one outlet to another along the rim of the basin, the discharge being always through the lowest available point on the rim. It is not unlikely that when the ice came into the northeast part of the Superior basin the drainage was along or near the present course from the Superior into the Huron basin, but when it covered the eastern end of the Northern Peninsula higher lake levels were produced with discharge southwest and eventually the ice completely occupied and filled the Superior basin. During the progress of the extension of the ice, the lakes which were standing in front of it laid down their sediments and these became covered with glacial material when the ice passed over them. The presence of these sediments in the bluffs of the deeper valleys thus bears witness to the existence of lakes whose shores are no longer traceable because completely effaced by the advancing ice. At the culmination of the last glacial stage or ice advance, the ice border reached beyond the watershed between the Lake Superior basin and the Mississippi River. At this stage the waters escaping from the ice were drained down the Wisconsin and St. Croix and other streams which lead to the Mississippi. Then the ice border began to recede with the waning of the ice edge, and shrunk back to the north of the present divide between the Mississippi and the Lake Superior drainage. When this occurred a ponding of the waters in front of the ice again took place. Clear evidence of the ponding of waters is found in the shore lines which stand so high above the present levels of the lakes. These shore lines will now be discussed in order from higher to lower, and the names which are applied by geologists to the different levels of the lakes will be used. A new name is usually given whenever the drainage of the lake shifted from one outlet to another; or in other words the younger lakes are direct successors of the older with changes in level and shiftings of the lines of discharge.



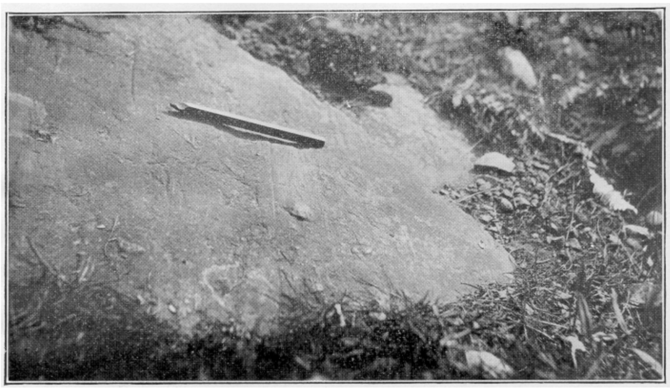
A. GLACIATED ROCK BOSS NEAR CHAMPION, MICHIGAN. THE ICE MOVED FROM RIGHT TO LEFT IN THE PICTURE. (PHOTO BY L. H. WOOD, 1909).



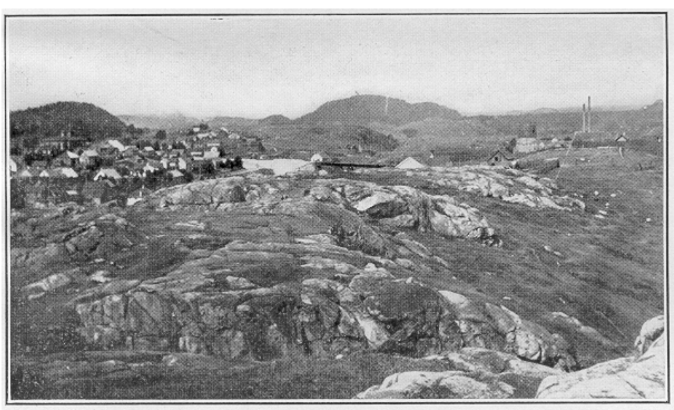
B. HEAVILY GLACIATED GRANITE KNOBS IN HURON MOUNTAINS, 14 MILES NORTH OF CHAMPION, MICHIGAN. (PHOTO BY L. H. WOOD, 1909).

LAKE ONTONAGON.

The oldest and highest of the large glacial lakes in the Northern Peninsula is one which was held in the basin of the Ontonagon River to the south of the Copper Range. During the existence of this lake, the southern edge of the ice sheet appears to have rested on the Copper Range so that the waves were unable to form a shore line on the north side of the lake. The shore is more or less distinctly traceable along the south border in southern Houghton, southern Ontonagon and northeastern Gogebic counties, as indicated on the general map of the Peninsula (Plate I). This lake had the surprising altitude of more than 700 feet above Lake Superior, the outlet which led west from Gogebic Lake being about 720 feet above the level of the Lake, or 1,320 feet above sea level. Over the area covered by this Lake there is generally a deposit of fine loamy material; but it is not of sufficient depth to greatly conceal the glacial deposits which underlie it. In the eastern part of the old lake area, from Trout Creek northward to Pori, there are extensive deposits of sand, but as a rule the old lake bed is of a clayey character rather than sandy. Its northeastern limits in southern Houghton County are at a gravel plain which extends from Sidnaw to Frost Junction. During the life of this lake, the ice appears to have been occupying the district immediately northeast of this gravel plain, and the outwash from the ice carried the gravel out into the edge of the lake as far as the currents or streams could make their way.



A. ILLUSTRATING PROTECTION FROM ICE ABRASION IN THE LEE OF A SMALL OBSTRUCTION. ROCK SURFACE NEAR ISHPEMING, MICHIGAN. (PHOTO BY L. H. WOOD).



B. GLACIATED ROCK SURFACE EAST OF ISHPEMING, MICHIGAN. (PHOTO BY L. H. WOOD).

There are several small areas within the limits of Lake Ontonagon which are not covered with the sand or silt which prevails so widely on the old lake bed. It is probable that they were covered by the ice at the beginning of the development of this lake and became uncovered only as the ice melted back near the end of the period when that lake had its existence. The existence of the lake as already noted was determined by the presence of the ice as a barrier on the north, and it continued in existence at this high level only so long as the ice prevented the escape of the water by a line of discharge lower than the one leading west from Gogebic Lake.

The existence of this lake seems to have been rather brief, for the outlet is only a small channel, usually but a fraction of a mile in width and 20 to 40 feet deep. Such a channel might have been formed in a few centuries if not in a few decades. In all probability the life of the lake was not more than one to two centuries, and lasted merely during the melting back of the ice from the high lands on the south edge of the Ontonagon basin to the north slope of the Copper Range. The outlet, which has an altitude of 1,320 feet at its head, falls to about 1,120 feet, or 200 feet in the short distance between Gogebic Lake and the Michigan-Wisconsin line. Thus it is certain that the outlet stream flowed rapidly and if it had been long continued a better defined channel must certainly have been formed.

LAKE DULUTH.

The lake next in age and next lower in level is Lake Duluth, which occupied a large part of the western end of the Superior basin. It is named Lake Duluth because of the prominence of its shore lines in the city of Duluth, Minnesota. This lake began as a small body of water at the extreme western end of the Superior basin with an outlet southward through the Brule River into St. Croix River, a tributary of the Mississippi. As the ice border melted back toward the northeast the lake became greatly expanded until it covered the slope bordering Lake Superior as far east as the Keweenaw Peninsula. It is a matter of interest that the shore of this lake is not found far to the east of the Keweenaw Peninsula for the reason that the ice sheet still remained in that portion of the Lake Superior basin and extended up onto the bordering south shore during the whole of the life of Lake Duluth. The lake came to an end, or rather the waters were drawn to a lower level, by the opening of a lower line of discharge than that through the Brule-St. Croix drainage.

The outlet through the Brule at the beginning of the lake was about 470 feet higher than the present level of Lake Superior, but during the existence of the lake the outlet was cut down about 50 feet and a channel of that depth and nearly a mile in width leads across the present divide between Lake Superior and the Mississippi River drainage. As a consequence of the cutting down of this outlet, the shore of the lake was correspondingly lowered and new shore features established at the lower levels. There is a double and in places a triple system of beach ridges along the old shore, separated by intervals of 25 to 50 feet.

The elevation of the shore, which was 470 feet at the head of the outlet at the beginning of the life of the lake, is slightly lower at the extreme southwest end of the Superior basin because the region of the head of the outlet has been elevated a few feet more than the western end of the Superior basin. The lowest point of the highest shore line in Carleton County, Minnesota, is only 450 feet above Lake Superior. As one follows the shore line eastward or north eastward along either the north or south side of Lake Superior, the upper limit of lake action is found to become higher and higher above Lake Superior. On the Keweenaw Peninsula near Calumet it reaches an altitude of 700 feet above the present lake and is apparently fully as high at points near the Minnesota-Canada line on the north side of Lake Superior. No accurate measurements have yet been made in that region. In this connection, however, it may be remarked that Professor A. C. Lawson at one time made a series of spirit levelings on the north coast of Lake Superior. They were carried high enough to reach the highest beach only in the vicinity of Duluth, though he at the time supposed he had reached the highest beach at many points on the coast further northeast.

Some of the best developed beaches of Lake Duluth occur in the vicinity of Calumet, where the shore was exposed to waves rolling in from the northwest. A series of a half dozen or more gravelly ridges separated by intervals of twenty feet (more or less) are present on the slope immediately northwest of the Tamarack mine, and on Centennial Hill in the north part of the city, is found the highest beach at an altitude of 1,303 feet above the level of the sea, encircling the hill like an atoll or coral reef in oceanic waters, the ridge itself being slightly higher than the portion of the hill which it encloses.

The beaches are also well displayed in the vicinity of Greenland and Rockland, where they are developed on small islands that stood in the lake as indicated on the map (Plate I).

The railway station at Greenland is close by the highest shore, while that at Rockland is about one-eighth of a mile south of the shore and at a considerably lower level. The northern ridge of the Porcupine Mountains was encircled by this lake and its shores are especially well developed on the north slope of that ridge in a series of beaches corresponding to the lowering of level caused by the cutting down of the outlet. Lake Duluth extended but little beyond the immediate border of Lake Superior from the Porcupine Mountains westward, but in the Ontonagon drainage basin there were shallow bays extending back southward some distance beyond the Copper Range up several branches of the Ontonagon River.

The bed of this lake is in large part occupied by a red clay deposit full of pebbles, and consequently a product of the ice rather than the lake. There seems to have been but a. thin coating at best of lake sediment. This is the natural result of the steepness of the slope, for lake sediments are usually found only in deep and quiet parts of the old lake beds and it is probable that during the lowering of the waters of the lake the wave action would remove the greater part of the sediment which had been laid down during a higher stage. *There are places, however, as for example, along the bluffs of the Ontonagon River between Rockland and the Victoria mine where exposures of nearly pebbleless red clay of great depth are to be seen.* It is probable that this clay is a lake rather than a glacial product, and it is likely to have been formed during the advance of the ice in a lake much older than the one formed on the recession as outlined above.

LAKE ALGONQUIN.

Further study will be necessary to determine the manner in which Lake Duluth gave place to a later lake, Lake Algonquin, which occupied the eastern part as well as the western part of the Superior basin and also the Michigan and Huron basins. Probably studies on the Canadian side of Lake Superior will bring out evidence of outlets which would have been in operation after the abandonment of the Brule-St. Croix outlet and before the beginning of Lake Algonquin. But this region is as yet unexplored, so that the matter must be left in this uncertain condition at present.

Lake Algonquin began in the southern end of the Lake Huron basin and increased in size with the melting back of the ice until eventually it became confluent with a lake in the Michigan basin, known as Lake Chicago, and later with the waters of the Superior basin. Its outlet at first was southward from Port Huron along the present line of discharge of Lake Huron, but as the ice melted away from the district to the east of Lake Huron, a lower outlet was opened which led the drainage directly from Georgian Bay to the Ontario basin, an outlet known as the Trent Outlet. The lake discharged in this direction until an elevation of the land toward the north raised the Trent outlet to such a height that the lake could no longer discharge through it and a return was made to the St. Clair outlet. It is probable that at the time when the waters of Lake Algonquin became confluent with those in the Superior basin, the Trent outlet was still in operation, for a large part of the elevation which took place in this region seems to have occurred at a late time when the ice had melted back out of the lake basins.

The waters of Lake Algonquin were so extensive as to cover the greater part of the Northern Peninsula from the meridian of Munising eastward. Only a few small islands in this area rose above the level of its waters as indicated on the map. (Plate I.)

In the southern part of the Peninsula near Gladstone and on the Garden Peninsula east of Big Bay de Noc, the altitude of Lake Algonquin was about 120 feet above Lake Superior, but at Marquette it was about 340 feet and just north of Sault Ste. Marie it was fully 400 feet, while at the southern end of Lake Huron at the head of the St. Clair outlet the altitude is only five feet above Lake Superior. The fact that the waters stood so high on the eastern end of the Northern Peninsula of Michigan points to the continuance of the low conditions of the country there at the time of the greatest extent of Lake Algonquin, and by inference the low conditions which continued in the eastern end of the Northern Peninsula continued in the region of the Trent outlet. Under this interpretation the Trent outlet was in operation down to the time when the lake was covering the eastern part of the Superior basin and the district between the Superior basin and Lake Michigan.

To restore the altitudes which were then prevalent one must sink the district at the north end of Green Bay about 115 feet and the region near Marquette about 340 feet and that near the Sault about 400 feet below its present elevation and give the lake an altitude of about 600 feet, or possibly less, above sea level. The highest shore of Lake Algonquin has an elevation approximately 200 feet below the highest shore of Lake Duluth and 150 feet below the lowest shore. This latter amount is therefore about the measure of the lowering of the lake in the course of the change from the Brule-St. Croix outlet to the most expanded state of Lake Algonquin. There was not a sudden drop, however, from the lowest beach of Lake Duluth to the highest beach of Lake Algonquin, for in this interval of 150 feet between the two shore lines there are several other shore lines which mark the persistence of the waters at different levels for a time sufficiently long to permit the formation of such features. The occurrence of features of this sort as suggested above raises the question of the existence of an outlet north of Lake Superior at a time between the abondonment of the Brule-St. Croix outlet and the extension of Lake Algonquin into the Superior basin.

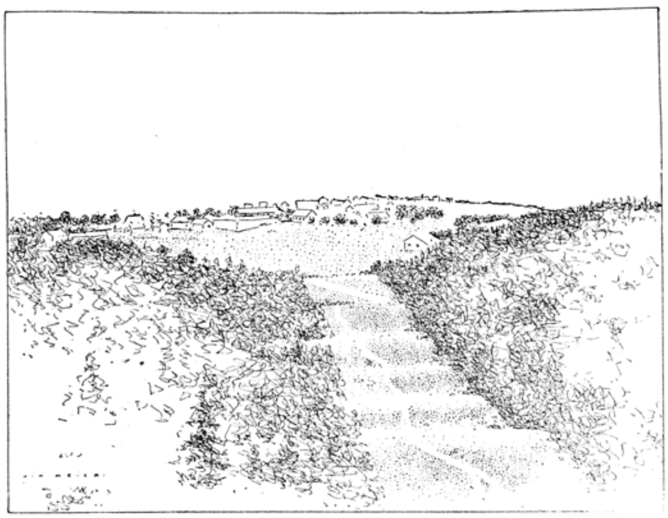


Fig. 1. View from the observatory looking across the short target range toward the Fort on Mackinac Island.

While Lake Algonquin was in existence considerable elevation of the land took place. In passing from the southern part of the lake to the northern, the beaches are found to split up into several members; the waters fell away from the beaches at the north while they were still washing southern portions of the shore. There are several places in the Northern Peninsula in which a succession of beaches marking a lowering of the lake areas may be seen to good advantage. One of the best known places is on Mackinac Island between the fort and the highest point of the Island, and especially along the line of the Target Range where half a dozen or more beaches with intervals of 15 to 20 feet are plainly developed. (Fig. 1.) A similar series may be seen north of Sault Ste. Marie, Ontario, near the edge of the Granite Highlands. On Sugar Island east of Sault Ste, Marie there are several beaches, but the highest one is not up to the full limit of Lake Algonquin. A fine series may be seen along the range line immediately south of Grand Marais, and several beaches are easily traced through the western part of the city of Marquette. The beaches are best developed where the waves were working upon loose textured material which could easily be thrown up into ridges. They are poorly developed in the clayey districts along the border of Lake Superior from the Keweenaw Peninsula westward, not only in the Northern Peninsula of Michigan, but across Northern Wisconsin into Minnesota. They are also poorly developed where the coast is broken by rock knobs as in the district northwest from Marquette. They may be seen to good advantage all around the Michigan and Huron basins, because there was much less elevation there and the waters were held at different levels for longer periods than on the borders of Lake Superior where rapid elevation was in progress.

In the eastern part of the Northern Peninsula in Chippewa County and the northern edge of Mackinac County there are very thick deposits of red clay which seem to have been laid down in the waters of Lake Algonquin. In some cases the wells have penetrated to a depth of 100 feet or more without striking any pebbly material. As a rule, however, the boulder clay lies within a few feet of the surface and may be seen outcropping on low knolls and ridges at many places within that region.

There are extensive deposits of sand in the eastern part of the Northern Peninsula below the level of the highest beach of Lake Algonquin; but these it is thought were laid down in large part during the melting away of the ice; for they are associated closely with the moraines of the region and do not have a distribution such as would be consistent with the courses of lake currents.

NIPISSING GREAT LAKES.

During the entire existence of Lake Algonquin, the Ottawa valley is thought to have been covered by the ice sheet so that there was no opportunity for an eastward discharge into it from Georgian Bay, but as soon as the valley was vacated by the ice, a low outlet became available for the eastward discharge of the waters of the basins of Superior, Huron and Michigan. The altitude of this region was then sufficiently low to be below the St. Clair outlet from the southern end of Lake Huron, and that outlet did not come into use until the elevation had proceeded far enough to bring the eastern outlet through the Ottawa up to the same level as the head of St. Clair River. During the discharge of the water eastward from Georgian Bay to the Ottawa River, and also for a considerable period while the water was discharging through both the Ottawa and the St. Clair outlet, there was a body of water in the three lake basins Superior, Michigan, and Huron known as the Nipissing Great Lakes. The extent of the Nipissing waters was but-little greater than that of the modern lakes, for the shore at its highest point on the northern coast of Lake Superior and at the head of the Ottawa outlet near North Bay, Ontario, is only 120 feet above Lake Superior. On the borders of the Northern Peninsula, the altitude is from about 10 feet to 50 or 60 feet above the level of the present lakes, and is usually within a mile or two of the present shores. This may be seen by reference to the general map (Plate I).

It is a matter of some interest to know that the beach known as the Nipissing Beach represents the work of the Nipissing Great Lakes during the two-outlet stage; for there was a rise of water during the change from the single discharge through the Ottawa outlet to the double discharge through the two outlets which completely submerged the shore lines formed in connection with the single outlet, except perhaps in a small area on the northeast coast of Lake Superior which suffered more elevation than the head of the Ottawa outlet. It will be readily understood that regions within the reach of the lake which were uplifted to an altitude less than that of the outlet would become submerged.

At the time of the Nipissing Great Lakes there was a strait from Lake Superior to Lake Huron along the line of the St. Mary's River, for the waters then stood about 50 feet higher at Sault Ste. Marie than the head of the rapids in St. Mary's River. The old banks of the strait may be readily traced through the city of Sault St. Marie and on the borders of the St. Mary's River. In places there is a bluff thirty to fifty feet in height at the base of which numerous boulders which drifted into the strait on the breaking up of the ice on Lake Superior in the spring months were stranded. They testify to the presence of ice gorges of considerable magnitude which probably blocked up the head of the strait more or less while they were being melted away.

On White Fish Point a large number of ridges of sand and sandy gravel which extended the point several miles beyond its former limits were developed at this time. The area occupied by these sand ridges is indicated on the map (Plate I). At the city of Escanaba the currents of this lake gathered up the sandy material laid down at the mouth of the Escanaba River and strung it out in a long ridge which reaches from the mouth of the river beyond the city and occupies a width of about a mile and a length of five or six miles. The city thus stands on a bar of Lake Nipissing, while the swamp back of the city represents a bay which was then submerged. At Au Train there is a similar accumulation of sandy and gravelly material filling in the space between Au Train Lake and the coast of Lake Superior. There are also very extensive sandy bars along the shore of Lake Michigan immediately west of the straits of Mackinac filling the space between Brevort Lake and Lake Michigan shore. They cover a space one to two miles in width and eight to ten miles in length. These several places are perhaps the most striking examples of the development of sand ridges in connection with the Nipissing Great Lakes in this Peninsula, but the wave work along the shore is a conspicuous feature throughout almost the entire coast of Lakes Superior and Michigan and Huron. The land survey plats made by the Government surveyors often indicate the position of this shore as the "former coast line," its features being strikingly similar to that of the present coast and its separation from it is slight both in altitude and distance.

The change from the Nipissing Great Lakes to the modern Great Lakes came about with the abandonment of the eastward outlet through the Ottawa River. This it is estimated took place at a comparatively recent date, geologically speaking, and may have been not more than three thousand years ago if we may judge from the amount of work done by the Niagara River at the falls since the entire drainage of the Upper Great Lakes was thrown that way.

DEPOSITS ON LAKE BEDS.

A large portion of the country covered by these old lakes has glacial deposits within a few inches of the surface and in places the lake beds are entirely free from any lake sediment. There are, however, localities in which the lake sediments have considerable thickness. The sediments range from fine clay to coarse sand or even pebbly material. The sandy and pebbly material is usually found closely connected with deltas of streams that entered the lakes while the finer deposits occur in what were deep parts of the lake beds. In the eastern part of the Peninsula, in Chippewa and northern Mackinac counties, there are extensive areas of lake clay in which wells penetrate in some cases to a depth of 100 feet or more before entering glacial material. In the Ontonagon basin and on the slope of the Copper Range toward Lake Superior there are thin deposits of fine lake sediments usually but 1 to 2 feet in thickness. In the basin southwest from Keweenaw Bay the fine lake sediments in places have considerable depth, but over much of the basin they are thin. The fine lake sediments give a fine soil for grass and oats and other small grains, and large parts of the districts covered by them are already turned into farm land.

CHAPTER IV.
CLIMATIC CONDITIONS.

TEMPERATURE.

The state of Michigan being very largely surrounded by the Great Lakes, possesses a greater degree of insular climate than any other state in the Interior. As a result, the temperature is less extreme both as regards heat and cold than in similar latitudes in states not thus favored. The mean annual temperature for the Northern Peninsula is about 40° Fahrenheit, 4° lower than for the entire state. There are nearly every year a few days in which the temperature rises above 90° and a few in which it falls below 20° in a large part of the peninsula. For the four months, June, July, August and September, the temperature averages through a great part of the Peninsula slightly above 60,° and as this is the main part of the growing season, the conditions are favorable for the growth and maturing of crops of various kinds.

There is considerable variation in the climatic conditions in passing short distances inland from the shore, the effect of the evaporation from the lake being most marked within a limit of 10 miles or less. Where highlands face directly upon the shore of Lake Superior, as in the Copper Range, the Porcupine Mountains, the Huron Mountains and the tableland east from Munising, the conditions are especially favorable for escaping early frosts in the autumn, because of the rise of the air from the lake to these highlands. Very often the highlands on the slope toward the lake escape frosts for nearly a month later than low lying districts in the interior of the Peninsula, or even the land immediately back of these ranges. The ranges facing upon the lake will therefore be especially favorable places for the cultivation of orchards and raising of fruits of all classes, as well as the growing of cereals.

In latitudes as high as those of the Northern Peninsula, the summer months are characterized by very long days and also by a large amount of sunshiny weather. Daylight extends from 3 a. m. to 9 p. m., thus giving light for three fourths of the twenty-four hours in the longest days of June. This great amount of sunshine produces a remarkable effect on the growth of vegetation, so that it is much more rapid than in districts a few degrees farther south, and this compensates to a great degree the disadvantages of the shortness of the season.

PRECIPITATION.

The rainfall in the Northern Peninsula averages about 34 inches, and there are few places in which it falls below 31 inches. A large part of it, 18 to 25 inches, comes in the growing season, so there is little or no deficiency of moisture for watering the crops. The interior of the western portion of the peninsula has an exceedingly high snowfall owing to the fact that the winds rising from Lake Superior laden heavily with moisture become chilled and precipitate snow, not only throughout the winter months, but often from early in October to the beginning of May, so that the ground is frequently covered almost continuously for half the year. There is, however, a belt along the coast of Lake Superior where precipitation is in the form of rain for a larger portion of the year than on the highlands in the interior. The amount of precipitation decreases perceptibly in passing southeastward from the high tablelands in the western portion of the Peninsula to the border of Green Bay and Lake Michigan, owing to the fact that these districts are in the lee of the higher land and the air becomes warm in descending and is able to hold the moisture.

The following data and maps with reference to temperature and precipitation, taken from the Reports of the United States Weather Bureau, will serve to set forth the precise conditions at points widely distributed over the Peninsula. The precipitation maps bring out the variability of rainfall in different years. Portions of the Peninsula which are high in the amount of rainfall one year may be comparatively low another. In some years the western end of the peninsula has dry conditions because of the extension eastward of these conditions from the Great Plains. In other years the same district is within the sweep of moist winds rising from Lake Superior which give it larger rainfall especially on the elevated portions. There is usually a comparatively high rainfall along the Lake Superior coast near Marquette. This is probably because of the occurrence of winds from the lake which upon rising toward the elevated uplands that there border the lake closely are cooled and made to develop clouds and rain.

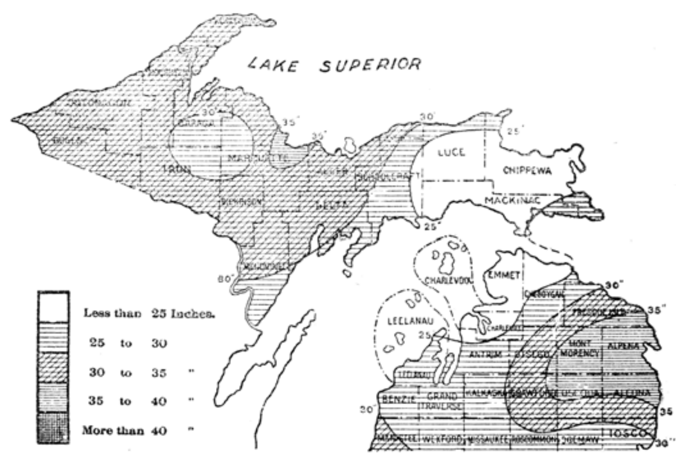
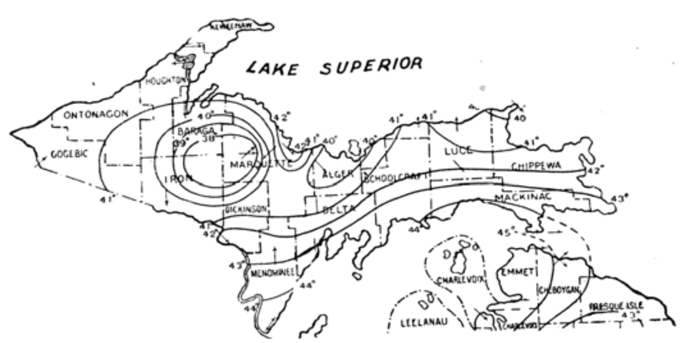


Fig. 2. A. Annual rainfall map of Northern Michigan for 1906.



B. Mean annual isotherms and prevailing winds for 1906.

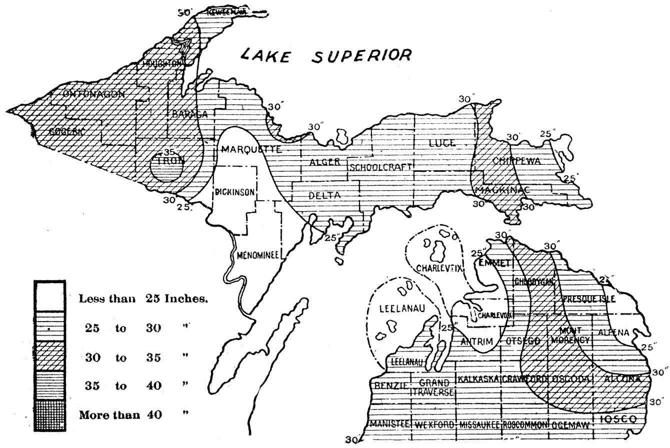
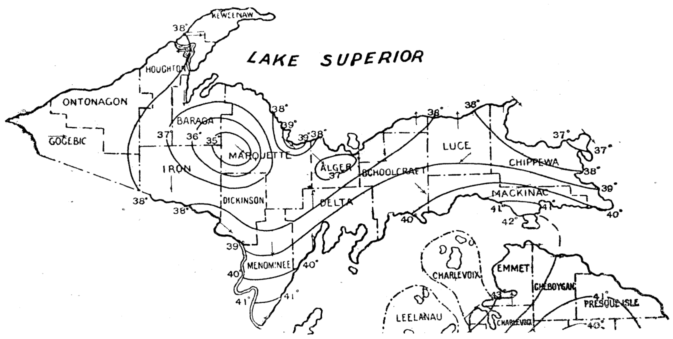


Fig. 3. A. Annual rainfall map of Northern Michigan for 1907.



B. Mean annual isotherms and prevailing winds for 1907.

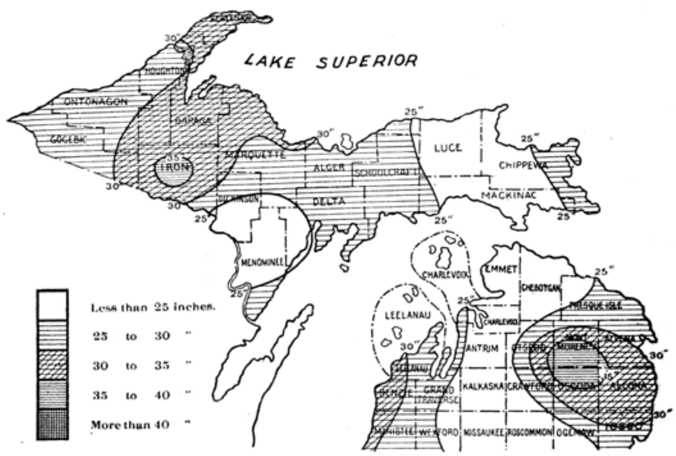


Fig. 4. A. Annual rainfall map of Northern Michigan for 1908.

B. Mean annual isotherms and prevailing winds for 1908.

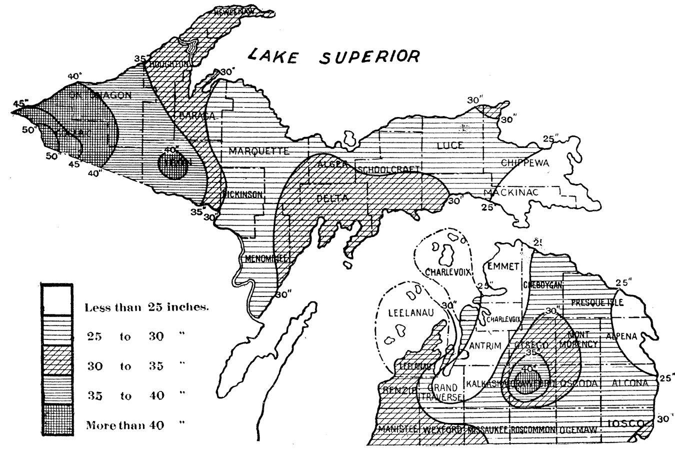
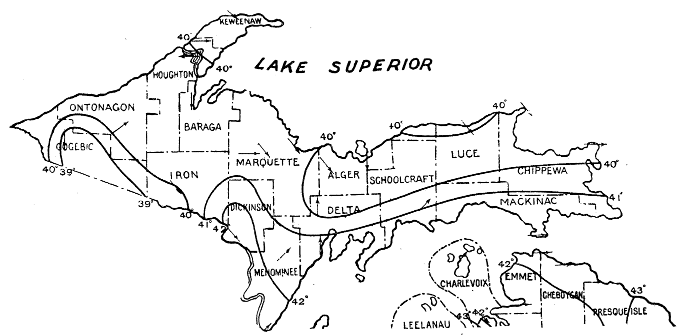


Fig. 5. A. Annual rainfall map of Northern Michigan for 1909.



B. Mean annual isotherms and prevailing winds for 1909.

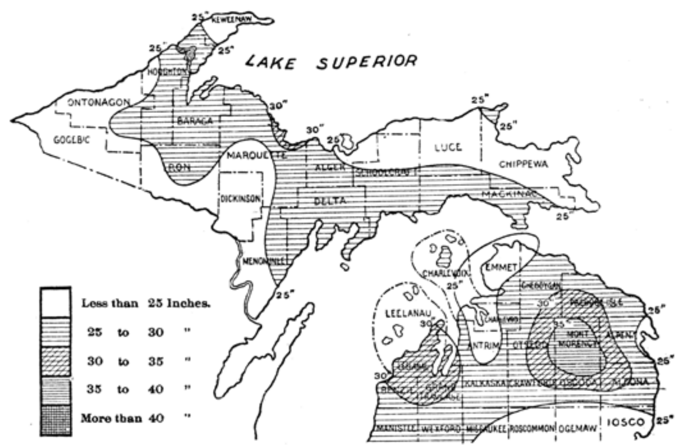
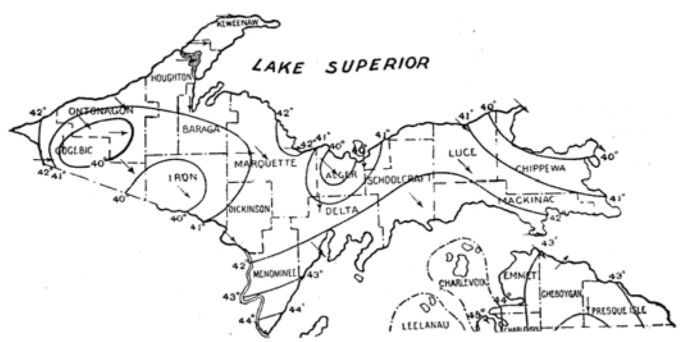


Fig. 6. A. Annual rainfall map of Northern Michigan for 1910.



B. Mean annual isotherms and prevailing winds for 1910.

The time of the latest frosts in spring and of the earliest in the fall is perhaps the most important condition shown by the weather Bureau records. This condition for the five years, 1906 to 1910 inclusive has been worked out from the Weather Bureau data and is here presented. Conditions at Grand Haven, Lansing, and Detroit are also given for the sake of comparison. It will be noted that the Northern Peninsula station, located on the shores of the lakes have generally a more constant condition of freedom from summer frosts than those in the interior. Indeed they are free from frosts for nearly as long a period as roost of the stations in the Southern Peninsula. But in the interior of the Northern Peninsula there is danger of local frosts any month of the summer. The records do not make clear whether the summer frosts are in a given case severe enough to seriously injure crops. In some cases it is known that little or no damage is done by the late spring or early fall frosts. Thus it is stated in the Annual Report for 1906 of the Northern Peninsula Experiment Station at Chatham that no damage could be observed from frosts that occurred May 28 and 29 and June 12, not even on corn and buckwheat which on June 12 were several inches high. The same was true of frosts on September 1 and 28, the first severe frost being that of October 11. The real season between killing frosts for that station in 1906 extended from May 20 to October 11, or 144 days instead of the 81 days between June 12 and September 1 which the Weather Bureau Records would suggest. In some cases it is known that these summer frosts are sufficiently severe to injure tender vines such as cucumbers, and melons without affecting the grains and vegetables which form the main crops of the region. *In general it may be stated that there are six months of the growing season throughout the peninsula, from May to October inclusive.*

The tables serve to illustrate the statement made above; that frost is especially liable to occur on the landward side of ranges that front on Lake Superior at times when the lakeward slope is untouched. It will be noted also that points situated on Lake Superior have an exceptionally long season between spring and fall frosts. This is true even on Isle Royle in latitude 48°.

Reference may be made to the reports of the Weather Bureau for the details of temperature, precipitation, etc., which can not be presented here for lack of space. Reference should also be made to the annual reports of the Upper Peninsula substation for results of experiments with a large variety of grains, vegetables, forage plants, and orchard and small fruits. These reports present a careful digest of the effect of climatic conditions on the crops.

PERIOD BETWEEN SPRING AND FALL FROSTS AT NORTHERN PENINSULA STATIONS.

Station.	Alt. Ft.A.T.	1906.	1907.	1908.	1909.	1910.	Average summer.	Latitude.
Baraga	623	——— Sept. 29.	119 d., M. 29 to S. 25	——— Sept. 14.	98 d., M. 26 to Sept. 1	106 d., M. 29 to S. 12	108 d. (3 yr.)	46°47'
Bergland	1300				——— Sept. 1.	111 d., Jn. 10 to S. 29	111 d. (1 yr.)	46°35'
Blaney		110 d., Jn. 12 to S. 30	112 d., Jn. 2 to S. 22	106 d., Jn. 14 to S. 28		——— Aug. 31	109 d. (3 yr)	46°11'
Calumet	1246	136 d., M. 26 to O. 9	123 d., M. 27 to S. 27	141 d., M. 12 to S. 30	155 d., M. 10 to O. 12	136 d., M. 30 to O. 12	138 d.	47°15'
Chatham	875	81 d., Jn. 12 to S. 1	116 d., M. 31 to S. 24	80 d., Jn. 15 to S. 3	73 d., Jn. 18 to A. 30	97 d., Jn. 8 to S. 13	89 d.	46°22'
Deer Park	610	153 d., M. 10 to O. 10	140 d., M. 27 to O. 14	——— M. 8 to ———	156 d., M. 11 to O. 14	141 d., M. 25 to O. 13	147 (4 yr)	46°47'
Detour	600	135 d., M. 28 to O. 10	121 d., M. 28 to S. 26	162 d., M. 3 to O. 12	161 d., M. 4 to O. 12	146 d., M. 17 to O. 10	145 d.	46°00'
Eagle Harbor	622	154 d., M. 7 to O. 8	122 d., M. 28 to S. 27	149 d., M. 6 to O. 2	147 d., M. 20 to O. 14	140 d., Jn. 3 to O. 21	142 d.	47°27'
Escanaba	612	140 d., M. 20 to O. 7	111 d., Jn. 7 to S. 26	151 d., M. 1 to S. 29	140 d., M. 10 to S. 27	162 d., M. 14 to O. 23	141 d.	45°45'
Ewen	1147		111 d., Jn. 7 to S. 26	110 d., Jn. 11 to S. 29	85 d., Jn. 8 to S. 1	45 d., Jl. 18 to S. 1	88 d. (4 yr.)	46°33'
Grand Marais	610	135 d., M. 28 to O. 10	138 d., M. 28 to O. 13	157 d., M. 8 to O. 12	161 d., M. 5 to O. 13	142 d., Jn. 1 to O. 21	146 d.	46°41'
Houghton	668	153 d., M. 9 to O. 9	133 d., M. 21 to O. 1	150 d., M. 5 to O. 2	163 d., M. 10 to O. 20	166 d., M. 14 to O. 27	153 d.	47°07'
Humboldt	1536	103 d., M. 20 to A. 31	109 d., Jn. 8 to S. 25	96 d., J. 15 to S. 19	——— A. 21	——— A. 19	103 d. (3 yr.)	46°30'
Iron Mountain	1111	152 d., M. 11 to O. 10	104 d., Jn. 10 to S. 22	106 d., J. 15 to S. 29	147 d., M. 4 to S. 26	133 d., M. 27 to O. 7	128 d.	45°48'
Iron River	1504	109 d., Jn. 13 to S. 30	117 d., M. 28 to S. 22	146 d., M. 6 to S. 29	75 d., Jn. 18 to S. 1	49 d., Jl. 23 to S. 10	99 d.	46°06'
Ironwood	1520	122 d., M. 28 to S. 27	——— M. 27 to ———	147 d., M. 7 to S. 29	114 d., M. 10 to S. 1	125 d., Jn. 3 to O. 6	127 d. (4 yr.)	46°27'
Ishpeming	1536	70 d., Jn. 12 to A. 21	——— M 29 to ———	106 d., J. 15 to S. 29	91 d., Jn. 18 to S. 17	144 d., M. 31 to O. 23	100 d. (4 yr.)	46°29'
Isle Royale	610	154 d., M. 8 to O. 9	141 d., M. 30 to O. 18	——— S. 3	166 d., M. 10 to O. 23	159 d., M. 14 to O. 20	155 d. (4 yr.)	48°
Mackinac Island	600	144 d., M. 24 to O. 11	134 d., M. 27 to O. 8	——— May 8	156 d., M. 11 to O. 16		145 d. (3 yr.)	45°51'
Maple Ridge	957	80 d., Jn. 13 to S. 1	107 d., Jn. 7 to S. 22	112 d., M. 14 to S. 3	110 d., M. 11 to A. 30	106 d., Jn. 8 to S. 22	103 d.	46°04'
Marquette	734	142 d., M. 20 to O. 9	138 d., M. 11 to S. 26	151 d., M. 4 to O. 2	164 d., M. 4 to O. 15	175 d., M. 5 to O. 27	154 d.	46°32'
Menominee	581	153 d., M. 9 to O. 9	126 d., M. 27 to S. 30	149 d., M. 3 to S. 29	140 d., M. 10 to S. 27	177 d., M. 4 to O. 28	149 d.	45°06'
Newberry	773			——— M. 3 to ———	138 d., M. 27 to O. 12	92 d., M. 30 to A. 30	115 d. (2 yr.)	46°22'
St. Ignace	593		96 d., M. 28 to S. 1	157 d., M. 5 to O. 9	153 d., M. 11 to O. 11	157 d., M. 5 to O. 9	141 d. (4 yr.)	45°51'
Sault Ste. Marie	614	152 d., M. 10 to O. 9	121 d., M. 28 to S. 26	145 d., M. 10 to O. 2	154 d., M. 11 to O. 12	130 M.d 14 to S. 22	140 d.	46°30'
Thomaston	1347	125 d., M. 28 to S. 30	107 d., Jn. 7 to S. 22	80 d., Jn. 15 to S. 3	79 d., Jn. 14 to S. 1	——— Jl. 18	98 d. (4 yr.)	46°32'
Victoria Mine	1263				——— O. 2	139 d., Jn. 3 to O. 20	139 d. (1 yr.)	46°41'
Watersmeet	1581				75 d., Jn. 18 to S. 1	68 Jn. 12 to A. 19	71 d.	46°16'
Wetmore	878	82 d., Jn. 11 to S. 1	106 d., Jn. 11 to S. 1	91 d., Jl. 30 to S. 29	73 d., Jn. 18 to A. 30	103 d., Jn. 11 to S. 22	91 d.	46°22'
Whitefish Point	610	152 d., M. 11 to O. 10	145 d., M. 28 to O. 20	112 d., M. 13 to S. 3	152 d., M. 14 to O. 13	168 d., M. 13 to O. 28	146 d.	46°48'
STATIONS IN SOUTHERN PENINSULA FOR COMPARISON.								
Detroit	730	154 d., M. 10 to O. 10	156 d., M. 11 to O. 14	160 d., M. 2 to O. 9	171 d., Ap. 26 to O. 14	198 d., Ap. 13 to O. 28	167 d.	42°20'
Grand Haven	628	154 d., M. 10 to O. 11	146 d., M. 21 to O. 14	160 d., M. 2 to O. 9	168 d., M. 4 to O. 19	167 d., M. 14 to O. 28	159 d.	43°03'
Lansing	881	153 d., M. 10 to O. 10	139 d., M. 28 to O. 14	153 d., M. 2 to O. 2	161 d., M. 4 to O. 12	168 d., M. 14 to O. 29	155 d.	42°44'

CHAPTER V.
NOTES ON AGRICULTURAL CONDITIONS.

The time given to this investigation was too brief to permit more than a general survey of soil characteristics and boundaries. This should be borne in mind when consulting the table given below. The attempt has been made to present in this table simply the dominant characteristics rather than the varied range of characteristics of a given tract. For instance, if the table classes a certain township as having 12 square miles of swamp, 10 square miles of sandy till, and 14 square miles of limestone till, it should be understood that any one of these may contain small patches of other sorts of soil, such as sand or sandy gravel, and that under sandy till may be included a soil of varied texture, one acre perhaps being clayey enough to class as clayey till, another so sandy as to fall into that class, while 10 or 20 acres around them are of sandy till, the dominant phase.

The term *clayey till* as used in the tables is not restricted to compact or close-textured deposits but embraces also a loose textured loamy material nearly as pervious as the sandy till but containing a larger amount of fine earthy material. The clayey till is, however, rather compact and close textured in parts of the Ontonagon basin and on the borders of Lake Superior west from the Keweenaw Peninsula. It is especially loose textured in the drumlin areas of Iron County and Menominee County. This difference is noted in the Land Survey Plats, the compact till along the borders of Lake Superior being classed as red clay while the till of the drumlin districts is classed as a loam. The drumlins have usually a liberal amount of clay as a matrix in which the small stones and coarse sandy particles are inbedded. But among the drumlins there are often found deposits of much looser texture with very little clay in their matrix. Both kinds of clayey till are proving to be excellent farm land and bid fair to be kept up without much fertilizing where intelligently tilled.

In most cases the general map of the surface geology can be used as a soil map through some distinctions have been made in the table which are not brought out on the map. For instance, the large till plain which extends northward from Menominee County nearly to the border of Lake Superior is made up in part of the loose textured clayey till and in part of sandy till. In almost every township there are frequent changes from one to the other which would require a great deal of detailed work to map properly. The proportion of each kind of till was estimated in the field but the boundaries were not worked out. The table, therefore, contains the results of these field estimates but the map does not show the extent of each class of till.

Throughout the Northern Peninsula *the morainic areas have a prevailing loose textured deposit classifiable generally as sandy till rather than clayey till, there being as a rule a smaller amount of fine earthy material in the morainic areas than in the till plains*. In places the moraines are composed of very sandy material but as a rule they have sufficient earthy material to render the soils on them productive. Where the moraines are prominent so as to rise 50 to 100 feet above the bordering districts they will often escape frost that touches the lowlands. They are especially well calculated not only because of this topographic feature but because of their loose and mellow soil for the growth of fruit trees. The moraines which front on the Great Lakes have additional protection from frosts as already indicated in the discussion of the climatic conditions.

It will be seen by the table below that about 30% of the Northern Peninsula has a sandy till and 12 per cent a clayey till. These two classes of till make up the greater part of the moraines and till plains, the remaining part being occupied by swamps and lakes and small areas of sand or sandy gravel. These tills and the 2.88 per cent of the peninsula classed as glacial lake clay and the 4.14 Per cent classed as limestone till give a total of very nearly one-half the area of the Northern Peninsula which all promises to be good farm land. Of the remaining part of the peninsula considerable areas can be converted into fair farm land. The swamps and lakes which embrace 4.146 square miles, or 25 per cent of the entire peninsula, may by proper draining be reduced to perhaps three-fourths their present extent. The reclaiming of swamp lands by merely clearing off the timber and removing the obstructions along the drainage lines has already been proved successful in large areas of the Southern Peninsula which in an early day were unhealthy malarial districts. The same methods applied to the Northern Peninsula it is thought would reclaim 1,000 to 1,500 square miles of the present swamp areas and turn them into as productive land as the best soils of the peninsula. There are also large areas which though remaining boggy because of the impossibility of draining thoroughly may still be made profitable for the growth of cranberries and other water loving plants. On the Surface Geology Map only the larger swamp areas can be represented.

There are extensive tracts of *laminated red clay* in the eastern end of the peninsula which are classed as glacial lake clays in the table below. These tracts were originally wet and poorly drained but have now been turned into productive farm land by simply clearing the brush away and opening a few ditches. They are especially well adapted to grass and already have a wide reputation as hay producers. There is a small tract of similar land southwest from the head of Keweenaw Bay which is as yet largely unimproved. Elsewhere the glacial lake clays are generally very thin so that the glacial deposits beneath them come to the surface at many places and the forest trees extend down into them. Such tracts have been classed as till tracts in the table.

By *limestone till* is meant a deposit of reddish clayey material, usually only a few feet thick, which is thickly set with limestone fragments and fine calcareous material produced by the grinding up by the ice sheet of the limestone upon which the deposit is laid. In parts of the area the limestone affords a subterranean drainage so that the waters percolate down through the till into it instead of finding escape over the surface. Many of the depressions on the surface included small swamps when in a forested condition but after clearing up they were changed into productive farm land so that the swamps remaining in such areas are now so small that they are scarcely worth considering. *The limestone till is considered one of the best soils of the northern Peninsula and is already extensively farmed.* The main belt lies along the coast of Lake Huron and Lake Michigan with convenient access to lake ports for shipment of produce, and is also traversed by the Soo Line Railway through a large part of its length.

The calciferous sandstone of Alger County and southeastern Marquette County where standing above the level of the Glacial Lake Algonquin has a rich and easily cultivated soil fully as good as that of the limestone till along the southern border of the peninsula. The western portion of it is embraced in a till plain, but the eastern portion, from the vicinity of Au Train River eastward, is morainic. On the till plain the rock is generally within a few feet of the surface but in the morainic part it is usually covered to considerable depth. The morainic belt was largely covered by the waters of Lake Algonquin and the effect of the submergence was to enrich rather than deplete the soil or surface portion of the deposit. This, however, was not the case in parts of the till plain area of western Alger and eastern Marquette counties. The coating of drift there was so thin that over extensive areas the fine material was largely washed away so that the surface is now thickly strewn with sandstone and the coarse material of the drift, making the cultivation of the land very difficult. There are, however, only a few townships of this district in which the drift was so thin as to be washed away by the action of the lake.

It is a rather surprising fact that scarcely 8 per cent of the peninsula is occupied by rocky knobs and ridges, for the western half is generally considered a mountainous district. The actual area embraced in the knobs is considerably less than indicated in the table for the table simply aims to show where the knobs constitute the dominant .phase of the region. Where cities have been *built among these knobs, as at Ishpeming and Negaunee, one will find the soil covered tracts among them developed into rich garden plats. For general farming, however, these rocky areas are rather forbidding.* The lightest soils of the peninsula are those classed as sandy and sandy gravel, and which embrace about 17.5 per cent of its area. These will require intelligent treatment and careful cultivation if they are to be farmed successfully for any period of years. Methods of cultivation are already devised by which the sandy soils are kept in a state of nature without the destruction of the cover of humus which they carry and which when once destroyed can not be replaced in a long period of years. In European countries such tracts are turned into forest preserves and made to yield a rich return for the labor and investments. Those countries, however, have the advantage of a strict surveillance to guard against fire and depredations such as would be difficult to maintain in this thinly settled region. What shall be done with these tracts of light soil is a problem that will repay intelligent study and experimentation.

To sum up the conditions in the Northern Peninsula it may be stated that 60 to 65 per cent may be turned into productive farm land, thus leaving only 35 to 40 per cent of light soil, rocky areas, and swamps difficult to reclaim.

In the table below the townships are taken up in order by ranges beginning at the east and proceeding westward. The townships of a given range are taken up in succession, from south to north. While this has the advantage of orderly arrangement it has the disadvantage of breaking up the tracts of soil of any particular class. To determine the limits of these tracts, however, reference may be made to the soil or surface geology map which is an indispensible accompaniment of the table.

[Soil Classes by Townships]

ERRATA.

Corrections to tables in Publication 7, Geological Series 5, beginning page 55.

	Swamp and lake.	Rock knobs.	Sandy till.	Sandy gravel.	
T. 47, R. 27 W.	6	18	5	7	
T. 47, R. 19 W.	2	1	4	—	
		Lake clay.			Sandy.
T. 46, R. 19 W.	3	1	22	8	1
T. 46, R. 20 W.	4	—	30	—	2

SOIL CLASSES BY TOWNSHIPS.

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Lime-stone till.*	Clayey till.*	Sandy till.*	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
Drummond Island (R) (1)	30			95				
Lime Island				1				
Neebish Island	2					16		
Sugar Island	30	9				11		
T. 41, R. 4 E. (R.)	1						3	
T. 42, R. 4. E.	3			4			4	
T. 41, R. 3 E. (R)	5						3	
T. 42, R. 3 E.	12			6				13
T. 43, R. 3 E. (R)	4			10			2	
T. 41, R. 2 E. (R)	1						2	
T. 42, R. 2 E.	8			5			15	8
T. 43, R. 2 E.	22	2		2				10
T. 44, R. 2 E.	3	3					2	
T. 45, R. 2 E.	4			2		1	2	
T. 46, R. 2 E.	2							
Les Cheneaux Island (R)					11			
T. 42, R. 1 E. (R.)	3			31				
T. 43, R. 1 E.	2	19		10				5
T. 44, R. 1 E.	5	20					3	4
T. 45, R. 1 E.	5	8					3	20
T. 46, R. 1 E.	3	27			1	3		
T. 47, R. 1 E.		18						5
T. 42, R. 1 W (R)	6			12		5	7	
T. 43, R. 1 W	4	15		15		2		
T. 44, R. 1 W	2	20				12	2	
T. 45, R. 1 W	12	4			1	12	7	
T. 46, R. 1 W		33			2	1		
T. 47, R. 1 W	5	18				1	2	
T. 41, R. 2 W. (R)	2							
T. 42, R. 2 W	12			10			2	
T. 43, R. 2 W	5	14		17				
T. 44, R. 2 W		36						
T. 45, R. 2 W	14	10				8	4	
T. 46, R. 2 W	6	28					2	
T. 47, R. 2 W	5						3	
Bois Blanc Island (R)	10					30		
Round Island	1							
Mackinac Island				2.5				0.5
St. Martins Island	2							
T. 40, R. 3 W				3				
T. 41, R. 3 W	2			1				
T. 42, R. 3 W	5	8		2			6	
T. 43, R. 3 W	2	26		8				
T. 44, R. 3 W		36						
T. 45, R. 3 W	10	24				2		
T. 46, R. 3 W	6	7				10		13
T. 47, R. 3 W	3					5	15	3
T. 40, R. 4 W	5			8				
T. 41, R. 4 W	24			10				
T. 42, R. 4 W	26			10				
T. 43, R. 4 W	12			24				
T. 44, R. 4 W	15	2		4			10	5
T. 45, R. 4 W	20						16	
T. 46, R. 4 W						10	2	24
T. 47, R. 4 W	4				1	8	4	

(1) R—Reported by Russell.
*The term *till* is applied to a glacial deposit of comingled coarse and fine material, slightly if at all assorted by water action.

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Lime-stone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 41, R. 5 W	4						12	
T. 42, R. 5 W	18							12
T. 43, R. 5 W	16			18			2	
T. 44, R. 5 W	21			9			6	
T. 45, R. 5 W	10					6	15	5
T. 46, R. 5 W	4					32		
T. 47, R. 5 W	5					18		
T. 50, R. 5 W							2	
T. 51, R. 5 W							1	
T. 42, R. 6 W	2						2	19
T. 43, R. 6 W	20					16		
T. 44, R. 6 W	12					6	18	
T. 45, R. 6 W	18					15	3	
T. 46, R. 6 W	21					15		
T. 47, R. 6 W	8					24		
T. 48, R. 6 W	10					3	10	
T. 49, R. 6 W	10						14	
T. 50, R. 6 W	13						17	
T. 42, R. 7 W	3							5
T. 43, R. 7 W	17					9		10
T. 44, R. 7 W	22					6	8	
T. 45, R. 7 W	26					8	2	
T. 46, R. 7 W	28					8		
T. 47, R. 7 W	13					23		
T. 48, R. 7 W	3					24	9	
T. 49, R. 7 W	20						16	
T. 50, R. 7 W	10					3	21	
T. 42, R. 8 W	1							
T. 43, R. 8 W	16					10	6	
T. 44, R. 8 W	10			10		6	10	
T. 45, R. 8 W	24					12		
T. 46, R. 8 W	34					2		
T. 47, R. 8 W	14					22		
T. 48, R. 8 W	6					30		
T. 49, R. 8 W	20					12	4	
T. 50, R. 8 W	2					10	12	
T. 43, R. 9 W	5					10	12	
T. 44, R. 9 W	7					25	4	
T. 45, R. 9 W	14					20	2	
T. 46, R. 9 W	27					4	5	
T. 47, R. 9 W	31					5		
T. 48, R. 9 W	13					23		
T. 49, R. 9 W	6						2	28
T. 50, R. 9 W							8	
T. 42, R. 10 W	2						3	
T. 43, R. 10 W	12			10			10	
T. 44, R. 10 W	11			12		3	5	5
T. 45, R. 10 W	8	2				26		
T. 46, R. 10 W	26					10		
T. 47, R. 10 W	23					13		
T. 48, R. 10 W	24					6	6	
T. 49, R. 10 W	3					3	6	24
T. 41, R. 11 W	3			1			2	
T. 42, R. 11 W	10			21			2	
T. 43, R. 11 W	21			12				3
T. 44, R. 11 W	20				2	10		4
T. 45, R. 11 W	4				3	29		
T. 46, R. 11 W	25					3		8
T. 47, R. 11 W	3					13		20
T. 48, R. 11 W	21					1	14	

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 49, R. 11 W	6						4	26
T. 41, R. 12 W	2						3	
T. 42, R. 12 W	23			11			2	
T. 43, R. 12 W	16							20
T. 44, R. 12 W	19				15	2		
T. 45, R. 12 W	22				14			
T. 46, R. 12 W	21					4		11
T. 47, R. 12 W						23		13
T. 48, R. 12 W	12					24		
T. 49, R. 12 W	10					8	18	
T. 50, R. 12 W							2	
T. 41, R. 13 W	3						8	
T. 42, R. 13 W	24			11		1		
T. 43, R. 13 W	18				12			6
T. 44, R. 13 W	14				18		4	
T. 45, R. 13 W	30					6		
T. 46, R. 13 W	26						10	
T. 47, R. 13 W							36	
T. 48, R. 13 W	4					30	2	
T. 49, R. 13 W	3					8	4	20
T. 50, R. 13 W							3	
T. 41, R. 14 W	2						6	
T. 42, R. 14 W	15			21				
T. 43, R. 14 W	24						12	
T. 44, R. 14 W	26						10	
T. 45, R. 14 W	28						8	
T. 46, R. 14 W	26					5	5	
T. 47, R. 14 W	3					5	28	
T. 48, R. 14 W	8					28		
T. 49, R. 14 W	3					12	15	
T. 41, R. 15 W	1			1			3	
T. 42, R. 15 W	18			6			6	6
T. 43, R. 15 W	18						12	6
T. 44, R. 15 W	26						10	
T. 45, R. 15 W	34						2	
T. 46, R. 15 W	18						18	
T. 47, R. 15 W	9					8	19	
T. 48, R. 15 W	4					32		
T. 49, R. 15 W	5					9	12	
T. 40, R. 16 W							1	
T. 41, R. 16 W	7					3	10	
T. 42, R. 16 W	17			14			5	
T. 43, R. 16 W	18					12		6
T. 44, R. 16 W	26				2		8	
T. 45, R. 16 W	29						7	
T. 46, R. 16 W	30						6	
T. 47, R. 16 W	19					8	9	
T. 48, R. 16 W	5					21	8	
T. 39, R. 17 W	2			7				
T. 40, R. 17 W	10			15				9
T. 41, R. 17 W	1			20			3	12
T. 42, R. 17 W	10			10				16
T. 43, R. 17 W	5					5	6	20
T. 44, R. 17 W	15					6		15
T. 45, R. 17 W	23						5	8
T. 46, R. 17 W	18					8	10	
T. 47, R. 17 W	9					27		
T. 48, R. 17 W	1					19		
T. 38, R. 18 W				2				
T. 39, R. 18 W	7			19				

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 40, R. 18 W	6	1		5		6		6
T. 41, R. 18 W	8	6		4			18	
T. 42, R. 18 W	8	2					3	23
T. 43, R. 18 W	2					16		18
T. 44, R. 18 W	10					26		
T. 45, R. 18 W	19					5		12
T. 46, R. 18 W	8					18		10
T. 47, R. 18 W	3					24		
T. 48, R. 18 W				9			2	
T. 37, R. 19 W				3.5				
T. 38, R. 19 W	3			23				
T. 39, R. 19 W				9				
T. 40, R. 19 W	3			5			9	
T. 41, R. 19 W	8			2		6	20	
T. 42, R. 19 W	4					26		6
T. 43, R. 19 W	16					10		10
T. 44, R. 19 W	18					18		
T. 45, R. 19 W	5					3		28
T. 46, R. 19 W	3	1				15	1	8
T. 47, R. 19 W	2					3		
Grand Island	2					18		
T. 38, R. 20 W				1				
T. 39, R. 20 W	2						4	
T. 40, R. 20 W	3	2		1			18	
T. 41, R. 20 W	18						18	
T. 42, R. 20 W	6						30	
T. 43, R. 20 W	16						20	
T. 44, R. 20 W	20							16
T. 45, R. 20 W	4					16		16
T. 46, R. 20 W	4					30	1	
T. 47, R. 20 W	2					12	2	
T. 38, R. 21 W	2			2			2	
T. 39, R. 21 W				28			8	
T. 40, R. 21 W	10			16			10	
T. 41, R. 21 W	3			15		2	16	
T. 42, R. 21 W	8			24			4	
T. 43, R. 21 W	16					20		
T. 44, R. 21 W	4					32		
T. 45, R. 21 W	4					32		
T. 46, R. 21 W	3					32	1	
T. 47, R. 21 W						17	5	
T. 48, R. 21 W						2		
T. 38, R. 22 W				2			2	
T. 39, R. 22 W							14	
T. 40, R. 22 W	4						18	
T. 41, R. 22 W	8			18			10	
T. 42, R. 22 W	10					26		
T. 43, R. 22 W	16					20		
T. 44, R. 22 W	18					18		
T. 45, R. 22 W	12					24		
T. 46, R. 22 W	3					33		
T. 47, R. 22 W	3					30	2	
T. 48, R. 22 W	1					4	1	
T. 38, R. 23 W	6						15	
T. 39, R. 23 W. (R)	18						3	15
T. 40, R. 23 W. (R.)	15					7	4	10
T. 41, R. 23 W	20					16		
T. 42, R. 23 W	10					26		
T. 43, R. 23 W	16					20		
T. 44, R. 23 W	21					15		

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 45, R. 23 W	12					24		
T. 46, R. 23 W	8					28		
T. 47, R. 23 W. (R)	6					18	6	
T. 36, R. 24 W. (R)	2						11	
T. 37, R. 24 W. (R)	10					4	8	
T. 38, R. 24 W. (R)	21					10	5	
T. 39, R. 24 W. (R)	12					24		
T. 40, R. 24 W. (R)	14					22		
T. 41, R. 24 W. (R)	10					26		
T. 42, R. 24 W	10					26		
T. 43, R. 24 W	24					12		
T. 44, R. 24 W	24					8		4
T. 45, R. 24 W	10					14		12
T. 46, R. 24 W	2					30	4	
T. 47, R. 24 W	4					20	6	
T. 34, R. 25 W	1.5				5		5	
T. 35, R. 25 W	4				5	17	5	
T. 36, R. 25 W	3				6	21	6	
T. 37, R. 25 W	4				16	16		
T. 38, R. 25 W	6				10	20		
T. 39, R. 25 W	6				10	20		
T. 40, R. 25 W	8				12	16		
T. 41, R. 25 W	12				10	14		
T. 42, R. 25 W	12				8	16		
T. 43, R. 25 W	15					21		
T. 44, R. 25 W	17					7		12
T. 45, R. 25 W	4					3		29
T. 46, R. 25 W	2		5			11		18
T. 47, R. 25 W	1		8			15		12
T. 48, R. 25 W	1		20			3		5
T. 49, R. 25 W			5				1	2
T. 32, R. 26 W	1						1	
T. 33, R. 26 W	6				10	4	4	
T. 34, R. 26 W	6				18	8	4	
T. 35, R. 26 W	10				18	8		
T. 36, R. 26 W	4				24	6		2
T. 37, R. 26 W	4				23	6		3
T. 38, R. 26 W	4				25	5		2
T. 39, R. 26 W	6				20	8		2
T. 40, R. 26 W	6				20	6		4
T. 41, R. 26 W	6				18	8		4
T. 42, R. 26 W	12					24		
T. 43, R. 26 W	14					22		
T. 44, R. 26 W	18					11		7
T. 45, R. 26 W	5		6			7		18
T. 46, R. 26 W	4		14					18
T. 47, R. 26 W	2		28					6
T. 48, R. 26 W			24					12
T. 49, R. 26 W	4		25					5
T. 50, R. 26 W	4		5					5
T. 51, R. 26 W						3		
T. 31, R. 27 W							2	
T. 32, R. 27 W	5				6	12	3	
T. 33, R. 27 W	5				20	8	3	
T. 34, R. 27 W					17	8		2
T. 35, R. 27 W	5				27	2.5		1.5
T. 36, R. 27 W	4				27	4		1
T. 37, R. 27 W	1.5				32	2.5		
T. 38, R. 27 W	4				30	2		
T. 39, R. 27 W	4				20	10		2

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 40, R. 27 W	2				34	10		
T. 41, R. 27 W	3		3		16	10		4
T. 42, R. 27 W	4				30	12		
T. 43, R. 27 W	6				15	15		
T. 44, R. 27 W	8					25	3	
T. 45, R. 27 W	5				5	24		4
T. 46, R. 27 W	8		3			5		20
T. 47, R. 27 W	16		18			2		7
T. 48, R. 27 W	12		14			6		4
T. 49, R. 27 W	4		18			8		6
T. 50, R. 27 W	2		18			12		4
T. 51, R. 27 W	4		10			5	8	
T. 52, R. 27 W	0.5		1.5				1	
T. 58, R. 27 W	3		11					
T. 59, R. 27 W			1.5					
Manitou Island			2					
T. 32, R. 28 W						5		
T. 33, R. 28 W						4.5		
T. 34, R. 28 W					7			1
T. 35, R. 28 W	2					10	22	1
T. 36, R. 28 W					2	16		13
T. 37, R. 28 W					2	23		3
T. 38, R. 28 W	2.5					25		4.5
T. 39, R. 28 W	4		2			20		10
T. 40, R. 28 W			16			5		15
T. 41, R. 28 W	3		5			8		20
T. 42, R. 28 W	9		8			7		12
T. 43, R. 28 W	10					10		16
T. 44, R. 28 W	10					16		10
T. 45, R. 28 W	10					18		8
T. 46, R. 28 W	6		4			6		20
T. 47, R. 28 W	5		8			8		15
T. 48, R. 28 W	5		20			5		6
T. 49, R. 28 W	4		20			6		6
T. 50, R. 28 W	2		6			18		10
T. 51, R. 28 W	5		12			12		7
T. 52, R. 28 W	3		8			2	4	
T. 58, R. 28 W	3		25			5		
T. 59, R. 28 W	1		6					
T. 34, R. 29 W					4			11
T. 35, R. 29 W	2				1	6		1
T. 39, R. 29 W	4		6			6		10
T. 40, R. 29 W	2		24			5		5
T. 41, R. 29 W	4		14			6		12
T. 42, R. 29 W	6		5		2	14		9
T. 43, R. 29 W	5		5			18		8
T. 44, R. 29 W	10		2			12		12
T. 45, R. 29 W	4					17		15
T. 46, R. 29 W	4		4			14		14
T. 47, R. 29 W	10		12			10		4
T. 48, R. 29 W	6		18			6		6
T. 49, R. 29 W	6		30					
T. 50, R. 29 W	5		16			5		10
T. 51, R. 29 W	5		16			10		5
T. 52, R. 29 W	4		12			6		2
T. 57, R. 29 W	8							6
T. 58, R. 29 W	5		24			5		
T. 59, R. 29 W			9					
T. 39, R. 30 W			1			2		9
T. 40, R. 30 W	5		12			12		7

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 41, R. 30 W	2		14			5		14
T. 42, R. 30 W	5		5			12		14
T. 43, R. 30 W	8				23	5		
T. 44, R. 30 W	10					16		10
T. 45, R. 30 W	9		1			25		1
T. 46, R. 30 W	8		4			15		9
T. 47, R. 30 W	8		17			5		6
T. 48, R. 30 W	12		17			5		2
T. 49, R. 30 W	5		28					3
T. 50, R. 30 W	3		25			6		2
T. 51, R. 30 W	6		6			24		
T. 52, R. 30 W	1				8	14	2	
T. 53, R. 30 W						3		
T. 56, R. 30 W	6						6	
T. 57, R. 30 W	12		4			10	10	
T. 58, R. 30 W	5		21			10		
T. 59, R. 30 W			1.5					2
T. 39, R. 31 W								25
T. 40, R. 31 W	1		3			5		12
T. 41, R. 31 W						7		11
T. 42, R. 31 W	6					10		20
T. 43, R. 31 W	5		5		2	10		14
T. 44, R. 31 W	5				5	16		10
T. 45, R. 31 W	6				5	22		3
T. 46, R. 31 W	9				14	13		
T. 47, R. 31 W	14				3	19		
T. 48, R. 31 W	5		15			12		4
T. 49, R. 31 W	6		30					
T. 50, R. 31 W	4		17			15		
T. 51, R. 31 W	10		2			23		
T. 52, R. 31 W	4				10	10		
T. 53, R. 31 W						1.5		
T. 55, R. 31 W	8						6	
T. 56, R. 31 W	10					4	20	
T. 57, R. 31 W	3		12			21		
T. 58, R. 31 W			20			8		
T. 41, R. 32 W	1					2		7
T. 42, R. 32 W	4		4			6		22
T. 43, R. 32 W	13		8		3	2		10
T. 44, R. 32 W	10		6		5	15		
T. 45, R. 32 W	10		1		4	15		6
T. 46, R. 32 W	9		2		8	14		3
T. 47, R. 32 W	14		2		5	15		
T. 48, R. 32 W	7		10			16		3
T. 49, R. 32 W	5		20			11		
T. 50, R. 32 W	7		24			5		
T. 51, R. 32 W	4				12	16		
T. 52, R. 32 W	2				4	2		
T. 53, R. 32 W	1					6		
T. 54, R. 32 W	8					17		
T. 55, R. 32 W	8					24	4	
T. 56, R. 32 W	5		5			20		6
T. 57, R. 32 W	3		18			5		10
T. 58, R. 32 W	2		4					4
T. 41, R. 33 W								1
T. 42, R. 33 W	5		4		5	22		
T. 43, R. 33 W	5		1		4	21		5
T. 44, R. 33 W	6		4		6	14		6
T. 45, R. 33 W	9				4	20		3
T. 46, R. 33 W	9				3	24		

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 47, R. 33 W	16				2	18		
T. 48, R. 33 W	6		20			10		
T. 49, R. 33 W	4		15			14		3
T. 50, R. 33 W	3		14		2	16		
T. 51, R. 33 W	4				10	10		
T. 52, R. 33 W	10				6	6		
T. 53, R. 33 W	16				9	9		
T. 54, R. 33 W	4					15		
T. 55, R. 33 W	5		10			16		5
T. 56, R. 33 W	3		13			12		4
T. 57, R. 33 W	2		3			2		6
T. 42, R. 34 W	6				9	7		2
T. 43, R. 34 W	7				14	15		
T. 44, R. 34 W	4				16	11		5
T. 45, R. 34 W	16				4	16		
T. 46, R. 34 W	14				6	16		
T. 47, R. 34 W	13					17		6
T. 48, R. 34 W	6		3		5	20		2
T. 49, R. 34 W	3					15		18
T. 50, R. 34 W	5				9	22		
T. 51, R. 34 W	6				22	5		3
T. 52, R. 34 W	15				6	15		
T. 53, R. 34 W	15					21		
T. 54, R. 34 W	9		3			24		
T. 55, R. 34 W	6		3			25		2
T. 56, R. 34 W	3					12		
T. 42, R. 35 W	3		3		18	10		2
T. 43, R. 35 W	7		1		15	13		
T. 44, R. 35 W	7		1		20	6		2
T. 45, R. 35 W	7				8	21		
T. 46, R. 35 W	15				6	15		
T. 47, R. 35 W	6		1		3	16		10
T. 48, R. 35 W	5					21		10
T. 49, R. 35 W	6	6				20		4
T. 50, R. 35 W	6	24				6		
T. 51, R. 35 W	6	6	1			23		
T. 52, R. 35 W	10					26		
T. 53, R. 35 W	6					30		
T. 54, R. 35 W	12				4	20		
T. 55, R. 35 W	5					20		
T. 42, R. 36 W	4					9		4
T. 43, R. 36 W	3				20	10		3
T. 44, R. 36 W	5				15	13		3
T. 45, R. 36 W	8		1		15			12
T. 46, R. 36 W	5		1		5	25		
T. 47, R. 36 W	1				3	20		12
T. 48, R. 36 W	2				3	12		19
T. 49, R. 36 W	6	12				14		4
T. 50, R. 36 W	8	15				10		3
T. 51, R. 36 W	6					30		
T. 52, R. 36 W	6		2			24	4	
T. 53, R. 36 W	5				16	10		5
T. 54, R. 36 W	7				10	10		
T. 55, R. 36 W	0.5				1.5			
T. 42, R. 37 W	1					2		
T. 43, R. 37 W	6					28		2
T. 44, R. 37 W	3				26	4		3
T. 45, R. 37 W	4				6	14		12
T. 46, R. 37 W	4		1			25		6
T. 47, R. 37 W	4		2		5	16	9	

SOIL CLASSES BY TOWNSHIPS.—*Continued.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 48, R. 37 W	4				2	11	16	3
T. 49, R. 37 W	3				2	16	11	4
T. 50, R. 37 W	3				8	25		
T. 51, R. 37 W	5		4		12	12		3
T. 52, R. 37 W	5				12	19		
T. 53, R. 37 W	7				20			
T. 43, R. 38 W	1					10		
T. 44, R. 38 W	4					32		
T. 45, R. 38 W	6					20		10
T. 46, R. 38 W	10		1			15		10
T. 47, R. 38 W	4.5		1.5		10	20		
T. 48, R. 38 W	4				18	14		
T. 49, R. 38 W	5					4	27	
T. 50, R. 38 W	4		2		24	6		
T. 51, R. 38 W	5		3		24	4		
T. 52, R. 38 W	6				28		2	
T. 53, R. 38 W	5				14			
T. 43, R. 39 W	1.5							1.5
T. 44, R. 39 W	6					20		10
T. 45, R. 39 W	5				4	18		9
T. 46, R. 39 W	5		1			18		12
T. 47, R. 39 W	2				9	25		
T. 48, R. 39 W	2				21	13		
T. 49, R. 39 W	2				29	5		
T. 50, R. 39 W	4		3		27	2		
T. 51, R. 39 W	4				28		4	
T. 52, R. 39 W	4				10		8	
T. 44, R. 40 W	10					16		2
T. 45, R. 40 W	8					14		14
T. 46, R. 40 W	4				4	28		
T. 47, R. 40 W	4				28	4		
T. 48, R. 40 W	4				17	11	4	
T. 49, R. 40 W	4		1		21	10		
T. 50, R. 40 W	2		2		24	6	2	
T. 51, R. 40 W	4				26		4	
T. 52, R. 40 W	1				2		1	
T. 44, R. 41 W	6					12		
T. 45, R. 41 W	5				10	21		
T. 46, R. 41 W	5		1		2	28		
T. 47, R. 41 W	4				21	11		
T. 48, R. 41 W	4				32			
T. 49, R. 41 W	4		4		26	2		
T. 50, R. 41 W	5		5		24	2		
T. 51, R. 41 W	3				25		2	
T. 44, R. 42 W	2					6		
T. 45, R. 42 W	4				10	22		
T. 46, R. 42 W	5		2		7	22		
T. 47, R. 42 W	10		5		18	3		
T. 48, R. 42 W	9				27			
T. 49, R. 42 W	6		7		2			
T. 50, R. 42 W	5		2		27			
T. 51, R. 42 W	3		4		16	2		
T. 45, R. 43 W	5.5				15			
T. 46, R. 43 W	2		6					
T. 47, R. 43 W	4		12		10			
T. 48, R. 43 W	10		4		15	7		
T. 49, R. 43 W	6		4		12	14		
T. 50, R. 43 W	6		3		25	2		
T. 51, R. 43 W	2		16		6			
T. 45, R. 44 W	6				6	12		

SOIL CLASSES BY TOWNSHIPS.—*Concluded.*

Location.	Swamp and lake.	Glacial lake clay.	Rock knobs.	Limestone till.	Clayey till.	Sandy till.	Sandy.	Sandy gravel.
	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.	Sq. Mi.
T. 46, R. 44 W	6		15			15		
T. 47, R. 44 W	6		10		10	10		
T. 48, R. 44 W	6		6		18	6		
T. 49, R. 44 W	5		6		11	14		
T. 50, R. 44 W	4		13		12	7		
T. 51, R. 44 W	1		3		1			
T. 45, R. 45 W	4		2		2	6		
T. 46, R. 45 W	15		5			16		
T. 47, R. 45 W	5		15		8	8		
T. 48, R. 45 W	5				16	15		
T. 49, R. 45 W	5		13		18			
T. 50, R. 45 W	3		3		12	6		
T. 45, R. 46 W	1		2			1.5		
T. 46, R. 46 W	6		15			15		
T. 47, R. 46 W	6		24			6		
T. 48, R. 46 W	4		4		18	10		
T. 49, R. 46 W	7		6		7	5		
T. 46, R. 47 W	1		3			2		
T. 47, R. 47 W	2		10		6	3		
T. 48, R. 47 W	9				17	10		
T. 49, R. 47 W	3		3		6	8		
T. 48, R. 48 W	3		3		10	12		
T. 49, R. 48 W	1				4	1		
T. 48, R. 49 W	1.5				5	2		
Totals	4,146	479.5	1303	689	2030.5	5,039.5	1236	1680
Percentage	24.97	2.88	7.85	4.14	12.23	30.35	7.45	10.11

NOTE.—Isle Royale is not included in the above table, and has not been visited by the writer. From descriptions given by Dr. A. C. Lane in his report on the island (Geology of Michigan, Vol. VI, Part 1), and from the Land Survey Plats, it appears that nearly 75 per cent of its area of 207 square miles, or about 150 square miles should be classed under "rock knobs." The remainder seems to be about equally divided between swamp and sandy gravel. Lane reports the soil to be all water washed material.

CHAPTER VI.
WATER POWER IN THE NORTHERN PENINSULA.

But few discharge measurements have been made on the streams of the Northern Peninsula nor has there been a complete investigation of the localities best suited for dam sites or development of water power. In the course of the writer's investigations notes were taken as to the location of some of the cascades and rapids but it is not likely that more than half the cascades were seen. These notes are presented here merely to direct attention to the possibilities of water power development.

The region is peculiarly well adapted to furnish valuable water power for several reasons. The streams of a considerable portion of the peninsula not only have their sources at a high altitude but in many cases their sources are in tracts thickly set with lakes which impound the water and yield it steadily to the streams. The glacial deposits of the region are also in large part so loose textured as to absorb a considerable portion of the rainfall and thus prevent great freshets and at the same time yield the water slowly to the streams and maintain a good flow in dry seasons. The amount of rainfall in the open season between May and October, being from 18 to 25 inches, is sufficient to maintain a fair stage of water in most of the streams.

The development of the water power is likely to be in most cases in the lower courses of the streams where fall is very rapid. The rapidity of fall has some disadvantage in that only short sections of the stream can be turned into impounding reservoirs, but the large amount of impounding by lakes in the head water portions of some streams tends to give considerable regularity of flow.

The following official reports contain data bearing on the Northern Peninsula water power.

BIBLIOGRAPHY OF NORTHERN PENINSULA WATER POWER.

Tenth Census of the United States, 1880, Vol. 17, Water Power, Part 2. Presents a report on the Menominee River and its adaptibility to water power, and also on Montreal River.

U. S. Geological Survey, Water Supply Paper No. 49, pp. 259-260. Gives scanty notes on a few Northern Peninsula streams.

U. S. Geological Survey, Water Supply Paper No. S3, Stream Measurements in 1902, Part II, pp. 241-262. Presents a good discussion of the effect of inhabitation. Discusses Dead River, Carp River, Menominee River, and Iron River and gives discharge measurements and gage readings.

U. S. Geological Survey, Water Supply Paper No. 97, Stream Measurements in 1903, Part I, pp. 485-498. Good records of gage heights and stream discharge on Dead River taken at Forestville. 1898 to 1902 and at the Hoist in 1903. Also measurements on Carp River near mouth taken in 1903, and on Menominee River and Escanaba River for 1903, and Iron River for 1900-1903.

U. S. Geological Survey, Water Supply Paper No. 129, Stream measurements in 1904. Discharge measurements are reported for Escanaba River near mouth, Menominee River near Iron Mountain, and Iron River near Iron River.

U. S. Geological Survey, Water Supply Paper No. 170, Stream measurements in 1905, Part VI, pp. 12-17. Discharge measurements for 1905 at same points as in Water Supply Paper No. 129.

U. S. Geological Survey, Water Supply Paper No. 156, Water Powers of Northern Wisconsin by Leonard S. Smith, pp. 42-56. Embraces a good discussion of Menominee River and brief one of Montreal River.

U. S. Geological Survey, Water Supply Paper No. 206, Surface water supply in 1906, pp. 17-20. Reports the discharge measurements on Escanaba River near mouth and on Menominee River near Iron Mountain.

U. S. Geological Survey, Water Supply Paper No. 244, Surface water supply in 1907-1908, Part 4, pp. 29-40. Gives discharge measurements on Escanaba River near mouth, on Menominee River near Iron Mountain and at Koss, Michigan, and presents a view of Lower Quinnesec Falls.

U. S. Geological Survey, Water Supply Paper No. 264, Surface water supply in 1909, Part IV, pp. 36-43. Gives measurements on Escanaba River near mouth, on Menominee River near Iron Mountain, and at Koss, Michigan.

Report of International Waterways Commission on the regulation of Lake Erie, 1910, pp. 32-46, 105-116. Gives discharge measurements of St. Mary's River.

THE LAKE SUPERIOR DRAINAGE IN MICHIGAN.

The Lake Superior watershed extends but a few miles into Michigan, and its tributaries in the State are, therefore, small. The largest tributary in the eastern portion is Tahquamenon River which discharges into Whitefish Bay at Emerson and drains about 800 square miles. Seventeen other streams between Sault Ste. Marie and Marquette are called rivers, but none of them has a drainage area of 200 square miles, while the majority drain less than 100 square miles each. In the western portion the Ontonagon drainage system is far larger than any other, yet it embraces only 1,250 square miles.

These tributaries differ greatly in their drainage characteristics owing to topographic conditions. The principal difference is due to the relations to rock ledges, some being characterized by rapids and waterfalls, while others are free from these features.

Several streams in the eastern part of the peninsula, Waiska, Shelldrake, Little Two Hearted and Big Two Hearted, and the two Sucker rivers, have no rock outcrops along their courses and few other features of especial interest. They descend at a moderate rate and have been of commercial value principally in carrying logs from their headwaters down to mills at or near their mouths. The large majority of the streams from Grand Marais westward descend over rock ledges and present conditions more favorable for power development. The only important streams in the eastern end of the Peninsula are St. Mary's River and Tahquamenon River.

ST. MARY'S RIVER.

The data here given are taken from the 1910 report of the International Waterways Commission on the Regulation of Lake Erie. The mean elevation of Lake Superior at the head of the rapids at Sault Ste. Marie for the 33 years from 1870 to 1903 was 601.91 feet above mean tide at New York. Below the rapids, which are about one-half mile in length, the altitude is 583.73 feet, thus giving a fall of 18.1.9 feet. The mean discharge for the same period was 82,000 second-feet. There is, however, a notable range in flow, the maximum annual mean since 1860 being 101,000 second-feet and the minimum 65,000 second-feet, while the maximum monthly mean discharge reached 128,700 second-feet and the minimum fell to 48,400 second-feet. A considerable diversion has been made already for power purposes and locks on the Canadian and American side. These are estimated to have used the following amounts of water in the three years from 1905 to 1907, inclusive:

	Second-feet.
The Canadian Lake Superior Power Company	6,000
The Michigan Lake Superior Power Company	8,500
The Chandler-Dunbar Water Power Company	1,400
The Canadian and American locks	600
Total	16,500

TAHQUAMENON RIVER.

The Tahquamenon River which enters the west side of Whitefish Bay at the southeast end of Lake Superior, has valuable undeveloped water power on its lower course near the line of Luce and Chippewa counties. The falls and rapids are distributed over a length of 5 miles. At the upper fall there is a cascade of about 40 feet then rapids amounting to 30 feet or more, at the foot of which is a cascade of 17 feet, termed the Lower Fall, located in Sec. 32, T. 49, R. 7 W. Below this fall the river is practically at Lake Superior level though probably fully 20 miles from the lake by the course of the stream, and nearly 10 miles by direct line. Above the falls there is an extensive swamp with a fall of but a few inches per mile from its western end near Laketon in western Luce County to the vicinity of the upper falls on the eastern edge of the. county. This constitutes a great equalizer of the flow.

SMALL TRIBUTARIES IN ALGER COUNTY.

The short streams in Alger County in many cases have cascades of considerable heght which could be turned into flumes or penstocks and made to furnish power for small establishments. One of the best streams for such development is the outlet of Grand Sable Lake near Grand Marais. This outlet has a fall of about 150 feet in its lower two miles. It is probable that several hundred horse power could be developed in case the whole outlet were carried in a penstock or flume and the whole fall of 150 feet utilized.

In the immediate vicinity of Munising four small streams each have cascades of about 40 feet near their mouths which might easily be turned to use for power.

The Au Train River has a series of cascades and rapids amounting to about 75 feet just north of the Munising Railroad bridge. The largest cascade is about 40 feet.

On Laughing Fish River three miles northwest of Rumley a series of cascades have an estimated total fall of about 100 feet.

There are several cascades between Munising and Grand Marais which are so remote from settlements or railway lines as to be less easily turned to use for power. One of these at Grand Portal cascades directly into Lake Superior from a height of about 60 feet.

CARP RIVER.

This small stream which enters Lake Superior just south of the city of Marquette flows through the mining regions near Ishpeming and Negaunee and offers conditions favorable for water power development. The discharge measurements on this stream for 1902 and 1903 are presented in Water Supply Papers 83 and 97. They were made at a weir erected by the Cleveland Cliffs Iron Company at a distance of only 500 feet from the mouth of the stream. The river has a drainage area of .86 square miles and the run-off in 1903 between March 10 and October 28 showed a range from 1.06 to 2.03 second-feet per square mile. In 1902 in the months from July to December the run-off was much lower, there being a range from .46 to 1.23 second-feet per square mile, or from 51 to 218 second-feet for the stream discharge. Near the headwaters of this stream there are several lakes which tend to equalize the flow, two of which have been drawn upon for municipal water supply by the cities of Ishpeming and Negaunee. It is reported in Water Supply Paper No. 83 that in 1902 an average consumption of 1.25 second-feet per day was drawn from Teal Lake by the Negaunee Water Company and 1.4 second-feet from Lake Sally by the Ishpeming Water Company.

This stream has a series of rapids in its lower course which offer favorable conditions for a development of a large fall. The Cleveland Cliffs Iron Company are developing the Carp River to furnish electric power for the mines which they operate in the Marquette and Swanzy districts.

DEAD RIVER.

Dead River enters Lake Superior in the north part of the city of Marquette and has a drainage area estimated to be 165.5 square miles. Of this 126.3 square miles are above a large cascade 14 miles from the mouth at a place known as the Hoist. The only storage reservoir of importance in the upper course is Silver Lake with an area of 1,600 acres and capable of draft to a depth of 10 feet, and this is controlled by the South Arm Lumber Company. The following statements concerning the most notable cascades on the lower course of the stream are taken from Water Supply Paper 83:

Lake Superior Powder Company, near mouth, 20 feet fall.

Valley Flour Mill, four miles from mouth, 18 feet fall.

Marquette Electric Light Plant utilizes 85 feet fall which may be increased to 112 feet, 6 feet above the dam and 18 feet below the tail race remaining undeveloped. The plant is located near Forestville, six miles from Marquette.

From 2 to 5 miles above Forestville are rapids aggregating two available falls of 100 feet each, owned by J. M. Longyear.

At the Hoist, 8 miles from Negaunee and Ishpeming, is a fall of 110 feet owned by the Oliver Mining Company.

Discharge measurements were made at the Hoist on seven dates in 1902 arid three dates in 1903, which taken together with the observations on the gage height afford the requisite data for a rating table for Dear River at ordinary stages for the ice-free period. This table is given in Water Supply Paper 97. With a gage height of 10.5 feet, which is about the minimum, the discharge is 79 second-feet. With a gage height of 11 feet the discharge is 228 second feet, and with a gage height of 11.25 feet the discharge is 315 second-feet. The gage height seldom reaches 12.5 feet and is ordinarily between 10.5 and 11.25 feet.

In addition to the measurements at the Hoist a record of gage heights was maintained at Forestville from October 15, 1898 to July 31, 1902 by J. M. Longyear, the results of which are published in Water Supply Paper 97. These show a mean discharge for the year 1899 of 294 second-feet with a range in the different months from 56 in February to 1,009 in April. For the year 1900 the yearly mean is 256 second-feet, and the range from 123 second-feet in March to 854 second-feet in April. In 1901 the Annual mean was 240 second-feet with minimum of 112 second-feet in February and August and a maximum of 760 second-feet in April.

IN HURON MOUNTAINS.

In the Huron Mountain region from Keweenaw Bay eastward to Lake Independence there are numerous cascades and rapids. The streams are all small but in many cases would yield power sufficient to justify development.

STURGEON RIVER.

The headwater portion of this drainage system as far down as T. 48, R. 35, is well calculated for power, there being lakes and porous deposits to regulate the flow as well as a rapid descent. But the lower course of the stream is through a low plain and in the lower ten miles there is a very sluggish flow.

STREAMS ON THE KEWEENAW PENINSULA.

The small streams on the Keweenaw peninsula, like those in Alger County, make such great descents within short distances that power of considerable value may be developed. At the mouth of Montreal River there is a cascade of about 30 feet. The streams on the western slope south of the Portage Canal are less favorable for water development. It is a clay district in which the flow is more irregular than in sandy districts and the fall is seldom concentrated in rapids and cascades.

ONTONAGON RIVER.

This widely branching system, heads in a series of lakes and loose textured moraines which give its headwaters a somewhat steady flow. Several of the branches then lead through a clay plain, the old bed of Lake Ontonagon, in which there is great irregularity in the run-off, the small tributaries ceasing to flow entirely in dry seasons, but furnishing considerable water in wet ones. Deep, narrow valleys have been cut in the lower courses of these branches and also in the main river where it passes through the Copper Range near Rockland thus giving favorable conditions for the construction of high dams to impound the water.

At Glen Falls three-fourths mile south of the Victoria mine in Sec. 31, T. 50 N., R. 31 W., a head of 100 feet could be obtained which would yield an estimated minimum of 4,500 horsepower. Discharge measurements in 1902 and 1903 at the highway bridge be-ween Rockland and the Victoria Mine, recorded in Water Supply Paper 97, show a range from 533 to 4733 second-feet, the former September 14, 1902, and the later September 17, 1903.

At Falls Station where the Duluth South Shore and Atlantic Railway crosses the Middle Branch there is a fall of 30 to 40 feet favorably located for the development of power.

PRESQUE ISLE RIVER.

This river has its headwaters in a system of lakes and moraines near the border of Wisconsin and Michigan at an altitude of more than 1,000 feet above Lake Superior. It makes a rapid descent in its passage across the Gogebic Iron Range, but is still over 600 feet above the lake where it leaves the range. Thence it descends through a narrow rocky gorge with numerous rapids.

BLACK RIVER.

Black River heads in a morainic belt near the Wisconsin-Michigan line and then traverses swampy tracts in its passage northward into the Gogebic Iron Range. There a rapid fall occurs which affords good conditions for power development. Along the remainder of its course there are rapids, while in the lower three miles are several falls eight to 40 feet high aggregating 205 feet, as determined by W. C. Gordon, (Ann. Report, 1906, Pl. XXXII).

MONTREAL RIVER.

Montreal River which forms part of the boundary of Wisconsin and Michigan was made a subject of statistics in the Tenth Census of the United States. The drainage area is 284 square miles and the low water flow is estimated to be 114 second-feet. The headwaters are in tamarack swamps at about 1,000 feet above Lake Superior, and the stream is about 900 feet above the lake as far down as the vicinity of the iron range at Ironwood and Hurley. Near these cities there are falls of 15.35 and 25 feet. About three miles from the mouth are cascades aggregating 78 feet fall with one cascade of 40 feet. Another cascade of 35 feet is only 1,300 feet from the mouth. Located as these falls are near an important mining center they should be made to yield valuable power.

LAKE MICHIGAN DRAINAGE IN THE NORTHERN PENINSULA.

The Lake Michigan watershed extends over a large part of the Northern Peninsula and embraces several rivers of importance in the development of water power. Those heading in the western part of the peninsula such as the tributaries of the Menominee, Ford River, and Escanaba River have their sources on a tableland 1,000 feet or more above Lake Michigan and are characterized by numerous rock rapids and cascades in their middle and lower courses and have lakes and extensive marshes in their headwater portion which serve to impound the water and equalize the flow. From the head of Green Bay eastward the rivers have their sources in districts standing only 200 to 400 feet above the lake. The streams usually rise in moraines or belts of thick drift and then pass southward through the limestone escarpments which lie near the shore of Lake Michigan. In their passage through these escarpments some of them have rock rapids but others make use of drift filled gaps in the escarpments.

MENOMINEE RIVER SYSTEM.

This river system has a drainage area estimated at about 4,100 square miles, of which 1,450 are in Wisconsin. It is especially well calculated to furnish valuable water power. The headwaters are in a tableland standing 1,000 to 1,200 feet above lake Michigan and several large tributaries unite at an elevation fully TOO feet above the lake, so that more than half the drainage is brought together at this high altitude. The fall of 700 feet to Lake Michigan is made in a distance of a little over 100 miles, thus giving an average rate of nearly 7 feet per mile. The fall, however, is far from uniform, there being cascades of considerable height as well as rapids separated by stretches of relatively slack water of considerable length.

There are also notable cascades above the nominal head of the Menominee both on Paint river and Michigamme river within the state of Michigan.

There is a fall on the Sturgeon river in Section 8, T. 39 N., R. 28 W., which it is estimated will develop 750 horse power, (Plate VIII A) and on the west branch of this stream in Section 35, T. 42 N., R. 29 W., a fall which is estimated at 150 horse power.

The Michigamme has a fall of 30 feet only 1,300 feet from its mouth estimated at 1,600 horse power, another in Section 32, T. 42 N., R. 31 W., estimated at 1,400 horse power, a third in Section 4 of the same township estimated at 1,000 horsepower, and a fourth, one mile above Mansfield estimated at 1,000 horsepower, (Plate VIII B) and a 40-foot descent in rapids 13/4 miles long whose lower end is about 6 miles above the mouth of Fence river. There are also rapids for ¾ of a mile, with a descent of 20 feet, 3 or 4 miles south of Republic.

On Paint river, near the mouth, in Section 12, T. 41 N., R. 32 W., is a fall estimated to develop 600' horse power. The Horserace rapids in Section 24, T. 42 N., R. 32 W., it is estimated will develop 1,200 horsepower. At Crystal Falls there is a descent of 18 feet at the dam with 1,200 horse power developed. There are also rapids a short distance below the mouth of Hemlock river with an estimated fall of 16 feet in one-half mile.

The cascades and rapids on the Menominee river below the junction of the Brule and the Michigamme are discussed in the water power report in the Tenth Census of the United States (Volume XVII) and also in L. S. Smith's report on water powers of Wisconsin[8] and in the several water supply papers of the U. S. Geological Survey dealing with the. Great Lakes drainage (Nos. 83, 97, 129, 206, 244, 264).

The following is mainly quoted from L. S. Smith's report to the Wisconsin Geological and Natural History Survey.

Menominee River varies in width from 200 to 600 or 700 feet far up toward the headwaters. For the first 7 miles from the junction of the Brule and Michigamme there are no heavy rapids, but, in the language of the lumberman, there is "strong water" all the way and probably many good water-power sites.

[8]Water Powers of Wisconsin. Bull. 20. Wisconsin Geological and Natural History Survey. 1908.

Bad Water Rapids.

The first notable rapids, known as the Bad Water rapids, occur 7 miles below the head of the river, in Sec. 31, T. 41 N., R. 30 W., at a point where the river, 100 feet wide, descends 5 feet over a ledge of rock. While definite information is lacking, it is likely that a dam could be built here, giving a head of 10 feet.

Twin Falls.

About 31/2 miles below Bad Water rapids, in Sec. 6, T. 40 N., R. 30 W., are the Twin Falls, about one-half mile apart. The vertical fall in each case is 12 feet, but the adjacent rapids are sufficient to increase the total descent to 28 feet. Twin Falls are being developed by the Peninsula Power Co. A dam with a head of 22 feet is being constructed at the lower falls which will raise the water to a depth of 121/2 feet over the upper falls and develop 5,000 horsepower which will be used principally in supplying power to the mines in the Menominee, Crystal Falls, Iron River, and Florence ranges.

Pine River Rapids.

For 6 miles below the foot of Twin Falls the total descent of the river is but 20 feet, and the only rapids worthy of note are those extending for about five-eights of a mile on both sides of the mouth of Pine River. Here an island divides the river into two channels with rocky bed. The descent of the rapids at this point is said to be 6 feet, but as the banks are high a dam could develop more than this. Pine River increases the drainage area by 586 square miles.

Horse Race Rapids.

The most important rapids between Twin Falls and Big Quinnesec Falls, called the Horse Race, are found in Sec. 7, T. 39 N., R. 30 W., both above and below the Chicago, Milwaukee and St. Paul railroad bridge. These rapids consist of two pitches, the upper of about 20 and the lower of 8 feet descent, separated by about 2,000 feet of less swift water. As the banks are high and the river-narrow, it seems likely that a dam could be economically constructed here to develop about 40 feet of head. This site is only 3 miles from Iron Mountain, Mich.

Big Quinnesec Falls.

A little over 7 miles below the mouth of Pine River, and 4 miles from Quinnesec, are the Big (Upper) Quinnesec Falls. These are located in Sec. 8, T. 39 N., R. 30 W.

At Upper Quinnesec Falls the river narrows to hardly more than 50 feet wide (map measurement) between rocky banks of igneous origin. Immediately at the foot of the falls the river widens out, and about 800 feet below is 700 feet across. On the Wisconsin side the banks are 80 to 100 feet high and on the Michigan side 30 to 40 feet.[1]

Below the falls the river descends only 2 feet to the mile for a distance of about 3 miles. At present only 54 feet of the total head is improved, one-half of the power being used to compress air for the supply of the Chapin Iron Mines at Iron Mountain, 31/2 miles distant. The remaining portion is to be harnessed in 1905 and used for operating mines at Norway, 9 miles away. On account of the local conditions it is unlikely that much more than the present head can be economically developed.

[1]Tenth Census, Vol. 17.

Lower or Little Quinnesec Falls.

Four miles below in Sec. 14, T. 39 N., R. 30 W., are the Little (lower) Quinnesec Falls, which, together with the upper falls, described above, form the most important powers on the river. For the greater portion of the distance between the upper and lower Quinnesec Falls there is comparatively quiet water. The greater part of the descent of 24 feet in this distance occurs in the lower 2 miles. Above the upper and below the lower falls the banks are generally high near the river, but between these falls the hills recede from the river an average distance of about one-half mile and are separated from it by a flat and in some places swampy area.

Above Little Quinnesec Falls the river runs southwest, but at the foot of the falls it suddenly turns at right angles and runs southeast, the water surging down an incline of about 45° and then plunging into the comparatively still water of the basin below. The total fall is 62 feet. A short distance above the falls the river is 250 feet wide, but narrows down at the pitch to about 50 feet. The falls are hemmed in by great masses of greenstone and schist rock. Along the Michigan side a steep cliff of greenstone at least 140 feet high forms the bank for a distance of a mile or more. A smaller, but similar, rib of rock forms the Wisconsin bank for about 700 feet.

Formerly, Little Quinnesec Falls were partially developed under 25 feet head for woodpulp grinding; but in 1898 they were redeveloped by the Kimberly & Clark Company for wood-pulp and paper manufacturing. A ledge of rock, which is used for a bridge pier, divides the falls into two channels. The present development gives a net head of 62 feet, equivalent to 8,370 theoretical horsepower. An actual installation of turbines, generating 5,800 horsepower, consumes all the available power.

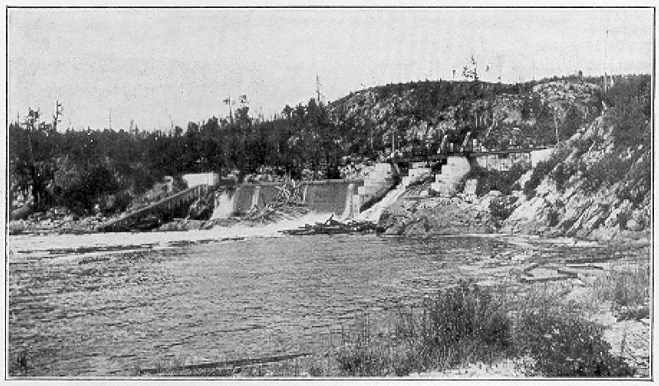
Sand Portage Rapids.

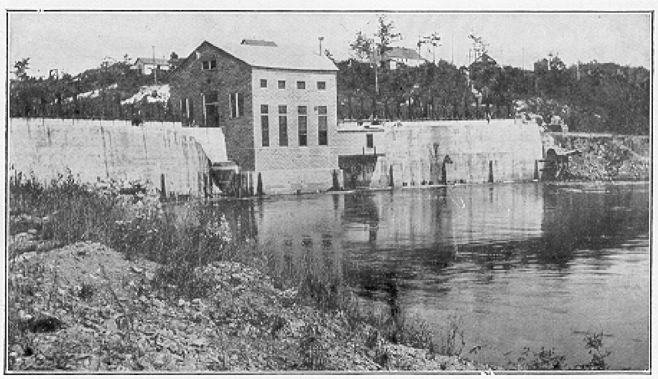
These rapids lie between Little Quinnesec Falls and the month of Sturgeon River. They receive this name because the Indians, in making their "carry" around part of them, passed over a large amount of sand. The rapids are scattered along a distance of 6 miles, in which space there is a descent of 60 feet. About half of this amount is concentrated in the 11/2 miles between the falls and the old cable bridge or ferry below. As the topographic map shows very high banks, fairly close together, a head of 25 feet or more may some day be developed here. The Chicago and Northwestern Railway is distant only 1.5 miles.

Between the above described dam site and a point 2.5 miles below, the river descends 27 feet. A point due south of Norway, Mich., and on the road leading from that city is probably the best location for the dam to develop this fall, but even here a dam not less than 700 feet long would probably be required.

Menominee River descends but 6 feet between this point and the mouth of Sturgeon River. This may be considered a part of the Sturgeon Falls power.

Michigan Geological and Biological Survey. Publication 7, Geology 5, Plate VII.





DAM AND HYDROELECTRIC PLANT OF THE PENN IRON MINING CO., STURGEON FALLS, MENOMINEE RIVER.

Sturgeon Falls.

From below the mouth of Sturgeon River to a point just above Pemebonwon River, a distance of 10 miles, the drainage area increases from 2,934 square miles to 2,993 square miles. In this stretch are Sturgeon Falls, one-half mile below the mouth of Sturgeon River, in Sec. 27, T. 39 N., R. 29 W. These Falls have high rock-ledge banks, with two pitches aggregating.13 feet. By backing the water a distance of about 3 miles this head could be increased to 15 feet. At the head of the falls the river narrows to about 200 feet, but at the foot it spreads out into a broad basin. In order to use the power it will probably be necessary to blast out a race in the rocks or build a flume and locate the mill at or near the foot of the rapids. This fall has been recently developed by the Penn Iron Mining Co. to furnish electric power for its mines at Vulcan and Norway. (Pl. VII.)

In the next 10 miles the river descends only 17 feet, with a fairly even grade, except for two or three small rapids. The largest of these, Nose Peak Rapids, is about 1,000 feet long and descends about 4 feet.

Pemena Dam and Rapids.

A logging dam which, together with the adjacent rapids, gives a fall of 14 feet in a distance of a quarter of a mile, is located in Sec. 30, T. 38 N., R. 28 W. The Minneapolis, St. Paul and Sault Ste. Marie Railway crosses the river 21/2 miles above the dam and passes within a fraction of a mile from it. The operation of a dam at this point for lumbering purposes greatly lessens the amount of available power.

From below Pemebonwon River to a point just below Pike River, a distance of 18 miles, the drainage area increases from 3,156 square miles to 3,566 square miles. Pemena, Chalk Hill, and White rapids occur in this distance.

About a mile above the mouth of Pemebonwon River, in See. 16, T. 37 N., R. 28 W., the Pemena rapids begin. They extend for a distance of about 2 miles, with a total descent of 20.2 feet.[9] The river bed is a metamorphic slaty schist, and the location is said to be favorable for a dam site. The Wisconsin and Michigan Railway runs parallel to the river at this point and is only 2 miles distant, and the Minneapolis, St. Paul and Sault Ste. Marie Railway crosses the river a few miles above.

[9] This statement is based on an accurate profile of the river, prepared by Mr. T. W. Orbison, C. E. from his actual surveys. The statement made in the Tenth Census, Vol. 17, p. 61, that the total fall is 70 feet, is evidently an error.

Chalk Hill Rapids.

In the 11 miles between the foot of Pemena rapids and the head of White rapids the river descends 38 feet, the grade being even except for three small rapids of from 3 to 6 feet each. Chalk Hill rapids, the most important of these three, are located in Sec. 6, T. 36 N., R. 28 W. They run over a slaty rock at a point said to be suitable for a dam, and if developed in connection with other falls about half a mile above would give a total head of 8 feet or more.

White Rapids.

Four miles above the mouth of Pike River, in Sec. 29 and 31, T. 36 N., R. 28 W., are the White rapids. The bed of the river is said to be gravel and boulders, and the banks are high enough to give a head of 30 feet, thus developing the fall for 3 miles. Even above this limit the river descends 10 feet in 11/4 miles. A head of 30 feet at ordinary low water would develop 5,350 theoretical horsepower.

From below Pike River to a point just above Little Cedar River, a distance of 25 miles, the drainage area increases from 3,566 to 3,792 square miles.

All the rapids thus far described have been over the pre-Cambrian crystalline rocks. In the next 28 miles the river crosses the Cambrian sandstone and "Lower Magnesian" limestone. No falls or rapids worthy of note occur until Grand Rapids are reached, immediately above the mouth of Little Cedar River, in Sec. 5, T. 34 N., R. 27 W. These rapids are caused by a descent over hard "Trenton" limestone, underlain by softer strata. They have a fall stated at 25 feet in a length of 3 miles, but of this fall only that in the lower 2 miles, amounting to 18 feet, can be cheaply developed. Both the Wisconsin and Michigan and the Chicago, Milwaukee and St. Paul railways pass within 2 or 3 miles of the site.

From below the mouth of Little Cedar River to the mouth of the Menominee, 23 miles, the drainage increases from 3,941 to 4,113 square miles.

Twin Island Rapids.

These rapids are situated about 7 miles below the Grand rapids and 16 miles from the mouth of the river. They extend for three-fourths of a mile and are said to descend 10 feet. The two islands lie one below the other, dividing the river into east and west channels. The bed of the river is limestone, the banks are steep, and a dam could be built across each channel to the islands. The total length of such dams is estimated at about 700 feet. A sawmill with a 6-foot head once occupied the east channel.

Schappies Rapids.

Located about 5 miles from the mouth of Menominee River, in Sec. 19, T. 32 N., R. 27 W., Schappies rapids extend for a distance of about a mile. During the winter of 1897 a survey was made of these rapids by a competent engineer, Mr. C. B. Pride, at a time of extreme low water. He found a discharge of 2,370 second-feet and determined that a head of 18 feet could be economically obtained. This power belongs to the Menominee River Boom Company. The Chicago, Milwaukee and St. Paul Railway is located about 3 miles distant.

Marinette and Menominee Dams.

The last series of rapids is found at Menominee. Michigan, near the mouth of the Menominee. The natural channel probably had about 12 feet descent here, but the Menominee River Boom Company built three dams, one above another, the upper one backing the water to the foot of Schappies rapids. The first of these dams, 850 feet long, located about 3 miles from the mouth of the river, develops a head of 7 feet.[10] Power is applied to two paper and pulp mills owned by the Marinette and Menominee Paper Company and also to a flouring mill. No statement of the turbine installation at the paper mills is made, but that at the flouring mill is 95 horsepower.

The third dam from the mouth is located on the west line of Sec. 1, T. 30 N., R. 23 E., (Wisconsin). This dam is 940 feet long and has a head of 18 feet. The middle or second dam is located about a quarter of a mile below the third dam and is 700 feet long, with a head of 7 feet. It is used for boom purposes only. The Marinette and Menominee Paper Company mill is located just below this dam, but it takes power through a canal from the third dam. Its turbines therefore work under a total head of about 24 feet.

The owners of these three dams state that each could be raised from 5 to 10 feet higher than at present.

[10]Data regarding the Marinette and Menominee dams furnished by the owners.

FORD RIVER.

Ford River drains a very narrow belt in eastern Dickinson, southern Marquette, northeastern Menominee and southern Delta counties. The headwater portion lies near the line of the Escanaba and Lake Superior Railway and some development of the water power has been made in connection with the lumbering operations. Most of the stream, however, flows through a region but sparcely settled so the power remains largely undeveloped. There are numerous short stretches of rapids along its course which will admit of development into valuable power.

ESCANABA RIVER.

The Escanaba River stands next to the Menominee in advantages for water power development and for some years a record of gage readings near the mouth has been maintained by the Michigan Geological Survey, the results of which are given in Water Supply Papers 97, 129, 170, 206, 244, 264. (U. S. Geological Survey.) The average low water flow which can be depended upon is about 500 second-feet as reported by P. L. Utley, Manager of Escanaba Traction Company.

The stream has its rise in the elevated granite area northeast of Lake Michigamme at an altitude of more than 1,000 feet above Lake Michigan and in its course to the lake drains a large part of southern Marquette County as well as portions of Dickinson and Delta counties. Its drainage area is estimated at 800 square miles.

There are numerous small lakes and marshy tracts in the head water portion as well as a prevailing loose-textured drift, all of which tend to equalize the flow. But the lower portion from below the junction of the main stream with the West Branch, west of Lathrop, is through a tract of boulder clay in which the run-off is much more irregular and this disturbs to some extent the regularity of the flow of the river near its mouth where the stream measurements have been made.

The most notable fall on the river is located about four miles northwest of Princeton and is known as "The Cataract" (a view of which is shown in Plate 9). The cascades and rapids give a descent of nearly 100 feet in less than one mile.

There are rapids for several miles in the lower course of the river which are being developed by the construction of two dams 20 and 32 feet in height the lower of which is already in operation for electric power and light for Gladstone and Escanaba. Just above these is another power undeveloped which will furnish 30 feet. Rapids farther up the river near Cornell in T. 41, R. 24 W., are also reported by Mr. Utley to afford good conditions for power development. A fall of 100 feet in 5 miles could-be developed by building two dams about 50 feet head each.

A. RAPIDS ON STURGEON RIVER NORTHEAST OF LORETTO.

B. FALLS ON THE MICHIGAMME RIVER ONE MILE NORTH OF MANSFIELD.

RAPID RIVER.

This small stream with a drainage area of about 130 square miles rises in southeastern Marquette County at an altitude about 500 feet above Lake Michigan and makes the descent to the lake in 30 to 35 miles, its mouth being at the head of Little Bay de Noc. Owing to the fact that its flow is through a clay country it has a rather low minimum discharge and rather high freshets. Cascades and rapids occur for a few miles above its mouth which may justify some outlay for power development. One cascade about 7 miles from the mouth is perhaps 20 feet in height.

A. FALLS ON THE ESCANABA RIVER WEST OF PRINCETON.

B. GORGE BELOW FALLS ON THE ESCANABA RIVER, WEST OF PRINCETON.

WHITEFISH RIVER.

This stream drains the northern end of the basin which is partly occupied by Green Bay and discharges into the head of Little Bay de Noc. The drainage area is only about 350 square miles and is largely a clay plain subject to great variation in run-off and a low minimum discharge. Its headwaters are on the western rim of the basin at an altitude fully 400 feet above Lake Michigan, or nearly 200 feet above the axis of the northern end of the basin at the divide between the Whitefish and the Au Train River. At Trenary the stream is about 250 feet above Lake Michigan, and there is a rock bed in much of its course below that village, in which rapids and small cascades occur which may justify considerable outlay for power development.

STURGEON RIVER.

Sturgeon River which enters near the head of Big Bay de Noc has a drainage only about one-fourth as large as the stream of the same name which flows into Lake Superior, but its entire drainage basin is in an area of lakes and pervious drift which tend to give it a regular flow. Its source is nearly 400 feet above Lake Michigan and its length about 40 miles. At present its drainage basin is very sparcely inhabited. It is unlikely, therefore, that water power will be developed in the near future although the conditions for developing it are otherwise favorable.

MANISTIQUE RIVER.

This river has the largest drainage basin of any stream whose basin is entirely within the northern Peninsula, the area being about 1,400 square miles. The basin is largely a sandy plain with rapid slope southward to the limestone escarpment which borders the north shore of Lake Michigan and through which the stream breaks at the city of Manistique. Much of the basin is in a swampy condition and efforts are now being directed to draining the swamps rather than to constructing dams to hinder the discharge of the water. There are large storage reservoirs in the Manistique lakes on the eastern border of the basin which favor the development of power in the vicinity of Germfask.

LAKE HURON DRAINAGE IN THE NORTHERN PENINSULA.

There are two small streams, Carp River and Pine River, each with a drainage basin of about 150 square miles, which discharge into St. Martins Hay at the extreme northwest end of Lake Huron. Carp River drains a limestone area and has a few rock rapids at which power might easily be developed. Its basin is however at present very sparsely settled.

Pine River drains a clay basin and has its course through a wide gap in the limestone escarpment so it is free from rock rapids. The headwaters on the western border of the basin are in sandy swamps which tend to maintain a steady flow through the dry season. These streams unite just below Rudyard at an altitude not more than 75 feet above Lake Michigan though distant 15 to 20 miles by the course of the stream. In this basin as in the Manistique there has been an effort to increase the run-off by ditching so that any water power development would be likely to offset some of the advantages of the improvements made by the artificial drainage.

CHAPTER VII.

WATER SUPPLY—UNDERGROUND WATERS,

In the area of crystalline rocks from the meridian of Marquette westward the glacial deposits alone are drawn upon to any great extent for water, the supplies in the rock formations being as a rule very limited. The glacial deposits are loose textured through out much of this area and water is found in great abundance where ever the deposits have sufficient depth to collect it.

In the sandstone formations on the borders of Lake Superior in the western as well as in the eastern part of the Peninsula water is found in abundance and in some cases flowing wells have been obtained. Such wells are likely to be struck on the low land bordering Portage Lake and around the head of Keweenaw Bay. Few tests have been made for flowing wells since springs abound and wells can often be obtained without entering the rock.

In the Ontonagon basin south of the Keweenawan range there is a thick deposit of clay which often must be penetrated before wells can be obtained. Flowing wells have been struck in the Ontonagon valley at Ewen at a depth of about 200 feet in sandy beds under the clay. It is probable that such wells can be obtained along other branches of the Ontonagon at levels slightly above the streams. The source of supply for these wells is probably in the district to the south where a loose textured drift is present at the surface, and where the altitude is much higher than in the clay covered part of the Ontonagon basin.

For the district east of the Meridian of Marquette the writer has already published in Water Supply Paper No. 160 of the U. S. Geological Survey a special report on the flowing well districts. A map from that report is here presented showing the extent of flowing well districts and also the areas not yet tested in which there is a probability of obtaining flowing wells. (See Fig. 7.)

Fig. 7. Map of the flowing well districts of the eastern part of the Northern Peninsula of Michigan.

The flowing wells are in part from glacial and lake deposits and in part from rock formations. In consequence of the dip of the strata water absorbed in the northern and central parts of this eastern end of the peninsula passes toward the basins of Lake Huron, Lake Michigan and Green Bay, and maintains sufficient head to flow at moderate elevations above these water bodies.

The most important districts with Bowing wells from glacial and lake deposits are found around Pickford, and between Rudyard and Fiber. There are also flowing wells in Emerson at the mouth of Tahquamenon River, and at several points in the Tahquamenon swamp above the falls—in the vicinity of Soo Junction, Newberry and Dollarville as well as in recesses in the moraines west and south of the swamp, notably at Strong and Eckerman and south of Dollarville. The special report may be consulted for data as to depth, rate of flow, temperature of water, etc. The water is generally of excellent quality.

The flowing wells from rock are found at numerous points along the north shore of Lake Michigan and the west shore of Green Bay and the borders of Big Bay de Noc and Little Bay de Noc, where altitudes are but a few feet above lake level. The quality of water is not so uniformly good as in the flowing wells from the drift since it sometimes holds in solution minerals which render it salt or bitter or sulphurous. The deep wells are more likely than the shallow ones to have these objectionable properties. Ordinarily wells in rock if 200 feet or less in depth have palatable water suitable for domestic use.

Over the greater part of the eastern half of the peninsula flowing wells can not be obtained, the altitude being too high. But it is not difficult to obtain good supplies of water at moderate depths. The driven wells are seldom more than 130 feet and many are 100 feet or less, while excavated wells are generally 50 feet or less.

The wafer is distributed so irregularly in the glacial and lake deposits, owing to their complexity and variety in constitution, that neighboring wells often vary greatly in depth and one can seldom forecast the depth necessary to obtain a well.

PUBLIC WATER SUPPLIES.

The following data concerning public water supplies of the Northern Peninsula were collected in 1906 and first published in Water Supply Paper No. 160 of the U. 8. Geological Survey. In some cases the data may need revision.

MUNICIPAL AND INSTITUTIONAL WATER SUPPLIES.

Town.	Ownership.	Source.	System.	Remarks.
Atlantic mine	P.	Creek and well		Partial domestic supply from well.
Baraga	P.	Keweenaw Bay		
Bay Mills	P.?	Whitefish Bay	T.	
Beacon	M.?	?		Hydrants for fire.
Bessemer	M.	Springs and impounded water		Springs for domestic use.
Blaney	P.	Creek		Operated by lumber company.
Crystal Falls	M.	Impounded water		
Dollar Bay	P.			Partial distribution for employees of Mining Co.
Escanaba	P.	Little Bay de Noc	D.	
Ewen	M.	Flowing wells		Partial system.
Garden	M.	Rock wells, 104-220 ft.		Partial system.
Gladstone	M.	Little Bay de Noc	D.	
Grand Marais	M.	Lake Superior	D.	
Hancock	M.	Filter gallery	R.	Manual American Waterworks.
Houghton	M.	Springs	R.	Reservoirs, high pressure and low pressure.
Iron Mountain	P.	Infiltration wells	R.	The wells are developed springs.
Iron River	M.	Iron River		
Ironwood	P.	Montreal River	T.	Manual American Waterworks.
Ishpeming	M.	Small lake	G. and D.	Manual American Waterworks.
Lake Linden	M.	Well and creek	D.	Manual American Waterworks.
L'Anse	M.	Spring fed creek	G.	Manual American Waterworks.
Laurium and Red Jacket	P.	Lake Superior	D.	Manual American Waterworks.
Mackinac Island	P.	Lake Huron	R.	
Manistique	M.	Indian Lake	G. and D.	Runs to reservoir in city.
Marquette	M.	Lake Superior	D.	High parts of city have private tanks.
State prison	St.	Small stream		
Menominee	P.	Green Bay	D.	Manual American Waterworks.
Munising	M.	Springs and Lake Superior	T.	Lake Superior for emergency.
Negaunee	M.	Teal Lake	D.	Manual American Waterworks.
Newberry	M.	Tubular wells	D.	
State asylum	St.	Tubular wells	T.	
Norway	M.	Impounded water	R. and D.	Manual American Waterworks.
Ontonagon	M.	Lake Superior	T.	Manual American Waterworks.
Palmer	P.	Springs and wells	Wm.	Partial system.
Quinnesec	M.	Mine water		Chiefly fire protection.
Rapid River and Masonville.	M.	Rock wells, 275 feet	D.	Fire hydrants on flowing wells.
Republic	M.	Springs and lake		Installed in 1906.
Rockland	P.	Springs	Wm.	Partial system.
St. Ignace	M.	Lake Huron	T.	
Sault Ste. Marie	M.	Whitefish Bay	T.	Base of tank 114 feet above Lake Superior.
Stambaugh	M.	Iron River	D.	Manual American Waterworks.
Vulcan		Impounded water		Supplied from Norway.
Wakefield	M.	Sandy Lake		Fire protection.

a. Abbreviations under ownership as follows: P.—Private; M.—Municipal; St.—State.
b. Abbreviations under system as follows: T.—Tank or standpipe; R.—Open reservoir; G.—Gravity; D.—Direct pressure; Wm.—Windmill.

ERRATA.

The author of this report did not have an opportunity to read proof and desires to append the following errata:

Page 25, 5th line from top, read *sandy* instead of *till*.

Page 83, 3rd line from top, read *sheet* instead of *edge*.

Page 35, 14th line from top, read *nearly 470* instead of *only 450*.

Page 51, 9th line from bottom, read *imbedded* instead of *inbedded*.

Page 51, 3rd line from bottom, read *though* instead of *through*.

Page 52, 11th line from bottom, read *4146* instead of *4.146*.

Page 68, 16th line from bottom, read *height* instead of *heght*.

Page 81, near middle, read *350* instead of *250*.