REPORT
OF THE
STATE BOARD OF GEOLOGICAL SURVEY OF MICHIGAN FOR THE YEAR 1903

BEING THE REPORT OF
ALFRED C. LANE
STATE GEOLOGIST.

BY AUTHORITY

1905.
ROBERT SMITH PRINTING CO., LANSING, MICHIGAN
STATE PRINTERS

FIFTH ANNUAL REPORT
OF THE
STATE GEOLOGIST
ALFRED C. LANE
TO THE
BOARD OF GEOLOGICAL SURVEY
FOR THE YEAR 1903.

Contents

LETTER OF TRANSMITTAL.

OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN.

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

HON. A. T. BLISS, *President*.
HON. L. L. WRIGHT.
HON. DELOS FALL, *Secretary*.

Gentlemen—In accordance with the precedent two years ago, I make my report somewhat fuller in the year in which there is no legislative work and include therein, beside the mere account of what has been done, spent, and published, an account of current scientific results which are of interest and not soon likely to find final shape in any other way.

I will, as last year, begin with an account of the state of the areal work, and follow with the discussion of various subjects.

TUSCOLA COUNTY.

Prof. A. C. Davis has completed his contour map of Tuscola county and the engraver is at work upon it. It may possibly be ready to include in this report.

SAGINAW COUNTY.

I have collected further material upon Saginaw county, where borings have greatly multiplied. The United States Department of Agriculture is proposing to undertake a soil map in Saginaw and Bay counties[1] as well as Oakland, for which we have furnished maps, which will be of interest. I do not want to publish a county report on Saginaw county, however, until I can feel that it is reasonably final. There is some reason to believe that the anticlinal which, as I have said, probably passes through Saginaw runs nearly north and south toward Kawkawlin, as is later mentioned in connection with oil and gas prospects generally.

BAY COUNTY.

Mr. W. F. Cooper has prepared his maps of Bay county. Two of them are given herewith as Plate 1. The one is a contour map showing the elevations above sea level. Saginaw bay is about 580 feet above sea level, so that the elevations above the bay may readily be obtained by subtracting this number. Upon this map we have printed in blue a map showing the area of flowing wells of fresh water. Probably a very much larger area would yield flowing wells, but they would have to be deeper and more or less salt. This also shows the shrinkage of these areas.

ARENAC COUNTY.

Mr. W. M. Gregory has continued his work upon this region, and a map and report embodying much of this work is printed in connection with the report on gypsum, Part 2 of Volume IX of our reports.

[1]Letter, Milton Whitney.

WASHTENAW COUNTY—ANN ARBOR FOLIO.

The joint topographic survey of the Ann Arbor sheet by this Survey and the United States Survey, which was referred to in the annual report for 1901; has been completed. The edition of the resulting map by the United States Geological Survey is out before this report. But it has seemed to me wise to issue, as there was a demand for it as a base map for University studies, as Plate II. It is a photolithograph of their original sheet on a larger scale. It also shows (what their map will not show) the area left in wood lot in a county which has now for some time been settled. Elevations were painted frequently on trees and bridges and a number of the more important bench marks are herewith given.

Above tide.

713.507—Ypsilanti, Mich. Corner of North and River Sts., on top of hydrant.
797.043—Ypsilanti. Corner of Summit and Cross Sts., in stand pipe north side; bronze tablet.
881.857—Ann Arbor. University library, in south wall of; bronze tablet.
874.962—Ann Arbor. University Mechanic's Bldg., in masonry 8 feet north of south door and 3 feet below first floor.
842.797—Ann Arbor. Court house, in southeast corner of; bronze tablet.
838.408—Ann Arbor. At northwest corner of Huron and Fourth Sts.; city engineer's bench.
908.551—Whitmore Lake. Near center of S. W. ¼ of Sec. 5, opposite brick hardware store, on root of large oak tree.
819.016—Dixboro. In front of brick school house; iron post. P. B. M.
824.608—Saline. Saline bank; bronze tablet in corner stone.
620.140—New Boston. Highway bridge over Huron river; northeast pier of, on top of rivet.
602.633—Trenton. Corner of Washington and Pine Sts.; on top of hydrant.
587.214—Gibraltar. Edward Hall's residence. U. S. Coast and Geodetic Survey bench.
602.263—Flatrock. In front of Dr. Turner's residence; on root of large maple.
694.650—Milan. West of R. R. station, on north side of road, on root of hickory tree.
863.279—Dexter. M. C. R. R. stone arch, northeast corner of, on top of cap stone.
873.818—Hudson Mills. At cross roads; iron post. P. B. M.
882.925—Dover. At junction of roads, on boulder at west end of culvert.
735.7—Crossroads. Ridgeway.
699.3—Crossroads. Britton.
700.5—Wabash R. R. Britton.
702.5—D. T. & M. R. R. Britton.
700.2—Cone. Wabash crossing.
702.0—Milan. Center of.

Above tide.

691.9—Milan. Bridge.
721.0—York. Center of.
638.2—Maybee. Crossroads at station.

The geodetic or astronomical position of a number of points will also be found tabulated in Bulletins 201, p. 73, and 216, p. 213, of the United States Geological Survey, to be obtained gratis from the Director at Washington. One great advantage of the completion of this quadrangle is that the United States Survey have now engaged Prof. I. C. Russell of the University and Mr. Frank Leverett to prepare a geological map and description of the folio, which will serve as a model and be a great stimulus and aid to students both at the University and at the State Normal College.

THE FOREST RESERVE AREA.

In order to do what the Board could within the sphere of their work as at present defined to aid intelligent progress in solving the question of keeping up the lumber supply which has been so vital to Michigan in the past, Dr. Burton E. Livingston, of the University of Chicago, a native of Grand Rapids, who prepared for the 1901 report an interesting paper on the soil and plant relations of Kent county,[1] was employed to make a similar study of the soil and forest relations of a proposed forest reserve, as shown on the map given herewith, which accompanies his report.

[1]Discussed and some slight corrections made in Science, Aug. 14th, and Oct. 2, 1903.

THE RELATION OF SOILS TO NATURAL VEGETATION IN ROSCOMMON AND CRAWFORD COUNTIES, MICHIGAN.

BY BURTON EDWARD LIVINGSTON.

INTRODUCTION.

That there is a marked relation between the natural vegetation of the State and the nature of the soils has long been known, at least in a general way. To determine exactly what this relation may be, both quantitatively and qualitatively, is, of course, a problem which it will take a long time to solve. A beginning can best be made by a careful study of small areas, and such a beginning was made in 1900 and 1901 by the present author in his study of the distribution of soils and vegetation in Kent county.[1] The investigations reported in the present paper were made in the summer of 1902, the area chosen being those townships of Roscommon and Crawford counties which embrace the lands set aside by the Legislature of 1901 as the Michigan Forestry Reserve, together with portions of certain adjacent townships. The work was carried on under the auspices of the Bureau of Forestry of the United States Department of Agriculture, in conjunction with the Board of Geological Survey of Michigan. A very brief report of the general conditions within the Reserve has already been published by the Michigan Forestry Commission.[2]

The method of attacking the problem was to plot upon a map the nature and extent of the various soil areas, and to do the same with the different types of vegetation. These types are known to botanists as plant societies, formations, or associations, and these are the units used in the study of vegetational distribution.[3] To determine the vegetational types, lists were made of the predominant plants in the different areas, and in the following discussion the types will be characterized by brief lists of the more important forms. Having once marked upon the map these two sets of data—of soil and of vegetation—the relation between the distribution of the two can be quite readily studied. Of course, this study goes hand in hand with the mapping and is not entirely a later deduction.

[1]Livingston, B. E., The distribution of the plant societies of Kent county, Michigan; Ann. Report Mich. State Board Geol. Survey, 1901, pp. 81-103. Idem, The distribution of the upland plant societies of Kent county, Michigan, Bot. Gaz. 35, 36-54, 1903.

[2]Livingston, B. E., The soils and vegetational possibilities of the Michigan Forestry Reserve. Report Mich. Forestry Commission, 1902, pp. 38-40.

[3]For some remarks upon this method of study the reader is referred to the paper on Kent county, loc. cit.

The accompanying map (Plate III) shows all of Roscommon county and the southern half of Crawford county. Careful study was made of Townships 21, 22, 23, 24, and 25 N., Ranges 2, 3, and 4 W.; of Township 26 N., Ranges 3 and 4 W., and of parts of Townships 22 and 23 N., Range 1 W. The total area studied embraces about 600 square miles.

TOPOGRAPHY.[1]

The region consists of a series of ridges and depressions. The former are sometimes several miles wide, but more often narrow; they are always comparatively low, seldom rising more than 150 to 200 feet above the level of Higgins and Houghton lakes, which lie in the center of the Reserve. These ridges are terminal moraines, left by the ice sheet as it melted back at the close of the last glacial epoch. Between them are lower and more level stretches consisting, for the most part, of plains which gently slope downward from the ridge margin to the nearest stream. These were produced by the outwash of materials from the ice margin at the time the moraines were being formed, and their surface has been more or less eroded by water action since that time. Owing to the fact that they were formed by water action, the material of these plains is quite thoroughly freed from finer particles, and thus consists largely of sand. Gravel deposits are very rare throughout the region, and in the true sand plains it is seldom that one finds even good sized pebbles. It appears that the water from which the material was deposited was not moving swiftly enough to transport the gravel, but carried sand and clay. The finer particles, clay and loam, were carried away in the streams, but the sand remained in its present position.

The ridges, on the other hand, are more heterogeneous in composition. They were not so thoroughly washed by water while they were being piled up, and hence contain considerable quantities of finer particles, clay and loam, and of coarser ones, gravel. Sand is the predominating substance in their composition, however. They are usually bordered by rolling slopes of loamy sand which descend gently to the sand plains. A few of the ridges contain clay enough to make this soil best described by the term clay loam, or even loamy clay.

The whole country is underlain by clay, but this is generally far from the surface, sometimes 100 feet or more. Some of the depressions have clay surface soil. They were probably under cover of the ice sheet at the time of formation of the neighboring moraines and sand plains, or were the bottoms of glacial lakes.

The lowest portions of the depressions, whether these have sand or clay as surface soil, are almost always occupied by swamps or lakes. Through the swamps the very lowest part is often marked by a meandering stream channel, the line of drainage for all the region which lies between the neighboring ridges.

[1]For much valuable aid in interpreting the glacial topography, I am indebted to Mr. Frank Leverett, of the U. S. Geological Survey, in whose company it was my pleasure to make a hasty survey of a large part of this region.

To understand more accurately the mutual relation of these ridges and depressions, the reader is referred to the map (Plate III). Ridge or moraine margins are there denoted in black by a hachured line, the hachures extending toward the depression. Swamp and channel margins as well as the limits of soil areas are marked by full red lines. Rulings in red denote the nature of the soil, as described in the map legend, swamps and stream channels are not ruled. Following is a description of the topography of the region.

From near the center of T. 26 N., R. 3 W., a ridge of gravelly and loamy sand about a mile in width extends eastward and a little southward across T. 26 N., R. 2 W. North of this moraine a gently sloping sand plain extends to the channel of the main stream of the Au Sable, a mile or more distant. Southward there is first a narrow strip of sand—apparently an old glacial channel—and beyond this a somewhat rolling stretch of gravelly and loamy sand rises to a second ridge, very similar to the first, which lies, approximately, in an east and west direction across the southern part of T. 26 N., R. 3 W. The two sand plains connect around the western end of the first named ridge, from which point an embayment of the plain extends southwest for a mile to the southeast corner of Sec. 20 of this township, cutting into the plateau-like rolling plain which borders the second ridge. The northern and western boundary of the lower plain is the channel of the Au Sable, and the swamp which surrounds the marl lake southeast of Grayling village.

From the vicinity of the last named lake the plain extends nearly two miles southwest into T. 26 N., R. 4 W., and is here surrounded by loamy rolling land. From the valley of the small creek which enters the Au Sable near the township line, westward to Portage lake, is a strip of swamp land varying from a half mile to two miles in width, and this is continued west of the lake in the broad swamp through which the Manistee river makes its beginning. The fact that the two river valleys are joined here in this manner made portage possible in the old days, and gave a name to the lake which lies in the line of connection. North of this portage swamp and of the lake, sandy plains extend to the upper Au Sable channel and to the northern limit of our area, except in the northwestern part, where rises the end of another gravelly and loamy morainic ridge. Between the main stream and its north branch lies a block of rather high, slightly rolling, loamy sand, on the northern edge of which is situated the town of Grayling.

In the south central portion of T. 26 N., R. 4 W., lies another ridge of hills, of gravelly and loamy sand, about three miles in length by two in width. North and northeast from this hilly area rolling loamy plains extend to Portage lake and the swamp already described, and to the lobe of sandy land projecting southwestward from the Au Sable channel.

Directly south of the last named moraine is another ridge of somewhat smaller size. Westward and southward it slopes through a rolling loamy plain to a plain of almost pure sand, about half a mile away.

Northward this rolling plain joins the two ridges at their western ends, but between their eastern portions is an area of somewhat clayey loam which extends eastward about three and one-half miles, broadening beyond the ridges until it is nearly three miles wide from north to south. The latter area is level. To the east it joins the hilly clay loam of a long, narrow ridge which extends across T. 25 N., R. 3 W., and almost across T. 25 N., R. 2 W. The last named ridge slopes northward through loamy sand to the sand plain which separates it from the second ridge described. Southward it slopes in the same manner to the most extensive sand plain of our area. This plain extends from north and east of Cheney, southward through the last mentioned ridge by a very narrow valley directly south of the village, thence westward along the northern margin of the Beaver creek swamp to the limits of our map, thence northward to end about a mile south of the Manistee river swamp. East of Cheney it borders the northern edge of the ridge, excepting where its margin bends northward to give place to a small low area of clay which lies just north of the center of T. 25 N., R. 2 W. This area of clay is quite unique in this portion of the region. Southeast of Cheney the gravelly and loamy material of the ridge extends to the channel of the south branch of the Au Sable.

Southward from the Beaver creek swamp the land rises gradually to another ridge of gravelly and loamy sand, which extends along the north shore of Higgins lake and bends southward to end in the southwestern part of T. 24 N., R. 2 W. This ridge is broken through by a sand-bordered swamp a mile north of the center of the western boundary of the last named township. Southward from the east-and-west portion of this ridge, rolling loamy sand extends to the Houghton lake swamp, to Higgins lake, and to the swamp of The Cut, the latter being the outlet of the lake. I am informed by residents that The Cut suffered much deepening and widening some twenty years ago by the driving of logs through it. This very probably lowered the level of Higgins lake several feet, as the well-marked sand beaches of the latter would seem to indicate. Near its beginning the stream passes through a small area of low clay, the northernmost of the group of semi-swamp clays in the vicinity of Houghton lake.

The triangle of dry land lying between the South Branch and its tributary, Robinson creek, is nearly all a sand plain. Near the streams it is loamy and in its southern part rises a small ridge of gravelly and loamy sand. South of the ridge a mile or more of swamp extends to the abrupt mass of hilly land known as the Murray hills, in the northern part of T. 25 N., R. 2 W. These are of sandy clay, rather heavy and excellent for cultivation. South of the Murray hills lie the Jackson hills of gravelly and loamy sand, the two being joined by a plain of loamy sand, and forming together a great island entirely surrounded by swamp. Northwest of the latter ridge is another similar one (T. 23 N., R. 2 and 3 W.), also an island, but surrounded by a band of low clay. Another ridge, of the gravelly type, about one mile in width, follows closely the southern shore of Higgins lake. Southward from the latter moraine, loamy sand extends to the margin of the great Houghton lake swamp and to that of The Cut. A great swamp complex extends from the Muskegon river along the northern shore of Houghton lake, and continues in an easterly direction, southward of the Jackson hills already mentioned, to connect with the swamp of St. Helen's lake. On the west it also extends far to the south, connecting with the maze of swampy stretches which form the valleys of Bear, Wolf, Town Line, Knappen, and Denton creeks. North of Houghton lake are a number of irregular low islands, some of clay loam, some of clay, and some of loamy sand. These are shown on the map and need not be described in detail. West of the lake is a large low clay mass in the southwest portion of T. 23 N., R. 4 W.

South of Houghton lake lies another ridge termed Norway hill, extending from Sec. 3 of T. 22 N., R. 4 W., to Sec. 33 of T. 22 N., R. 3 W. Excepting in its northwestern part, it is surrounded by loamy sand plains, which slope to sandy bottomed swamps on the southwest, south, and northeast. These swamps, in the valleys of Town Line creek, Wolf creek and Bear creek, are cut up in an irregular and fantastic way by dry ridges of loamy sand. The same is true of the swamps lying southeast of Houghton lake, about Denton and Knappen creeks. The highest part of Norway hill contains a considerable amount of clay on or near the surface. About a mile and a half from its northwestern extremity, this ridge is broken through by a clay plain about half a mile in width. This plain bends sharply to the northwest on either side of the ridge, and continues in the direction beyond the end of the latter. West and southwest of Houghton lake are also patches of drained land, and much of the swamp itself has a clay bottom not far beneath the surface.

St. Helens lake (T. 23 N., R. 1 W.) is nearly surrounded by swamp land. East of it is a sand plain which abuts upon the lake at the site of the abandoned lumber town, with its lonely railroad station and school house fast going to ruin. Here, too, at the time of this study, was a small saw mill, cutting into lumber what was still good of the many "deadhead" logs lifted from the lake bottom. This whole region is being improved by a Chicago company and I was told that much of the swampy region will soon be artificially drained. South of the lake a plain of loamy sand rises to a small ridge of the gravelly type, and still farther south to the great hilly area which cuts across the southeastern part of our region. The latter is the northern edge of a broad terminal moraine which can be traced across several counties. It is of loamy soil, partly of the sandy type, but for the most part containing considerable quantities of clay. Northwestward it slopes downward to irregular areas of loamy sand and clay which reach out into the great swamp maze already mentioned.

SOILS.

The soils are nearly all sandy. The only exceptions to this statement are the few low clay areas mentioned in the preceding paragraphs, together with the Murray hills, parts of Norway hill, and portions of the great southern ridge in T. 21 N., R. 1 and 2 W., which are the only ridges which can truly be called clayey. The surface soil of these ridges contains considerable quantities of sand, however. The other ridges are of gravelly and loamy sand, that is their surface soil is mostly of sand, but with a sufficient admixture of fine particles to produce a marked difference in physical properties from that of the true sand plains, while they also contain pebbles and sometimes scattered boulders. The slopes downward from these ridges are of sand, either pure or loamy. They seldom contain many pebbles of any considerable size, thus being more thoroughly washed by water than are the ridges. The true sand plains contain little or no loamy material and no pebbles. They are of a fine, grayish white sand, which drifts readily by the wind when loosened. I have seen the surface soil actually blown away and piled in miniature dunes along the wire fences, in places where the worst of the sandy soils had been attacked for cultivation.

Obviously, difference in degree of water-washing, and hence of sorting of particles, determines these different soil characters. Sandy soils are composed of coarse particles and contain much silica, loamy soils are of finer particles and contain considerable quantities of alumina, while clay soils are of still more finely divided materials and contain a much larger percentage of alumina. Since all of this material was transported to its present position by glacial action, and since it must have been quite thoroughly mixed by this agency, it is reasonable to suppose that, had it not been water washed during and after its deposit, it would be at least fairly uniform in its mineral constituents. The washing process sorted the soils accordingly to size of particles, but also according to their chemical nature. This is partly due to the fact that alumina breaks down into fine particles more readily than does silica. It is also due to the fact that, in well-washed soils, even the less soluble constituents are apt to be actually dissolved and washed out to a greater or less degree. Thus, phosphates and sulphates are usually less abundant in well-washed soils than in those less thoroughly washed.

In this glaciated region, fine soils, such as clay, were either deposited under the ice of the glacial epoch, and hence not well washed, or else they were deposited from deep and very slowly flowing water. The former variety therefore usually contains many coarser particles, as loam, sand, and pebbles. In the case of loamy soils, a good part of the fine material has been washed out, but a considerable amount remains with the sand, so as to give it a loamy character. Since the washing here was not thorough, pebbles are often found amongst the sand and loam. This is especially so of the ridges. The water which flowed over such soils at the time of their formation must have been moving with a velocity such that it deposited or left unmoved sand and gravel together with some finer material caught between the coarser particles, but carried away most of the latter. Sandy soils are still more thoroughly washed; the gravel was left farther up stream, usually on the slopes of the ridges, while the clay was held in suspension, to be deposited at a lower level, where the velocity decreased.

On account of the difference in size of particles which results from water washing, there naturally follows a corresponding difference in the size of the interstitial spaces of the soil; the finer the component particles, the smaller must be the spaces between them. And, because of this, there comes to be a corresponding difference in water holding power and water lifting power. The surface tension of water films is greater, and hence more effective, over small surfaces than over large ones, and film surfaces are greater in coarse than in fine soil. Thus, the smaller the particles of any soil, the more water it can hold and the higher it can lift this liquid from a lower level. Warming[1] quotes Wollny as having shown that quartz sand consisting of grains over 1 to 2 mm. in diameter can hold only one-tenth as much water as that with grains 0.01 to 0.07 mm. in diameter. Schimper[2] states that loose sand has a water capacity of 13.7% of its volume, while clay exhibits this property to the extent of 40.9%.

[1]Warming, R., Lehrbuch der ökologischen Pflanzengeographie, übersetzt von Dr. E. Knoblauch. Bearbeitet von P. Graebner. Berlin, 1902, p. 55.

[2]Schimper, A. F. W., Pflanzengeographie auf physiologischer Grundlage. Jena, 1898, p. 94.

The nature of the soil particles themselves often plays an important part in determining the water-retaining and water-lifting power. Especially is this so in the case of humus, which is composed of organic debris, decayed plant parts and, to some extent, of animal offal. Pure humus has a great power to hold and lift water. This is partly because of its very fine particles, but is also to be traced in part to the actual penetration (by imbibition) of the liquid into the intermolecular spaces of the organic substance itself. Thus, by admixture of humus to a coarse (and therefore porous and permeable) soil, the water-retaining power of such a soil is increased.

The filtering power, or permeability to water, of a soil increases, of course, with decrease in its capillary power. Also, its permeability to air increases in the same way.

A general exposition of this question of size of particles, water-retaining power, etc. is to be found in either of the two works just cited. A much better treatment, however, has appeared in the publications of Briggs[1] and Whitney.[2] The reader is referred especially to the writings of the former author.

[1]Briggs, L. J., The mechanics of soil moisture. U. S. Dept. of Agric., Div. of Soils, Bull. 10, 1897.
Investigations on the physical properties of soils, U, S. Dept. of Agric., Field Operations of the Div. of Soils, 1900. 1901, p 415-421.

[2]Whitney. M., The Division of Soils, Year book U. S. Dept. of Agric. 1897, pp. 120-135.
Soil Moisture. U. S. Dept. of Agric., Div. of Soils, Bull. 9, 1897.

TABLE I.—SHOWING RESULTS OF ANALYSES OF SOILS OF NORTHERN MICHIGAN.

COMPILED FROM TABLES BY R. C. KEDZIE.

	Location.	Tittabawassee valley.	Mecosta county.	Gaylord.	Missaukee county.	Lake county.	Averages, six samples Crawford and Oscoda counties.
Physical description.	Nature of soil	Clay.	Loam.	Loam.	Loam.	Sand.	Sand.
	Water capacity	51.40	45.40	39.60	39.10	35.30	33.50
	Forest type	Hardwood.	White pine	Hardwood.	Hardwood.	Jack pine.	Jack pine.
Chemical description.	Silica	67.20	75.54	91.92	69.39	92.48	94.22
	Alumina	6.81	10.62	2.93	8.35	2.22	....
	Fe	7.91	3.80	0.90	5.80	1.59	1.88
	Ca	1.64	0.94	0.40	1.15	0.35	0.37
	Mg	1.23	0.48	0.13	0.98	0.30	0.06
	K	1.85	1.96	0.61	1.95	0.73	0.85
	Na	1.15	1.25	0.28	1.15	0.32	0.27
	H_2SO_4	0.30	0.26	0.10	0.25	0.08	0.01
	H_3PO_4	0.49	0.44	0.14	0.28	0.14	0.08
	Nitrogen	0.72	0.12	0.07	0.11	0.04	....
	Organic matter	7.48	2.97	2.20	4.73	1.22	3.16

Chemical analyses of a number of Michigan soils have been made and published by Kedzie.[1] Tables I and II, showing chemical constituents and water capacity, are compiled from his pages. The samples described are all from the portion of the State in which lies the Forestry Reserve. The amount of the different chemicals found in the soils are stated in per cent, of total air-dry weight, excepting in the case of water capacity, which is dry soil volume, and is thus comparable to our retaining power,—although this is not stated in the original papers.

It will be noticed in the tables that sandy soils usually exhibit a marked scarcity of soluble salts. This fact may be explained in part by the "leaching" action of the percolating waters as well as by the thorough washing to which these soils were subjected at the time of their deposition. The water of precipitation percolates rapidly through these porous soils and may often wash the soluble salts down toward the level of the ground water, a process which is termed "leaching."[2]

TABLE II.—RESULTS OF ANALYSES OF JACK PINE SAND NEAR GRAYLING.

COMPILED FROM TABLES BY R. C. KEDZIE.

Condition of soil.		Virgin soil.	Cultivated and green-manured for 3 years.	
			Spurry, vetch and peas plowed under.	Spurry, vetch and red clover plowed under.
Chemical description.	Silica	94.97	94.30	95.02
	Alumina	1.03	0.61	0.49
	Fe	0.86	1.17	0.78
	Ca	0.20	0.24	0.22
	Mg	0.12	0.17	0.15
	K	0.20	0.23	0.30
	Na	0.90	0.58	0.62
	H_2SO_4	0.06	0.05	0.05
	H_3PO_4	0.05	0.04	0.01
	Nitrogen	0.03	0.05	0.04
	Organic matter	1.61	2.50	2.35

In humus soils, it is probably not to the point to determine humus content and water capacity after the humus has been mixed with the lower layers; the effect of the organic substance is very much more marked when the humus lies as a distinct layer on the surface than when it is distributed through the underlying soil. The humus layer acts like a sponge filled with water, and allows the water to pass slowly down into the underlying layers, and thus keep them moist much longer than they would otherwise be. The samples described above were probably taken from surface soil, perhaps reaching a depth of eight to ten inches; nothing is said regarding this question in the reports from which these data were derived.

Table III represents the water capacity of several soil samples collected by the author in Roscommon and Crawford counties. The determinations were made in the Hull Botanical Laboratory of The University of Chicago. In this table water capacity denotes the amount of water which the soil is capable of holding, measured in per cent, of total *volume* of dry soil. This is the only way to secure data which can be used in comparing this property in different soils, as has been pointed out by Whitney.

TABLE III.—SHOWING WATER CAPACITY OF ROSCOMMON AND CRAWFORD SOILS.

Sample, No.	Township.	Soil.	Topography type.	Forest type.	Water capacity, volume per cent.	
					Subsoil.	Surface.
1	21, 4	Clay loam	Plain	Hardwood	43.5	(Humus) 74.1
2	22, 4	Grav. loam	Ridge	Norway	45.9	" 40.0
3	25, 4	Sand	Plain	Jack	37.0	" 38.0
4	22, 4	Loamy sand	Plain	Norway	43.5	Like subsoil.
5	22, 4	Clay	Plain	Hardwood	56.9	Mainly humus (79. + ?)

It is noticeable that the sub-soil of sample 1 has the same water capacity as that of the sample 4, but the surface humus of the former brings the total water-retaining power up to a point far above that of the latter.

The surface of sample 4 was apparently like the subsoil, it contained very little humus.

The discussion of the relation of the nature of the soil to that of the vegetation will be reserved until the types of vegetation have been described.

[1]Kedzie, R. C., The jack pine plains, Mich. Agric. Exp. Sta. Bull. 37. Also 27th Ann. Rpt. Secy. State Bd. Agric. 1888, pp. 207-210.
Idem, The Soils of Michigan, Mich. Agric. Exp. Sta., Bull, 91. Also, 32d Ann. Rept. Secy. State Bd. Agric. 1894, pp. 403-415.

[2]Whether leaching occurs in such soils to a greater extent than the opposite process (i. e. the lifting of soluble salts to the surface layers by evaporation), is an open question. Alkali spots seem far from rare even in humid regions. The whole question seems to need investigation. See Cameron, F. K., Soil solutions, etc., Bull. 17, Div. of Soils, U. S. Dep't. of Agric., pp. 36-39, 1901. Also Means, Thos. H., On the reason for the retention of salts near the surface of soils. Science N. S. 15:33-35, 1902, and some discussion of the same by Hilgard, E. W., The rise of alkali salts to the soil surface, ibid 314-315, 1902.

THE TYPES OF VEGETATION.

The vegetation of the region may be sub-divided into several types or plant societies. These grade more or less into one another, but there are few places where an observer would be puzzled to determine what particular type he was in. There are to be distinguished, four types on the uplands and three on the lowlands. These will be described in the following paragraphs.

I. THE TYPES CHARACTERIZED.

Practically all the area under discussion has been lumbered. A virgin pine forest is almost entirely unknown now, though some of the finest pine of the State was cut here. What hardwood areas there are have been left almost untouched until recently, except for the removal of the white pine originally scattered through "them. But the hardwood, too, is now being rapidly removed, and it will not be long before there will be none left. In the lowlands, the merchantable arbor-vitae or white cedar has very largely been removed, as has also much of the spruce and even considerable quantities of tamarack. In the present description, will be presented first a characterization of the original vegetational cover, as well as this can be determined at the present time. Then will follow a description of the present conditions. The types to be found here are as follows: 1. On the uplands,—A. the Hardwood Type, B. the White Pine Type, C. the Norway Pine Type, D. The Jack Pine Type; and on the lowlands,—E. the Open Meadow Type, F. the Tamarack-Arbor Vitæ Type, and G. The Mixed Type.

1. The Upland Types.

A. THE HARDWOOD TYPE.—There is very little hardwood in the region studied, but what there is is typical of all northern Michigan. Areas so covered have not been so thoroughly lumbered as those covered with pine forests. The original form of this type comprised the following characteristic trees: sugar maple, beech, hemlock, red and American elm, balsam fir, yellow birch, some spruce, and scattered white pine, the latter of enormous size, together with such low forms as raspberry, squaw-berry, Lycopodium clavatum, yew, June-berry, Echinosperum virginicum, American pennyroyal, red-berried elder, Solidago caesia, etc. Maple, beech and hemlock made up three-fourths of the forest, sometimes one and sometimes another of the three being most numerous.

Lumbering has affected this type very little, excepting by the removal of the white pine and some of the hemlock. Hardwood lumbering is now going on in the areas covered by this type, in these operations everything is being removed which is merchantable. Fires have not injured this form of forest to any great extent, and the original humus usually remains.

B. THE WHITE PINE TYPE.—This is typical pinery, often containing little besides white pine. Usually, however, there is an admixture of Norway pine, and often of hardwoods. The type is quite sharply distinguished from the preceding, but not nearly so well marked off from the following type, into which it grades in many places.

As has been stated, there is at present hardly any of this type in the region under discussion. In lumbering, all the pine was removed and the subsequent fires have killed practically all the young growth of this tree as well as the scattering hardwoods. Over vast stretches originally covered with white pine there are now no trees at all. They are regions of dwarfed white and red oaks, red maple, and a number of shrubs. The oaks and maples are rarely more than twice as high as a man; they are burned down every few years, and exist here at all only because of the fact that they sprout from the roots which are seldom killed by the fires. These shrubby oaks and maples thus possess enormous roots which are partially dead or dying, gnarled and contorted and deformed by frequent burning. It is these which are called "grubs" by dwellers in the region. For an interesting description of how maples, oaks, etc., are able to attain to a great age in this manner, and still not be over a few feet in height, the reader is referred to Beal's paper on this subject.[1] It is accompanied by excellent illustrations.

Among the lower forms occurring here may be mentioned the following:—Stag-horn sumach, Monarda fistulosa, brake, huckleberry (Gaylus-sacia resinosa), blueberry (Vaccinium pennsylvanium, canadense and vacillans), sweet fern, Solidago concolor, witch-hazel, etc. The ground between the blackened stumps is now thoroughly covered by densely growing sweet fern, huckleberry, and blueberry, the growth of the former of these being so luxurious that the numerous prostrate logs are often entirely hidden from sight, so that passage through these old "pine slashings" is rendered very difficult.

C. THE NORWAY PINE TYPE.—At the time of lumbering, this type consisted mainly of the species for which it is named, but usually contained scattering white pine and more numerous, though often dwarfed, red and white oaks and red maples. The present aspect of this type is much the same as that of the preceding. The two oaks, red maple, and seedling Norway are the characteristic trees now. Seedling Norways are more numerous than in the preceding type, perhaps because of the greater number of seed trees here as well as the somewhat greater ability of this species to withstand fire than that possessed by the white pine. The low plants are much the same as in the last, Solidago caesia of that type is replaced here by S. juncea, and Liatris scariosa is common here, while in the other group it was of rare occurrence.

C. THE JACK PINE TYPE.—This is the most open of the series and occurs in the most sterile sands of the area. The only trees are the jack pine, scarlet oak, choke cherry, and seedings of Populus tremuloides and P. grandidentata. All but the pine and oak are hardly more than shrubs. The pines occur in two forms, one with a tall trunk and a crown of short branches at the summit, the other with branches longer and extending nearly to the ground. The former is called by lumbermen "black jack pine," the second "yellow jack pine." The shape of the tree is of course caused by its place of growth, the former occurring in dense groups, the latter in the open.

Besides the trees, there occur as characteristic on the jack pine areas the following low plants:—Brake, Solidago nemoralis, the three blue-berries above mentioned (but not huckleberry), bearberry, sweet fern, sand cherry, pin cherry, Andropogon scoparius and furcatus, Danthonia, Liatris cylindracea, dwarf willow, reindeer lichen, etc. This type comprises the worst part of what is called "the plains."

[1]Beal, W. J., Observations on the succession of forests in northern Michigan, 27th annual report Bd. of Agric. Mich., 1888, pp. 74-78.

2. The Lowland Types.

For the most part, the swamps which were originally wooded have not been denuded of forest. Where they contained white pine, that was taken out, leaving the other trees, which protected the undergrowth and soon produced a dense, almost jungle like formation. Within the past few years the merchantable arbor-vitae and tamarack have been removed from these swamps, but there are almost always left enough small trees to produce shade. Also the swamps have not been subjected to burning nearly so often as the uplands, and are generally in much more nearly their original condition than are the latter. The three types may be described as follows:

E. THE OPEN MEADOW TYPE.—This is treeless or nearly so, partly open hay meadow, largely of "blue-joint," (Calamagrostis canadensis), partly of bulrush and cattail marsh, and partly of sphagnum bog. It grades into the other two types.

F. THE TAMARACK AND ARBOR-VITAE SWAMP.—This is the typical swamp of the region. It contains tamarack, arbor-vitae or white cedar, black and white spruce, and balsam fir, which form dense and often impassable, thickets. In some localities the tamarack occupies almost all the ground to the exclusion of other trees, and in other places the same is true of the arbor-vitae. But there is not nearly so much tendency here for these two trees to form separate and distinct types as is found farther south.[1] There the tamarack seems to occupy the portions of the swamp lands which are most poorly drained, the arbor-vitæ growing best in localities where drainage is more thorough, yet still not complete enough for the river swamp vegetation. Here the question of drainage does not appear to play so important a part.

G. THE MIXED SWAMP.—This formation is found near swamp margins, especially where the underlying clay is near the surface. Thus, it often occurs along lines where the hardwood forest reaches down toward the swamp. It may be looked upon as intermediate between the tamarack and arbor-vitæ type and that of the hardwood. There is always a great mingling of species here, Among the trees are: Tamarack, arbor- vitæ, the spruces, balsam fir, white and yellow birch (Betula papyrifera and lutea), black ash, hemlock, mountain ash, sugar maple, Prunus serotina, white pine, June-berry, etc., together with such low forms as raspberry, blackberry, brake, Lycopodium clavatum, yew, alder, and Ilex verticellata. The relative proportions of the different trees vary from one locality to another, and nothing definite can be stated in this regard.

[1]For a description of the conditions further south in the state, the reader is referred to the author's paper on Kent county, loc. cit.

II. THE DISTRIBUTION OP THE FOREST TYPES.

The actual distribution of the different vegetational types is shown by green lines on the accompanying map. (Plate III.) The upland types are denoted letters, each area bearing a letter to denote the type which it represents. Thus H, denotes hardwood, W, white pine, N, Norway pine, and J, jack pine. Thus these letters stand for types A, B, C, and D. respectively. Of the lowland formation the open meadow is represented by the conventional sign for marsh where it exists over broad areas. The extent of the areas occupied by the types F and G was not carefully enough worked out to be placed upon the map.

The main facts of distribution are presented in the following paragraphs. The upland and the lowland types will be considered separately.

1. The Uplands.

The Hardwood Type occurs in this region always in soils which contain considerable amounts of clay. Such soils are always covered to a depth, of several inches with leafmold or humus, and in this layer the seedlings of hardwood and hemlock grow and thrive. The white pine type occurs on the Murray hills, on the most clayey parts of Norway hill, and on the great northwestern moraine, in T. 21 N., R. 2 W. These soils are often as clayey as those of many of the hardwood areas, but are higher and therefore better drained. It also occupies most of the gravelly ridge in T. 25 N., R. 2 W. Very often the swamp margins are occupied by this type, especially where the slopes are not abrupt, a condition which gives humus a chance to collect in and upon the sand.

The Norway Pine Type occupies gravelly ridges and loamy sand plains. The soil here is somewhat better than in the locations held by the next type, but it is generally too poor for profitable general agriculture. As will be seen by a glance at the map, most of the uplands studied were originally covered by this type.

The Jack Pine Type occupies only the most thoroughly washed of the sand plains. Excepting in the northern two tiers of townships and in T. 24 N., R. 2 W. there is practically none of this type in the area. These localities lie in the valley of the Au Sable. The parts lying about the head waters of the Muskegon have abundant plains of loamy sand, but these support the type of Norway pine. This fact has no connection with the rivers themselves, however, for farther down the Muskegon are to be found typical jack pine barrens. The soil of this type is almost worthless for agriculture; it is light and dry, and where the surface is broken it is apt to be wind blown, and often forms small traveling dunes. This has been the fate of many once cultivated fields in the northern portion of the Beaver Creek valley and also still farther north in the neighborhood of Grayling.

2. The Lowlands.

As has been said, the distribution of the lowland types was not worked out with accuracy. Great difficulty was experienced in studying such areas, for the swamps are often almost utterly impassable. The greatest areas of open marsh encountered are marked on the map, as already described. There are doubtless many areas of like nature which were not seen at all, but these cannot be of very great extent. In the swamps the ground is covered with a layer of humus, usually of the nature of peat, and there seems to be no difference in this substance between the sand and the clay areas. Neither is there any apparent difference in the swamp vegetation whether it is upon sand or clay.

THE RELATIONS BETWEEN THE DISTRIBUTION OF FOREST TYPES AND THAT OF SOIL TYPES.

The nature of the types seem to be very closely dependent upon the nearness of the underground water level to the surface, and upon the nature of the soil. The former factor determines at once whether the vegetation shall be classified as upland or lowland. The distinction between these two classes is more evident at first sight than it is after closer study; it is difficult to state just how far the water level may recede from the surface and still support a lowland type of forest. Very few determinations have been made in this regard. Mayr[1] states for northern Wisconsin, that where the water level is less than one inch below the soil surface, the vegetation is of the swamp form, while if it is lower than one or two inches the soil bears white pine or some other upland type. This was on sandy soil. Warming[2] has determined the depth of water level in various soils in Denmark. He finds Juncus and Carex forms holding the ground until the water level is about 9 inches below the surface; with water at a depth of 12 to 15 inches, grasses grow well, forming what we should term a moist meadow. With the water from 18 to 24 inches below the surface all grains grow well; this seems to represent our fertile uplands. With the water still lower the soil becomes poor for grains. Data from natural vegetation have, as far as I know, not been gathered. My own observations are not accurate enough here to be of value.

The more water there is in the soil, the less is the access of air to the roots of the plants growing therein. This is because air diffuses much more slowly when in aqueous solution than in the form of a gas. Gas diffusion is checked by the filling of the interstices of the soil with water, and hence most of the oxygen which reaches roots in wet soil must do so by diffusing as a solute in the water. Since ordinary plants cannot grow without rather free access of oxygen to their roots, it follows that a soil saturated with water is very poorly adapted to their growth.[3] This is perhaps the reason why saturated soils are usually occupied by a vegetation of entirely different aspect from that found on soils which are dryer, thus we have swamp or lowland types of vegetation contrasted with those of the upland. Swamp plants are able to live with a scanty supply of air to their roots, but since uplands plants cannot, it is possible to have too much water in the soil for the well being of the latter. Thus, areas with much water are occupied by typical swamp plants, often probably, because they alone are able to live in this situation.

Besides this primary classification of the vegetation groups into those of upland and lowland, there is evidently another classification lying within each one of these two classes. Thus I have characterized four types of forest on the uplands and three on the lowlands. These types seem also to be dependent upon the nature of the soil, at least in the uplands. The considerations will now be taken up in detail.

[1]Mayr, EL, Die Waldungen von Nordamerika. Munich. 1890.

[2]Warming, R., Bot. Tid. 21, 1897. For a résumé of this paper I am indebted to one of my students Mr. G. H. Jensen.

[3]Wollny, R., U. S. Dept. of Agric. Exp. Sta. Record 4, pp. 528-543, 627-641, 1895. Compare also Plat, V in the Annual report for 1901.

I. Factors Determining Distribution in the Uplands.

(a) The Original Distribution.—Throughout the uplands excepting in the narrow swamp borders, and in the low clay plains about Houghton lake, the underground water level is far from the surface. The depth varies from 15 to 75 feet and even more.

Wherever the upland surface lies near the water level, its vegetation takes the form of one of two types, either the hardwood (on the low clay) or the white pine (on the low sand and loam). Farther above permanent water, the former of these types occurs only in one locality, in the northwestern part of the area, and there upon clay loam. Where the water level is not near the surface, the white pine type occurs only on clay and clay loam. The Norway type is found throughout the area on loamy or loamy and gravelly sand, and the jack pine type appears exclusively on sand which is hardly at all loamy, and thoroughly washed. Now and then there are found a few trees of jack pine (without, however, the other character trees of the type) in the loamy sand where the Norway predominates. I have seen some very small stretches of sandy land even on the great southeastern ridge, where jack pines were mingled with the stumps of the white pine and the small white and red oaks and red maples. But the purpose of the present classification is not to consider individual trees, but the complexes characterized by certain species. Thus, the occurrence of a few trees of a different type is not to be considered as invalidating the predominant type, especially since these are not accompanied by the other characterizing species.

The distribution of the upland types just described may be tabulated as follows:

TABLE IV.—RELATION OF WATER LEVEL TO VEGETATION TYPE.

	Position of Underground Water Level.	
Soil.	*Near Surface.*	*Deep.*
Sand	B, C	D
Sandy loam	B, C	C
Clay loam	A, B	B[1]
Clay	A, B	B

In the above table the different types are denoted by the letters already used in their description. It will be noticed that from clay to sand, with water level deeply seated, we have a series passing from the white pine type to that of the jack through the Norway. A single exception to this is the hardwood area on clay loam in T. 25 N., R. 4 W., to be spoken of in a later paragraph. But with the water level near the surface, the series runs from the hardwood of the Norway type, the jack pine not occurring at all. This observation seems to agree with those made by Mayr[2] in northern Wisconsin. He states that sand ridges rising out of a swamp usually bear white pine on the slope, then Norway, and, lastly the jack on the most elevated parts. The same author points out that white pine will grow well on poor sand if the water table is near the surface. This seems to be true here also.

[1]The hardwood in T. 25 N., R. 4 W.

[2]Mayr, H., loc. cit., p. 207.

To explain the distribution of the different types, either of two hypotheses may be resorted to. As has already been mentioned, the finer the particles of a soil, the greater its power to lift and hold water above the underground level. It is well known, too, that some soils contain more of certain salts than do others. Thus, the reason for the observed distribution on the uplands may be sought for either in the water-retaining power of the soil or in its chemical constituents.[1] That the depth of the water table itself sometimes plays an important part in determining plant distribution is shown by the above table. Along a swamp margin the increased amount of water may influence the plant growth directly. But how much of this observed influence is to be considered as indirect, is an open question. The presence of water alters a number of other soil factors. First, it checks free access of air. Thus, if jack pine roots need more air than those of Norway, this might explain why the former fails along swamp borders and the latter takes its place.

Secondly, with increase in water content, there follows a more equal distribution of the dissolved salts, for these can diffuse only through continuous water films, and the greater is the cross section of the latter, the more rapidly will diffusion take place. As a corollary to this statement, it follows that "leaching," the washing down of soluble salts out of the upper into the lower strata, cannot occur in a soil which is constantly filled with water. Moreover, in a moist or wet soil, if not in a, dry one,[2] the upward diffusion of salts during dry times would probably more than counteract the downward washing during heavy rains. The upper layers of a wet soil are apt to have more soluble salts after they have lain for a time than when first placed. This is, of course, on account of the evaporation at the surface, which increases the concentration of the soil solutions in the upper layers.[3] Of course this indirect effect cannot be exhibited unless there is a sufficient amount of salts in the more deeply lying soil. But in a glacial region such as this there can be little doubt as to the presence of these salts relatively near the surface.

Thirdly, the checking of the air access, coincident with the filling of the pores of the soil with water, must check the process of oxidation and accelerate the formation of humus.

Fourthly, the growth of the micro-organisms of the soil, the soil bacteria, etc., takes place much more rapidly in a moist than in a dry soil; they need moisture for development. However, excess of water is also deleterious to the growth of many of these organisms, so that a soil may be too wet for them. But flooding is not so fatal in sand as in finer soils.[4] It is well known that soil bacteria and micorhizal forms are very important in increasing the amount of nitrates in the soil, and thus it appears that a moist soil, even a wet soil if it be sandy, will gain nitrates much more rapidly than a dry one.

[1]For early papers on this subject see:

Thurmann, J., Essai de phytostatique appliquee à la chaine du Jura, Berne. 1849.

Nägeli, C., Sitzungsber. Akad. Wiss. München. 1865. Unger, Ueber den Einfluss des Bodens auf die Verteilung der Gewä chse. Wien. 1836.

A more recent paper dealing with this question of soil physics and soil chemistry as influencing vegetation is the following: Cowles, H. C., Bull. Amer. Bureau of Geog. 2: 1-26. 1901.

[2]See footnote, p. 16.

[3]Dr. Cameron of the U. S. Bureau of Soil, tells me that most soils have more soluble salts near the surface than in deeper layers.

[4]Gain, R., Action de l'eau du sol sur la végétation. Rev. Gen. Bot. 7: 16-26, 17-84, 123-137, 1895.

Fifthly, the curve of temperature changes in a moist soil is much flatter (i. e., the changes are less marked) in a moist than in a dry soil. This has been proved before,[1] and I have been able to substantiate it with Lake Michigan sand in pots. Rapid changes of temperature act deleteriously on plant growth. This is another reason for a dry soil supporting only the more hardy forms of plants.

The chief points of difference between a moist and a wet soil may be tabulated as follows:—

TABLE V.—DIFFERENCES BETWEEN DRY, WET AND MOIST SOILS.

Condition of soil.	Dry.	Moist.	Wet.
Water for roots.	Too little.	nough for most plants.	More than needed for most plants.
Soluble salts, origina y near surface.	Sometimes leached downward.	Still near surface.	Still near surface.
Soluble salts originally in low layers.	Questionable.[2]	Partly in upper layers.	Partly in upper layers
Humus contents.	None.	Some.	Plentiful.
Oxygen content.	Plentiful.	Some.	Little.
Micro-organisms.	None.	Optimum.	Few.
Nitrates.	Little.	Much.	Some.
Temperature changes.	Rapid and great.	Intermediate.	Slow and small.

Whether it is determined by nearness of the underground water level of by the capillary power of the soil, there appears to be no doubt that the amount of water in the layers near the surface of a soil practically determines the nature of the vegetation in this region. Besides the general discussion of this matter to be found in Warming and Schimper (loc. cit.), the reader may refer to Gain[3] and Hedgcock.[4]

The other hypothesis for explaining these differences in vegetation rests on the chemical differences in the soils shown in the tables of analyses by Kedzie. From these tables it will be seen that the worst sands are not utterly lacking in any salt needed by plants. But it will be observed that there is a difference in the amounts of these salts found in the different soils, and it may be assumed that these differences are great enough to explain the variation in forest type. But the fact that exceedingly small amounts of mineral matter are needed by plants, together with the fact that all the necessary salts are present in considerable amount, makes this hypothesis exceedingly improbable.[5] From culture experiments with plants the author is convinced that the vegetation of the worst soils here discussed does not suffer from want of salts.

[1]Gain, E., Rev. Gen. Bot., loc. cit., p. 18.

[2]See footnote, p. 6.

[3]Gain, R., Recherchesur le le physiologique de l'eau dans la végétation. Ann. Sci, Nat. Bot. VII, 20: 63-215. 1894.

[4]Hedgcock, C. G., Botanical Survey of Nebraska: Studies in the vegetation of the state II. Lincoln. 1902.

[5]Since the preparation of this paper a similar conclusion has been reached in regard to sterility in agricultural soils by Whitnet & Cameron in Bulletin 22, Bureau of Soils, U. S. Dep't of Agric., 1903. Also, it has been shown by actual field test that coarseness of soil particles alone can produce a sterile soil, in spite of a plentiful supply of salts. See Livingston, B. E., and Jensen, G. H., an experiment on the relation of soil physics to plant growth. Bot. Gaz. 38: 67-71, 1904.

It appears here, as in Kent county, that the hypothesis of Cowles[1] that the nature of the vegetation depends upon the physiographic stage, will hold in a general way. The physiography of the Southern Peninsula of Michigan depends very largely upon glacial topography, however, so that if we wish to trace backward beyond the soils the chain of cause and effect which determine plant distribution here, we come at length upon the purely geological agencies which, at the end of the last glacial epoch, caused one locality to be left a till moraine, another a sandy or loamy one, and still another a sand plain or clay plain, or a pond.

Of the upland series, the hardwood type of vegetation seems to need the most water, the most soluble soil content, and the most humus. Probably this is the reason why this type occupies the moister soils of the uplands, no matter whether these are moist through nearness to the underground water table or through greater lifting power of the soil itself. The types of white, Norway, and jack pine seem to require less water in the order of their arrangement. Probably the Norway and jack require more air in the soil than either the hardwood or the white pine. The typical tree forms of both the last named types occur in the mixed swamp quite commonly, but I have yet to see either Norway or jack pine in soil which is wet the greater part of the year. Throughout the region it seems that each type occupies soils which correspond in water content to its needs. It must be remembered here that a sand or loam soil near the water level may contain much more water than one of loam or clay where the water is farther from the surface. This idea offers, perhaps, an explanation for the occurrence of hardwood on low loam in T. 25 N., R. 4 W. Addition of surface humus has also perhaps, raised the water-holding power of the soil to the neighborhood of that manifested by clay itself. The subsoil is such here that the white or Norway type might be expected.

[1]Cowles, H. C., The physiographic ecology of Chicago and vicinity; a study of the origin, development, and classification of plant societies. Bot. Gaz. 31: 73-182. 1901. Idem, the plant societies of Chicago and vicinity. Bull. Geog. Soc. Chicago, 2: 1-76. 1901.

(b) The present distribution: The statement so frequently met with that the white pine will not come up after it has once been cut off and the ground burned over, seems to strike wide of the truth in this region. The writer visited almost every square mile of the uplands, and he is thoroughly convinced that scattering seedlings of white pine are now evident on practically all areas originally covered by that species, which have not been recently subjected to the action of fires. Seedlings of the Norway are now, however, more numerous on these areas than are those of the white itself. They are plentiful throughout the region on light soils excepting the very lightest. Fires destroy the young growth of the white pine and also prevent humus formation. Thus, as long as the fires are allowed to occur so frequently, the water capacity is not apt to rise and the growth of nitrifying bacteria is not apt to increase. But the presence of the few white seedlings is evidence that the species can grow if protected. Indeed, the best young stands of any kind that I have seen are of this tree, and they promise exceedingly well for reforestation.

As has been said, the Norway is coming in quite freely in the areas originally covered by this species and by the white. The degeneration goes no further, however; I have almost never seen even individual jack pines appearing in any of these areas. Indeed, there is evidence in some places that the Norway is rapidly advancing its seedlings into the areas held by the jack.

The hardwood forest reappears quite rapidly when cut. This is doubtless in part due to the fact that this material does not burn so readily nor so violently as do the pines. The scattered white pines which formerly characterized these forests in the eyes of the lumbermen, are not returning. They were perhaps only a relic of a past generation of forest.[1] Hemlock is reproducing well and will return with the beech and maple if, through lack of humus, the soil does not become too dry for the seedlings. The sugar maple is best for reclaiming cut over lands. Its saplings stand close together and do not seem to suffer from one another's shade, while they prevent the dying out and oxidation of the surface soil.

The work of Sherrard[2] in this region resulted in a map and statistical study of the tree growth of township 25 N., R. 4 W., as well as a general discussion of the forestry conditions of the reserve. The township thoroughly studied originally contained practically no white pine, but the other types are well represented here. Sherrard's oak flat and oak ridge are all originally Norway land. For statistics of growth, etc., the reader is referred to his paper.

[1]See the author's Kent county paper, loc. cit., also Whitford, H. N., The genetic developement of the forests of northern Michigan. Bot Gaz. 31: 289-325. 1901.

[2]Sherrard, T. H., The Michigan Forestry Reserve. Rept. Mich. Forestry Commission. 1902. pp. 28-54. 1903.

2. The Lowlands.

The three types of lowland vegetation seem to follow in some degree the conditions of soil moisture. In this case it seems better, however, to arrange the types in the reverse order, and to present them as following conditions of drainage. As has been stated, all three types are composed of forms which can withstand a great deal of moisture. No positive evidence can be given as to whether or not there is any difference in water content between the soils of the open meadow and those of the tamarack and arbor-vitæ forest. Nothing has been made out regarding the conditions which decide in favor of one or the other of these. But the mixed type is always found on the better drained portions, where there are hummocks raised out of the saturated soil, and where the general level is a few inches higher. Often this better drainage seems to come about merely by accumulation of vegetable debris, a fact which suggests that perhaps in time the conifer swamp might give way to the mixed, and this at last possibly to the hardwood.

Attention has already been called to the fact that this series of types has not been seriously altered by the hand of man. The large white pines have been taken from the mixed swamp, as have also many of the most valuable tamaracks and arbor-vitæs, but the forest conditions have not generally been destroyed.

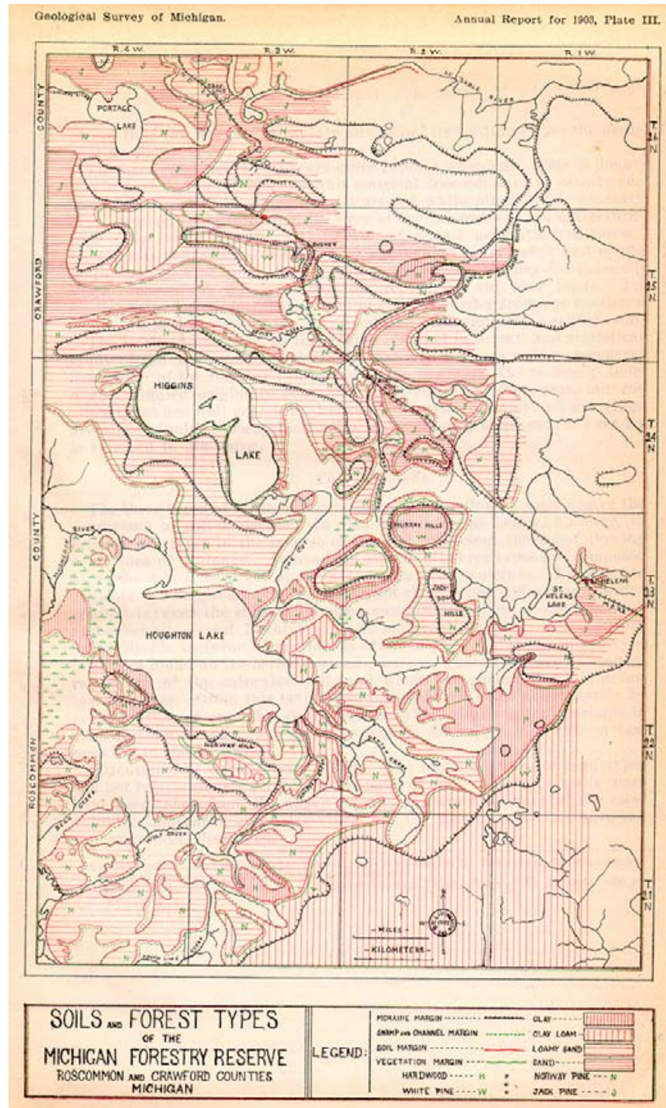

Plate III. Soils and Forest Types of the Michigan Forestry Reserve. Roscommon and Crawford Counties, Michigan.

RELATION OF THIS REGION TO KENT COUNTY.

The predominance of the pines in the region tinder discussion is an expression of the fact that the flora here is a typically northern one. Only one pine is found in Kent county, and there it grows in poorer soil than it holds here. The presence there of hickory, and the better growth of the black, red, and white oaks, is an indication of a more southern flora. The factor which keeps the jack pine out of the more southern county can hardly be one of latitude merely, for this species occurs along with the white pine on the dunes at the extreme southern end of Lake Michigan.

The hardwood forests of the two regions are very nearly the same in character. In the northern part of Kent county the hemlock begins to play the important part with the hardwood which we find it playing farther north.

A study of the transition zone between these two areas will be necessary before the working out of the exact relation of the various societies can be attempted.

RELATION OF THIS REGION TO THAT FARTHER NORTH.

The student of plant distribution who has formed any definite theories as to the relation of plant societies to topography and soils from working in the southern part of the State and in Indiana and Illinois, will be much surprised, if not actually shocked, by a visit to the region of the Straits of Mackinaw. On the island of Mackinac, for example, occur most of the tree forms found in Kent county, but growing, apparently, without relation to the soil condition. Norway and white pine, beech, sugar maple, red maple, tamarack, arbor-vitae, balsam fir, spruce, basswood, hop hornbeam, etc., will be found growing side by side on well drained uplands, in clay or sand or loam, or even upon partially bare rock. As to why this is, nothing can be said before more of the State has been studied in detail. It is useless to conjecture at the present time, although the problem appears to be a fairly easy one to answer.

THE FUTURE OF THE REGION.[1]

Since there has been considerable discussion in the state concerning the utility of these lands for various purposes, it may be well to consider this subject briefly here. On the uplands most of the different kinds of soil have been tested for agriculture, the clay hills and the clay plains, both of comparatively small extent, make excellent farming land. The gravelly and loamy sand of most of the ridges is easily tilled, and, with enough care, yields good crops, but the soil is too light, and the amount of energy necessarily expended in cultivation is much greater than in heavier soils.

[1]This has, in part, already appeared in the report of the State Forestry Commission, loc. cit.

On the worst sand plains, originally covered with very open stands of jack pine and scarlet oak, tillage is almost out of the question. With constant manuring and cultivation, this sand can be held in place and made to produce fair crops, but the expense, in time and energy, if not actually in money, make such crops cost much more than they will actually bring on the market. Some of this land is so situated that irrigation would be possible, and this may some time become a practical line of investment. The grazing of cattle on the Norway and jack pine plains is practicable, and is being carried out successfully by several holders in Roscommon county. Several forms of bunch grass and the shade of the scrubby oaks and pines, are the valuable features. But it requires many acres for a few cattle, and it is doubtful whether the small landholder can ever accomplish much in this direction. Practically all the small holders who are succeeding at grazing, are pasturing their cattle, in good part, on the lands of the State and of other individuals.

The swamps which are abundant in the region, would all make excellent garden land if properly cleared and drained. It appears that the most promising use to which to put the swamps is that suggested by A. C. Lane, of the Michigan Geological Survey, namely, to derive fuel peat from them. Samples assayed from 52% to 75% combustible material.

A number of tests have been made of the ability of the ridges and more loamy plains to support apple trees, with considerable promise of success.

The feasibility of reforestation seems practically proved. Every student of plant growth who has worked in the region[1] has become convinced that the main reason for the failure of natural reforestation here lies in the repeated and destructive fires.

With the fire nuisance removed, it is quite certain that nearly all of the upland area would spring up to seedlings of white and Norway pines. Further than this, it seems very probable to the present writer that, if the land which will now support nothing better were kept covered with Norway forest, it would eventually become (through the accumulation of humus) capable of supporting a good growth of white pine, which might be planted among the Norways when the time was ripe for it. How long this process of amelioration might take, it is useless at present to conjecture; there is no locality in the region which is free from fires, and thus no possibility of collecting data for this purpose.

During the past season much advance has been made by the State Forestry Commission on the Reserve. A thorough mapping is in progress, and the fire nuisance has been largely under control.

[1]A number of such writers are the following:—

Roth, F., On the forestry conditions of northern Wisconsin. Wis. Geol. and Nat. Hist. Survey. Bull. 1. 1898.

Spalding, V. M., The White Pine. U. S. Dept. of Agric., Div. of Forestry. Bull. 22. 1899.

Whitford, H. N., Bot. Gaz. 31: 289-325. 1901.

Sherrard, T. H., loc. cit.

Davis, C. A. Rept. Mich. Forestry Comm. 1902. P. 24-28. 1903.

Roth, F., ibid. P. 34-37.

Skeels, F. E., ibid., P. 40-47.

Beal, W. J., ibid., P. 52-58.

McLouth, C. D., ibid. p. 48-51.

CONCLUSION.

It appears from these investigations that the main factor in determining the distribution of the forest on the uplands of this region, is that of the size of soil particles, the sorting of which dates back, almost entirely, to the glacial epoch. The size of particles determines the amount of air and moisture in the soil, and these in turn determine the amount of humus formation and the growth of nitrifying organisms, and, to some extent at least, the amount of soluble salts.

A factor of less relative importance, because applicable only over small areas, is that of the nearness of the underground water level to the surface. This affects the uplands only along swamp borders.

In a broad way, physiography may be said to determine the vegetational distribution here. The physiographic features depend largely upon glacial topography. Thus geological factors have, in one way or another, determined the nature and distribution of surface soils and the distance below the surface of the underground water level, and so these factors have determined vegetational distribution.

It is probable that many dry soils may at length become moist enough to support one of the more moisture loving types of vegetation, simply by increase in humus content, which must go on slowly at first but more rapidly as the amount of this substance increases. This is merely an application of one of the general principles of forest succession pointed out by Whitford (loc. cit.).

The lowlands are covered with a vegetation which seems to be able to bear excess of water and paucity of oxygen in the soil. From the open meadow and coniferous swamp, we pass, with better and better drainage, through the mixed swamp to the hardwood or the white pine of the uplands.

It appears that the natural reforestation of the pine areas with the Norway, and, to some extent, at least, with white pine, is practicable if the fires can be suppressed. Orcharding gives some promise of success on the ridges and loamy plains, and, together with Forestry, offers probably the best use to which to put this region which contains so little good land for general agriculture. The New York Botanical Garden, December 7, 1903.

Dr. L. L. Hubbard's work on the felsitic areas on the end of Keweenaw point gave us such a new idea of their field relations and shows that the earlier geological mapping was so inaccurate that it has been deemed worth while to study a similar area in the Porcupine Mountains in some detail. This was begun some time ago under his direct supervision but has been continued by Mr. F. E. Wright, Assistant State Geologist, last summer. Part of his report of progress is given herewith.

REPORT OF PROGRESS IN THE PORCUPINES.

BY FRED EUGENE WRIGHT.

REPORT ON THE PROGRESS MADE BY THE PORCUPINE MOUNTAIN PARTY DURING THE SUMMER OF 1903.

The Porcupine Mountain region lies in the northwest part of Michigan not far from the Wisconsin boundary line and is located in the townships and ranges:

T. 51 N., R. 42, 43, 44 W.

T. 50 N., R. 42, 43, 44, 45 W.

T. 49 N., R. 43, 44, 45 W.

In all an area of about 230 square miles.

Observed from a distance the Porcupine hills appear as high, steep ridges and knobs rising from 600 to 1,200 feet above the level of Lake Superior. A bird's eye view of the same exhibits a definite arrangement of these elevations and cliffs, so sharply carved on the land surface as to attract the attention of the most casual observer. If examined closely the influence of the geologic structure of the region, the relation of the rock masses one to another is found to have been the chief factor in moulding the topography to its present form.

The rock formations underlying this area consist largely of eruptive rocks of various types and interbedded sandstones and conglomerates belonging to the Keweenaw series. They have been studied by a number of geologists in the past, chief among whom was Irving and his assistants, who in his classical report on the copper bearing rocks of the Lake Superior region,[1] devotes an entire section to the Porcupine district. He describes in detail several of the typical rocks of the region and their relation one to another, correlates strata found here with those of other districts of the Keweenaw series, and gives an excellent geologic map of the area.

Since Irving's report was published work done by later observers, especially by this survey, has brought to light facts which tend to alter to a certain extent the conceptions held by Irving. The present writer. however, desires to reserve the discussion of the conclusions reached by Irving and later geologists until after he himself has covered the entire region. In the following paragraphs the methods employed on the survey in making the topographic and geologic map will be considered briefly and also several of the salient geologic facts which were noted in the course of the summer's field work.

In order to obtain at once a powerful aid in deciphering the geologic structure of the district the survey decided to make a topographic map of the region in conjunction with the geologic map. The geologic structure has had such a pronounced effect on the land structure of the Porcupine hills that many important points which arc valuable in the structural investigation, can be deduced from a good topographic map alone.

[1]U. S. G. S., Vol. V. Monograph. Pages 206-225.

Accordingly the month of May (May 6—June 6) was spent in establishing bench marks along the range and township lines and roads through the townships. During this time the writer had the efficient aid of Mr. C. W. Corey as Wye level man, Mr. W. R. St. Clair as water level man, and Messrs. C. W. Dodge and H. Dodge as rodmen.

A system of closed levels was run with the Wye level from Union bay along the Nonesuch road to the Nonesuch mine and back to the correction line; then W. to M. W. Cor. Sec. 30, T. 51 N., R. 42 W., then E. to the S. E. Cor. Sec. 36, T. 51 N., R. 44 W., and from there N. along the range line between T. 51 N., R. 43 W. and 44 W. to the lake shore. Wye levels also ran from the crossing of the Nonesuch road and correction line E. to the S. W. Cor, Sec. 36, T. 51 N., R. 43 W., closing on the same B. M. that the water level line along the White Pine road closed on. Bench marks were established at convenient points along the road and on every corner along the correction line and range lines. The bench marks were inscribed on trees as follows:

B. M.
M. G. S.
248.21

the number 248.21 giving the measured elevation above the shore of Lake Superior of a notch cut at the base of the tree bearing the inscription. Care was taken to select good hardy trees which will stand for many years to come. The elevation above sea level can be found by adding 601.19 feet to the given altitude. In all 20 miles of line were run with the Wye level. The usual methods of checking to insure accuracy and to prevent mistakes were used. The error found by checking back to the lake was 0.89 feet for 16 miles of rough forest leveling. The level of the lake on the date of departure and arrival of the party was ascertained at the Government Lake Survey office in Houghton. It is probable, however, that the level was not exactly the same for the coast of the Porcupine hills as at Houghton owing to the seiches and tidal influences. The change in actual lake level may have had some influence upon this result. At the very utmost the error of any bench mark is less than one foot and sufficiently accurate for the aneroid work where 50-foot contour lines are drawn.

Besides the exact Wye level work along the correction line, which is to be used instead of lake level in the future work of the survey in the inland townships, a series of closed water level lines were run from Union bay along the Carp Lake road to the Carp Lake mine and Carp Lake with checks N. along range line between T. 51 N., R 42 W. and 43 W. to Lake Superior, and S. along the range line to Wye level bench mark at the correction line. The Carp Lake bench mark was checked by running up from the lake along a logging road in Sees. 9, 16 and 15 and over ridge into 22 of T. 51 N., R. 43 W. The White Pine road along the E. Tangerine of T. 51 N., R. 42 W. was leveled as far as the correction line where a check on the Wye level bench mark on S. W. Cor. Sec. 36, T. 51 N., R. 42 W. was possible. The average error of the water level work was 0.45 feet per mile. The Wye level party were able to cover on an average 0.8 of a mile daily. The country on the whole was fairly rough and the foliage so dense that long sights could not be taken. An average of 00 turning points were required for each mile. With the water level about twice the distance could be covered in a day or 1.6 miles on an average. In running the level lines through the dense forest it was found necessary to reblaze the section lines and thus clearly mark the path for the leveling parties so that they should not waste time in hunting for old blazes, lines and corners. At the same time future work could be planned most advantageously.

The bench marks thus established served as a basis for the general contouring of the area which was effected by the use of aneroid and barograph. This topographic mapping was carried on in connection with the geologic mapping until the end of the field season (Oct. 1). While accomplishing this latter work the writer had the able assistance of Mr. A. F. Benson as geologist and Mr. W. C. Gordon, Mr. C. W. Dodge, Mr. G. W. Garrey and Mr. C. A. Wright as compassmen, during various periods of the summer.

The lake shore is evidently sinking in the Porcupine Mountain district. The greater part of the coast line is rocky and bounded frequently by reefs of sandstone and conglomerate dipping toward the lake. Along the shore of Sees. 16 and 17 of T. 51 N., R. 43 W. old cedar trees 12—14 inches in diameter are so near the water's edge that their bark for the first two feet has been worn off by the beating waves. They have not reached their present position by individual slipping from the higher protected plane, for the ground immediately behind them is covered by a dense, low marshy cedar thicket. If there had been any slipping the entire outlying belts must be in a similar state of movement as evidences of the sinking of the shore are noticeable along the whole coast line of the map.[1] On the shore S. W. of Lone Rock in Sec. 24, T. 51 N, R. 44 W., dead trees, still upright and firmly rooted in the coarse shingle which lines the coast at this point, stand 6 to 8 feet from the shore and under 6 to 8 inches of water. On the shore of Sec. 17, T. 51 N., R. 43 W. an old fisherman's cabin extends almost to the water's edge. It is apparently on its original site, which, however, must be lower now than at the time of its erection for no fisherman would build a shack within reach of high waves. The old Carp Lake road along the lake shore in Sec. 15, T. 51 N., R. 42 W. had to be abandoned and another built farther inland because of the encroaching lake. Old corduroy stakes slipping toward the lake still mark the course of the former road. A thin belt of swamp and cedar thicket frequently extends along the lake shore for considerable distances (map). Mr. Redner of Bessemer, who has often camped at the old La Fayette landing in Sec. 24, T. 51 N., R. 44 W., states that 10 or 12 years ago the shore of that point was sandy and like the usual Lake Superior beach. At present, all of the finer sand has been washed away and only the coarse shingle remains. Further evidence of the encroachment of the lake on the land is the discrepancy between the lengths of the section lines and shore sections as determined by the original government surveyors and the present survey. The difference is considerable in certain sections. In Sec. 24, T. 51 N., R. 44 W., the shore opposite Lone Rock is low and swampy. The ground 100 paces inland is not over 10 feet above Jake level. At a point 110 paces inland loose shingle was observed covered with a slight coating of vegetable matter and soil. Evidently this shingle was deposited in place by wave action at the times when the lake level was higher than at present. Whether this took place during the period of existence of Lake Superior and is then due to a fluctuating shore line or during the period of the former lakes Great Nipissing, Algonquin or Warren, is a matter of conjecture. The frequent lake terraces at the 100-foot and 500-foot contour level point to old shore lines of the former lakes and render the first idea of fluctation not improbable.

[1]Dr. L. L. Hubbard in Vol. VI, p. 47 of this survey describes the local slipping of large blocks of sandstone at Bare Hill, Sec. T. 58 N., R. 28 W. due to the undermining action of the waves which destroyed the underlying support. See also Rominger in Geol. Survey, Mich. V, PL I, p. 136.

The phenomenon of coastal sinkage in this region was first noted by Mr. Stuntz[1] who cites the sluggish nature of the Ontonagon river near its mouth as evidence. C. K. Gilbert in his "Recent Earth Movements in the Great Lakes Region,"[2] finds that the basin of the lakes has been canted toward the southwest, the exact direction of tilting being S. 27° W. Using the present surface of the lakes as datum plane he bases his conclusions on a thorough discussion of all available data from gage stations, on a series of gage station observations made under his direction on the position of the old shore lines of the vanished Iroquois, Warren, Algonquin, and Great Nipissing, on the observed drowning of streams and formation of wet swampy belts near the shore. In considering the Lake Superior region Gilbert emphasizes the importance of a verification of the observation of Stuntz who found the sinking of the lake shore to be more rapid than that indicated by the gage readings. The establishment of a gage station with a set of precise bench marks near the lake shore would be of great assistance in later years in solving this problem.

In the short time allotted to its work it was impossible for the survey to take up this question and examine it thoroughly and determine, if possible, the approximate yearly sinkage.

Old lake terraces constitute a characteristic feature in certain sections of the Porcupine area. The lake terraces about the 500-foot level are particularly noticeable. On the map of Plate I, the 500-foot contour line follows a sinuous course, completely encircling the range cliffs through T. 51 N., R. 43 W., and also wrapping around the slopes south of this ridge. The appearance of numerous swamps at the 500-foot level in the three townships of the map and the shallow level divide between the N. W. branch of the Union river and Carp river also indicate the presence of a former lake in which the cliffs of T. 51 N., R. 43 W. stood out as bold rock masses. On their N. side the beds of tough conglomerate appear to have imposed a limit on the encroaching waves. At the foot of these north slopes immense blocks and outcrops of this conglomerate are abundant.

Underlying the 500-foot contour belt are sandstones, which succumb easily to erosive agencies. The valley of Carp lake is probably due largely to erosion not of a former river but of the vanished lake which originally covered this area. The sandstones were broken down by the pounding action of the waves, while the more resistent melaphyre belts withstood the process more forcibly and hence stand out at present as imposing cliffs with Carp lake and river valley intervening. The flow of Carp river from Sec. 19, T. 51 N., R. 42 W. to Sec. 36, T. 51 N., R. 44 W. is slow and sluggish. Carp lake can only be counted as a widened part of the river. It is shallow in all its parts and full of weeds. Why the Carp river coming as it does from the southwest does not continue in its easterly direction and enter the Union river instead of bending sharply to the west is one of the problems still unsolved in this connection. The drainage problem and its dependence on the structure is certain to be productive of bountiful results in the future work of the survey in this district. Faulting, especially dip and slide faulting, may have had more or less influence in causing this valley to assume its present shape. Glacial erosion is another factor to be considered. Glacial boulders of variable size occur in many parts of the area, even along the steep north slope of the range of cliffs in T. 51 N., R. 43 W. No distinct glacial striae were observed, however, during the summer's work.

[1]On some recent geologic changes in northeastern Wisconsin: Proc. Am. Ass. Adv. Sci. Vol. XVIII, 1870. pp. 206-207.

[2]Annual Report U. S. G. S., XVIII, Pt. 2: 601-647.

Evidence of faulting were noticed in Secs. 19 and 27 of T. 51 N., R. 42 W., Secs. 21, 22, 29, 30, of T. 51 N., R. 43 W., and Sec. 36, T. 51 N., R. 44 W. At the foot of the steep north and northeast slopes in Sec. 24, T. 51 N., R. 43 W., and Sec. 19, 20, 29, of T. 51 N., R. 42 W., numerous springs approximately along the 550 contour line indicate strongly a probable fault plane. Union spring, in Sec. 20, T. 51 N., R. 42 W., evidently bears an intimate relation to this probable fault plane. Irving[1] describes and pictures a fault of considerable proportions in Sec. 19, T. 51 N., R. 42 W., along the Carp river—his first mention of a fault in this region. The details of this area, however, have not been worked up sufficiently well as yet to admit of a general discussion at present. Along the cliffs in T. 51 N., R. 43 W., block faulting is apparently common. In tracing a bed of melaphyre along one part of the cliff it is not an unusual occurance to encounter a bed of sandstone in the same horizon. The shattered character of the rock at such points, however, points to a probable block faulting and slipping of one part of the rock mass relative to the other.

At the old Lafayette mine in Sec. 36, T. 51 N., R. 44 W., slide faulting[2] seems to have been the indirect agent which guided the copper to its present resting place. The mine is situated at the base of a steep cliff, the continuation of the series of melaphyre ridges across T. 51 N., R. 43 W. The shafts are sunk along the contact of the melaphyre and the underlying sandstone. The melaphyre from the contact to the top of the cliff is more or less shattered and is full of secondary epidote, calcite, and copper. The slide faulting was used to advantage in sinking one of the three test pits, all of which are less than 75 feet deep. The west wall of the westerly shaft is a slickensided fault plane, vertical and with margins nearly parallel to the dip of the formation (dip about 30° to N. strike N. 50° E.). Neither dip of melaphyre beds nor of strike on slickensides could be determined within several degrees. The copper which has suffered hydration and carbonization colors the wall light green on a variegated background of chlorite. The fact that the copper has likewise been acted upon by the sliding movement indicated that it must have been precipitated either before or during the period of faulting. Epidote veins traverse the face of the escarpment in a plane almost parallel to the dip and strike of the rock. The copper appears to be confined to them. The epidote veins show evidences of slight faulting probably due to minor dislocations of the block resulting from inner differential strains in the rock mass in its new position. A second set of minor, nearly vertical epidote veins can also be observed here and there. They are barren of copper and do not cling to the adjoining rock as the larger copper bearing veins. The sandstone below the melaphyre is usually buried beneath the talus debris. It is a fine-grained, dark red, almost quartzitic sandstone, jointed and full of calcite veins. Occasionally threads of malachite may be seen penetrating from the contact into the underlying sandstone. They extend downward a few feet at the most and are evidently a result of deposition from above.[3] In the melaphyre at this location the copper is confined to an epidote zone of fracturing and slipping—as though the conditions which deposited the copper and formed the epidote had found easy access to the clefts of the broken rock. The epidote was formed first, then the calcite and lastly the copper. The periods of crystallization of the three, however, overlapped, some of the copper having been precipitated before all of the calcite had formed. The solutions must have entered at the very outset before much faulting had taken place as the epidote and copper veins show slickensides—are frequently noticeably displaced. Unfortunately large veins were not exposed, on which the amount of slide could be determined, as has been done at several points on the Keweenaw range.[4]

Copper in similar veins was also noticed on the face of the cliff in Sec. 21, T. 51 N., R, 43 W. It is an interesting fact that all the mines in this area have been located at the junction of the melaphyre belt and sandstone, the horizon of the Lafayette mine. The Carp lake mine, the Cuyahoga, the Union, and the Halliwell all owed their existence to the indications of copper observed at this contact, which is readily recognized by the peculiar appearance of the underlying sandstone noted above. The sandstone is frequently interlaced with a network of secondary veins of calcite. Fracture and jointing planes are common and seem to have been produced by the action of the overlying melaphyre.

The Union spring mentioned in connection with the faulting of the region is one of the largest in Michigan. Almost circular in outline, it has a diameter of about 40 paces and is nearly 8 feet deep. The water is cold and unusually clear; it issues from several points on the bottom of the pool near the west end, and keeps the sand in the near vicinity in a state of constant agitation and as if a strong stream of water were ever flowing from underground pipes placed several feet below the surface. The number and position of these points of emergence varies from day to day. On August 31st water was observed coming up from three points while on September 6th, only two points were visible and then in different positions. A full grown stream flows from the northeast end of this spring. It is a remarkable fact that notwithstanding the immense amount of water which passes up through these openings not a single gas bubble is seen to rise to the surface. The surface is still and quiet and does not belie the strong current underneath. At a point about 80 paces below the outlet of the spring a cross section of the stream was taken and the average rate of flow measured. From the data obtained a conservative estimate placed the capacity of the spring at over 750,000 gallons of water per 24 hours, enough to supply a village with the purest water obtainable. A well-blazed trail leads from the Carp lake road to the spring (map).

[1]Loc. cit., p. 215.

[2]Compare Mich. Geol. Survey, Vol. VI, pt. 2, p. 94-96, where Dr. L. L. Hubbard discusses "Topography as affected by slide faulting" in certain parts of the Keweenaw range. Also Dr. A. C. Lane in Mich. Geol. Survey, Vol. VI, pt. 1, p. 33-43, for faults in the Keweenaw rocks on Isle Royale.

[3]Especially noticeable on the escarpment S. W. of the Carp lake mine.

[4]Michigan Geological Survey, Volume VI, part 2, pp, 86-96.

One fact of general interest was observed in the outer conglomerate belt which is well exposed at the mouth of Carp river in Sec. 33, T. 51 N., R. 44 W., where it forms the protecting arm of the small bay used by the fishermen in their summer work. The conglomerate consists of rounded pebbles of various rocks, felsite, melaphyre, sandstone, and occasionally jaspilite. The size of the jaspilite pebbles varies from 1 to 15 cm. in diameter. The nearest known outcrop of jaspilite is on the Gogebic range, and these pebbles were probably transported from there from a distance of nearly thirty miles. It remains to be seen whether the jaspilite in this conglomerate is distributed uniformly or only locally. The pebbles may have been transported by wave action or by a river. At any rate the occurrence of these jaspilite pebbles add an additional proof to the fact that the Huronian rocks were highly metamorphosed and altered, and the iron ore beds largely formed in pre-Keweenawan times; that the time interval between the formation of the Huronian rocks and those of the Upper Keweenaw series was an extremely long one.

The melaphyre belts have a pronounced effect on the compass needle and occasionally change the magnetic variation as much as 10°. It was originally the intention of the survey to use the dip needle as a possible aid in tracing fault planes in the melaphyre. Owing to other work and unfavorable weather this was neglected. The method will be used in the future, however, and its applicability to this region thoroughly tested.

The felsite area was left practically untouched the past summer. In Sec. 19, T. 51 N., R. 42 W., the felsite is rather basic and exhibits long drawn out vesicles and amygdules, the direction of elongation of which is northeast and southwest, the probable direction of the flow of the felsite. The felsite in this case was probably a superficial flow.

The observed fact that all the streams that flow into Lake Superior in T. 51 N., R. 42 and 43 W., are compelled by a sand bar at their outlet to bend abruptly to the west is an interesting phenomenon in connection with the study of shore currents and shore sinkage. On the lake shore of Sec. 8, T. 51 N., R. 42 W., the occurrence of enormous blocks of conglomerate, 20 tons or more in weight (2 meters high), resting on logs, give a good idea of the tremendous lifting power of the lake waves in time of storm. Ice blocks may have assisted in this work. The original point on the conglomerate ledge from which these blocks were broken off may frequently be seen ten or twenty paces distant. A peculiar feature of the drainage in the Porcupine hills is the frequency with which streams of considerable size disappear underground, deserting their old creek bed for long distances, only to reappear further on. In the Little Carp river in Sec. 19, T. 51 N., R. 42 W., excellent examples of pot holes were noticed. Thick beds of red clay are exposed along the Iron river in Sec. 36, T. 51 N., R. 42 W. The roots of upturned trees form in general a flat disk like aggregate which evidently extended into the ground but a short distance. They are shallow roots and indicate a water level near surface.[1] Deep roots are rare. Outcrops are not common owing to the heavily wooded condition of the land. With the exception of the small clearings at the Carp lake, Union, and Halliwell mines, the land is covered with virgin forest. The trees are hardy and indicative of good soil underneath. The kinds of trees over the various formations differ. The area near the correction line in T. 51 N., R. 43 W., on the felsite is densely covered with hardwood, while hemlock predominates in other parts. At present the only articles raised are oats and vegetables. (These at the Nonesuch mine in Sec. 1, T. 50 N., R. 43 W.)

The distribution of the tree belts is especially noticeable in this district. In certain parts the boundary lines of the various tree belts were so sharply defined that they could be mapped accurately. These belts and the predominating trees in each belt were recorded in the field notes and will probably be made use of in the later report of the region. Several factors enter into consideration in this connection, the habitat of the tree, the discussion of the underlying and resultant soil, the topography as affecting the influence of the sun's rays, the drainage, etc., which tend to make the problem a difficult one. It may be stated that any one interested in the study of fungi (mushrooms), ferns, mosses, and in fact all botanical, zoological, biological problems could find abundant and varied material for investigation among the wooded slopes of the Porcupine hills. During the month of September, Mr. A. G. Ruthven of the Biological department of the University of Michigan, accompanied the survey party and was well satisfied with his results.

The physical condition of the soil and atmosphere vary so rapidly in the various-parts of the district that a great variety of forms result.

The quality of the land survey in the Porcupine hills is good. Only one extremely poor survey of a section was found. The line between Secs. 7 and 18 of T. 51 N., R. 42 W., is 500 paces too short while that between Secs. 8 and 17 of the same township is as many paces too long. All section corners in the territory on the map were visited by the survey; those enclosed in a small circle on the map were found in good condition. Two were missing, the southeast and northeast corners of Sec. 30, T. 51 N., R. 43 W. Several later corners have been squared by woodsmen at these two points but the originals have disappeared.

Points of access to the Porcupine Mountains are by way of Ontonagon or Lake Gogebic. The road from the latter place is very poor and serves only as a difficult trail. The road from Ontonagon is good, steel bridges having been erected over the larger rivers by the township board.

[1]See Annual report for 1901, Plate V.

Mr. Ruthven remarks:

"The forest about the Porcupine Mountains consists chiefly of hardwoods and hemlocks with an abundance of ferns in the moist places. The loam about the roots of these ferns was found to be the most favorable collecting ground for terrestrial molluscs, although many are found among the moist leaves in wet places. A few were also found in decayed logs.

"The river and creek shells were found, most abundantly, in the pools .at the sides of the streams, but *Limnea desidiosa* occurs in the swift water on the very brink of the falls in Union creek. *Valvata tricarinata* was found only in Union river, although a careful search was made for it in the other rivers. It occurs here, however, in great abundance, chiefly in the pools and along the sides of the stream where it may be found clinging tightly to the bare sandstone rocks and sometimes in a current so swift as to carry it down stream when its hold is loosened.

"Ontonagon county marks, in this part of Michigan, the northern limit of Cope's Alleghenian district based on the distribution of reptiles and batrachians. The district, according to Cope, is characterized by having no species peculiar to it. This conclusion is borne out by the list[1] above, for all forms collected range both north into the Canadian and south into the Carolinian districts with the exception of *Hyla pickeringii* and *Chrysemys marginata* which do not extend north of Lake Superior.

"In all the rivers of this region, with the exception of the Union, the brook and creek types of molluscs, such as the *Physa's* and *Limnea's*, persist, as the rivers are followed down stream, although in fewer numbers. This, however, is not the case in the Union river. For as this river is followed down, the brook and creek forms give way to *Valvata tricarinata*. The number of individuals of all species of molluscs is also much greater in this river than in the others, both in the headwaters and farther down stream. These differences in the fauna are probably due to the differences in the rocks over which the rivers flow. For the rivers seem to differ in no other way and all open within a few miles of each other. With the exception of the Union, the rivers of this region flow through sandstone and shale, rocks containing practically no lime. They are therefore, unable to support the larger river snails, which require a large amount of lime in the construction of their heavy shells. Union river, on the other hand, drains, on the east, a ridge composed of melaphyre lying between two beds of sandstone. Melaphyre is an eruptive rock which contains a large amount of lime, and, consequently, Union river contains more lime than the other streams explored. A fact which perhaps explains the presence of *Valvata tricarinata* and the larger number of individuals found here."

"Owing to the close proximity of the mountains to the lake, the streams, which have their origin on the north side of the mountains, have cut out each its own channel down to the lake, and only those, which head on the farther slope, unite to form the larger rivers which are compelled to flow around the mountains to find an outlet. As the streams have their origin in mountain springs, the waters are clear and cold, and the currents swift. They have cut deep gorges in the sandstone through which they rush, leaving many little eddy pools among the projecting outcrops on either side. Their bed consists almost entirely of the solid sandstone over which they flow except at their mouths where the currents become sluggish and silt is deposited forming a bottom of mud and debris. The sluggishness of the rivers in the lower portions is due to the formation of the beach across their mouths which, acting as a dam, causes the water of each stream to spread out into a small lake or pond. On the edges of these ponds, the typical pond conditions are reproduced, as is shown by the rushes and sedges, and fauna of the dragon fly larvae and tadpoles. This gives rise to a curious mixture of pond and river conditions, and a consequent intermingling of the faunas characteristic of each habitat."

[1]See Sixth Report Mich. Acad, of Science, p. 190.

Mr. Walker, in a letter, commenting on the mollusks of this region says:—"The fauna of Ontonagon county is very similar to that of Marquette county around Huron mountain, but the list is not so large owing to the fact that Huron mountain has been thoroughly worked. The fauna is essentially a northern one, the county not being far enough west to be affected by the upper curve of the Transition Zone which, according to Merriam, touches the southwestern extremity of Lake Superior. Just where this line is to be drawn, however, is, I imagine, a very dubious question.

SUBJECTS.

We next proceed to take up various subjects of geological interest upon which work has been done throughout the State.

HYDROGRAPHY.

The systematic collection of well records all over the State has been continued with the efficient aid of the Michigan Press Clipping Bureau. From June to October, Mr. W. F. Cooper was detached to work under Mr. M. L. Fuller of the U. S. Geological Survey, the hydrographic division, in a special examination of the lowest and most thickly settled tier of counties. His report is as follows:

WATER SUPPLY OF THE LOWER PENINSULA OF MICHIGAN,

W. F. COOPER.

In Water Supply and Irrigation Papers of the U. S. Geological Survey, numbers 30 and 31, Mr. Alfred C. Lane has published the results of his investigations in the Lower Peninsula of Michigan, the date of publication being the spring of 1899. Since that report was printed a large amount of information has accumulated. In this report of progress it is not intended to cover all the results already enumerated in Mr. Lane's report, although I have used all the well records upon which his report was based. In this report it is also intended to state the results given statistically in the administrative report submitted at the end of the fiscal year 1903, at which date 408 additional schedules had been obtained relating to detailed and general information upon the Water Supply of the Lower Peninsula. The data obtained in the office during that time are relative to springs, flowing wells, wells in which the water does not reach the surface and water supply or supplies for cities and towns. During a portion of June, July and August, 1903, detailed field work was carried on in the southern tier of counties, including Lenawee, Hillsdale, Branch, St. Joseph and Cass. The results of this field work will form a separate part of this report, the first portion relating to flowing wells, springs, and the sections of several wells in which the ground waters do not reach the surface.

CHAPTER I. ARTESIAN WELL AREAS.

In the artesian districts here described, it should always be held in mind that our information is not always complete. On the other hand, in places where artesian flows are described as occurring, there are generally only certain wells (it may be only one well out of many) where the water reaches the surface, such a well generally being found on low ground. While in several places flowing wells are found scattered continuously over a large extent of territory, being either bunched together, or forming a considerably elongated basin, it will rarely if ever be true that such an area is entirely continuous. In such basins the flows are generally found in the lower ground, while on the higher ground the water may be several feet below the surface. In such cases they may best be described as semi-artesian. Without minute contouring actual artesian areas cannot be satisfactorily located, and scarcely then without a more complete knowledge of the Pleistocene. In the case of flowing wells from the bed-rock it is possible to obtain much more satisfactory data. When the elevation of the surface is contoured, the dip and thickness of the water bearing strata determined, it will be possible to present more satisfactory determinations on account of the greater stability of conditions under which the water bearing formation was deposited. In this connection Mr. Lane is of the opinion that the Marshall sandstone will furnish artesian flows in valleys north of Lansing for a considerable distance. With these limitations in mind the following artesian basins are described, the greater part being from the Pleistocene.

In Monroe county, Prof. W. H. Sherzer has described[1] an area of artesian water which includes the northeastern part of Ida township, T. 7 S., R. 7 E., the northwestern part of LaSalle township, T. 7 S., R. 8 E., and the southern portion of Raisinville T. 6 S., R. 8 E. Another area in the same county extends south of Frenchtown, through Monroe and the northern part of Erie township, T. 8 S., R. 8 E. Forming a trend in the same direction flowing wells are found at Rockwood, Wyandotte and Delray in Wayne county, being approximately along the western shore of the Detroit river and its outlet. West of and parallel with this area, Prof. Sherzer who is engaged in the preparation of a report on Wayne county informs me that the area he has described in Monroe county is continued as follows: "A second belt extends northward, the prolongation of the artesian areas in the northeastern part of Monroe county, into Huron (T. 4 S., R. 9 E.,) and Brownstown (T. 4 S., R. 10 E.) townships, and reaches up into Springwells (T. 2 S., R. 11 E.), just west of Detroit. There are two or three wells on Michigan avenue, but none any distance north. They seem to fail because of the moraine which leads northwest from Detroit and has too high an altitude to permit flow."

Mr. Frank Leverett informs me that:—"F. B. Taylor calls this an interlobate Huron-Erie moraine and his Detroit moraine leads in from Mt. Clemens as shown in Water Supply paper No. 30, plate 2." In Brownstowns and Huron townships the wells will average 25-30 feet. They generally carry Cl, Ca, Fe, and S. In the district described as artesian in Monroe county, water is sometimes found 8 feet below the surface, but this may be due to lowering the water level since the report was printed.

In Macomb county east of the Detroit moraine (See Water Supply paper No. 30, U. S. G. S., plate 2) artesian water is struck at Roseville and Lakeshore in Erin township, T. 1 N., R. 13 E., at Mt. Clemens, New Baltimore, and New Haven and also near Adair in St. Clair county. At New Haven the wells are from 18 to 30 feet deep. How far north this area is continued has not yet been ascertained. In Erin township this strip of county extends 5 miles west of Lake St. Clair. Mr. Wm. G. Kern, a driller living at Roseville writes that rock (Antrim or Ohio Devonian black shale) is generally struck at a depth of 110 to 150 feet. He gives the following section of the drift from that locality:—

Erin township	Feet.
Yellow clay	10-20
Strong blue clay	40-50
Putty blue clay	20-50
Sand or hardpan extending to rock.	

Under that either sand which is water bearing, or hardpan which usually extends to the rock. Throughout this area gas often accumulates from the decomposition of the Antrim shale and may produce artesian flows. The water is also often strongly sulphuretted.

On the east side of the Port Huron-Saginaw moraine there is an area adjacent to Port Huron where flows have been struck between the moraine and the present shore line of Lake Huron. In this territory flowing wells are found very restricted at Port Huron, Wadham, North Street, Atkins, Zion and East Greenwood in St. Clair county, while in Sanilac county artesian reservoirs have been tapped at Lexington and Minden City. This area is from 3 to 4 miles wide and adjacent to Lake Huron. It is probable that flowing wells could be obtained at various other points in that area above the Coldwater shale, which is a poor producer of water.

Another artesian basin extends in a northeasterly direction, and more or less parallel with the eastern flank of the Defiance moraine lying south of Adrian and water rises nearly to the surface over all of the southeastern part of Lena wee county. There are flows as far southeast as Ogden Center, Blissfield and Britton. "In Milan township, Monroe county (T. 5 S., R. 6 E.) Mr. Frank Leverett states that there are 40 wells or more in the narrow strip just below the Arkona beach between the village of Milan and section 30 Milan township, which range in depth from 10 feet to 84 feet, all from sand and gravel beds below till. The level to which water rises is about 690-695 feet A. T. There are about 50 flowing wells in a district along and near the Belmore beach between section 31, T. 4: S., R. 6 E., and section 15, T. 5 S., R. 5 E. that are from 35 to 160 feet deep. The deepest ones are from the rock, but those 130 feet or

[1] Michigan Geological Survey, Volume VII, Part I.

less are from sand and gravel below till. The head in this second district is 740 feet A. T. more or less. There is another small flowing well district east of Saline river extending from section 28, T. 4 S., R. 6 E. northeast along the Belmore beach to section 23 of the same township with a dozen or more wells 125 feet more or less in depth, with head about 740 feet A. T. Some reach the top of the rock. There are three flowing wells 50-80 feet deep in section 17 T. 4 S., R. 6 E. with head about 750 A. T."

There are artesian flows at Ypsilanti in the low river bottom at about 680-690 feet. Those at the water works are 62 to 631/2 feet deep and have a head not more than three feet above the surface. Concerning the extension northeast from here in Wayne county Prof. W. H. Sherzer writes as follows:

"The most westerly basin lies just east of Belmore beach, no wells being found on the beach or to the west in Wayne county except at Northville as indicated below. The wells of this belt are mostly confined to a belt 3 or 4 miles eastward of the beach and the head is between 710 and 735 feet A. T. There are breaks in the belt, wells being most numerous in Canton (T. 2 S., R. 8 E.) and the southern part of Plymouth (T. 1 S., R. 8 E.) townships. As I remember it a good average would be about seventy feet for these wells. Nearly all give more or less salt, some being so strong that the water cannot be used. Lime is unevenly distributed, some having so little that the water is soft, others carry a considerable amount. Almost or quite ail have iron, occasionally also sulphur. Sulphates are very generally absent or in traces only. The flows at one time were much heavier, but owing partly to the increasing number of wells and their filling up with sand, the flow is much diminished. Some are reported able to rise 20-25 feet, but others barely reach the surface. The temperature averages about 51° F., with a range of about 3° on either side." In this territory the flows are situated between Denton and Plymouth. There is another district at higher altitude near Northville, 775-800 feet. In Oakland county I believe this basin is continued in the southern and southeastern part, where flows are found at Farmington, where the head is 700-730 feet; at Franklin, head about 760 feet; at Birmingham and Rochester where the head is 750 feet. Thence in the same direction in Macomb county at Washington, 710 to 740, Armada is about 760 feet, and Memphis 760 feet more or less. Mr Lane adds the following note: "In general on the lakeward side of the till ridge in the lowlands, or close to a well marked drop in the topography, flowing wells are liable to occur." Prospectively then we would expect to obtain flowing wells in the territory above mentioned, the distance varying in the lowlands between the moraines, but hardly exceeding 6 miles in width.

It will be observed that this belt is approximately parallel to the one previously described, but extends father north, the ice having retreated toward Lake Huron basin in the meantime, thus forming a greater extension of the basin in which flows would be produced. At Plymouth in August, 1892, Dr. M. V. B. Saunders drilled a well with medical properties, the flow being struck at a depth of 97 feet. John E. Clark, professor of chemistry and physics in the Detroit College of Medicine, made the following analysis.

Analysis of Plymouth well water.	Grains to the U. S. gallon.
Chloride of sodium	14.384
Sulphate of sodium	.372
Bi-carbonate of sodium	5.276
Bi-carbonate of potassium	1.730
Bi-carbonate of calcium	5.471
Carbonate of magnesium	2.906
Alumina and ferric carbonate	1.736
Silica	.500
Organic and volatile	1.298
Total solids	33.673

Carbonate of lithium, present, amount not estimated
Carbonic acid gas, not estimated.

The remedy has proven efficacious in stomach, kidney and bladder troubles.

Birmingham which is situated in T. 2 N., R. 11 E. has obtained numerous flows in sand and gravel varying in depth from 60 to 150 feet. The amount of flow varies from 3 to 150 gallons per minute, being somewhat inversely greater according to the depth of the well. The temperature is 50°. Imlay City is situated between morainic ridges, and so are Attica and Lapeer, and flows are obtained at each of these places. From Lapeer a flowing well tract leads southwestward past Farmer's Creek to Ortonville in the northern part of Oakland county. Concerning the flowing wells at Ortonville, Mr. Leverett sends the following note, based on statements made by E. E. Cassedy, well driller: "There are about 100 flowing wells at and near Ortonville 35 to 70 feet deep from sand under a bed of blue clay. The strongest well flows 40 gallons a minute from 11/4-inch pipe, but these strong flows are found only in the ravines along Kersley creek, and the head there is 18 feet above the surface. On the plain each side of the ravine, the head is only 1 to 4 feet above the surface and flows are weak." "The deepest well in Ortonville is at Mrs. Storms Arnold's, the depth being 149 feet. No rock was struck." "'Northwest of Ortonville, in the western part of Atlas township, T. 6 N., R. 8 E., Chas. Cheney has a well 111 feet deep in which some coal was found at about 105-108 feet. First rock at 98 feet. Water flows two feet above surface and is a hard water well, 3.5-inch with casing."

West of Ortonville in section 5 of Groveland township, T. 5 N., R. 8 E., Jas. Algoe has a flowing well 118 feet deep, that did not reach rock. The head is 10 feet above the surface. Altitude of well about 900 feet A. T. It fills 11/4-inch pipe full at a height of 4 feet above the surface." At Thornville southeast of Lapeer flows are also found in a drainage valley off the moraine. At Lapeer the city water works has from 5 to 8 wells, and pump from 300,000 to 500,000 gallons every 24 hours, with a very little lowering. The water was found at a depth of 280 feet in the drift. An analysis of this water has already been given in Water Supply paper No. 31.

In Washtenaw county flows are found at Ann Arbor, Fredonia, Sylvan and Manchester, from gravel beds in the drift. At Brooklyn in the southwestern part of Jackson county there are flows from the rock, and at Trumbulls west of Jackson artesian wells have been drilled. At Marengo and Albion in the eastern part of Calhoun county there are also flows which are used for a city water supply in the latter place. Parma which is situated between Albion and Trumbulls has no flowing wells. The basin is probably quite localized. In the well put down for the Albion water works in 1902, the depth of the well was 175 feet, and the flow, which was obtained from the Marshall sandstone, amounted to 300 gallons per minute. This formation is famous as a good water producer in the greater part of its basin in lower Michigan. In a later part of this report will be found 13 analyses made by Prof. Delos Fall from wells in Albion. They originally appeared in a supplement to the Albion Recorder.

The flowing wells at Brooklyn are also from the eastern side of the Marshall sandstone area and occur at a depth of 40 feet in the rock, which is said to outcrop on the farm of Geo. Knowles.

The Ann Arbor Water Company has kindly furnished me with the log of a well situated in the city limits, being section 29 of T. 2 S., R. 6 E.

Boring for Ann Arbor Water Co.	Feet.
Surface	12
Quicksand	33
Dry gravel	3
Dry gravel and stones	12
Clay, hardpan, and layer of sand and cobble stone	25
Quicksand	5
Blue clay	5
Hardpan	12
Fine water gravel	7
Clay hardpan, gravel and streaks of water sand	9
Total	123

Geographically there is an area which extends in a southeasterly direction through the eastern part of Allegan, and through Barry county as far as the northwestern part of Calhoun county. From the last named place flowing wells are found in a northeasterly direction through Eaton, Ingham, Clinton, Livingston and Genesee counties. This territory does not form, that is it is not one geological basin in either the Pleistocene formation or the underlying sedimentary rocks. Flowing wells may, however, be found in the low ground in the territory above named, (but that is quite prospective). Flows have, however, been found in Allegan county at Burnip's Corners, Moline, Wayland, Hopkins and Otsego; in Barry county at Hastings, Pritchardville, Prairieville, Hickory Corners and Assyria, as well as at Bedford in the northwestern part of Calhoun county. In Eaton county at Bellevue, Olivet, section 8 of T. 2 N., R. 5 W., Petreville, Potterville, Windsor and Millett artesian basin or basins have been tapped. In Ingham county there are flowing wells at Stockbridge, Leslie, Eden, Mason, Leadley’s, Dimondale, Lansing, Okemos, Meridian and Webberville; in Clinton county in the basin of the Lookinglass river at Wacousta, DeWitt and Bath; in Shiawassee county at Shaftsburg, Morrice, Byron, Burns, Durand, Vernon and Owosso; in the northern part of Livingston county at Oak Grove and Madison; while in Genesee county, Flushing, Flint, Atlas and Davison are represented. As thus defined we have a broad segment of a circle swinging three-fourths across the lower peninsula, and doubtless including several local basins.

At Burnip’s Corners it is 5 miles to the nearest flowing well; one or two deep wells drilled without obtaining water; the usual depth of water being from 15 to 45 feet deep, being in coarse gravel.

At Wayland flowing wells are 30 to 60 or 20 to 200 feet deep, all under strata of clay, except one which is through into the Marshall sandstone.

Hastings with a population of 3,000 has such a supply that the pumps cannot lower it. At or near Petreville there is a flowing well with medicinal qualities, 165 feet deep. The flow rises 19 feet above the surface. Near Potterville there are two wells, 40 and 150 feet deep with an ample flow, the water being hard and alkaline.

The flows at Dimondale and Millett are in a tributary of the Grand river.

At Leslie, Mr. Arthur J. Tuttle has kindly sent me a record of the strata passed through in his two wells, which is as follows:

Tuttle Wells at Leslie.	Feet
Drift	30-40
Slate	60-70
Sandstone	10

A softer bed of sandstone was penetrated by the drill at this depth which caused the water to flow just to the surface. Below this a flint rock (probably $FeCO_3$) 2-4 inches, and then sandstone to 160 feet underlaid by a honey comb rock filled with water which rose 10 feet above the surface. This well was drilled by Frank Dodge in 1899, while an earlier well which flows was made by Sanford Bros, of Jackson, Mich., about 1868. The wells flow about 3 barrels per minute. The temperature of the water is about 54° and is slightly mineralized with iron and sulphur. An analysis has been given by Mr. Lane in Water Supply paper No. 31. The beds of coal measure sandstone in which these wells are found are more or less local in deposition and while almost always water-bearing would not furnish flowing wells where the top of the drift accumulation is higher than the head of the water in local synclines. Mr. Lane in his report on coal,[1] has represented a continuous bed of sandstone running from Leslie to Lansing along the Michigan Central R. R, which would probably furnish flowing wells in the lower reaches of the Grand river basin, including here more particularly Sycamore creek and its tributaries.

At Mason a number of wells have been put down for the city water supply, of which the following will serve as an example:

Well at Mason, Mich	Thickness.	Feet.
Surface	3	3
Gravel	2	5
Water gravel	1	6
Gravel and sand	14	20
Hardpan	8	28
Hardpan and shale	4	32
Fire clay	2	34
Black slate or shale	10	44
Lighter shale	10	54
Hard rocks	2	56
Sand and water	31	87
Sand rock	16	108
Slate	12	112
Sand rock	6	118
Light shale	6	124
Light sand rock	5	129
Shale	2	131

This is in the coal formation, underlying the central portion of the lower peninsula of Michigan.

The mineral well at Lansing is from the Marshall formation. Mr. Lane has given an analysis in his Water Supply paper No. 31. At Flint, Mr. C. B. Berry, medical director of the Oak Grove Sanitarium, has given a section of the beds passed through.

	Feet.	Inches.
Clay and gravel	33	
Sand rock	85	
Flint rock		8
Black slate		10
Coal		10
Slate	2	
Hard sand rock	15	
White slate	5	6
Flint rock	0	8
White slate	9	6
Sulphur rock	0	7
Blue slate	16	
White slate	0	6
Blue rock	28	
Sand rock	67	6
Total	265	

[1]Mich. Geol. Surv., Vol. VIII, Pt. 2.

The water is obtained in the basal bed of [Marshal. L.] sand rock passed through. The flow is 9 gallons per minute.

Along the first correction line of the U. S. Government Linear Survey there is a broad belt where flows have been struck at numerous places. In Tuscola county there are flowing wells at Cass City, Novesta, Wilmont, Mayville, Caro, Akron, Wisner, Fairgrove and Gilford. At Caro a well having a capacity of 400,000 gallons per day was struck at a depth of 274 feet. The water at this depth is pronounced excellent for drinking or other purposes, and its temperature 47°. I believe that Mr. Lane recommended that Saginaw obtain its water supply from this vicinity. Such wells as this might prove a solution of the problem if the supply is permanent.

Prof. C. A. Davis, who is engaged in the preparation of a report on the geology of Tuscola, has kindly sent me the following notes:

"(1) Beginning with the Bay shore and working inland is a region from 4-6 miles wide, in which most of the wells which go into the rock are salt or at best strongly brackish. The district is flat and clayey (clay till or lake clays) to the rock surface, with here and there low sandy tracts or ridges scattered over the surface. From some localities boulders and thin layers of gravel are reported on top of the rock and this overlaid by compact clay or hardpan. The hardpan is generally reported, whether the boulders are or not. This belt runs from a point about a mile north of Unionville where there is a brackish well, southwest through Akron township, includes practically all of Wisner, the northwest corner of Fairgrove and about all the northwest half of Gilford, with the deeper wells salty or brackish, less so to the east, however, along the south line of the township, clear across the township to the east. In Denmark township, brackish water is found along the north border from the northeast corner of section 3 westward, and southeast half of 2, thence westward in deeper wells though some of the shallower areas are not brackish. South of this are no brackish wells until the southwest 1/4 of section 16 is reached. There are brackish wells also on the west side of 21 and on the south side of 30, but none east that I found, and the brackish water is practically out of the county in the southwest corner of section 31 of Denmark township, although a deep well at Vassar of more than 400 feet depth is decidedly brackish.

"Throughout this belt there are numerous flowing wells, but many others do not flow and never have, while some used to flow and have stopped, as the number of wells put down has increased. It seems possible that these brackish waters came from the coal measures and from the shales and finer sandstones or even from coal strata as is sometimes reported. The flows from these wells where they flow at all are seldom large and often are very small and feeble, and there is frequent testimony that the head has lowered perceptibly, all, of course, showing that the basin from which they come is not of large extent or is poorly supplied with water, the latter being most probable from the character of the rock, which is not porous. Near the edge of this formation where it overlies the sandstones below, it sometimes happens that the sandstone is reached and then large flows result, which although salty or brackish, are sometimes manifestly getting the salt from the overlying strata since the owners report that before they pulled the casing out the water was much fresher, or entirely fresh. In some cases I advised casing down through the rock to near the bottom of the hole to shut off all water except that from the sandstone, and the quality of the water was improved by this means in two wells under my observation.

"(2) East of this salty belt and sharply distinct from it in the character of the water, is another tract elongated to the south west and extending nearly parallel with the border of the bay, in which the water is very fresh and free from both lime and iron salts, only traces of any mineral water being found in it. The water comes from sandstone in these wells, and because of the abundant supply of good water easily obtained there is a great development of drilled wells in the west side of Columbia township and in the east half of Akron and southward through Fairgrove. Here the rock is from 70 to 100 feet below the surface with local valleys and depressions in the rock surface which makes some greater depths.

Most of the well records show some coal or black shale and it is fair to infer that the sandstone is, in part at least, Carboniferous, but to the eastward it seems possible that this runs without any marked division into the sub-carboniferous sandstones which crop out in the Cass river valley. There are some local faultings in these rocks which may complicate matters geologically, but there is no evidence that such faults affect the water supply, that I have been able to discover. The flows in some of the wells from this belt are large and strong but there is no great head and 3-4 or possibly 6 feet would be the average maximum height above the surface to which the water would rise when I visited the wells, though an occasional well, usually in a depressed place would be reported as rising 10 or 15 feet when piped up that far. On the other hand it was a common occurrence to have the report that the well formerly (lowed but stopped when another one was put down near by. It seems probable that the sandstone is more or less discontinuous in this area since some holes have been put down which gave no water at all and the beds of sandstones were interbedded with shale in many of the records. It is certain that in some wells greater depth is reached than in others but whether this means that the water always came from the greatest depth reached by the drill, of course we have no means of knowing. This belt extends northeast into Elmwood township and southwest into Fairgrove and Gilford and Denmark, but on account of the occurrence of morainal and beach ridges to the east it is frequently true that the land surface is so far above the rock, and the head, that while the water rises some distance in the well tube it does not flow. A high morainal ridge runs down from Gagetown to Vassar and along the foot of it to the west and strong beach lines which of course act as reservoirs and give abundance of water in the form of springs so that the deeper wells are not needed. On the moraines the wells are mainly shallow since the till is gravelly and water-bearing gravels are common and productive enough for domestic uses. In Cass valley there are great deposits of gravel and sand, in which good water is abundant and here also no deep wells are put down until Vassar is reached. Here there are a group of wells in the river valley 40-60 feet deep all in the sandstone, from which the city supply is taken. There are also some private wells in the lower part of the town. The flows are all on the river terraces, and the water is free from salt and mineral matter. Near the P. M. R. R. station, or rather the junction of the M. C. and P. M. R. R., is a deep well, which flows a large steady stream, but I was unable to get a record of it as the former owner was dead and the record lost. It was said to be 400-600 feet deep, probably to the Marshall sandstone. This is drinkable but salty and unpleasantly full of other minerals.

"Southwest of Vassar, at and near Tuscola village, is another group of flowing wells in the river valley. These are shallow and from the Carboniferous sandstone. They are from 40 to 70 feet deep. South of Vassal-about 7 miles are a few flowing wells along the foot of the water laid moraine, that comes down from Millington and across Arbela township from about the middle of section 13 to 31. These do not reach the rock but the flow is from gravel below the till on the north side of the foot of the moraine. There are only two or three such wells that I could learn of. Most of the rest of the county is either too high to have flowing wells, or too sandy to need them, the water supply coming almost exclusively from dug wells, throughout the township south and east of the Cass valley, and where these are not sufficient as on the moraine in the southeast corner of the county the elevation is too great to secure a flow, and there are very few drilled wells in that entire district."

Since the report on Huron county was printed seven wells have been drilled by the Coryell Drilling Co. at Bad Axe, which are said to be able to produce about 4 million gallons of water every 24 hours, the Marshall sandstone being the source of the supply. These flow at times.

In Saginaw county flowing wells are obtained in almost any locality, except that in the southern part of the county they are rather restricted to the river valleys. At Chesaning an abundant supply is obtained from the Coal Measure sandstone which is utilized for the village water supply. Also at Fergus, St. Charles, Swan Creek, Merrill, Burt, Birch Run, Blackmar, Frankenmuth, Bridgeport, and at numerous other places flows have been obtained either from the drift or the underlying sedimentary strata.

In Bay county artesian water is found in sections 1, 2, 3 and 12, Williams township, T. 14 N., R. 3 E., in sections 7 and 18 of Monitor township, T. 14 N., R. 4 E., while recently Mr. Theodore Archambeau while drilling for coal in the valley of the south fork of the Kawkawlin river tapped a flowing well near the line of sections 3 and 10. Also in Kawkawlin township there are flowing wells at the corner of sections 29, 30, 31 and 32, which is the remnant of a larger basin which opened out to the east, extending as far as the north fork of the Kawkawlin river. In Beaver township, T. 15 N., R. 3. E., this area embraces parts of sections 33, 35, 26, 28, 21, 23, 14, 15, 11, 12, 2 and 3, the greater part of the basin being adjacent to the south fork of the Kawkawlin river. Also in Kawkawlin township there is an area between the State road which follows the Algonquin beach line and Saginaw bay, where flows are obtained as far south as section 23, T. 15 N., R. 4 E. On the west side of the State road this area is extended into sections 3-5 of the same township. Fraser township T. 16 N., R. 4 E. is abundantly supplied with flowing wells in the area adjacent to Saginaw bay and east of the State road, the same area being extended up Michie creek and into sections 4-6, 8-10. This latter area extends northward into Pinconning township, T. 17 N., R. 4 E. the greater part of the basin being in or adjacent to sections 33, 28, 22 and 15, thence swinging southeast through sections 14 and 23, where the Saginaw bay area is met, an angle with the State road and passing into the bay in section 7, T. 17 N., R. 5 E. To the south of the union of these basins the area adjacent to the bay extends down into Frazer township. An isolated area is in the southeastern part of section 10, T. 17 N., R. 3 E. Most of these wells are in the drift, and are found in gravel or a sandy gravel overlying the rock. The following section taken from a test hole record for coal will serve to illustrate the stratigraphy of the deposits; the record being in the N. E. 1/4 of the S. E. 1/4 of section 24, T. 15 N., R. 4 E.

		Total.
Sand	25	25
Clay	35	60
Sand	4	64
Gray shale	15	79

Mr. Floyd D. Owen has given the results of analysis of Bay county waters in the report of the State Board of Geological Survey of Michigan for the year 1902.

In the deep well at the plant of the North American Chemical Co. at South Bay City, a flowing brine was struck in the Berea grit at a depth of 2,170 feet, the flow amounting to 1.25 gallons every 31/2 minutes. An analysis has been given in Water Supply paper No. 31.

In Arenac county the Bay county basin is continued with interruptions flows being found at Standish, Omer, Twining, Turner and AuGres. The prospects for obtaining flows adjacent to the bay and east of the place above named is fair. Furthermore in Iosco Co. at Whittemore, Alabaster, East Tawas and AuSable, flows have been obtained both in bed rock and the Pleistocene; while in Alcona county at Killmaster and Alcona, and at Alpena, there are flowing wells, the greater part of the flows being adjacent to the shore of Lake Huron.

At West Branch, Rose City, and thence north to Indian River there are flowing wells with a great abundance of flow. These lie in basins between high moraines, which have been described by Mr. Lane in Water Supply report No. 30.

Returning again to the south we find in the basin of the Maple river artesian wells at Ashley, Hubbardston, Pewamo and Muir, situated at its junction with the Grand river, with Ionia and Lowell farther down stream. At Ashley the flow is found 260-278 feet with 3 feet head, temperature 52° F. Again at Hubbardston a flow was struck in a sand and gravel bed of the Pleistocene at a depth of 210 feet, where the water rose 20 feet above the surface. The flow at Pewamo is ample and occurs at a depth of 35 feet, while at Muir 5 miles west J. Hale and Sons obtained flows at a depth of 240 feet and another at 300 feet, showing the great variability of the Pleistocene from which these waters were obtained. At Ionia, Mr. H. R. Welker writes me that he struck flows at 27 feet, in the drift and at 313 feet in the bed rock, the flow increasing to a depth of 320 feet.

In the basin of the Pine river at Alma, Breckenridge and Pleasant Valley there is a bunch of flowing wells. "At Alma in 1897, the entire number of flowing wells in the town was 76, of which 9 had a depth of less than 50 feet, while 7 were over 100 feet deep, the greatest being at the Sanitarium engine room, which is 144. The depth of 13 is unknown, while 37 range in depth from 55 to 80 feet. The greatest flows occur at a depth of less than 100 feet as the following table will show:"

	Feet deep.	Barrels per day.
Brainard's	49	634
Strubele's	71	532
Fullerton's	62	450
Pringle's	85	450
Hutchinson's	55	270

In this connection I cannot do better than quote an article which appeared in the Alma Record, Friday, Sept. 10, 1897, prepared by a student of Alma College, under the direction of Prof. C. A. Davis, regarding the wastefulness of the drinking water supply. "Allowing each individual in Alma and Ithaca three pints of water per day, the little well near Clubb's shop would be sufficient for both towns. Assuming that the 71 unmeasured flows are as strong as the ones just referred to, the whole amount of water that issues from the earth within our narrow limits is 222 times what we use, and would slake the thirst of Detroit, Grand Rapids and Toledo. What a waste of water! Eventually the underlying fountains will be drained down to the level of their lowest outlet, and we shall have to scrape acquaintance with the pump handle." In such cases nature exacts her own remedy. For when the flow falls below the surface the basin has an opportunity to become refilled. However, as suggested in the article, it is better to introduce the stop-cock or the simple round plug with a small hole.

At Pleasant Valley in the southwestern part of Midland county the flows occur in interstratified beds of gravel and are found at depths varying from 26 to 60 feet. This portion of Michigan is all deeply covered with the drift.

North of Pleasant Valley there is another artesian area around Alamando and Coleman, in the northwestern part of Midland county, and in the basin of Salt river tributary to the Tittabawassee. In Gladwin county north of there, numerous flows are found at Beavertown, Gladwin, Wheatley, McClure, section 6 of T. 19 N., R. 2 W., and at Butman. The probability of finding flows in Range 2 west of Gladwin county is excellent, as well as in R. 1. W, township 19 and 20 north. At Gladwin water was found in sandstone at a depth of 350 feet, the flow amounting to 100 gallons per minute. Mr. Geo. Shaley, engineer of the Gladwin water works, informs me that small flows are also found there, in the drift at a depth of 100 feet.

In Isabella county at Loomis and at Clare just across the line in Clare county, flows have been obtained. Also at Mt. Pleasant, Jordan, Leaton, Rosebush, Brinton, and Sherman City in Isabella county the same water supply is obtained, as well as at Barryton, a short distance west of Sherman City, in the northeastern part of Mecosta county. At Mt. Pleasant water is found in gravel at a depth of 205 feet. Mr. Leverett informs me that much of the northern part of Isabella county is high moraine, flows being obtained only at the localities mentioned above, or on lowland tracts.

In a sand and gravel area extending southeast from Mecosta county into the southwestern corner of Isabella county, and thence south through Stanton as far as Belding in the northwestern part of Ionia, there are a number of flows where land is low among the moraine ridges. This area affords a good opportunity for further prospecting. At Mecosta, Remus, Millbrook, Blanchard, Edmore, Cedar Lake, Vestaburg, Stanton, and Belding, artesian basins are tapped. At these localities the depth of water varies, being 35 feet at Millbrook, 30 feet at Blanchard, 40 feet at Stanton, where it is used for fire and domestic purposes, and 130 feet at Belding. where the water is found in sand. It will be noticed that the depth increases to to the south as far as our records show.

In the southern part of Newaygo county, in the basin of the Muskegon river, there are several artesian wells. At Fremont, section 5, T. 12 N., R. 14 W., Brunswick, Sitka, and Newaygo, there are flows, as well as a separate basin on the south side of the moraine at Grant, Bailey, Plumville, Grove and thence west and south along a tributary of the Grand river as far south as the latitude of Kent City. At Fremont water bearing beds are found at 18, 100 and 200 feet in the drift, the flow being about 15 feet above the surface for the deeper wells and 15 inches for the most shallow. The temperature is 51°. In the deepest wells the flow is given at 1,800 gallons per hour. The water is hard except in the well 18 feet deep. In Newaygo the depth to water varies from 30 to 44 feet. The wells both here and at Fremont are in the drift.

In the basin of the Muskegon river there are several flowing wells in the southern part of Osceola county at Reed City, Hersey, Evart, Sears, at Marion in the northeastern part of the county, and at McBain in the southwestern part of Missaukee. It is not impossible that flows would be obtained between these places, as well as in the environment of the places last mentioned. At Reed City flowing wells are found in inter-stratified beds of sand and gravel at a depth of 300 feet. Three miles southwest of the city the depth is only 100 feet. In the deeper wells the water is hard, becoming softer in the more shallow wells. At Marion there are only a few flowing wells out of a number of records that I have received. The depth at that place varies from 30 to 60 feet. McBain situated northwest of Marion has a flowing well at 30 feet, while another well having a depth of 140 feet rose to within 15 or 30 feet of the top.

In the highlands north and east of McBain I have not obtained the records of any flowing wells. In this region water is found at a depth of from 25 to 175 feet at Morley in Missaukee county; from 20 to 70 feet at Fletcher in the southeastern part of Kalkaska, at a depth of 200 feet at Grayling, 176 feet at Frederic, and 90 feet at Gaylord. Flowing wells will probably be found all the way down the AuSable river.

At Indian River there are numerous flowing wells, the basin extending along the south and west side of Burt Lake, north along the Sturgeon river past Topinabee, Mullets Lake, and thence to Cheboygan. West from Burt Lake flows have occasionally been found, and there are numerous wells at Harbor Springs, which is almost due west of Indian River. Mr. Daniel Foreman, a driller residing at Harbor Springs, informs me that flowing wells have been found for a distance of 26 miles east of that place,

At Indian River the depth to water varies from 93 to 189 feet. In two wells 108 and 142 feet deep, the head forces the water 20 feet above the surface, while another well 110 feet deep rises 35 feet above the ground, which is the greatest elevation given. Again in the well record having a depth of 175 feet, the water rises 30 feet above the surface. Not having the elevation of the wells it is impossible to arrive at any satisfactory conclusion relative to depth and head. In all the wells the water is hard and impregnated with iron. The temperature is given at 48° F. in four wells varying from 108 to 142 feet deep, and as 44° F. in one well 110 feet deep. The flow is given as 100 gallons per minute at 142 feet, 180 at 110 feet, and 200 at 112 feet; while in another lot the flow would average four barrels per minute in three wells having an average depth of 106; and three barrels per minute fm four wells with an average depth of 135. Not until the elevation above tide is determined for some of the different wells, and the amount of flow actually gaged as given in Schlichter's paper can any reliable conclusions be arrived at concerning the relation of depth and head. Mr. G. P. Cowley has sent me the following record of strata passed through in one well there:—

Well at Indian River.	Feet.
Sand	40
Hardpan	7
Sand	12
Gravel	5
Sand	25
Clay	15
Gravel	5

In three other wells the amount of surface sand varies from 40 to 45 feet; with from 53 to 60 feet of clay overlying the gravel in which the water is found. At Topinabee there are two wells with a depth of 119 feet, the flow being in the drift. In one well the water will rise 11 feet above the surface, in another from six to eight feet. The temperature in the Sanitas deep well belonging to H. H. Pike's Sons is 48°. To Mr. Horace L. Pike I am indebted for an analysis of the water from this well, which was made by Prof. I. V. S. Stanislaus of Notre Dame University.

Physical examination showed:—

Color	none
Odor	none
Taste	perfect
Reaction	neutral

Chemical examination in parts per 1000.

Chlorine	.0145
Free ammonia	none
Nitrogen in nitrates	.0023
Total hardness	.0202
Permanent hardness	.0171
Organic and volatile matters (by loss)	.0182
Total solids	.1146

The inorganic constituents proved potassium, sodium, and magnesium bi-carbonates and chlorides, with sodium phosphate and calcium.

At Harbor Springs flows are found from 45 to 320 feet in depth as at Mr. E. Shay & Son's well. All the wells are said to be in the drift. In Mr. Shay's well the flow amounts to 100 gallons per minute, the temperature being 45° F. Mr. Lane has given an analysis of this well in Water Supply paper No. 31. Mrs. Chas. Roe writes me that flowing wells were first discovered there by driving piling 200 feet from shore for Roe & Co.'s steamboat dock. The flow was struck at a depth of 45 feet, and was of sufficient strength to lift heavy piles after being driven down.

Along the latitude of Harbor Springs and Indian River, artesian water has been struck at Rogers City on the shore of Lake Huron. Mr. F. C. Larke, president of the village council has sent me the following section of beds passed through:—

Well at Rogers City.	Feet.
Coarse gravel	10
Hardpan with streak of gravel	80
Limestone	21

In the basin contiguous to Lake Michigan and south of Harbor Springs, there are artesian basins all the way down to the Indiana state line. Adjacent to Grand Traverse bay and Pine Lake flows are found both at Boyne and Boyne Falls; near Bellaire, Williamsburg, South Boardman and Traverse City. In the little finger of the lower peninsula, forming Leelanaw county, there is a flowing well near Provement, and farther down the coast at Empire, Frankfort, Beulah, Thompsonville and Onekama. East of Onekama, in the basin of the Manistee river, there is an artesian basin at Yates and another around Fife Lake. However, just west of Fife Lake and around Summit City, water is found at a depth of 94 feet, gradually increasing to the south, until on the north side of the Manistee in section 4 of T. 24 N., R 10 W., water is found at a depth of 135 feet. In these wells water does not reach the surface. Likewise east of Yates at Wexford, it is 47 feet to water, near Farnsworth 127 feet, while in Antioch township, T. 23 N., R. 11 W., the depth varies from 60 to 128 feet. The area of non-flowing wells is continued on to the southeast where at Cadillac the depth varies from 125 to 225 feet to water.

Around Ludington flows are again struck. In Oceana county there are several separate areas of flowing wells near Hart, Elbridge, section 24 of T. 15 N., R. 17 W., Shelby, section 18 of T. 14 N., R. 17 W., Marshallville and Holstein.

Muskegon and Fruitport both have artesian wells, and in the valley of the Grand river we find flows at Eastmanville, Lament, and Georgetown, 19 miles east of the shore of Lake Michigan.

Again adjacent to the lake at West Olive, Gibson, Hamilton on the Rabbit river, and at Ganges there are flowing wells, while at Casco, seven miles south of Ganges, it is 160 feet to water which does not reach the surface.

In Van Buren, Cass and Berrien counties, the civil divisions correspond to an enlarged artesian area. This region is rather heavily belted with moraines running parallel with Lake Michigan, and flowing wells are only found in the lower areas. In this territory flows have been obtained near South Haven, Lacota, Grand Junction, Geneva, Breedsville and Bangor in the basin of the Black river; around Watervliet, Hartford, Lake Cora, Paw Paw, and Keller in Van Buren county, in the basin of the Paw Paw; in Cass county there are a few flows near Marcellus, Penn, Pokagon and Dowagiac; while farther west in Berrien county there are artesian wells at Niles, Berrien Springs, Buchanan and New Troy.

Throughout this considerable extent of the lower peninsula, the depth to artesian water varies. At Boyne the depth to water-bearing gravel is 70 feet, the temperature being 50°. At Bellaire the water is also found in the drift at the depth of 100 feet. The capacity is 4,000 gallons per day, and is used in the city water supply.

At Williamsburg, Mr. John H. Russell of Detroit, obtained flows at 45, 821/2, and 87 feet, the water coming from interstratified gravel beds in the till. Most of the flows there occur at a depth of from 58 to 65 feet, the average depth being 61 feet. The water rises from 10 to 20 feet above the surface, the average elevation for six wells being 14 feet. Mr. Russell gives the temperature as 43° for one well 87 feet deep, and 45.5° for another well 821/2 feet deep. In two other wells 58 and 60 feet deep the temperature is given as 42°, while another well 64 feet deep is 45°. Mr. Emery Rose has sent me the following section of beds passed through there:—

Emery Rose well at Williamsburg.	Feet.
Sand	16
Blue clay	20
Sand	2
Blue clay	22
	60

I am also indebted to Mr. Russell for an analysis of the water from his well 45 feet deep which was made by John E. Clark:—

	Grains per U. S. gallon.
Sodium chloride	.2571
Sodium sulphate	.0085
Potassium sulphate	.0431
Magnesium sulphate	.5051
Magnesium carbonate	1.6671
Calcic carbonate	6.8410
Ferric oxide	.5004
Aluminic oxide	.3169
Silicic acid	.4907
Lithia carbonate (present but not estimated.)	
Organic matter	trace
	10.6299

Detroit College of Medicine, March 6th, 1893.

At Provemont there is an artesian well 780 feet down which was drilled about 1853. The flow amounts to one barrel per minute. I am obliged to Mrs. Florence M. Whitfield for an analysis of this water, which is as follows:—

Analysis of Whitfield well at Provemont.	Grains per U. S. gallon.
Sulphate magnesia	14.295
Sulphate alumina	4.172
Sulphate lime	6.005
Chloride sodium	1.240
Carbonate silica	1.96
Hydroxide of iron	.269
Total	27.941
	Cubic inches.
Sulphuretted hydrogen	10.09
Carbonic acid gas	29.14
Total	39.23

At Empire the flow is found in gravel at a depth of 60 feet.

East of Frankfort there are several flowing wells at Beulah, near the head of Crystal lake. The depth of water varies from 97 to 163 feet, the amount of flow in one well is stated to be 270 barrels per day, in another 300 barrels, the deeper wells having the greater head. Mr. H. T. Smith has sent me the following section of his well:—

	Feet.
Gravel and sand	10
Blue clay	20
Sand, solid clay and gravel	67

At Onekama, the shore of Portage lake is surrounded by a flat 20 to 40 rods broad, on which a flow may be obtained by driving a pipe, beginning at 15 to 20 feet with a one-half inch stream, and increasing in volume, in head, for greater depth. Mr. Davis' wells at 60 to 100 feet have a very strong flow, throwing a stream horizontally 10 to 20 feet.

At Hart the depth of water is 173 feet with head sufficient to throw the water 20 feet above the surface. Mr. Lane has obtained the following section of beds passed through at the Potato Starch factory situated there:—

Hart Potato starch factory well.	Feet.
Clay till	43
Water gravel	1
Plastic clay	129
Cavity	1
Total	174

The temperature of the water as determined by Mr. Lane with a standard self-registering thermometer was 49.5°, August 23, 1902.

Elbridge, situated 61/2 miles east of Hart has a flow at a depth of 93 feet, the water rising 20 feet above the ground.

Mr. Isaac Timmons sends me the following sections of beds passed through there:—

Elbridge.	Feet
Sandy soil	30
Clay, into water-bearing gravel	63
	93

Southeast of Elbridge in section 25 of T. 15 N., R. 17 W., Mr. Amos Rellinger has the following log:—

	Feet.
Sand	24
Gravel	2
Clay, water-bearing sand	89
	115

In Muskegon county, according to C. D. McClouth, flowing wells are quite common along the shore, ranging in depth from 35 feet at Montague to some 250 feet at the south line of the county. Around Fruitport wells have a head of about 30 feet above the lake, or six feet above the ground.

In the southwestern portion of the lower peninsula, the variation in conditions producing flowing wells are very considerable. Six and one-half miles southeast of South Haven an artesian well has a depth of 228 feet, with the following section:—

Well near South Haven.	Feet.
Sand	20
Clay	170
Soft rock (Coldwater shale)	38
	228

Near Watervliet there are two wells with a depth of 45 and 50 feet, the flow being in sand and gravel, while another well in the drift is 89 feet in depth. In all these wells the flow is 10 feet above the surface. In the wells 50 and 89 feet deep the temperature is given as 50°. The water is hard, in common with the most of the wells in the Pleistocene. Near Hartford I have the records of two wells in the drift which are 44 and 58 feet deep, the water rising seven and ten feet above the surface. At Paw Paw flows are found in the lower levels of the Paw Paw valley at depths variously given as from 40 to 100 feet.

For artesian conditions in Cass county the reader is referred to the special report on that territory.

CHAPTER II. SPRINGS AND NON-FLOWING WELLS.

At numerous localities in the lower peninsula of Michigan water horizons reach the surface. A large number come from gravel beds in the drift. In other cases where beaches have been left during the later stages of the Pleistocene or lacustrine epoch, small surface springs flow from the base of the beach. I suspect that in rare cases springs will be found to indicate interracial deposits. The valley of the AuSable and the high cliffs around Frankfort and Newaygo may expose such formations. Where the margin of overwash sand and gravel beds lie above the till, fine springs are frequently found. When these areas have been indicated it will be possible to locate springs with quite a reasonable degree of certainty. Bed rock is so infrequently exposed in the lower peninsula as to make it a small factor in water supplies of this character. However, in the Traverse formation near Alpena, I have seen quasi springs in sink holes where the subsurface drainage has eroded away the overlying limestone. Again as at Barron lake the water is derived from springs which serve as a water supply for Niles. In this connection it might be well to gage streams issuing from inland lakes, with a view to utilizing such water for city and town use. The water supply of Adrian, which is a source of serious consideration, might be obtained from lakes in the northwestern part of Lenawee county, but I doubt if the supply would be in the least adequate. In most cases our inland lakes are either drying up, or are represented by beds of muck. In this chapter it is intended to give all the information obtained relating to the geographical distribution of springs, but it is not presumed that the information is complete. Analyses of 12 springs have been obtained. Part of these have already been given in Mr. Alfred C. Lane's Water Supply report No. 31. The rest will be given at the end of this chapter.

In the valley of the Huron river above Ann Arbor there are a number of fine springs near Delhi in the same area. In the valley of the Paw Paw there is a spring southeast of Benton Harbor and another near Hartford in Van Buren county. In Jackson county there are a number of springs in Springport township, T. 1 S., R. 3 W., in the drainage basin of the Grand river. This area is indicated as covered with interlobate sand and gravel in plate 2 of Water Supply paper No. 30. In the same county springs have also been found near Brooklyn and Napoleon in the southeastern part of the county.

In Wayne county there is a spring at Plymouth in the northwestern part of the county. At Dorr and Moline in the basin of the Rabbit river springs are found in a region covered with sand and gravel. This is also true of Anderson in the southwestern part of Livingston county. In the eastern part of Oakland county there are springs near Thomas, Pontiac, and Troy, as well as in Macomb county near Mt. Clemens, and at Fraser in the southern part of the county.

In the basin of the Grand River there are similar water supplies at Spring Lake, Nunica, Crockery, Eastmanville, Grand Rapids, Bowen, Ionia and Lansing. This region is mostly covered with sand and gravel. Farther east in about the same latitude they are found at Owosso and St. Clair adjacent to the St. Clair river. In the northern part of Gratiot county, in the basin of the Pine river, there are springs in section 23 of T. 12 N., R. 4 W., near Elwell, Alma, St. Louis, and at Midland, where the Pine unites with the Tittabawassee river. In Oceana county there is a spring at Hesperia in the valley of the White river. Thence east at Big Rapids in the valley of the Muskegon we obtain similar flows. In Bay county springs are often found at the foot of beaches which were deposited in lake basins during the glacial retreat. The flow is quite limited. In the basin of the Muskegon river in Osceola county there are numerous springs in LeRoy township, T. 19 N., R. 10 W.; and near Marion in the northeastern part of the county. Also at Tustin, near the headwaters of the Manistee, springs are found. In Hatton township, T. 18 N., R. 4 W., there are similar flows along the headwaters of the Tobacco river. Likewise in .the valley of the Tittabawassee near Highwood, springs are abundant. In the valley of the Manistee there are similar water supplies at Manistee, in Springville township, T. 23 N., R. 12 W., east of Beulah three miles, Manton in the northeastern part of the same county, and at Cadillac. In section 18, T. 21 N., R. 1 W., and near Butman in the northwestern part of Gladwin county springs also occur.

At Frankfort and around the shores of Crystal lake there are springs at rather numerous locations. In Oscoda county there are springs at Luzerne and Mio in the valley of the AuSable river.

In the area adjacent to Grand Traverse bay and Lake Michigan, similar water supplies have been located on the eastern shore of Torch lake in T. 30 N., R. 8 W., near Norwood, in Jordan township, T. 31 N., R. 6. W., as well as at Levering. At Topinabee there is a spring of which an analysis will be given further on. At the headwaters of the Sturgeon river there are also a number northeast of Gaylord. In the basin of the Thunder Bay river, springs are also found at Big Rock, Atlanta and Alpena. While this list is not in any way complete it will serve to give some idea of the very general distribution of this source of water supply in the lower peninsula of Michigan.

Analyses of Springs.

<u>Benton Harbor.</u>

Four of these analyses have already been printed in Water Supply No. 31. The additional records here given were made by Prof. E. G. Smith of Beloit College, Wisconsin. They belong to the same group as the Eastman springs.

"Bimini" Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.052
Sodium sulphate	0.524
Sodium chloride	0.104
Sodium phosphate	0.017
Sodium borate	trace
Sodium bi-carbonate	0.262
Magnesium bi-carbonate	3.557
Calcium bi-carbonate	7.484
Iron bi-carbonate	0.075
Alumina	0.034
Silica	0.542
Total	12.651

"Winans," Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.104
Sodium sulphate	0.314
Sodium chloride	0.093
Sodium phosphate	0.023
Magnesium sulphate	0.419
Magnesium bi-carbonate	3.126
Calcium bi-carbonate	5.564
Iron bi-carbonate	0.039
Alumina	0.058
Silica	0.402
Total	10.142

"Golden Fountain," Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.116
Sodium sulphate	0.262
Sodium phosphate	0.040
Sodium chloride	0.093
Magnesium sulphate	0.180
Magnesium bi-carbonate	3.213
Calcium bi-carbonate	8.206
Iron bi-carbonate	0.384
Manganese bi-carbonate	trace
Alumina	0.017
Silica	0.408
Total	12.919

"Psyche," Benton Harbor.	Gallon of 231 cubic inches. Grains.
Potassium sulphate	0.104
Sodium sulphate	0.507
Sodium chloride	0.016
Sodium phosphate	0.017
Magnesium bi-carbonate	2.257
Calcium bi-carbonate	6.604
Iron bi-carbonate	0.025
Alumina	0.058
Silica	0.513
Total	10.101

Analysis of water from a surface spring at Spring Lake, Ottawa county, Michigan. The color is clear; taste, saline; temperature, about 60° F. It is the property of E. C. Dyer of Chicago, but I obtained my information from Geo. H. Hammond of Spring Lake village.

Spring Lake.	Grains per gallon.
Potassium chloride	4.2880
Sodium chloride	405.5330
Calcium chloride	113.4200
Magnesium chloride	36.2000
Sodium bi-carbonate	0.9537
Calcium bi-carbonate	0.1808
Iron bi-carbonate	0.0060
Magnesium bi-carbonate	0.0640
Manganese bi-carbonate	0.0647
Magnesium bromide	2.1700
Sodium sulphate	46.7000
Silica	0.5030
Alumina	traces
Total fixed residue	629.3684

C. Gilbert Wheeler, Professor of Chemistry, University of Chicago.

Prof. I. V. S. Stanislaus of the University of Notre Dame has made an analysis of a spring belonging to H. H. Pike's Sons of Topinabee.

Topinabee Hill Springs. Physical examination showed:—

Color	none
Odor	none
Taste	soft
Reaction	neutral

Chemical examination: —

	Parts per 1,000.
Chlorine	.0155
Nitrogen and nitrates	.0037
Total hardness	.0210
Permanent hardness	.0180
Organic and volatile matters (by loss)	.0190
Total solids	.2410

The inorganic constituents contained potassium, sodium, calcium, magnesium bi-carbonates and chlorides, in small quantities.

NON-FLOWING WELLS.

In this report it is not intended to give any detailed account of ground waters which do not reach the surface. For those who are interested in geological work in the lower peninsula, however, it has been thought well to print all the sections which have not yet been published, inasmuch as they either fill in gaps of territory not heretofore covered or correlate sections already printed. Primarily these sections are intended for reference to those engaged in geological work in the lower peninsula or adjacent states.

To Mr. T. B. Pettit of Benzonia, Mich., I am indebted for the following log, which is in section 27, T. 26 N., R. 15 W.:—

Benzonia well.	Feet.
Sandy loam	4
Clay	19
Sand and gravel	50
Total	73

Mr. F. E. Deckrow, in a well put down for Chas. Richardson on section 16 of T. 25 N., R. 2 W., went through 90 feet of blue clay, the water being found in a gravel bed underneath. The water rises within 22 feet of the surface. In another well 186 feet deep, for Jacob Karner, T. 28 N., R. 4 W., the first 10 feet was of clay loam, the balance being sand. A third well made by the same driller for Mr. A. House in section 17, T. 28 N., R. 3 W., has a depth of 200 feet. The first 10 feet was sandy loam, the balance being sand and gravel. The water raised 10 feet.

At Highwood water is found at a depth of from 8 to 20 feet in gravel below the clay, the water in some wells rising to within 18 inches of the surface. To Mr. W. G. Hay of West Saginaw, Michigan, I am indebted for the record of the following holes which were put down by Mr. A. J. Utter while prospecting for coal in the vicinity of Highwood, Gladwin county. In no case was bed rock reached. In well No. 3 the water rose within 18 inches of the surface.

Report on Wells at Highwood

Well No. 1.

N. E. ¼ of S. E. ¼, Section 26, Town 18 N., R. 1 East.

1 ft. Surface.
2 ft. Sand.
37 ft. Putty clay.
13 ft. Hardpan.
2 ft. Shell rock.
27 ft. Sand; coarse river sand, indicating a wash out, or where the bed rock dips down to a great depth.

82 ft.

Well No. 2.

S. E. ¼ of S. E. ¼, Section 27, T. 18 N., R. 1 East.

1 ft. Muck.
3 ft. Sand.
35 ft. Putty clay.
16 ft. Hardpan.
12 ft. Putty clay.
5 ft. Hardpan.
20 ft. Putty clay.
8 ft. Hardpan.
16 ft. Putty clay.
5 ft. Hardpan.
25 ft. Red marl.
31 ft. Sand (wash out).

176 ft. Total.

Well No. 3.

N. W. ¼ of N. E. ¼, Section 3, Town 17 N., R. 1 East.

32 ft. Clay.
9 ft. Hardpan.
12 ft. Putty clay.
2 ft. Hardpan.
39 ft. Quicksand (not through sand).

94 ft. Water to within 18 inches of the surface.

Well No. 4.

S. E. ¼ of N. E. ¼, Section 34, Town 18 N., R. 1 East.

1 ft. Muck.
2 ft. Quicksand.
37 ft. Putty clay.
10 ft. Hardpan.
16 ft. Hard black gravel clay.
14 ft. Hard black gravel clay.
32 ft. Hard black gravel clay.
14 ft. Hardpan.
35 ft. Red marl, streaked with gray.
1 ft. Sand.

162 ft.

Well No. 5.

S. E. ¼ of S. E. ¼ of Section 13, T. 18 N., R. 1 W.

1 ft. Muck.
1 ft. Sand.
1½ ft. Marl.
2 ft. Sand.
12 ft. Putty clay.
5 ft. Hardpan.
15 ft. Putty clay.
8 ft. Hardpan.
11 ft. Putty clay.
10 ft. Hardpan.
22 ft. Putty clay.
4 ft. Sand and gravel—good vein of water in this gravel.
9 ft. Hardpan.
40 ft. Gravelly clay.
20 ft. Putty clay.
33 ft. Hardpan.
38 ft. Quicksand.

232½ ft. (Still 12 ft. of sand.)

Mr. John Sisson of Imlay City has sent the following log of his well. It is situated in Section 33 of T. 8 N., R. 12 E.

Well near Imlay City.	Feet.
Clay	4
Fine water sand	50
Quicksand	6
Coarse gravel	1
Blue putty clay	19
Shale rock? (Coldwater)	73
	153

The Antrim Iron Co. at Mancelona has a well from 250 to 300 feet deep, the depth to principal source of water being 65 to 70 feet. Sand and gravel formed the greater part of the strata passed through. A bed of clay 10 to 20 feet thick was struck at 160 to 215 feet from the surface.

This well apparently did not reach the rock. To the Antrim Iron Co. I am indebted for the following analysis:—

Mancelona. Antrim Iron Co.	Grains per U. S. gallons.
Silica	.5240
Oxides iron and alumina	.1458
Carbonate of lime	7.4646
Carbonate of magnesia	2.4493
Sulphate of lime	.5248
Sodium and potassium chlorides	trace
Sodium and potassium carbonate	.3218
Total solids	11.4303

The Michigan Sulphate Fibre Co. of Port Huron has very obligingly sent me through their manager, Mr. O. L. E. Weber, the following sections, analysis and data. I quote from Mr. Weber's letter and report:—"Well No. 1 was drilled in the spring of 1898, our object being a search for either gas or oil for fuel purposes. Six-inch and eight-inch pipe was used to the slate and smaller pipe continued down. At a depth of 266 to 267 feet from the surface we encountered quite a strong flow of gas, pressure of which ran up to over 75 lbs. gauge, and the entire pressure was blown off in about two days through a seven-inch pipe and has not recovered since. Analysis of the same you will find as the last item in the description of these wells. At 575 feet we began to get traces of salt and the well was discontinued at 600 feet. The following is the data of the material passed .through as given by Mr. A. Morrison, the well driller.

Wells 2, 3, 4, and 5 were drilled in the fall of the year 1900, our object this time being a search for a supply of water for our mill. The following is a description of the four wells:—

Data of material gone through in well No. 1, Port Huron.	Feet.
From surface to 78 feet, drift sand	78
From 78 feet to 102 feet, blue clay	24
From 102 feet to 107 feet, gravel drift clay with pebbles	5
From 107 feet to 187 feet, slate	80
From 187 feet to 215 feet, top lime rock	28
From 215 feet to 266 feet, soap stone	51
From 266 feet to 311 feet, lime rock	45
From (266 feet to 267 feet), gas	
From 311 feet to 319 feet, soap stone	8
From 319 feet to 321 feet, lime rock	2
From (319 feet to 321 feet), gas	
From 321 feet to 415 feet, soap stone	94
From 415 feet to 417 feet, middle lime	2
From 417 feet to 482 feet, lower soap	65
From 482 feet to 600 feet, lower lime	118
	600

Well No. 2, Port Huron.

From surface to 48 feet, sand and drift.
From 48 feet to 64 feet, blue clay.
From 64 feet to 72 feet, coarse gravel.

Well No. 3, Port Huron.

From surface to 46 feet, sand or drift.
From 46 feet to 62 feet, blue clay.
From 62 feet to 70 feet, gravel.
From 70 feet to 101 feet, blue clay and 1 foot of black

sand.
From 101 feet to 391 feet, black shale.
From 391 feet to 491 feet, soap stone.
From 491 feet to 521 feet, lime rock with strong flow of gas.
From 521 feet to 651 feet, soap stone.
From 651 feet to 728 feet, lime rock with indications of petroleum.

This well showed very little water on top of bed rock. Well was cased with 46 feet of wooden conductor, 10 inches diameter on the inside. One hundred and four feet of eight-inch pipe to bed rock.

Well No. 4, Port Huron.

From surface to 48 feet, sand or drift.
From 48 feet to 65 feet, blue clay.
From 65 feet to 74 feet, gravel with large supply of. water.

Well No. 5, Port Huron.

From surface to 48 feet, sand or drift.
From 48 feet to 65 feet, blue clay.
From 65 feet to 76 feet, gravel.

Wells 2, 4 and 5 are cased with a wooden conductor 46 feet deep, 10 inches inside diameter and continued with 10-inch iron pipe to the depth of the well excepting No. 5 which has a 12-inch instead of a 10-inch pipe.

The wells are stopped at the bottom with wooden plugs, each with about 400 1/2-inch holes extending up from the bottom of the pipe about seven feet.

Water in the wells rose to within about 19 feet of the surface and at the time observations were taken this was about one foot below the surface of Black river. The wells were pumped 10 hours a day for about two weeks with the idea of freeing the water from the iron held in suspension, but it did not free it to any appreciable extent. The following is an analysis of the water:—

Suspended matter 66.00 parts per million, mostly clay carrying iron. The filtrate analyzed as follows:—

	Parts per million.
Silica (SiO_2)	27.40
Iron and alumina (Fe_2O_3 Al_2O_3)	1.15
Lime (CaO)	128.80
Magnesia (MgO)	33.85

The following is an analysis of gas from well No. 1: —

Marsh gas (Methane)	88.64%
Hydrogen	2.27%
Carbon monoxide	0.20%
Nitrogen	8.89%
Total	100.00%

CHAPTER III. TOPOGRAPHY AND WATER POWER OF LENAWEE, HILLSDALE, BRANCH, ST. JOSEPH AND CASS COUNTIES.

In the descriptive portion which pertains to this chapter, the elevations are given above tide. By this is meant the elevation above the average sea level height of New York bay. This is the zero which has been adopted by the U. S. Government, and all topographic elevations are stated as so many feet or fractional parts of a foot above this datum or zero. In the contour lines which are represented on the maps forming part of this report, each line is intended to represent the same constant elevation above sea level, or above tide as it is usually stated. This is generally abbreviated A. T. In this connection I cannot do better than quote Mr. Alfred C. Lane as to the proper significance of contours.[1] "As we have said, in 1896, Lake Huron had been retreating. Imagine the process suddenly reversed, and the lake suddenly raised 10 feet and the new shore line marked upon the map. Suppose the lake raised 10 feet more, and the resulting shore line marked upon the county. Such lines would be called contour lines and all points of a given contour line are obviously at the same level above the lake." In the maps presented in this report the contour lines are represented at intervals of 50 feet of vertical elevation, and are only approximately located, but one line of elevations having been taken through each township. In the map of Lenawee county it will be observed that the lowest line is marked 700 A. T. This means that if Lake Erie were to rise 130 feet from its present elevation of about 570 feet above tide the shore line of the lake would wash the hills and plains and form inlets up the valleys as approximately indicated by the 700-foot line A. T. The same would be true of each successive line of greater elevation. In the different intervals islands would appear. These imaginary islands are represented by contour lines which entirely enclose a certain amount of land. Such areas will be observed northeast of Tecumseh and at Prospect Hill in the northwestern part of Lenawee county. It will be readily observed that there is a great advantage in having a common base as a reference plane from which to estimate all points of elevation, and in this report it may be understood that sea level in New York harbor furnishes such a base. High water of 1838 in the great lakes is supposed to be 584.34 feet above it (i. e., 584.34 A. T.).

[1]Michigan Geological Survey, Vol. VII, part 2, P. 42. 10

Highest Elevations.

Within this area the highest elevation is at Bunday hill, situated in section 8 of Somerset township, Hillsdale county, T. 5 S., R. 1 W., the altitude being 1,284 feet above tide as given in the report of the U. S. Lake Survey. At another station in the northwest quarter of section 29, T. 6 S., R. 1 W., the elevation is 1,247 A. T. In the intervening area about the lowest elevation is near Jerome Station where the surface drops to 1,105 A. T. This axis of elevation runs north and south, very nearly one mile east of the line between ranges 1 and 2 west. The northern limit is Bunday hills, while southward the elevation at Pittsford geodetic station is 1,149 A. T., the depot at Pittsford being 1,087 A. T. These elevations form part of a morainal accumulation which was deposited by the Huron-Erie glacier lobe. This area of greatest elevation forms the divide between the waters of Lake Erie and Lake Michigan and is approximately one-third of the distance across the state going west.

Lenawee County Moraine.

On the east side of the Hillsdale watershed the elevation falls quite rapidly to the east, in Lenawee county. The highest elevation within this county is Prospect hill, which is about 100 feet lower than Bunday hill, or 1,184 feet A. T. Where the Raisin river enters Monroe county the altitude is less than 650 A. T., making the extremes of elevation 634 feet. Prospect hill is located in section 13 of T. 5 S., R. 1 E. The Huron-Erie glacier lobe deposited in its retreat a great amount of morainal accumulation in the northwestern part of this county including the Prospect hill area, the principal moraine leading from Hudson northeast in an irregular line to the northeastern corner of section 5, T. 5 S., R. 3 E.

Inside of this area the greater part of the lakes in Lenawee county may be found. Posey lake, northeast of Hudson, is 933 A. T. This has an outlet into the Tiffin river. Devil's lake is 1,051 feet A. T. Pickerel lake in the northeast quarter of section 14, T. 5 S., R. 1 E., is 971 feet A. T., being very nearly on the same elevation as Deep lake, which is on the other side of Prospect hill. Lake Dody and Lake Washington, situated southeast of Cambridge in T. 5 S., R. 2 E., both have an elevation of 996 A. T. Goose lake, southeast of Woodstock, is about 1.005 A. T.

Later Huron-Erie Moraines.

East of this principal moraine last described, there are three small inlying moraines, deposited by the same Huron-Erie glacier lobe. As will be seen on the map, they trend southwest, ending at the north, west of Tecumseh, and at the south, northwest of Adrian. For the most part they are in townships 5 and 6 S., and R. 3 E. The elevation of the most westerly one reaches a height of 860 A. T. The extension of this moraine to the south causes Wolf creek to form a loop in the same direction, before emptying into the Raisin river at Adrian.

Moraine West of Hillsdale.

West of Hillsdale there is another very considerable area of glacial accumulation which has a northwesterly trend, the northern limit being near the road from Jonesville to Quincy, the southeastern end is about three miles west of Pittsford. On both flanks there is a chain of lakes and ponds which either form areas due to the unequal amount of glacial accumulation, the melting of buried or surface ice masses, or glacial drainage valleys which have become filled up by glacial or post-glacial erosion, the lakes representing glacial mill ponds, as it were. Within this area the highest elevation of which I have any knowledge of, is the station of the U. S. Lake Survey. This is situated in the west half of section 27 just southwest of Hillsdale. The elevation is 1,238 feet A. T. The elevation of the Lake Shore depot at Hillsdale is 1,085 A. T. On the road leading south from Hillsdale and two miles west of the range line, the highest elevation is 1,219 feet A. T. This is four-tenths of a mile north of the east quarter post of section 10. Thence south the elevation drops to 1,042 at Cubb lake in section 34, T. 7 S., R. 3 W. This forms the southern extremity of the same chain of which Sand lake is the northern link. Cubb lake is near the headwaters of one of the feeders to St. Joseph of the Maumee. Camden, which is situated on another tributary of the same stream, is in the southwestern part of the county and is approximately 988 feet A. T. The main branch of the St. Joseph of the Maumee is in the southeastern part of Hillsdale county. Near the northeast corner of section 28, T. 7 S., R. 1 W., the elevation is 926 A. T. A feeder which starts about one-half mile south of Pittsford has an elevation of 1,025 A. T. Laird creek, another branch of the same stream, has an elevation of 985 A. T., just north of the east quarter post of section 16, T. 8 S., R. 2 W. Burt creek, another feeder, is 905 feet A. T., a few feet east of the northeast corner of section 23, T. 8 S., R. 2 W. Where this creek heads in Bird lake the elevation is 1,040 A. T.

Moraine at Reading.

Another deposit of morainal accumulations is west of the Hillsdale moraine. The main trend is north and south of Reading. At the Lake Survey station in the northwest quarter of section 24, T. 7 S., R. 4 W., the elevation is 1,208 A. T. Four and one-half miles south the elevation at Camden is 988 A. T. as already given. To the north the elevation drops to 1,081 A. T. within six miles.

Moraine North of Hillsdale.

North of Hillsdale there is a knoll of morainic material which accumulated on the southern border of the Saginaw shoulder. In the southeastern quarter of section 29, T. 5 S., R. 3 W., the elevation is 1,150 A. T. The area is quite circumscribed.

Moraine in Western Branch County.

On the western side of the Hillsdale watershed in Branch county, there are several irregular areas of morainic deposition. The ice retreating to the northwest deposited in the western part of Branch county a moraine which leads northeast, west of Bronson, within two miles west of Union City. From there the course southwest is about parallel with the St. Joseph river. At the station of the U. S. Lake Survey in the southwest quarter of section 16, T. 7 S., R. 8 W., the elevation is 997 A. T.; at the northeast corner of section 33, T. 5 S., R. 7 W., the altitude has fallen to 975 feet. Matteson lake, situated within this area, has an elevation of 889 feet. The drainage is all westward into the St. Joseph river.

Lakes in Central Branch County.

After the deposition of this moraine there was a period of recession, during which time the drainage was parallel with that of the moraine last deposited, and in front of the retreating ice mass. This may account for the chain of lakes which extends northeast of Bronson towards Girard. The lakes appear to be formed of ice drainage outlets which were locally dammed up by either glacial or post-glacial material.

To the south and east of Coldwater there are several lakes within the limits of the Huron-Erie lobe. The Huron-Erie glacial lobe entered Michigan in the southeastern part of Branch county, forming a scattered, irregular moraine south of Quincy. North of Quincy the deposits are to be referred to as the Saginaw shoulder, which extends as far west as Coldwater, thence east to Jonesville and northeast to Mosherville in Hillsdale county.

Lakes in Southeastern Branch County.

Marble lake, situated between the Saginaw shoulder and Huron-Erie glacier, has an elevation of about 1,000 A. T. Coldwater lake is 950 feet above tide. California P. O., which is situated on the Huron-Erie lobe, is about 1,031 feet A. T. The highest elevation which has been determined on the Saginaw shoulder in the northeast part of Branch county, is in the southwest quarter of section 8, T. 6 S., R. 5 W. The station of the Lake Survey situated there has an elevation of 1,060 A. T.

Glacial Drainage.

Mr. Leverett informs me that as the great ice mass retreated north from Branch county the united drainage from the Michigan lobe on the west, the Saginaw shoulder which had not yet reached the form of a lobe, in the center, and the Huron-Erie lobe on the east, poured their united drainage down what is now the valley of the St. Joseph river. At that time it must have presented the appearance of a great glacial Amazon, the united waters laden with sediment, forming a stream many times greater in volume than the present river.

Sturgis Moraine.

St. Joseph county has a fine, well marked moraine in the southern portion, which Mr. Leverett has designated the Sturgis moraine. On the west it almost reaches the road which runs southwest from Centerville to Constantine reaching into section 16, T. 7 S., R. 11 W. From there the main axis of the moraine trends east and south of Burr Oak. Near the east quarter post of section 18, T. 7 S., R. 10 W., and just south of the northeast corner of section 19, in the same township and range, the elevation is 942 feet A. T. North and south from here the elevation falls rapidly. To the north, the east quarter post of section 30, T. 6 S., R. 10 W., is 830 A. T. South the descent is even more abrupt. In the creek which crosses the line, four-tenths of a mile north of the east quarter post of section 31, T. 7 S., R. 10 W., the elevation is 823 feet A. T. This creek runs in a valley 61 feet high on the south side and 70 feet high going north, draining into Klinger's lake, and thence on into the Fawn river. Where the U. S. Lake Survey Station was situated in the northeast quarter of section 22, T. 7 S., R. 10 W., the elevation is 1,037 feet A. T. This is the highest point that I know of either on this moraine or in St. Joseph county. East of here, where the moraine is crossed by the G. E. & I. R. R., the greatest surface elevation is 960 feet A. T. This is 23/4 miles north of Sturgis. Sweet lake, on the south side of the moraine, and east of Sturgis, is 895 feet A. T.

Topography in St. Joseph County.

West of Sturgis the country is a plain, gently sloping to the west. In the valley of the St. Joseph river the country is level going from Nottawa to Mendon, Leonidas and Colon, the same topography being found between Three Rivers, Moorepark and Parkville. South of the St. Joseph river on the road leading from Parkville to Centerville, the land is rolling with un-drained hollows. The east side of the St. Joseph river valley is level as far as White Pigeon and two miles east of there.

Interlobate Moraine.

In the western part of St. Joseph county and the eastern part of Cass there is a pronounced interlobate moraine. Going south from Vandalia the crest of this moraine is a well marked ridge trending east and west and having an extreme elevation of 977 feet A. T. This is one-tenth of a mile north of the east quarter post of section 28, T. 7 S., R. 14 W. One mile north from here the descent is 100 feet. To the south the elevation drops 117 feet in 11/2 miles. Where the U. S. Lake Survey station was situated in the northeast quarter of section 27, T. 7 S., R. 14 W., the elevation is 1,010 feet A. T. In the southeastern part of T. 8 S., R. 13 W., the top of the moraine leads southeast, being 903 feet high in the southeast quarter of section 33, T. 7 S., R. 13 W.

In the semi-morainic area of this interlobate moraine the main trend is towards the northeast. At Jones the elevation is 921 feet A. T., the great mass of the moraine increasing in elevation northward. Northwest of Jones, Bald hill is 1,070 feet A. T. Another hill situated about three-tenths of a mile south and one-half mile west of the east quarter post of section 16, T. 6 S., R. 13 W., has an elevation of 1,115 feet, which is probably the highest elevation in Cass county. This pronounced interlobate moraine is continued northeast into St. Joseph county. In the north half of section 33, T. 6 S., R. 12 W., there is a knoll having an elevation of 1,011 feet. North from here the descent into the drainage valley of Rock creek is quite rapid. Fabius, situated on the southern side of this interlobate area, has an altitude of 896 feet. Going north from Fabius the topography is hilly, many lakes being imprisoned in the moraine. Forming a pronounced ridge on top of this elevated moranic area is a hill range trending southwest through sections 6, 5 and 4, of T. 6

S., R. 12 W., and sections 33, 34 and 26 of T. 5 S., R. 12 W. Within this area the elevation is above the 950 foot contour line, culminating at a height of 1,011 feet A. T. The topography has much of the appearance of one moraine being built on top of another. This may be due to a readvance of the ice. Rock creek; which bounds this interlobate moraine area on the north has an elevation of 825 feet at Howardsville and 839 feet on the road leading south from Marcellus. This creek meanders through a rolling country, and may have drained the front of the ice during its subsequent retreat.

Lakes of the Interlobate Moraine.

There are numerous lakes in the area of this interlobate moraine. Lake Baldwin and Long lake are situated in front of the morainic deposit in the southeastern part of Cass county, and are long, crooked lakes which have the appearance of drainage channels from off the ice, which were later obstructed by glacial or post-glacial drainage. In sections 21, 22, 23, 24, and 13, T. 7 S., R. 14 W., there is a chain of lakes draining into Christian creek. The most important of these are Curtis, Day, Sharps, and Clear lakes. The lakes are within the moraine and may have originated by the melting of ice masses forming the so-called "kettle-holes," by obstructed glacial drainage, or by the unequal deposition or settling of glacial debris. On the line between sections 21 and 22 the stream channel connecting these lakes has an elevation of about 838 feet A. T. In the less sharply morainic area southwest of Jones, Bear lake is without any outlet and is of morainic origin. The elevation is 883 feet A. T. Skyhawk lake on the road from Marcellus to Jones is on the northern edge of this moraine and drains into Rock creek. The elevation is 847 feet A. T. In the area west of Three Rivers in St. Joseph county there are numerous lakes imprisoned in the moraine area. Pleasant lake, in section 9, T. 6 S., E. 12 W., has an elevation of 58 feet above the Michigan Central depot at Three Rivers, the respective elevations being 795 and 853 A. T. The region is heavily covered with sand and gravel and may represent a cusp dumping ground.

Lake Michigan Glacier Lobe.

The eastern border of the Lake Michigan glacier lobe enters the lower peninsula a few miles east of the southwest corner of Cass county. From here there is a well defined morainal area leading to Cassopolis, varying in width from one to three miles. At Cassopolis the moraine is somewhat interrupted by glacial drainage from Stone lake which empties into Pokagon creek. Northeast from Cassopolis the east side of the moraine is west of and approximately parallel to the Grand Trunk R. R., leaving Cass county near the northeast corner of section 2, T. 5 S., R. 13 W. There is also a pronounced morainal ridge running northwest through section 3, T. 5 S., R. 15 W., north through section 22, T. 5 S., R. 15 W., and on up to Kalamazoo.

The elevation of this moraine is quite considerable. At the U. S. Lake Survey station in the southeast quarter of section 4, T. 8 S., R. 16 W., the altitude is 896 feet above sea level. On the road from Barren lake to Edwardsburg the moraine rises from an elevation of 774 to 859 feet A. T., on the west side, the greatest elevation being 894 A. T., in the east half of section 36. Going on towards Edwardsburg the drop is from 862 to 823 feet A. T. Just west of Cassopolis the greatest elevation is 931 above sea level. The west front of the moraine has an altitude of 889 feet on the same road. West, from there the drop is quite rapid, the elevation of the old glacial channel on the north line of section 33 being 826 feet or 32 feet lower than the same drainage outlet between the east side of the moraine and the city of Cassopolis. On the road leading north from Penn the foot of the moraine has an elevation of 896 A. T., at the east quarter post of section 9, T. 6 S., R, 14 W. Just north the crest rises 48 feet. One mile north the elevation has increased to 968 A. T. at the east quarter post of section 4. The greatest elevation that I obtained within this tract is one-tenth of a mile west of the northeast corner of section 27, T. 5 S., R. 13 W., where the altitude is 982 feet A. T. On the western side of the moraine and east of Dowagiac, the west crest of the morainal accumulations are marked by a fine hill range well adapted for fruit culture. The elevation here is 943 feet A. T., and is four-tenths of a mile east of the northwest corner of section 3, T. 6 S., R. 15 W., the elevation of the corner being 840 A. T. The moraine falls off rapidly towards La Orange and is recessed by a creek valley, which heads in northeast of Volinia. On the quarter line road in section 22, T. 5 S., R. 15 W., the greatest elevation that I obtained was 895 A. T., which was one-tenth of a mile west of the east quarter post. Seven-tenths of a mile west the west front of the moraine is 891 feet above sea level. Mr. Leverett makes the elevation through here 930 feet A. T., and it is in deference to him that the 900 foot contour line is run. Very nearly one mile west the Michigan Central profile has an altitude of 842 feet A. T. To the west Dowagiac creek served as the cusp drainage for the west side of this lobe.

Lakes in Western Cass County.

Within this general area the elevations of several lakes were obtained. Barron lake, which serves as a water supply for Niles, is 754 A. T., or 75 feet above the Michigan Central depot there. Eagle lake, near Edwardsburg is 823 feet above sea level. Stone lake, which supplies Cassopolis with water, has an elevation of 857 feet A. T. The lake at La Grange, which is really a great mill pond, is 810 A. T.

Intermorainic Area.

In the area between the Michigan moraine and the interlobate area, the country is rolling, the present surface drainage being into the St. Joseph river. Christian creek is the largest stream in this territory. Most of the intermorainal area is contiguous to the

Grand Trunk R. R., and that furnished data for the altitudes. At Edwardsburg, the elevation is 829 A. T., increasing to 891 feet A. T., at Cassopolis and 888 at Marcellus.

ELEVATION OF STREAMS.

During the course of this work considerable information was obtained relative to the elevation of streams. Given the amount of fall and the quantity of flow in the stream channel, we have two of the principal factors which determine its utility for water power. While the stream elevations here given are not always accurate, I believe that the amount of error is less than five feet. The gaging of streams does not fall within the province of this report. In Michigan, Mr. Robert E. Horton has had the establishment of water gage stations, over 60 stations being recently set. The results are published annually in the Water Supply and Irrigation Papers (49, 65, 75, 83), issued by the Division of Hydrography of the U. S. Geological Survey. In this connection it should be mentioned that Mr. Horton has published some results of his work on water power in Water Supply paper No. 30, p. 22, et sequor, and in the Proceedings of the Michigan Engineering Society for 1901. In Water Supply and Irrigation paper No. 83, p. 265, the results of gage readings at Mendon are given.

In the report of the tenth census there is considerable information relative to dam locations in the southeastern part of the state.

Naming of Streams.

At the outset it was found that the nomenclature for streams is not very uniform or consistent. In the map of Branch county in Volume V of the Michigan Geological Survey report, Coldwater river is indicated as flowing into Hog creek, in the northern part of Branch county. Also in Rand-McNally's sectional map of Michigan there are two Bear creeks in St. Joseph county, while the Tiffin river in the western part of Lenawee county is formed by the union of another Bear creek and Hillsdale creek, the two streams uniting above Hudson. In the blue print maps which were used in the field, the St. Joseph river is called Nottawa creek, in its course in St. Joseph county above Three Rivers, being properly designated in its upper reaches in Branch and Hillsdale counties. In Rand-McNally's sectional map of Michigan Nottawa creek is represented as rising in the southern part of Kalamazoo county. From there the course is approximately parallel with the St. Joseph river, the outlet of the stream being three miles east of Mendon.

I believe that Mr. John F. Nellist's blue print maps which were used in field work are largely based on county atlases. In the same blue print maps Prairie river in the southern part of Branch county is indicated as emptying into another Hog creek, which otherwise is known as Spring creek, in its course through Centerville, and on to the St. Joseph river. The Pokagon creek on our blue print maps is called Putnam creek in the Rand-McNally map. I have used the former name as preferable. In Hillsdale county there are three St. Joseph rivers. One which has already been mentioned in the northwestern part of the county, passing through Jonesville and Litchfield. The other two are tributary to the drainage into Indiana, one flowing southeast through Camden. The third, which runs southwest in the same territory has a handle, being designated as St. Joseph of the Maumee, which is at least specific, if somewhat cumbersome.

I have not presumed to establish the nomenclature in all these cases. In the case of Nottawa creek the error is obvious and the name should be used as designated on Rand-McNally's map. The name Prairie river I have used instead of Spring creek, the duplicate name of Hog creek being only used for the stream in the northern part of Branch county. This is in accordance with common usage. The other streams are relatively unimportant. It is obvious, however, that there should be established some clear and consistent nomenclature.

Elevation of Streams and Dams.

In the list of improvements only the location of such dams and the elevation of stream courses are given as were obtained incidental to the main question of water supply. What I have endeavored to do is to determine wherever possible, and with as much accuracy as possible, the elevation of the different streams which will give some idea of their utility for water power when properly gaged, the elevation of the streams being obtained below the dams unless otherwise mentioned.

The River Raisin, according to Mr. Leverett, has an elevation of about 645 feet A. T. at Deerfield; of 664 feet above the dam at Blissfield; of 686 A. T. at Palmyra. Mr. Leverett makes the elevation at the R. R. crossing in section 21, Raisin township, 703; four-tenths of a mile east of Sutton of 715 A. T. At Tecumseh the altitude of the stream below the dam is 744 feet as determined by the U. S. Topographic Survey. The dam at this point is 18 feet high. The altitude below the dam at Clinton as determined by the Topographic Survey is 799 feet; at the Lenawee-Washtenaw county line of 808 feet A. T. Near Somerset Center the elevation is about 1026 feet A. T. Dams have been put in at Deerfield, Blissfield, Palmyra, Tecumseh, Clinton, River Raisin, and various other points as far up as Somerset Center. That at Palmyra is 5 feet high, but washed out this year, and at Somerset Center 11 feet. The mill at Somerset Center is situated not far from the head waters of the stream, which is fed by a large spring.

South Branch of Raisin River.

The south branch of the River Raisin is 731 feet above tide at Adrian and 831 feet high on the line between sections 2 and 3, T. 7 S., R. 2 E. Wolf creek is 935 A. T. high at Springville in T. 5 S., R. 2 E. and about 730 feet A. T. where it empties into the south branch of the River Raisin near Adrian.

Black Creek.

Black creek heads northeast of Hudson, emptying into the River Raisin about three miles west of Blissfield. On the section line 3 and 4, T. 8 S., R. 4 E. the elevation is 686 A. T.; 1/2 mile south of Jasper the height is 723 A. T.; near the northeast corner of section 15, T. 8 S., R. 2 E. the elevation is 783 A. T.; at the northeast corner of section 9; T. 8 S., R. 2 E. of 793 A. T.

Tiffin River.

Where the Tiffin river is crossed by the Lake Shore and Michigan Southern R. R. in section 24 of T. 8 S., R. 1 E. the elevation of the track as given by Mr. Leverett is 794 feet and of the stream about 775 feet A. T. One-tenth of a mile south of the northeast corner of section 36, T. 7 S., R. 1 W. the height is 869 feet A. T., the elevation increasing to 887 feet three-tenths of a mile south of the northeast corner of section 25 in the same township and range. At Hudson the stream is 898 feet above sea level. There are dams in the river in section 36 and at Tiffin.

In Cass county there are several small powers. Christian creek formerly had a dam at Vandalia. The elevation of the stream there is 861 A. T. One-half mile south of the northeast corner of section 9, T. 7 S., R. 14 W. the elevation is approximately 847 feet A. T.

Pokagon creek is 730 feet high at Pokagon falling 55 feet where the stream crosses the road, six-tenths of a mile west of the northeast corner of section 31, T. 6 S., R. 15 W. This makes the fall very nearly 9 feet per mile. If the same rate is continued down stream to where the creek empties into Dowagiac creek, two miles west of Pokagon, the elevation would be approximately 712 A. T. for both streams. Mr. Leverett gives the elevation of Dowagiac creek on the north line of section 16, T. 6 S., E. 16 W. as 720 A. T. In the northeast quarter of section 27, T. 5 S., R. 16 W. the elevation of the north fork is about 723 A. T. increasing to 728 feet near the northeast corner of section 24, T. 5 S., R. 16 W. The south fork of this stream is 800 feet A. T. below the 10 foot dam at La Grange. The millpond here floods over several fractional sections of land. Near the corner of sections 1, 2, 11, and 12, T. 6 S., R. 15 W. there is another power utilized by a farmer for a feed mill. Between the two forks of Dowagiac creek is situated what is known as the Marguerite mill. This is on the quarter line of section 13, T. 5 S., R. 16 W. The creek there is tributary to the north fork of Dowagiac creek and is 738 feet A. T. The darn is 8 feet high. There are probably a number of small powers along Dowagiac creek and its tributaries which could be utilized for local milling purposes or village electric light plants.

St. Joseph River.

The St. Joseph river of lower Michigan and northern Indiana rises north of Hillsdale and empties into Lake Michigan at St. Joseph. In St. Joseph county at Constantine the stream has an elevation of 762 feet A. T. Mr. James E. Bunn, city clerk of Three Rivers informs me that "the water in the St. Joseph river below the darn at the St. Joseph cement bridge is 14.5 feet below the top of the rail of the Michigan Central R. R. track at their depot."

"The water in the race adjacent to the M. C. depot is 8 feet below the top of the rail at that point."

"The water in the St. Joseph river below the dam at the St. Joseph cement bridge is 11.2 feet below the top of the rail of the L. S. & M. S. R. R. tracks at their depot."

"These measurements were taken in August, 1902, when the water was at an ordinary stage—neither low nor high. At the present time (Nov. 10, 1903) there would be considerable difference, owing to the low stage of the water."

The elevation of the Michigan Central tracks at their depot is 795 feet A. T., which would make the elevation of the river 780 feet A. T.

In the east half of section 10, T. 6 S., R. 11 W. the river is approximately 795 feet A. T. under the bridge. One-tenth of a mile south of the east quarter post of section 27, T. 5 S., R. 10 W. in the village of Mendon, I made the elevation 826 feet A. T. There is a gage located here. Where the stream is crossed by a bridge in the northeast quarter of section 3, T. 6 S., R. 9 W. the altitude is approximately 835 feet A. T.

In Hillsdale county the river has an elevation of 991 A. T. at Litchfield, and of 1085 feet at Jonesville. There are dams at both places, the one at Jonesville being an overflow dam between 6 and 7 feet high.

Fawn River.

This empties into the St. Joseph river in Constantine, where as we have seen, the elevation of the main stream is 762 feet above tide. Where this tributary river is bridged in the northwest quarter of section 28, T. 7 S., R. 11 W. the height is 797 feet. At the intersection of the G. R. & I. R. R. one mile south of the Michigan state line the elevation has increased to 855 A. T. This stream drains the region south of the Sturgis moraine, and a small part of northern Indiana.

Prairie River.

This water course, which is otherwise known as Hog creek or Spring creek in its lower reaches, has two forks in the south central part of Branch county, one rising in Pleasant lake, the other in Cook lake. Westward the river passes near Burr Oak, through Centerville, emptying into the St. Joseph river not far south of Three Rivers. The following elevations were obtained: Just south of the Michigan Central R. R. at Centerville the height is 803 A. T. Where the stream is crossed by the G. R. & I. R. R. less than one-half mile east of Nottawa the elevation of the stream is 825 feet above sea level.

Just north of the northeast corner of section 22, T. 7 S., R. 9 W. the altitude has increased to 859 feet A. T.

In Branch county one-tenth of a mile south of the northeast corner of section 26, T. 7 S., R. 8 W. the height is 911 A. T., increasing to 930 feet, two-tenths of a mile north of the southeast corner of section 32, T. 7 S., R. 7 W.

Portage River.

This stream unites with the St. Joseph river at Three Rivers, where as we have seen, the elevation is 780 feet A. T. Three-tenths of a mile south of the northeast corner of section 27, T. 5 S., R. 11 W. the height is about 820 A. T. Where the stream is crossed by the G. R. & I. R. R. in section 22, T. 5 S., R. 10 W. the elevation is 835 feet A. T. This stream rises in the eastern part of Kalamazoo county running southwest.

Bear Creek.

This water course runs across the southeastern part of Kalamazoo county, emptying into Nottawa creek west of Leonidas. Where the two streams unite two-tenths of a mile west of the east quarter post of section 20, T. 5 S., R. 9 W. the elevation 838 feet A. T.; dam 4 feet high.

Hog Creek.

This water course runs northwest from the west central part of Hillsdale county to its junction with the St. Joseph river at Union City in the northern part of Branch county. At the north quarter post of section 23, T. 5 S., R. 6 W. the elevation of the stream is 945 feet above sea level, increasing to 967 feet A. T. at the northeast corner of section 29, T. 5 S., R. 5 W.

The elevation of numerous small water courses were obtained, but it is believed that the elevation of all the streams that can have any economic development is given.

CHAPTER IV. WATER SUPPLY OF LENAWEE, HILLSDALE, BRANCH, ST. JOSEPH, AND CASS COUNTIES.

LENAWEE COUNTY.

Flowing Wells.

Within the limits of this county there are two principal areas in the lower parts of which flows have been obtained. In the eastern part of the county there are several flowing wells east of the Belmore beach, which follows approximately the road running northeast and southwest through Ridgeway, and west of the line 700 feet A. T. This area leads northeast of Lenawee Junction. I have not obtained the records of any flowing wells west or south of the River Raisin.

Within this area beginning at the northeast flows have been obtained at Britton, southeast of Ridgeway, Holloway, at the northeast of Raisin Center, in the east half of section 32, T. 6 S., R. 4 E., and at Lenawee Junction. At Britton the depth of wells varies from 25 to 50 feet deep, the elevation being about 698 to 700 feet A. T. In the east half of section 32 the flow is found in gravel at a depth of 186 feet; surface elevation 725 A. T. At Lenawee Junction the water is also found in gravel in the drift at a depth of 135 feet, the elevation A. T. being 714 feet. Most of the flows through here are small. It is quite noticeable that the depth increases to the south, which will have to be taken into account in prospective drilling.

Tipton-Rollin Artesian Area.

Another belt trending southwest from Tipton is described by Mr. Wm. Beebe of that place as being from 1/2 to 2 miles wide and extending northeast and southwest of Tipton for a distance of over 40 miles, the wells varying from 12 to 150 feet in depth, but mostly from 50 to 70 feet in depth. At Tipton the head is 900 A. T., the wells being 25 to 75 feet deep. In the valley of Wolf creek artesian wells are found at the southeast corner of section 1, T. 6 S., R. 2 E., at a depth of 81 feet. One mile south two flows were found at a depth of 94 and 76 feet the greater flow coming from the more shallow well. In section 10, T. 6 S., R. 2. E., at an elevation of 966 feet A. T., a fairly strong flowing well throwing water 10 feet above the surface was obtained at a depth of 58 feet. The water is slightly chalybeate both here and at Tipton. South from Rome Center and three-tenths of a mile east of the northeast corner of section 28, T. 6 S., R. 2 E. there is a strong flowing well at an elevation of 900 feet A. T. This is in the basin of the south fork of the river Raisin. The most westerly flow that I obtained any information of in this area, is the southwest quarter of section 27, where a flowing well is found at an elevation of 982 feet A. T.

The flowing wells in this tract are all found in the area between the 900 and 1,000 foot A. T. contour lines. In the low areas the probabilities for obtaining flows are fair, especially east of the morainal tract running south from Stoddard.

Addison and Woodstock.

In the northwestern part of the county flows are occasionally found at Addison and Woodstock at a depth of 25 feet. This is west of the Huron-Erie moraine.

Ground Waters.

In reviewing the water supply data for the rest of this county I have begun at the southeastern part of the county and worked by townships north and west, after the manner of the original linear survey. The advantage of this plan, however, is that some approximation is made to the altitude of the land, the difference of elevation affecting to a greater or less extent the depth at which water can be obtained. But this is mostly within circumscribed areas where the elevation is abrupt.

In the territory between Sisson, Blissfield and Riga the land is a plain varying in elevation from 665 to 700 feet A. T. The depth of wells is from 82 to 95 feet, water generally being obtained in beds of gravel. In one well in section 5, T. 8 S., R. 5 E. the rock was struck at a depth of 602 A. T. or 88 feet below the surface and the water is soft. In two wells in section 16, T. 7 S., R. 5 E. salty water is found at a depth of 82 to 95 feet. Water in bed rock will probably be salt?

In T. 6 S., R. 5 E., which includes the civil townships of Ridgeway and part of Deerfield the topography is level through the central portion. The elevation increases from 675 feet A. T. in the southern portion to 740 A. T. at Ridgeway. The depth to water is variously stated as from 13 to 100 feet. Wells having a depth of 13 feet are doubtless surface waters. Not only are they liable to contamination but the supply is generally insufficient in summer. Such sources of water supply should be deepened. Water is found in the drift and is generally hard. In two of the wells having the greatest depth of 87 and 100 feet the water is brackish. In general it would seem that a fair supply of water could be obtained at a depth of less than 30 feet. In a well 200 feet in depth situated in section 33, T. 6 S., R. 5 E. no water was found.

Macon Township.

The township of Macon corresponds to the government township of T. 5 S., R. 5 E. The elevation increases over 100 feet from the eastern border of the county to the divide east of the Raisin river. A fair amount of water is obtained at a depth of 20 feet or less, the water being hard. One well situated in section 27 entered rock at a depth of 120 feet, or 622 feet A. T. Mr. Frank Leverett is engaged in the preparation of a report on this, and the adjoining township to the west, in connection with his work on the Ann Arbor Quadrangle. The results are to be published by the U. S. Geological Survey.

Ogden Township.

In Ogden township, T. 8 S., R. 4 E. the well records showed a depth of from 60 to 115 feet. The township is a plain going north and east from the center, the elevation within that area being from 709 to 714 feet A. T. outside of Black creek, which is about 15 feet below the level of the surface, in the north central part. The water is found in gravel beds in the drift. In three wells having a depth of from 80 to 115 feet the water is impregnated with salt and sulphur. Around Ogden Center the average depth of wells is 100 feet.

Palmyra and Raisin Townships.

These occupy townships 6 and 7 S., R. 4 E. In this area all the wells of which I obtained information are found in gravel beds in the Pleistocene. The wells vary in depth from 37 to 180 feet, the water being generally hard, except in the well 37 feet deep. There are no wells mentioned in which salt or sulphur occurs. It is in a portion of this area that flowing wells are found. As has been mentioned Mr. Leverett is reporting on Clinton township to the north.

Fairfield and Madison Townships.

These lay south and west of Adrian in R. 3 E. South of Adrian the country is hilly for three or four miles, being rolling south of Fairfield and west of Jasper. Most of the wells are shallow, water being obtained at a depth of from 14 to 47 feet, the elevation increasing somewhat to the north. Water is obtained in sand and gravel beds in the drift, being generally hard. The supply is abundant.

Adrian and Franklin Townships.

These are townships 5 and 6 S., R. 3 E. and contain the flowing wells found at Tipton, and southwest from there. Like the wells south from here the water is hard. In Adrian township water is generally found at a depth of less than 40 feet in the drift, increasing somewhat in depth northward. Two miles south of Tipton water is obtained at a depth of 62 feet, which is the average depth for wells at Tipton.

Seneca and Dover Townships.

These are the government townships of 7 and 8 S., R. 2 E. East and north of Seneca P. O., which has been renamed Ennis, the country is rolling. Water is obtained from the drift in wells varying in depth from 30 to 110 feet. The Avater is generally hard. In two wells having a depth of 42 and 65 feet, in the southern part of Dover township the water contains iron. In several of the wells having a depth of less than 40 feet the supply is limited or decreasing. In a well 110 feet deep the capacity is 50 barrels per day. It would probably be well to go to a depth of over 50 feet for water supply. Mr. Chas. Middleton, section 27, T. 7 S., R. 2 E., states that the first 20 feet was red clay, changing to blue, with occasional beds of gravel. Under that 48 feet of sand in which the water was obtained.

Rome and Cambridge Townships.

These are townships 5 and 6 S., R. 2 E. The Huron-Erie moraine runs along the western part of Rome township and east northeast through Springville in Cambridge township. Dr. E. J. Ross of Rome P. O. writes that the east half and the southwest quarter of Rome township is rolling being composed of a heavy clay. The northwest quarter is "hilly and sandy." On the road from Tipton to Cambridge and south of Cambridge to Onstead the country within the moraine is hilly, with overwash beds of sand and gravel.

The average depth for wells around Rome center is 75 feet, the depth varying from 45 to 145. In two wells dug there the depth is 85 and 91 feet. The water rises 75 feet. Water is obtained in the drift from beds of sand or gravel. It is either hard or contains iron. In Rome township the supply is abundant, and as we have seen, the water head frequently reaches the surface producing flowing wells. To the north in Cambridge township the depth of wells varies from 16 to 48 feet, water in some cases being obtained about on a level with adjacent lakes. Where the supply has lowered, the causes seem to be local. The remedy probably lies in either having the wells sandpumped or increasing the depth. Wells are found in the drift.

Medina, Hudson, Rollin and Woodstock.

In this tier of townships, forming the western part of Lenawee county, the water is generally found in the drift. In one well in section 21, T. 6 S., R. 1 E., having a depth of 265 feet, the well entered rock at about that depth. This is 806 A. T. At the Hudson water works the city is supplied with 8 wells 6 inches in diameter, which are capable of supplying 300,875 gallons per day. In general throughout this region the supply is abundant at depths varying from 25 to 100 feet. Mention has already been made of the artesian wells in the northwestern part of the county.

HILLSDALE COUNTY.

Wright and Pittsford Townships.

These townships are located in the southeastern part of Hillsdale county, constituting townships 7 and 8 S., R. 1 W. Water is found in gravel beds at a depth of from 10 to 245 feet as at Pittsford. The supply is ample. Water is generally hard except in a well 71 feet deep which is reported soft. The depth at which water is usually obtained is from 35 to 95 feet. In the deep well at Pittsford the supply was obtained from water bearing gravel at a depth of 245 feet, the water rising 145 feet. This is situated on a heavy morainal deposit.

Wheatland and Somerset Townships.

These are townships 5 and 6 S., R. 1 W. Mr. A. C. Lane has represented the greater portion of this area as underlaid by the Marshall sandstone. In Wheatland, T. 6 S., R. 1 W., I did not obtain the record of any wells into the rock. But they would probably yield water as the Marshall sandstone is a good source of supply. In Somerset township, section 8, rock was struck at an elevation of 1,163 feet A. T., dropping in section 23 to 1,037 A. T. A flowing well was obtained in section 1 of Wheatland, and near Somerset. There is also a very fine flowing well in section 16, T. 6 S., R. 1 W. This is found in a narrow valley and is isolated. The amount of flow is 23.37 gallons per minute. Flows are also obtained at Jerome at a depth of 30 feet. Throughout the central part of these townships there is an abundant supply of hard water. Springs are abundant near Jerome.

Ransom and Jefferson Townships.

In these civil divisions constituting townships 7 and 8 S., R. 2 W., the depth to water in Ransom township varies from 20 to 90 feet, throughout the central portion the average depth being 53 feet. The land is rolling. In Jefferson township to the north the depth varies from 14 to 79 feet, the average depth around Osseo being given as 50 feet. There are no flows throughout here that I obtained information of. The water is hard and occasionally contains iron. Water is from gravel beds in the drift. Osseo is near the edge of a moraine which follows approximately the course of the Marshall sandstone. The drift accumulation is probably considerable, but an abundant supply of water is obtainable if the supply from the drift should fail. In Jefferson township the depth to water varies as much as the surface.

Adams and Moscow Townships.

These are townships 5 and 6 S., R. 2 W. Almost the entire area is represented as underlain by the Marshall sandstone in Mr. Lane's most recent geological map of Michigan. The depth to water varies from 18 feet near Lake Adams, where the surface elevation of the well is 1,136 A. T., the water being found at 1,118 and the elevation of the lake is 1,117. North from here in section 21, T. 5 S., R. 2 W., water is found in the Marshall sandrock at a depth of 95 feet at an elevation of 1,164 A. T., rock found at 50 feet. In a well in section 3, T. 5 S., R. 2 W., sandrock is said to have been struck at a depth of 14 feet; surface elevation 1,104 A. T. A well in section 21, T. 6 S., R. 2 W., entered rock at 70 feet; the well top is 1,160 A. T. The elevation of the rock surface, therefore, is from 1,090 to 1,115 in the central portion of Adams and Moscow, the average amount of drift being 50 feet more or less. Throughout this area there is an abundant supply of hard water both in the sand-rock and the drift.

Woodbridge and Cambria Townships.

These form townships 7 and 8 S., R. 3 W. of the linear survey. In this valley of a tributary to Cubb lake there are two flowing wells found in sections 22 and 26, T. 7 S., R. 3 W. The region is very hilly. Areas in which flows are likely to be obtained are constricted in area. The depth to water varies somewhat according to the elevation of the land. Thus we have a well 32 feet deep at a height of 1,048 A. T. in section 11, T. 8 S., R. 3 W., the greatest depth increasing to 96 feet at an elevation of 1,089 A. T. in section 34, T. 7 S., R. 3 W. Where relatively high elevations of land cover a considerable area the catchment basin generally increases with the surface. The reverse is true where the elevation approaches a knob formation.

Fayette and Scipio Townships,

These are townships 5 and 6 S., R. 3 W. Around Jonesville the depth to water is from 20 to 100 feet, at Hillsdale 35 feet, and at Mosherville 24 feet. In all three places an ample supply of hard water is obtained. The greater part of this area is underlain by the Marshall sandrock, forming a continuation of the region to the east. The greater part of the water supply comes from the bed rock. A spring on the farm of Arthur Merchant, in section 29, T. 5 S., R. 3 W. is said to flow from this sandrock. This is in the valley of the St. Joseph river.

Camden and Reading Townships.

Artesian wells have been obtained at Reading and in sections 18 and 19, T. 7 S., R. 4 W., the depth to water varying from 70 to 90 feet. This depressed area runs north and south, west of the elevation around Reading, and may furnish flowing wells at other localities. At Reading the Coldwater shale was struck at about 55 feet. In section 2, T. 7 S., R. 4 W. the Marshall ? sandstone was found under 22 feet of drift at 1,115 A. T. Again in section 22 of Reading township rock (Marshall?) was struck at 1,117 A. T. with an abundant supply of water. All the northeastern part of this township is probably underlain by the Marshall, which is a good bearer of water. The rest of this area is underlain by the blue Coldwater shales, with occasional thin beds of limestone. This is a poor water carrier, and wells will be sunk to best advantage in the overlying drift or soil formation. In Camden, T. 8 S., R. 4 W. the drift is 112 feet thick in section 15 and furnishes a steady supply of hard water.

<u>Allen and Litchfield Townships.</u>

These are townships 5 and 6 S., R. 4 W. Water is hard but there is an abundance of supply at depths variously ranging from 25 to 60 feet. The elevation of wells varies from 1,011 to 1,113 A. T. in the central portion of this area while the level reached by wells is from 997 to 1,098 A. T. This makes the extremes of the surface and water elevation very nearly the same. Marshall sandrock was struck at a depth of 15 feet in section 34, T. 6 S., R. 4 W., elevation 1,098 A. T.; in section 28, T. 5 S., R. 4 W., at about 28 feet or 997 A. T.; in section 13, T. 5 S., R. 4 W. at 40 feet or 1,027 A. T. The probabilities are that the eastern half of both of these townships are underlain by this water bearing sandstone, as well as the north and east half of Litchfield township.

BRANCH COUNTY.

This county is underlain almost entirely by the Coldwater shale, which as we have seen, is a poor water producer. Therefore throughout the county water is found in the drift formation at a depth of less than 100 feet. The water is almost uniformly hard, and occasionally contains iron. In lake regions wells are generally shallow, the depth to water being the same as the elevation of the lake surface.

<u>Algansee and Quincy Townships.</u>

In the central portion of these townships the depth to water is from 15 to 38 feet, the elevation of the water horizon rising and falling with the elevation of the surface. The supply is abundant, the wells at the Quincy water works having a capacity of 20,000 gallons per hour. The supply is generally sufficient for all needs.

<u>Kinderhook and Ovid Townships.</u>

These are townships 8 and 7 S., R. 6 W. In the former township the average depth is from 18 to 40 feet, the average depth around Kinderhook being 25 feet. In the township north, the depth varies somewhat in the hilly region. Thus in a well in section 21, the depth to water is 12 feet, the well being 856 A. T. North in section 16 the depth has increased to 90 feet, the surface elevation increasing 106 feet and the water horizon 28 feet. These elevations are more or less local. In section 18, T. 7 S., R. 6 W. the depth to water is 65 feet.

<u>Coldwater and Girard Townships.</u>

These are the government townships of 6 and 5 S., R. 6 W. In these two civil divisions the average depth to water is approximately 30 feet. The supply is abundant. In section 33, T. 6 S., R. 6 W. rock was struck at a depth of 36 feet elevation A. T. 960 feet. The water horizon varies from 900 to 1,000 feet A. T., oscillating more or less with the elevation of the surface.

<u>Gilead and Bethel Townships.</u>

These are respectively townships 8 and 7 S., R. 7 W. Around Gilead depth to water varies from 30 to 90 feet, the average depth being given as 30 feet. The supply is ample. The water horizon varies with the inequalities of the surface, maintaining throughout this area an average depth of approximately 25 feet in the central portion north and south. The supply comes from sand and gravel, and is abundant.

<u>Batavia and Union Townships.</u>

These constitute townships 6 and 5 S., R. 7 W. The average depth to water is very nearly the same as south of here or from 30 to 40 feet. Around Batavia the depth varies from 15 to 30 feet, increasing northward to 40 feet around Union City. The supply is ample except in the elevated morainal region north of Ensleys lake, where wells have been sunk to a depth of 50 feet, only obtaining a limited supply. I believe that a sufficient supply could be obtained within that area which is embraced approximately by the 950 foot contour line, by increasing the depth to 75 feet. The highest elevation that I determined within that tract is near the east quarter post of section 4, T. 6 S., R. 7 W. This is 990 A. T. At Union City a dry well 250 feet deep was sunk.

<u>Bronson, Mattison and Sherwood Townships.</u>

These townships are in the western part of the county and form townships 7, 6 and 5 S., R. 8 W. At Sherwood drilled wells are from 75 to 110 feet deep. On the moraine southeast of there the elevation increases 80 feet on the side of Mattison lake. In that neighborhood, however, wells sometimes strike water at an elevation of the lake surface, which is approximately 889 feet A. T. Through Mattison township the depth to water averages 45 feet, the elevation of the water horizon being 20 feet above the wells at Sherwood.

ST. JOSEPH COUNTY.

This county is also underlain by the Coldwater shale formation. Throughout the county water is generally found in sand and gravel beds in the drift or soil formation, properly known as the Pleistocene. I have not obtained any information relative to flowing wells in this territory, though there are numerous flowing wells at Klingers Lake and a few elsewhere in the county. The supply is generally ample. Like most of the wells from the drift the water is generally hard, and sometimes impregnated with iron.

Fawn River and Burr Oak Townships.

These form townships 8 and 7 S., R. 9 W. A fair average for wells in this locality would be 45 feet. On the south side of the Sturgis moraine, however, in section 5, T. 8 S., R. 9 W. the water horizon is at the same elevation as in Burr Oak township, the elevation increasing so that the distance to water, on an average, is 100 feet.

Colon and Leonidas Townships.

These are townships 6 and 5 S., R. 9 W. In this area the elevation of Sturgis lake is 835 feet A. T.; of Palmer lake 840 A. T. In the records of all the wells that I obtained between Leonidas, Colon, and thence on the road to Burr Oak, the elevation of the water horizon is within the elevation of these lakes. The maximum elevation obtained in this district is on the line of sections 2 and 3, T. 7 S., R. 9 W.; 909 A. T. The depth there to water would be about 69 feet, decreasing to 40 feet at Leonidas, where the elevation is 860 A. T., and to 25 feet in section 15. T. 6 S., R. 9 W., which is 866 A. T.

Sturgis and Sherman Townships.

In the Linear Survey these are townships 8 and 7 S., R. 10 W. Sturgis township lies south of the Sturgis moraine, or at least in its most pronounced development. On the road from Sturgis to White Pigeon the land is rolling for the most part, the fall amounting to 50 and 60 feet. The average depth to water in Sturgis township is the same as around Leonidas, amounting to 40 feet. The supply of water is abundant. At the Sturgis water works the capacity of the wells is 125,000 gallons per day. Mr. E. B. Gray, Supt. of the Sturgis water works, has very obligingly given an analysis of the water from the two wells there.

	Grains per U. S. gallon.	
Sturgis Water Works.	Open well.	Driven well.
Sodium carbonate	none	none
Lime carbonate	15.42	16.5
Magnesia carbonate	5.52	6.10
Lime sulphate	2.66	2.63
Magnesia sulphate	none	none
Sodium chloride	2.63	2.63
Free acid	none	none
Iron oxide and silica	0.20	0.23
Volatile organic matter	4.07	6.16
Total solids	30.50	33.80

It will be observed that the Sturgis moraine occupies the greater part of Sherman township to the north, the contour lines showing an elevation of 1,000 feet. Within this tract water in sufficient quantities is generally difficult to obtain, at depths of less than 100 feet.

Nottawa and Mendon Townships.

Going north these constitute townships 6 and 5 S., R. 10 W. Throughout this area the depth to water varies from 18 to 70 feet, the average around Mendon being variously given as from 20 to 70 feet in depth. The supply of water is generally ample.

Florence, Lockport and Park Townships.

These are townships 7, 6 and 5 S., R. 11 W. In these townships the water-bearing conditions seem quite fairly identical where I obtained records between Moorepark, Parkville, Centerville and thence southwest and west to White Pigeon. The average depth to water is 25 feet, wells varying in depth from 16 feet as in Sec. 3, T. 7 S., R. 11 W., to 40 feet in section 26, T. 5 S., R. 11 W. At Parkville the average depth is given as 14 feet the depth increasing to 27 feet at Flowerfield in the northwest portion of Park township. At the Three Rivers waterworks, and section 14 of the same township, flowing wells have been obtained in the valley of the St. Joseph river. The supply is ample.

Mottville, Constantine, Fabius and Flowerfield Townships.

In the Government Linear Survey these are respectively townships 8, 7, 6, and 5 S., R. 12 W. In Mottville township the average depth to water is very nearly the same as in the area last discussed. At White Pigeon the average depth is from 26 to 28 feet, decreasing to 20 feet at Mottville, which is in the valley of the St. Joseph river. At Constantine the topography is quite irregular as will be seen by referring to the contour map. Water is obtained there at depths variously ranging from 15 to 60 feet. Going north on the interlobate moraine a well in section 10, T. 7 S., R. 12 W. obtained an ample supply of water at a depth of 50 feet. The elevation of the well is 63 feet above the depot at Constantine. On the same moraine in the lower part of Fabius township water is generally found at a depth of 90 feet, increasing in depth northward, until in section 28, T. 5 S., R. 12 W., it is over 100 feet to water, which is found in the drift. In the valley of Rock creek, at a much lower elevation, there are springs at Howardsville.

CASS COUNTY.

Throughout this county the water supply is either obtained from the drift or from lakes or running streams. The county is underlain by shale rock, which is almost invariably a poor water producer. Flowing wells have been found in several localities, but apparently on low ground, with restricted areas. Most of the artesian wells are in the northern tier of townships. Northwest of Marcellus, at Fish lake, there is such a well 80 feet deep belonging to Dr. Davis. Two miles east of Wakelee there is another flow north of the interlobate moraine. Thence west in the township of Wayne, T. 5 S., R. 15 W., there are flowing wells at Glenwood, and at Dowagiac flows are obtained at 100 feet, which are utilized in the city water supply. West of Glenwood at Long lake there is another artesian well. In section 35, T. 5 S., R. 16 W., a flowing well 152 feet deep in the drift flows 1 barrel a minute. South of these localities a flowing well was obtained at a depth of 33 feet in section 19, T. 6 S., R. 14 W. There are also a few flows at Summerville in the valley of Dowagiac creek, the water being obtained from 30 to 100 feet.

Porter Township.

This civil division includes the government townships of 8 and 7 S., R. 13 W. Within this area there are generally 2 or 3 water horizons. In T. 8 S., R. 13 W., water is obtained at depths varying from 20 to 100 feet, but the elevation at which the water is found apparently varies more than the surface. In this area fine springs are sometimes found at the foot of the moraine. Going north the elevation increases after the crest of the moraine on the south side has been reached. Water through here is obtained at depths varying from 55 to 160 feet, the records showing that water was found at from 55 to 60 feet deep; at 120 to 125 feet; and from 160 to 165 feet in depth, the elevations of the water horizons A. T. respectively on an average of 835, 766, and 735 feet. The water is hard and is from beds of sand or gravel. In section 27, T. 7 S., R. 13 W., the following section was obtained:—

	Feet.
Surface soil and clay	3
Sand	53
Blue clay	2.5
Water bearing sand	23
Total	81.5

Newberg and Marcellus Townships.

These occupy townships 6 and 5 S., R. 13 W. In section 10, T. 6 S., R. 13 W., springs are found in great abundance. On the interlobate moraine in sections 9 and 16, T. 6 S., R. 13 W., the depth of water is from 100 to 130 feet, decreasing to 25 feet north towards Marcellus. In section 21 a well was sunk 199 feet without getting through the drift. The average depth to wells in Newberg township is 97 feet. At Marcellus the drift is over 208 feet thick. Drove wells there are from 12 to 25 feet deep, tubular from 60 to 100 feet. The average depth for wells in Marcellus township is about 45 feet.

Calvin, Penn and Volinia Townships.

These are townships 7, 6 and 5 S., R. 14 W. In the heavy morainic region in Calvin township, and adjacent thereto the depth to water varies from 50 to 90 feet, the average depth being about 65 feet. Northward in Penn, T. 6 S., R. 14 W., the average elevation is approximately the same, going north and south through the township. The water horizon, however, rises over 30 feet, making the depth to water 20 to 40 feet. At Penn wells are from 20 to 70 feet in depth; at Wakelee in the neighborhood of 50 feet, but occasionally 200 feet in depth. Around Vandalia the depth varies from 10 to 120 feet, those at 10 feet being surface water. Going north into Volinia the depth increases somewhat with the elevation, water being obtained from 60 to 115 feet, or on an average of 83 feet, more or less. Throughout these three townships there is generally an abundant supply of hard water.

Ontwa and Jefferson Townships.

These constitute townships 8 and 7 S., R. 15 W. Around Edwardsburg the depth to water is about 26 feet. The water is said to rise and fall in the wells, according to similar variations in the lake near Edwardsburg, but I am unable to find any very close agreement in the elevation of the water horizon and that of the lake surface which is over 10 feet higher.

In section 14 of Jefferson there are a number of springs. Going through this township on the road from Edwardsburg to Milton, the depth to water varies from 35 to 50 feet, the average of several wells giving 40 feet. In the hilly morainic region in the western part of this township the depth quite probably increases to 80 feet in places. At least this is true of the extension of this same hill region between Edwardsburg and Barron lake in Howard township.

La Grange and Wayne Townships.

In the Linear Survey these are townships 6 and 5 S., R. 15 W. The city of Cassopolis obtains a supply of soft water from Stone lake, which is supplemented by water from wells. Between Cassopolis and La Grange the depth to water varies with the surface, the water horizons in sections 22 and 26 being 35 feet below Stone lake. An abundant supply is obtained at a depth of 70 feet north of Cassopolis becoming less towards La Grange.

On top of the moraine which crosses the town line in section 4, T. 6 S., R. 15 W., the depth to water is 140 feet, as at Mr. Henry Springsteens. From here the elevation decreases to 30 feet in section 10, T. 5 S., R. 15 W. There are at least two water-bearing gravel beds in Wayne township, the lower water horizon in the morainal region probably outcropping in the springs at Glenwood, which are at very nearly the same elevation above tide.

Howard, Pokagon and Silver Creek Townships.

These are townships 7, 6 and 5 S., R. 16 W. Around Barron lake the depth to water is 20 feet increasing to 40 feet or over in section 4, T. 7 S., R. 16 W. On the road from Barron lake station to Edwardsburg, water is obtained on the moraine at 80 feet, at very nearly the top of the moraine or hill range. Between Pokagon and Dowagiac the land is rolling somewhat, the extremes of elevation being very nearly 50 feet. In this region water can be obtained at from 15 to 35 feet in depth. Around Pokagon the average is given as 25 feet with an ample supply of water. At Summerville there are a great many springs in the valley of the Dowagiac creek. The 11 flowing wells at Dowagiac which furnish part of the city water supply are 100 feet deep and have a capacity of 600 gallons per minute. The two dug wells 47 feet in depth, which are part of the same plant have a capacity of 400 gallons during the same time. The water is; hard and contains iron. I am indebted to Mr. Mann for a record there.

Dowagiac City Well.	Feet.
Black muck and fine sand	2
Sand and small stones	3
Fine sand	2
Stones and gravel	15
Sand and gravel	10
Water-bearing gravel	15
Total	47

ACKNOWLEDGMENTS.

General acknowledgment is due to a large number of persons who have rendered assistance, mainly by replies to schedules. I am particularly indebted to Alfred C. Lane for the free use of data accumulated in the office both before and since the publication of his water supply papers in 1899, and for criticisms and suggestions in this article. Mr. Frank Leverett has also greatly added to the completeness of this report. Thanks are due to him for the history of the glacial retreat as given in Chapter III and for several locations and names of the several moraines. Also for information and criticism relative to artesian wells, and the elevation of the River Raisin. For the altitudes in this report, however, I am almost entirely responsible. In obtaining these data, each line of aneroid elevations began and ended at the railroad station for nearly every day's work, and generally I was able to make a railroad depot at noon time, obtaining a check above tide on the barometer before and after dinner. In addition to this a self recording barometer was left at a railroad base, which gave the variation in feet per hour. Several railroad profiles have been obtained by Mr. Lane, and these were used to obtain independent elevations above sea level.

Finally, I wish to express my indebtedness to Prof. C. A. Davis of the University of Michigan for his notes on the water supply of Tuscola county. Prof. W. H. Sherzer who is engaged in the preparation of a report on the geology of Wayne county has also materially added to the completeness of this paper by his information on artesian wells there.

Lansing, Michigan, November 24, 1903.

ANALYSES OF LOWER PENINSULA WATERS.

In connection with Mr. Cooper's paper it seems well to give a number of analyses of waters that have been collected since the issue of Water Supply Paper No. 31, as such analyses are of interest to manufacturers and makers of boiler compounds, when the waters are liable to be used in boilers, and are also of interest medically and to cities. We divide them into three classes. (1) Surface waters; (2) shallow wells; (3) deep wells.

<u>1. Surface waters.</u>

Detroit river waters are illustrated by the following analyses for the Water Works Commissioners, all in grams per metric ton (parts per million).

DETROIT RIVER ANALYSES.

	1.	2.	3.	4.	5.
Calcium carbonate	33.00	5.10	57.49	28.2	79.2
Magnesium carbonate	....	.73	20.73	Mg Cl_2 3.50	1.53 1.14
Ferrous carbonate	8.14	21.00	trace.	8.9	.67
Sulphate of lime	....	2.54	17.80	43.3	1.20
Sulphate of soda	7.50	7.50	Na_2CO_3 5.75	....	Na_2CO_3 5.5
Sulphate of potash	2.83	2.88	trace.	K Cl 2.47	....
Phosphate of lime	31.10	51.92	....	(of Al) 0.58	....
Alumina	10.50	10.50	4.13	10.18	....
Silica	5.00	5.83	5.24	4.5	4.8
Chloride of sodium	trace.	trace.	3.93	.61	4.12
H_2S	....	trace.	....	....	....
Oxygen with permanganate	1.11	1.42	....	....	....
Total	98.07	108.39	115.16	103.7	108.0

1. S. H. Douglass, Feb. 11, 1854. Iron pipes, evidently imperfect. Note date.
2. S. H. Douglass, Feb. 11, 1854. Log pipes, evidently imperfect.
3. Frederick Stearns, (A. B. Lyons), inorganic constituents, Sept. 10, 1879, hydrant, quite unlikely to be so much sodium carbonate, better sulphate.
4. S. P. Duffield, 1861.
5. M. C. Fluke, 1877.

These analyses should be compared with analyses 4 to 8 and 5a, 6a and 7a of Water Supply Paper No. 31. The variation is more one of analytical combination and error, than in the quality of the water probably. No. 1 here is the same as No. 5 there, but is repeated for the sake of its companion No. 2. The total solids are 100—115 parts per million, and of these about 75 parts are calcium magnesium carbonates, more or less replaced by sulphates, of which there may be about 10 parts additional. There are about 5 parts silicia, 10 parts alumina, chlorine varies according to the purity of the water probably, but there is not less than 4 parts of chlorides, about half of which may be combined with potash. The hardness is accordingly about 5°. The presence of carbonate or sulphates of soda may account for the water being less hard than say Lake Michigan or Detroit river or most of the Michigan rivers. Probably the, waters from Georgian Bay also are less hard.

The analyses below show the water of Pine river at Alma.

PINE RIVER.

A. N. Clark, Analyst.

	Parts per thousand.	Parts per thousand.
Total solids	.26940[1]	.34148[2]
Inorganic matter	.22188	.26444
Organic matter	.04752	.09504
	.53880	.70096
Free ammonia	.00020	.00060
Insoluble in HCl	.01050	.01200
$(Al_2\ Fe_2)\ O_3$	.00300	.00730
Ca O	.07249	.07562
Mg O	.03098	.03084
$S\ O_3$	.02229	.03018
Cl	.00300	.00500
	.14246	.16154

To Mr. W. M. Courtis we owe a number of water tests, which though incomplete are of interest. They were mainly made for a special purpose,—to test the water for beet sugar or boiler purposes. The following two are of (1) Clinton lake and (2) Clinton river:—

CLINTON RIVER.

Character.	Both neutral carbonates.	
	1.	2.
Temporary hardness in parts per 1,000,000	105.3	....
Permanent hardness in parts per 1,000,000	34.0	....
Total	139.31	116.
Compared with Detroit river	2.7	2.2
Suspended matter	3.71	....
Solid salts	280.	....
Lime as carbonate	119.40	114.84
Magnesia carbonate	55.82	50.43
Soda and potash	1.65	....
Silica	2.24	288.
Alumina (with ferric oxide)	.29	14.73
Organic matter with crystallization water	100.40	108.
CO_2	present	in both.
Cl	traces	in both.
Phosphoric acid	....	trace.
Molassegenic salts (harmful in making sugar) very small	....	....

1Above dam-7:10 A. M., September 16, 1902.

[2]465-ft. below mouth of factory sewer-8:30 A. M., September 16, 1902.

The following tests are of Calumet river, which is a neutral carbonated water, a good deal like Clinton river, with the salts mainly carbonate of lime and magnesia, with traces of sulphuric acid and chlorine. For boiler water there should be 76% allowance.

CALUMET RIVER.

	Parts per million $Ca\ CO_3$
Temporary hardness equal to	134
Permanent hardness equal to	191
Total (19° or)	325
Solid salts	460
Compared with Detroit river, 4½ times harder.	

The character of the following Oxford water is unknown,—it may be a shallow well, but I think probably not. It is also a neutral carbonated water. I have made some emendations.

OXFORD.

	Parts per million gals. $Ca\ CO_3$
Temporary hardness equal to	140.6
Permanent hardness equal to	55.4
Total (11.4 or)	196.0
(Clarke's scale, Courtis 6.2.)	
Solid salts	233.38
Organic matter	58.8
Sulphuric acid	0.26
(For boiler water 9.81.)	

It is probably an ordinary hard (calcium carbonate) water. The following tests of a water from Pinconning were to test its fitness as a boiler water. It compares most closely with Owen's test of a surface water at Kawkawlin river, among his Bay county analyses (Annual Report for 1902). It is also neutral carbonated. The hardness is equal to 236 parts (per million Ca CO3).

PINCONNING.

Clarke's scale 3 to 4.	
Compared with Detroit river it is 2.14 times as hard.	
Suspended matter	350.
Solid salts	600

(It must undoubtedly be salty as so many of the Bay county waters are.)

Lime, magnesia, ferric oxide, organic matter, carbonic and sulphuric acids, and chlorine present.

2. Shallow wells and springs.

The following is an analysis of the Owosso mineral water, which comes out of the side of a moraine just north of town, flow—11 barrels per minute with a temperature of 50° F. This is practically the same as No. 227 of the Water Supply Paper No. 31. The analysis is by Prof. S. P. Duffield and reduced from grains per imperial gallon by dividing by 70 while the analysis there is the same but the gallon was assumed to be the U. S. gallon, which it proves not to be.

OWOSSO.

		Carbonate.
Calcium bi-carbonate	366.7	227
Magnesia bi-carbonate	272.8	157
Iron bi-carbonate	227.4	148
Sodium (and potassium) chloride	30.0	30
Silica and alumina	8.8	9
Total	905.7 904.9	571

The water is rather unusually strong in carbonates, and the salts must (see page 212 of part 3, of Vol. VIII) be in the form of bi-carbonates. But of course on evaporation this would be lost and the total solids left would approach the second set of figures.

On page 60 is given a partial test of the water of the Sanitas Spring, Topinabee, by Prof. J. V. Stanislaus. The water is from a well driven or drilled 130 feet through drift. The spring itself on August 17, was so piped that the temperature did not fall below 50°. It was a hot day. But near by a similar well at the railroad station had a temperature of only 48.8°, while near by at Indian River flowing wells ranging from 90 feet to 189 feet deep through 40 to 60 feet of sand and 20 feet of smooth clay had temperatures ranging from 47.6° up to 53° according to the amount of pipe and strength of flow.

These two are almost[1] at the extremes as regards hardness. I imagine the cause of this difference may lie in the fact that the Owosso spring draws from a comparatively narrow vein through the till, extracting all the lime it can from the highly calcareous till, while the Topinabee well taps a sand or gravel bed laid down in and full of water of an old glacial lake, which was relatively soft as melting ice generally is.

We have an interesting series of analyses near Durand. According to W. J. Richards, bed rock does not occur there until 180 to 210 feet down, so that the well record in Volume VIII, part 2, p. 199 must be corrected accordingly. The brown shale is then probably merely a pink or brown stratified clay. He says the springs south of town, analysis (4), are in lime beds. In putting down a well by the railroad he used water from the ditch but it was too salt. There is he says, 24 grains to the gallon, analysis (4), in a 200 foot well in the gravel. He has recently put down a well only 60 feet from the former Durand well 206 feet deep, with 51 feet of gravel. He thinks it would have been 210 feet to bed rock. Half way up West Main street there is a trough where the water has 6 feet head.

[1]Mrs. W. Peterson, West Olive, according to the U. S. experiment station at the Michigan Agricultural College has still softer water.

DURAND.

	4.	1.	3.	2.	5.
Depth	178 ft.	178 ft.	Spring.	91 ft.	Spring.
Calcium carbonate	87.1	46.0	206.	68.5	121.6
Magnesium carbonate	66.5	42.0	92.1	54.7	101.6
Sodium potassium sulphate	44.6	35.6	16.	14.8	8.9
Sodium potassium chloride	414.0	253.	17.2	57.3	25.6
Sodium potassium carbonate	34.3	158.2	36.0	93.0	23.0
Silica	16.3	4.0	2.2	8.2	4.5
Iron and Alumina	trace.	1.3	2.0	3.7	2.5
Total	661.5	540.1	375.5	300.2	290.7

We have arranged these analyses in order of decreasing amount of salts. Analysis (6) by Prof. Kedzie is stated in a slightly different form, but is not essentially different from 5 though only 50 feet deep. Nos. 5 and 6 represent the second water there and 4 and 1 the third, which is quite brackish. No. 6, the city water well, is about 6 to 10 rods from the plant, and goes through 10—18 feet of blue clay, then sand and a little gravel and hardpan, striking the water-bearing gravel from 50 to 55 feet down, i. e., the second water.

No. 6. Depth 50 to 58 feet.	Parts per million.
Calcium carbonate	66
Magnesium carbonate	73
Calcium sulphate	23
Sodium chloride	46
Silica	10
Alumina and iron	13
Organic (volatile at red heat)	66
Total	297
Temporary hardness (removed by boiling)	6
Permanent hardness	8
Total	14

In total solids this closely resembles Nos. 2 and 5.

As to boiler use:

1. Gives little scale, will give corrosion, pitting, perhaps foaming.

2. Gives some scale, medium hard, slight foaming.

3. Fair water, twice as hard as No. 2, but not as hard as usual, considering total solids.

4. Gives some scale but more corrosion.

5. Average feed water, with considerable scale of medium hardness but not corrosive.

The deepest well is about three feet above the crossing. Rigg's and Sherman's map varies from 80 at the north to 103 feet above their datum, the crossing being 93. The deepest well was put down by J. Coryell.

Other wells around here at Byron, etc., are salty, and we must imagine that the Durand wells barely escape striking the Michigan series and do get some of the salty waters thereof. In fact if it is really as deep to bed rock there must be a valley in the rock surface here into which these brackish waters might easily collect.

In Volume VIII, part 2, is also found an analysis of Goose lake near Cement City, showing the character of the water in one of the marl lakes, the main constituent out of 282 parts per million solids is 262 parts per million calcium magnesium carbonate.

The following analysis by W. M. Courtis labelled Detroit Water, is certainly not a surface water, but probably of a shallow well:

Character	salt
Suspended matter	18.94 per gal
Solid salts	235.667
Lime as carbonate	22.649
Magnesia	with the lime
Soda and potassa, as chlorides	213.018
Silica and ferric oxide	with lime
Carb. acid	present
Sulphuric acid	present
Chlorine	present

EATON RAPIDS.

Analysis of Eaton Rapids water made by F. W. Robinson for Prof W C. Eslow.

Total solids	1.550000
Loss on ignition	.270000
Free ammonia	.000360
Albumenoid ammonia	.000100
N_2O_5 Nitrates and nitrites	absent
Cl	trace
SO_3	.0683800
SiO_2	.0019000
Fe_2O_3 (etc.)	.00054
CaO	.0638000
MgO	trace only
CO_2	considerable—not estimated

Quantities are in parts per thousand. Well cased 35 feet only; 185 feet deep.

Passing now to the wells into bed rock, but not very deep and with so little mineral matter as to be palatable drinking waters, we have to compare with Nos. 243 to 247 from Eaton Rapids the following, which is like the other wells in this group, high in sulphates and iron, low in chlorides, a typical coal series water.

Ashley, Chesaning, and Maple Rapids have waters unusually strong in sulphates relative to chlorides. The analysis at Ashley is as follows:—

ASHLEY.

	Per million.
Calcium carbonate	40
Calcium sulphate	693
Magnesium carbonate	146
Sodium chloride	666.8
Silica	8.8
	1554.6

Albion is another place where the various wells have been carefully studied, where also there are flowing wells. In the set of 13 analyses by Prof. Fall given below, we note that Nos. 1, 2, 3, and 4 penetrate into bed rock, entering the Marshall sandstone. The depth of the other wells is not known but they are not deep. No. 1, artesian flowing, possibly the National Bank well, which is now descended to by steps from the side-walk. It used to flow above the street level and with force enough to spatter out of the cup, but now has lowered until there is not much head and it stops in dry weather. It is 200 feet deep, but the water is mainly at 100 feet, and yet the extra amount of chloride over 2 and 3 is doubtless from the greater depth.

ANALYSES OF ALBION WATER.

BY DELOS FALL.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Total solids	396.	309.	305.	332.	580.	600.	....	500.	228.	614.	....	428.5	571.
Chlorine	36.88	4.5	4.5	5.6	37.80	28.6	40.	74.3	7.14	32.8	32.8	51.4	42.8
Free ammonia	.228	.114	.082	.088	.096	.022	.08	.12	.046	.08	07	.08	.066
Albumenoid ammonia	.048	.042	.052	.054	.062	.12	.26	.42	.024	.32	.14	.35	.40
Temporary hardness	....	....	....	....	....	....	100.	....	28.5	14.3	....	5	107
Permanent hardness	....	....	....	....	....	....	100.	....	114.3	71.4	....	80.7	.93
Total hardness	307.	293.	293.	243.	279.	164.3	200.	....	142.8	85.7	157.1	85.7	200.
Nitrates	0.	.3	0.	.75	.15	....	....	....	....	....	....	....	....
Nitrites	Minute trace.	0.	0.	0.	0.	....	....	....	....	....	....	....	....

No. 2. The Warner Spring, flowing, the city water is the same as this and the following practically. The city supply comes from 4 6-inch wells and 4 8-inch wells from 110 to 114 feet deep, which used to flow with 8 to 10 feet head. They are close to the river bank. In July they are rather short of water. A partial analysis of this is given in Water Supply Paper No. 31, analysis No. 69.

No. 3. Parmenter well, 100 feet deep, similar to No. 2. These three first wells agree very closely, and the amount of ammonia and chlorine found are no sign of contamination. The hardness is considerably greater than in the 30-foot shallow well No. 9, and may point to nearly complete saturation with bi-carbonate in the absence of free CO_2.

No. 4 is from the Albion Manufacturing Co.

No. 7 was slightly turbid, yellowish, and had bad odor on standing.

No. 8 was considerably turbid, slightly green, and had hardly any odor on standing.

No. 9 was from a well 30 feet in the rock, clear, colorless, and odorless.

No. 10. Slightly turbid, colorless, odorless.

No. 11. Clear, bluish, odorless.

No. 12. Clear, slightly yellow, odorless.

No. 13. Clear, colorless, odorless.

In Lansing we have an analysis of the well of the Piatt Bros, which is a more or less mixed water. The analysis made at the M. A. C gave, in grams per ton:—

SiO_2	22.6	
Fe_2O_3	7	
CaO	147.6	
MgO	58.6	
Na_2O (48.6 Na)	65.5	
Cl	107.21	
SO_3	32.4	
CO_2	138.1	
		579
Total solids	680	
Loss on ignition (organic)	130	
		550
Inorganic matter present.		
Difference (O of Na_2O and Fe_2O_3)		29

This may be combined in various ways, for instance as:—

Calcium sulphate	54.9
Calcium carbonate	223.6
Magnesium carbonate	52.3
Sodium chloride	78.2
Sodium silicate	45.7
Magnesium chloride	78.6
	546.

This well is in the coal measures, and the presence of sulphates is significant, but the water is peculiar and has a peculiar history. It is 62 feet to bed rock and 115 feet deep. But it is only 125 feet from the Downey House well which, was put down 740 feet in hope of a flow. None was obtained, but it grew salty. So it was plugged at 72 feet. When the Piatt well is not pumping the Downey well[1] stands about 22 feet below the ground level, but when the Piatt well began to pump it dropped. The first of the year the Piatt well was not salt, but lately it has been so, as they are using it hard. It can give 17,000 gallons an hour, and they have used as much as 6,000 pounds. Evidently the Piatts are drawing from the Downey well below the plug.

[1]Proc. A. A. A. S. 1875.

A well at 1316 Washington avenue south, gave Prof. Kedzie:—

	Grams per litre.
Total solids	565.6
Organic	96
Inorganic	469.6
Chlorine	37.2
Sodium chloride	61.5

This was only between 30 and 100 feet deep.

The Kennicott Water Softener Co. have sent us the following analyses, obviously of rather shallow waters, though we do not know the exact source. Those at Midland and Benton Harbor are nearly saturated with incrusting solids.

Analysis of Water from Midland.

	Parts per million.
Calcium carbonate	126
Calcium sulphate	32
Calcium chloride	2
Magnesium carbonate	43
Magnesium sulphate	9
Magnesium chloride	9
Sodium sulphate	0
Sodium chloride	17
Sodium carbonate	0
Oxides of iron and alumina	3
Carbonic acid	78
Silica	62
Alkalinity	160
Suspended matter	29
Incrusting solids	237
Non-incrusting solids	17

Analysis of Benton Harbor Water.

Kennicott Water Softener Co., 1363, March 11, 1902.

	Parts per million.
Calcium carbonate	101
Calcium sulphate	18
Calcium chloride	trace
Magnesium carbonate	19
Magnesium sulphate	41
Magnesium chloride	0
Sodium sulphate	0
Sodium chloride	10
Sodium carbonate	0
Oxides of iron and alumina	2
Carbonic acid	8
Silica	6
Alkalinity	140
Suspended matter	37
Incrusting solids	224
Non-incrusting solids	10

Analysis of Niles Water.

Kennicott Co. 1396. Apr. 19.

		Parts per million.
$Ca\ CO_3$	4.02	69
$Ca\ Cl_2$	......	....
$Ca\ SO_4$	0.50	10
$Fe_2\ O_3$	0.05	1
$Mg\ CO_3$	1.57	27
$Mg\ Cl_2$	......	....
SO_3	0.47	8
$Na_2\ CO_3$	1.91	33
$Si\ O_2$	0.13	2
Na Cl	trace	....
Na	0	....
CO_2	1.28	2
Alk.	8.16	140
Sulp.	0	....
Incrust.	6.74	116
Non-incrusting solids	1.91	33

A report (Omaha Bee, Sept. 8, 1901) that there was a large amount of lithia found in a stream flowing into Little Traverse Bay by Prof. Kedzie was a mistake.

The following analysis by Prof. E. C. Kedzie of Carrier creek near Grand Rapids is also a typical hard water, but little more than saturated. There must be free carbonic acid and calcium sulphate in excess.

Calcium carbonate	160
Calcium sulphate	35
Magnesium carbonate	91
Soluble $Si\ O_2$	29
Sodium (and potassium) chloride	28
	315
Organic or loss	14
Total	329
Hardness 16°.	

S. O. Hickok at Allen, Hillsdale county, Michigan, has a well which yields:—

	Grams per gallon.
Sodium chloride	277.04
Calcium sulphate	33.04

In Saginaw recently[1] a well was put down in "middle ground," a former island in Saginaw river, to test the probabilities as a water supply.[2] The longer it was pumped the saltier it got as appears from the following tests, and it is apparent that the shallower wells in Saginaw are likely to have more or less admixture of salt from the abandoned salt wells whose casings have rusted.

[1]Saginaw Courier Herald 2:26:1903, 3:25:1903, 8:26:1903, 8:27:1903.

[2]It passed through lumber mill waste and salt, and at 12 feet river sand and then clay, then at 42 feet into fine gravel and then from 44 to 53 feet coarse gravel.

The following analyses were made by Heim Bros., reduced to parts per million.

June.	10	11	15	16	17	19	20
(Sodium) chloride	1,370	1,399	1,285	1,285	1,287	1,329	1,343
Total solids	2,630	2,809					
Hardness[1]			77°	77°	84°	87°	80.5°

[1]The hardness is probably largely sulphates as well as carbonates.

It may be worth while to include a few typical analyses of deeper waters, which may be classed as mineral waters or brines. I have spent some time in studying analyses of a large series of brines of the Napoleon series, analyzed by Hahn, but these have already been published, though in German. An analysis as yet unpublished, is the following, of the brine at St Charles, at a depth from 700 to 810 feet.

The statement is worked up by me from figures by A. N. Clark.

		Parts per thousand, grams per kilo-gram.
$Ca\ Cl_2$		48.100
$+2\ H_2O$	14.68	
$Ca\ SO_4$		.884
$+2\ H_2O$	.232	
$Mg\ Cl_2$		7.620
$Mg\ Br_2$		.200
FeO		.259
$Fe_2\ O_3$		.196
Balance chlorine as NaCl		222.460
		279.719
Water of crystallization		14.912
Solids by summation		294.631
Solids by evaporation		295
Specific gravity		1.183

This is a typical Marshall water, high in earthy chlorides, and low in sulphates. The North American Chemical Co. brine runs 40.3 $Ca\ Cl_2$ and 16 $Mg\ Cl_2$ with only .874 $Ca\ SO_4$.

The next important brine below, that of the Berea, is different, being very much freer from calcium magnesium chloride. This may be connected with its being isolated in a greater series of shales fairly free from lime and magnesia. The strata are also quite salt even close to their outcrop. For instance Mr. Cobb made the following determinations on a brine from Jason & Shumway's test well for oil:—

Sp Gr = 1.1426
Cl = 11.54

As sodium chloride 19.18% NaCl which would imply Sp. wt. 1.1441. Dow reports Sp. Gr. 1.139 and Br = .033 or $Mg\ Br_2$ = .0395.

Microscopic examinations of an evaporated drop shows no $Ca\ SO_4$ nor $(Ca\ Mg)\ Cl_2$, and there is no excess of specific weight over that of pure Na Cl solution which there would be the $(Ca\ Mg)\ Cl_2$ admixture appreciable. The refractive index is five times farther from that of water than that of saturated brine. This well is recorded below.

The next brine in order is that of the Dundee or Corniferous.

The following is an analysis of a sample from this horizon at Assyria:—

Sp. Gr. .... 1.1955=25.26% salt if all salt.

	Per cent.
Br	0.11
CaO	4.4
MgO	1.076
Cl	14.65

Whence

	Parts per thousand.
$Ca\ Cl_2$	87.02
$Mg\ Cl_2$	24.67
$Mg\ Br_2$	1.27
NaCl	119.66
	237.62

Laboratory of Prof. E. D. Campbell, E. E. Ware, Analyst.

Spectroscopic examination revealed strontium, bromine and lithium, and faintly perhaps barium. The presence of barium and strontium accounts for the absence of sulphates. No H_2S was noticeable, but the sample[1] also contained 1.044 grams of undissolved matter, chiefly calcium carbonate and clay, as the sample was taken while work was going on.

From the Company we have the following analysis of the Dundee or Corniferous water at Port Huron.

This is a new well 750 feet deep and said to be 100 feet in solid rock, i. e., Dundee. Compare Grand Trunk well on p. 277, Report for 1901.

Port Huron, Mich., July 8th, 1902.

From the analyses of Dr. E. Ristenpart, analytic chemist, of Patterson, N. J., and Prof. Kedzie of the Michigan Agricultural College, we obtain the following as the constituents of the Deep-spring Mineral Water:—

DEEP SPRING MINERAL WATER, PORT HURON.

	Parts per 1000.
Chloride sodium	66.6832
Chloride potassium	2.8181
Chloride ammonium	0.1431
Chloride calcium	5.2492
Chloride magnesium	6.7846
Bromide magnesium	0.0488
Iodide magnesium	0.0003
Bicarbonate calcium	1.7600
Bicarbonate iron	0.0140
Sulphate calcium	3.7721
Hyposulphite sodium	0.0177
Hydrosulphate sodium	0.0136
Carbonate sodium	......
Lithium chloride	......
Alumina	0.0033
Silica	0.0085
Sulphuretted hydrogen gas	0.3146
Carbonic acid gas	0.7147

[1]40cc.

WATERS OF THE UPPER PENINSULA OF MICHIGAN.

BY A. C. LANE.

As I mentioned in my last annual report, my papers on the water supply being absolutely exhausted, an early duty should be to cover the ground again in a fuller way, either under State or United States auspices, but I have not got around to it. I have, however, prepared a brief abstract of the situation as to water supply in the Upper Peninsula for Mr. Alfred E. Schultz, who is working that region in connection with Wisconsin for the U. S. Geological Survey, and we have also compared notes on the Marinette, Menominee, and similar wells. I have also had some correspondence with S. Weidman of the Wisconsin Geological Survey in the matter, and with W. C. Alden, who is working on the stratigraphy for the U. S. Geological Survey. We have agreed quite fairly well in our correlation of things, and as it means a rather closer correlation of the Michigan and Wisconsin strata it may be well to give the records in connection with the hydrography, as that appears to be their greatest importance, though they also have economic interest in connection with oil, shale and limestone questions.

The Upper Peninsula is well supplied with water. Fig. 5 of Water Supply Paper No. 30 shows that the precipitation is mainly between 30 and 35 inches; a very large proportion is snow (page 49), which is often four or five feet deep on the level, and very markedly affects the mean annual soil and well temperatures.[1] The latter are 43° or over, the former 40°.

The long series of analyses of the Marquette City water supply, by Vaughan,[2] give a good idea of the Lake Superior waters and its variations practically, and should be compared with the analysis of Lake Superior water far from land, given fully in Water Supply Paper No. 31, which is in brief as follows:—

Lake Superior Water, by W. F. Jackman.[3]

At 27° C. Sp. Gr. 1.0004.

	Grams per metric ton.
SiO_2	8.53
Al	.48
Fe	.69
Ca	12.80
Sr	1.34
Mg	2.78
$C\ O_3$	22.23
$S\ O_4$	3.73
B_2	trace
Na	3.18
K	very faint trace
Cl	2.43
N_2O_6	.77
Sum	58.96
Total residue	69.97
Inorganic residue	57.61
Loss on ignition	12.36
Free ammonia	.061
Albumenoid ammonia	.12
Oxygen consumed	1.77
Hardness temporary in grams per ton	48.57
Hardness permanent in grams per ton	38.28

[1]Page 246 Annual for 1901.

[2]Numbers 254, 261, 281, 297, 298, 301, 302, 303, 289, 306, 308, 317, 325, 327, 330, 339, 340, 344, 346, 347, 350, 352, 355, 256, 258, 360, 362, 366, 368, 374, 378.

[3]Taken in the summer of 1886, about 50 miles from Keweenaw Point and 50 feet below the surface.

ANALYSES OF MARQUETTE CITY WATER SUPPLY (LAKE SUPERIOR).

BY VICTOR C. VAUGHAN.

Number.	254[6]	261[5]	281[6]	297[7]	298[8]	301[9]
Date	3/21/95	5/24/95	7/25/95	12/17/95	1/17/96	2/17/96
Color[3]	....	....	....	Dirty yellowish	....	....
Odor[4]	....	....	....	Musty	Slightly musty	....
Reaction	alkaline	alkaline	....	....	....	....
Hardness[1]	3°	3.4	2°	3°	2.9	3
Total residue	68	60	100	190	160	190
Inorganic residue	34	10	90	60	110	60
Organic residue	34	50	10	130	50	130
Cl as NaCl	8.25	5.775	2	4.1	4.125	4.1
Potassium permanganate reduces	....	....	2	....	....	....
Free ammonia	0.01	.0004	0.005	0.006	.018	0.008
Albumenoid ammonia	0.076	.05	0.001	0.120	.132	0.120
Nitrates	....	faint tr.	....	trace	....	trace
Nitrites	....	....	....	....	....	....
No. of bacteria in 72 hours[2]	300	Liquefaction	72	325	Liquefaction	325

[1]Degrees of hardness are number of grains of calcium carbonate per U. S. gallon that could produce an equivalent hardness, i. e., each degree of hardness is equivalent to about 17 grams per metric ton of calcium, magnesium and ferrous carbonates.

[2]The result of inoculation was in all cases negative; no pathogenic bacteria were discovered.

[3]Colorless and odorless unless otherwise stated.

[4]Vegetable debris (sawdust, etc.) bacteria, diatoms.

[5]Microscope shows small inorganic deposit. The hardness and amount of Cl show an error in the amount of inorganic residue.

[6]Trace of sulphates, vegetable fibres.

[7]Inorganic matter and vegetable debris.

[8]Microscope shows deposit of inorganic matter.

[9]Microscope shows deposit of inorganic matter and vegetable debris.

ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONTINUED.

Number.	302	303	289[1]	306[2]	308[3]	317[4]	325[5]
Date	2/18/96	2/18/96	10/22/95	3/7/96	4/21/96	5/16/96	6/18/96
Color	....	....	....	....	....	....	....
Odor	....	....	....	....	....	....	....
Reaction	....	....	alkaline	alkaline	....	alkaline	alkaline
Hardness	....	....	3°	3°.8	4°	6°	5
Total residue	....	....	60	60	184	70	90
Inorganic residue	....	....	50	20	69	40	40
Organic residue	....	....	10	40	115	30	50
Cl as NaCl	....	....	3.30	8.25	6	3.30	4
Potassium permanganate reduces	....	....	....	....	....	....	....
Free ammonia	....	....	0.02	.045	0.03	0.040	0.05
Albumenoid ammonia	....	....	0.008	.14	0.1	0.03	0.02
Nitrates	....	....	traces	trace	....	....	....
Nitrites	....	....	....	....	trace	....	....
No. of bacteria in 72 hours	....	....	Liquefaction	150	Liquefaction	Liquefaction	120

[1]Trace of sulphates.
[2]Microscope shows little inorganic matter.
[3]Trace of sulphates, U. M. dead insect, vegetable debris, inorganic matter.
[4]Trace of sulphates, very small deposit.
[5]Trace of sulphates, small indeterminate granules.

ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONTINUED.

Number.	327[1]	330[2]	339[3]	340[4]	344[5]	346[6]	347[7]
Date	8/1/96	8/22/96	9/26/96	10/29/96	12/3/96	12/21/96	11/24/96
Color	....	....	....	....	....	....	Milky-Opalescent
Odor	....	....	....	....	....	....	
Reaction	....	....	....	....	....	....	Marked
Hardness	3	5	3.5	3.7	3.4	3.5	4.5
Total residue	90	120	100	75	57	66	77
Inorganic residue	81	105	80	46	32	44	18
Organic residue	9	15	20	29	25	22	59
Cl as NaCl	1.65	8.25	6.0	13.28	6.6	6.6	8.25
Potassium permanganate reduces	1	2	1+	2—	2	3—	4—
Free ammonia	0.006	0.008	0.0066	0.012	0.0066+	0.0004+	0.104
Albumenoid ammonia	0.04	0.0106	0.0133	0.0266	0.0480	0.0024	0.094
Nitrates	....	....	....	trace	....	....	....
Nitrites	....	trace	....	....	....	....	....
No. of bacteria in 72 hours	78	310	80	Liquefaction	Liquefied	17	Liquefaction

[1]U. M. small amount of vegetable fibres.
[2]Trace of sulphates: small amount of vegetable debris.
[3]Very small amount of organic debris.
[4]Small amount of vegetable debris.
[5]U. M small deposit, desmids, diatoms and debris.
[6]U. M. very small amount of vegetable matter.
[7]Large amount of deposit; infusoria, Vorticellæ, paramœcium, Uvella glaucoma, diatoms, ova, algæ debris.

ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONTINUED.

Number.	350[1]	352[1]	355[1]	356[1]	358[2]	360[1]
Date	1/26/97	2/25/97	3/24/97	4/22/97	5/20/97	6/22/97
Color	....	....	....	....	....	....
Odor	....	....	....	....	....	....
Reaction	....	....	....	....	....	....
Hardness	3.5	3°	4°.5	4°.2	3°.5	3°.5
Total residue	92	73	92	62	75	108
Inorganic residue	52	48	60	47	53	70
Organic residue	40	25	32	15	22	38
Cl as NaCl	8.25	8.25	8.25	6.6	6.6	6.6
Potassium permanganate reduces	2—	2—	2—	2	2	2+
Free ammonia	0.0026+	0.0023	0.0106+	0.004	0.0053	0.003
Albumenoid ammonia	0.0133	0.0154	0.0186+	0.0213+	0.0176	0.0064
Nitrates	....	....	trace	....	....	....
Nitrites	....	....	trace	....	....	....
No. of bacteria in 72 hours	Liquefaction	Liquefaction	Liquefaction	Liquefaction	Liquefaction	Liquefaction

[1]Small amount of vegetable matter.
[2]Very small amount of organic debris.

ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONCLUDED.

Number.	362[1]	366[1]	368[1]	374[2]	378[3]
Date	1/27/97	8/25/97	9/25/97	10/29/97	11/22/97
Color	....	....	....	....	....
Odor	....	....	....	....	....
Reaction	....	....	....	....	....
Hardness	3°	3°.5	3°.7	3°.5	3°.2
Total residue	217	190	188	180	94
Inorganic residue	156	152	148	148	70
Organic residue	61	38	40	32	24
Cl as NaCl	3.3	6.6	6.6	5.	4.95
Potassium permanganate reduces	2—	2—	2—	1.57	2+
Free ammonia	0.003	0.012	0.016	0.015	0.0133
Albumenoid ammonia	0.015	0.06	0.072	0.056	0.0106
Nitrates	trace	....	....	....	....
Nitrites	trace	....	....	....	....
No. of bacteria in 72 hours	170	340	630	5	36

[1]Small amount of organic debris.
[2]Few vegetable fibres.
[3]Very small amount of organic matter.

We see that it is usually clear and odorless, but occasionally in the winter it becomes turbid and foul (analyses 297, 347), or musty. The reaction is alkaline quite frequently.

The hardness of 3°, rarely over 4°, shows how soft Lake Superior water is relative to that of Lake Michigan.[1]

The total amount of solid residue *may* run up to 200 grams a metric ton in winter, when the organic matter accumulates under the ice, but usually is nearer 60 to 80, as in Jackman's analysis. The inorganic part of this is ordinarily 40 to 60 grams per metric ton, a minute quantity, which the hardness shows must be mainly calcium magnesium carbonates.

The chlorine estimated as sodium chloride varies from 3 to 6 grams per ton. These figures agree with that of the pure Lake Superior water, and show that on the whole the only difference is a varying amount of harmless organic matter, possibly due to sawdust.

To compare with the analyses of Lake Superior water in mid lake and at Marquette, we have the following of Lake Superior from the Calumet supply, Calumet and Hecla pumping plant, G. L. Heath analyst.

It agrees very fairly considering the minute quantities in most constituents, though as the quantities are so minute, relatively large errors may be due to impurity of chemical. The variation in the amount of strontium and potassium may be due to inadequacy of analytical methods. The total amount of "incrusting solids," that is the sulphates and carbonates of the earths is in Heath's and Jackman's analysis about the same—42.06 respectively 46.88 part per million.

[1]See analyses of Menominee Supply Nos. 250, 251, 309, 315, and those given in Water Supply paper No. 30, etc.

	Lake Superior, Jan. 6, 1903. Per million.
Suspended sediment	9.8
Iron and aluminum oxide	1.1
Calcium sulphate	2.0
Calcium carbonate	29.3
Magnesium carbonate	11.3
Sodium chloride	2.7
Potassium chloride	1.6
Difference organic, etc.	1.8
	63.9

The other Great Lake, the Green Bay Arm of Lake Michigan, is best illustrated by the Menominee Water Works analyses in the table below:—

GREEN BAY, LAKE MICHIGAN, MENOMINEE WATER WORKS.

ANALYZED BY V. C. VAUGHAN.

Color, odor, nitrites and reaction from inoculation none, unless so stated.

Number.	250[1]	251[1]	309	310[2]	311[4]
Date	2/2/95	2/2/95	4/27/96[3]	4/27/96	4/27/96
Reaction	alkaline	alkaline	alkaline	alkaline	alkaline
Hardness	8°	8°	9°.6	9°.5	9°.6
Total residue	260	250	147	150	147
Inorganic residue	190	200	100	100	100
Organic residue	70	50	47	5	47
Cl as NaCl	1.65	1.65	6	6	6
Free ammonia	.002	.004	0.01	0.01	0.013
Albumenoid ammonia	.06	.059	0.052	0.052	0.060
Nitrates	Faint trace	Faint trace	....	....	....
No. of bacteria in 72 hours	Liquefaction	Liquefaction	90	750	100

[1]Trace of sulphates.
[2]U. M. shows some inorganic matter and vegetable debris.
[3]Large deposit of inorganic matter, unicellular animals and plants and vegetable debris.
[4]Small deposit.

GREEN BAY, LAKE MICHIGAN, MENOMINEE WATER WORKS.—CONTINUED.

Number.	312[1]	313[2], 314[3], 315[3].
Date	5 2 96	5 2 96
Color	Brownish and cloudy	Slightly brown cloudy
Reaction	alkaline	alkaline
Hardness	7	9+
Total residue	170	150
Inorganic residue	90	100
Organic residue	80	50
Cl as NaCl	6+	6
Free ammonia	0.08	0.009
Albumenoid ammonia	0.10	0.095
Nitrates	....	....
No. of bacteria in 72 hours	Liquefied	Liquefied[3]

[1]Considerable deposit of inorganic matter, vegetable debris, infusoria.
[2]Considerable deposit of inorganic matter and vegetable debris.
[3]Result of inoculation in 314 +, in 313 and 315 negative.

The hardness, it will be noticed, is twice that of Lake Superior, and not unlike the analyses of Lake Michigan, given in Water Supply Paper No. 31. It may be taken, then, as very nearly that of Lake Michigan.

It is interesting and important to notice that it is not as soft as many of the artesian wells of the same region, so that the frequent objection to artesian waters, that they are extra hard, does not apply here. The extra hardness of the Lake Michigan water shows even in the ice, the following two analyses being made from examples of ice sent from Ishpeming, one from Teal Lake, near by, and one from Lake Michigan. It is obvious that much of the hardness has been frozen out, but not all.

ICE ANALYSES.

BY V. C. VAUGHAN.

Samples from Ishpeming, No. 171, from Teal Lake, No. 172 from Lake Michigan.

Number.	171[1]	172[2]
Date	4 18 93	4 - 93
Reaction	Slightly acid	Slightly acid
Hardness	1.0	2.0
Total residue	10.0	29.0
Inorganic residue	6.0	0.00
Organic residue	4.0	29.0
Cl as NaCl	0.2	0.8
Free ammonia	0.10	0.10
Albumenoid ammonia	0.06	0.06
Nitrates	.05	0.2
Nitrites	trace	....
No. of bacteria in 72 hours	19,400	3888

[1]U. M. monads and bacteria. See p. 148.
[2]U. M. shows bacteria.

The conditions are favorable for artesian wells throughout nearly all the area of the Paleozoic rocks in the eastern half. The dips are southerly and the divide is generally close to Lake Superior, so that flowing wells from bed rock may be expected along the Lake Michigan shore and up all the river valleys for a width varying according to the surface and rock topography. Artesian wells of this sort occur at Menominee, Escanaba, Gladstone, Rapid River, Manistique, St. Ignace, Newberry, and numerous other points. Notes concerning some of these are as follows:

At Menominee, Hon. S. M. Stephenson has put down at least two deep wells. The character of the water is probably shown by Vaughan's analyses Nos. 328 and

331. Back of the S. M. Stephenson house there was one put down in 1895-6, from 500 to 1,000 feet deep. The well started in the Trenton limestone and is said to obtain its water from a sandstone, probably mainly Potsdam. Though the analyses could not be found for me at Menominee, and it is said to contain much magnesia, I suspect that analysis No. 328 may be of it. I also think it possible that in dealing with unusually large quantities of salt for potable waters, the decimal point has been misplaced, for the total solids are disproportionately large. The head is 15 feet and the temperature 551/2° F., by Ther. No. 7536. Another well three miles west from No. 1, upon his farm, is 720 feet deep and 30 feet above the lake. The head is only one foot above the surface and the water is too hard for boilers. It starts in the Trenton, passes through some "slate and also white stuff and black slate." There was 60 feet of pipe, which may be to bed rock. Water was encountered at various levels, but a distinctly larger quantity at 620 feet. This may of course be a fissure in the Lower Magnesian or Calciferous, but is I think not far from the top of the Potsdam, and the base of the well may have reached the Archean. This may be represented by analysis 331.

MENOMINEE ARTESIAN WELL.

Number.	328[1]	331[2]
Date	8/1/96	8/24/96
Reaction	Slightly acid	....
Hardness	4°	8°
Total residue	2050	2054
Inorganic residue	1798	1783
Organic residue	352	271
Cl as NaCl	18.15	18.15
Sulphates	87.2	83.42
Potassium permanganate reduced	1	1
Free ammonia	0.0746	0.012
Albumenoid ammonia	0.0006	0.008
Nitrates	Trace	....
Nitrites	Trace	....
No. of bacteria in 72 hours	1260	3

[1]Result of inoculation positive, but it can hardly be due to bacterial contamination. It merely shows that this particular mineral water was not good medicine for the rabbit. The date renders it pretty certain that it is one of Mr. S. M. Stephenson's wells. L.
[2]Result of inoculation negative.

These analyses should be compared with that of the well of Hon. Isaac Stephenson, close by just over the Wisconsin line, which has, however, a much lower temperature, and hence probably a shallower source, though the surface piping may be in part responsible.

“Following the usual method of expressing the results of water analysis, the constituents have been grouped as follows":—[1]

	Grams per metric ton.	Grains per gallon.
Sodium chloride	119.50	7.649
Potassium sulphate	20.46	1.193
Calcium sulphate	727.60	42.432
Magnesium sulphate	182.34	10.634
Aluminum sulphate	47.27	2.757
Magnesium chloride	69.51	4.054
Magnesium bicarbonate	52.75	3.076
Ferrous bicarbonate	9.48	0.553
Silica	5.20	0.303
Sulphuretted hydrogen, not determined.		
	1,184.11	

[1]University of Wisconsin Chemical Laboratory. Compare Geol. of Wis. II, p. 153.

There is one thing common to the Menominee and Marinette artesian well analyses. In both the sulphates seem to predominate over the chlorides. Yet they probably do not represent water from exactly the same horizon. The Marinette Stephenson well, drilled in August, 1895, at the house of Hon. Isaac Stephenson, passed through lime rock and dolomite, and a little light and reddish sandstone (St. Peters? not much) and narrow strata of slate for the first 200 feet. Water was first struck in a crevice in the Lower Magnesian at 405 feet, with quite a flow. Then, at 410 feet, there was a big crevice, with a drop of four feet, which broke the cable, and the water has a greater flow, and 21 feet head. Below this[1] there was no increase in water, though they went down to "granite" at 716 feet, passing largely through "limerock" (dolomite). No water, that is no additional water pressure, was encountered below 415 feet and a rubber plug was put in at 457 feet, and the pipes go down to 415 feet, so that in the I. Stephenson well we have a water purely from that level, the Lower Magnesian, or Calciferous dolomite. This is more than we can be sure of in other cases. Mr. Stephenson reported the temperature at 49°, I made it 50.°5. There are a number of other wells which flow or have flowed in Marinette.

A well at Oakwood, three and a half miles south of the town, is said to be 9992 feet deep. A sample at 860 feet is a white sand, while one at 920 feet contains much feldspar, broken quartz fragments, etc., and is of a reddish color. Let run a few moments the temperature is 53°.

A well for oil and gas, two miles south of Stephenson's, put down in 1902-3, by a company of which Mr. H. B. Simcox was manager, may have reached the Precambrian at 850, where there was a change from white sand to red, the record being:—

Drift to bed rock	70	70
70 ft. 10-inch casing.		
(Trenton?). Very hard rock	300	370

150 ft. 8-inch casing, 450 ft. 6-inch casing; water at about 400, 500 and 600 feet.

(Calciferous?). Various layers, including "hurry up sands," which occur in beds a few feet thick, soft, but cutting the drill and themselves light, mixed with hard layers.

(Potsdam?). At end, white sandstone; bottom, red sand (granite?).

The temperature of a mixture of all the flows was 51.°8. Probably the plug in the Stephenson well cuts off a little warmer water from below.

Mr. A. C. Merriman also has two or three wells, the one at his house being 719 feet deep.

[1]A still more recent record with samples kept by the kindness of Mr. H. B. Simcox, shows the St. Peters sandstone well marked from 325 to

400 feet, so that the I. Stephenson well probably draws from that horizon.

[2] An error of an even hundred feet the depth of the well and the sample is to be suspected.

From a well at the water works, samples have been preserved, and the following are my notes of inspection, with the interpretation put on them, after consultation with S. Weidman, Alfred E. Schultz and Wm. C. Alden. Mr. Schultz writes that the records obtained at Marinette this summer all indicated that the St. Peters is not represented, although no first-class record and samples were available. Mr. Alden wrote to Dr. Weidman a letter given below, and various letters to me afterwards, the substance of which is that in a number of wells like the above the question is whether the St. Peters is absent and the limestone dolomite series to be divided between the Trenton and Lower Magnesian, or whether the erosion which he supposes to have taken place at the end of the deposition of the Lower Magnesian may not have cut it away entirely, so that the whole limestone series should be referred to the Galena-Trenton. In order to understand the question, the following abstract of the different strata of Eastern Wisconsin, compiled from Volume II of the Wisconsin reports, is given.

EASTERN WISCONSIN SECTION.[1]

HAMILTON, argillaceous limestone, page 395. Cement rock, fossiliferous.
Unconformity.
LOWER HELDERBERG (Monroe), p. 390, hard, brittle, angular, acicular or dark dolomite, laminated with alternating light and dark bands.
Unconformity.

	Feet.
NIAGARA, p. 335 ... White dolomites, generally very little impurity, divided into:	719-450
1. Guelph, like Racine but different in fossils.	
2. Racine, buff, gray or blue granular, fossiliferous—9 ft. thick below, rough.	
3. Upper Coral; thin bedded buff or bluish, fine, with chert and druses, splitting, very fossiliferous...	45-70
4. Lower Coral beds (p. 348). Massive, rough, with layers cherty or argillaceous or like the Byron, full of *Favosites* and brachiopods.	
5. Byron, white, smooth, fine, pure, mudcracks and ripple marks, tinged with gray or pink, conchoidal fracture ...	110
6. Mayville, rough, coarse grained, fossils ill preserved.	
1. Brecciated, vertical fissured ...	60-100
2. Even bedded white, pure, often porous, granular.	
3. Brecciated, cherty, gray ...	5-35
4. Hard heavy bedded, vertical fissures ...	6-12
5. Shaly impure, yellow to greenish ...	4-10
CLINTON. Irregular lens like masses of iron ore...	0-
Unconformity beneath. Lorraine and Utica often in contact.	
CINCINNATI (Lorraine & Utica), clayey shales and limestones, p. 315 ... Blue green, fine or impure, with fossiliferous grits, grading to limestone, sometimes sandy.	240
GALENA, lime and dolomite, impure, crystalline granular dolomite; greenish blue and often non-fossiliferous, impure earthy —*Murchisonia major*, more shaly to the N.	160
TRENTON subdivided into ...	53
1. Upper blue 1. Upper blue bed; *Lept. sericea*, Brachiopods *Bryozoa*, & *Chætetes* ...	15
2. Upper buff bed (p. 296); *Cyathophyllum*, lamellibranchs ...	55
2. Lower buff dolomite. 3. Low blue beds dolomite, cherty, blue green, thin impure, carbon, corals ...	25
4. Low buff beds, earthy yellow crystalline ...	25
ST. PETER'S sandstone (p. 286-289) ... Well rounded incoherent quartz grains light colored, laminated, cross bedded, iron ore nodules at top.	0-212
Probable erosion interval possibly the line between Cambrian and Silurian.	
LOWER MAGNESIAN (CALCIFEROUS), p. 268, granular dolomite, with 2-10% disseminated silica, chert nodules, quartz geodes and a little sand, sometimes oolitic, with some sand centers, irregular, at times brecciated...	62-141
Top eroded and very uneven, bottom even. Fossils very rare.	
POTSDAM (p. 260).	
1. Madison sandstone ...	35
Typically coarse grained, thick bedded, but soft, slightly calcareous, light colored ...	60

2. Mendota limestone,
Alternating sandy dolomites, sandy calcareous shales, and shaly calcareous sandstones. The dolomites are soft, granular, porous, thin bedded, buff colored with frequent sand seams. The shales are variegated yellow and red and characteristically purple, mottled, soft brittle, readily weathered. The sand stones are either white, buff yellow or orange calcareous, or a glauconitic green sand. Upper and lower limits ill defined.
Dr. Owen's fifth trilobite bed and *Dicellocephalus minnesotensis, D. pepinensis, Lingula aurora, L. mosia, Lingulepis pinniformis, Illænus quadratus.*
3. Light colored sand stone, mainly quartz, slightly calcareous, a little chert, limestone and granite.
4. Blue green shale, micaceous, calcareous.
5. Light colored quartz and sandstone.
6. Coarse non-calcareous sandstone with large grains of transparent light colored quartz.

[1]Chamberlin Geol. Wis. II Van Hise, Ore Deposits, p. 397.

Mr. Alden is inclined to accept the possibility of a suggestion which had independently occurred to me that the base of the deep Sheboygan well might be in the Potsdam, in which case the same may be true at Oshkosh and Marinette, and the Lower Magnesian also absent. On the whole, however, I am inclined to accept the older interpretation of Chamberlin as more likely to be right, as I think that the Potsdam water is not so hard and is not so much sulphated as the waters above.

MARINETTE WATER WORKS WELL.

The record of the manager, W. S. Kulm, through Mr. Schultz, is:—

Drift.	Thickness.	Total.	Comparison.
Surface sand gravel...	70	70	S. 70
Galena and Trenton—			
Gray limestone...	10	80	S. 80, S. 85.
Soapstone and limestone...	64	144	
Soapstone...	52	196	S. 144
Soft limestone...	44	240	S. 196
Hard gray limestone...	10	250	S. 240
Slate and limestone...	70	320	S. 250 ("slate". Gladstone 327 to 404
Soft flaky limestone ...	134	450	S. 320
Very hard limestone...	100	550	S. 450
Potsdam—			
Hard yellow sandstone...	10	560	Gladstone 642
Gray limestone...	20	580	
S. 550, 560 and 580 possibly mixed—			
Gray sandstone (small flow)...	90	670	
White sandstone...	46	716	S. 670 Gladstone 743
Reddish granite...	...	...	S. 712, S. 716

S. Stand for sample.

My notes on the samples are: —

Pleistocene—

70—red sand and gravel.

Galena?

80, 85—chipping limestone.

Trenton?

144—blue shales (compare 481 at Wagner's well).
196—coarse chipping limestone.
240—chipping limestone.
250—"slate" light blue and white.

St. Peter's sandstone absent or ignored, according to Alden.
Lower Magnesian=Calciferous.

320—chipping limestone, coarse.
450—coarse chipping, light colored limestone and dolomite.

Potsdam?

550—very white looking marly calciferous sandstone.
560—unwashed, white calciferous sandstone.
560—white and greenish calcareous sandstone.
670—white sand.
685, 700—rounded white sand.

Archean.

712—"granite" broken and loose.
716—dark red quartzite (also quartz).

Mt. Vernon, Ia., Nov. 5, 1903.

Dr. Samuel Weidman,
Wisconsin Geological Survey, Madison, Wis.:

My Dear Dr. Weidman—Your favor of the 3d inst. enclosing letters and well records from Mr. Alfred C. Lane is received.

In regard to the treatment of the Calciferous formation in Wisconsin, my observations in the southeastern part of the state have been entirely confirmatory of those of Dr. Chamberlin and his associates as presented in Volumes I and II of the Geology of Wisconsin, where the subject is fully discussed. As you know, the Lower Magnesian limestone, which has been regarded as the equivalent of the Calciferous of the east, is not a sandstone at all here, but a hard, gray, rough-textured dolomite carrying much chert and crystallized quartz. On the other hand, the St. Peter sandstone, which has been regarded by some as the equivalent of the Chazy limestone of the east, is here a loosely coherent, quartz sandstone, with rarely more than a slight calcareous cement, and that not always present. The lower part of this formation in many places is reddish and not infrequently is somewhat shaly. This has been noted at several places to the south and east of Madison. In the shaft of the Waterloo "iron mine," east of Madison, I found this summer above the typical Lower Magnesian limestone, the following beds, which I am inclined to regard as belonging to the lower part of the St. Peter group, though it is possible that they really belong with the underlying Lower Magnesian limestone:—

Interstratified buff and purplish rock, varying from a calcareous sandstone to a sandy limestone	3	feet
Fine grained, buff, arenaceous limestone	2	"
Similar bluish, fine grained rock, with fine grains of green color (green sand?) disseminated throughout, said to be shaly	4	"
Fine grained buff dolomite and shale, somewhat variable in character	18	"
Red and purplish arenaceous shale	6	"
Interbedded, thin layers of buff limestone and purplish limestone, shaly in part	4	"
These thicknesses are only approximte, the total being	33	"
Below this is the typical, rough textured, cherty, brownish-gray Lower Magnesian limestone, decidedly different in character from the above	28½	feet

I have not found any limestone layers in the lower part of the St. Peter group except in this locality. It may be that these correspond to the "Lime and sandstone in mixed layers," which Mr. Lane reports between the depths of 325 and 404 feet in the St. P. & Ste. Marie R'y [Gladstone] well record which you sent.

I think it not strange that we should find in Michigan that the St. Peter sandstone is not developed so well as in Wisconsin. We would expect to find a gradual change in both this and the Lower Magnesian to the types developed farther east. Some such change occurs in the later formation on going southwestward into northeastern Iowa, though the St. Peter sandstone continues above it. In the Geology of Allamakee county (Iowa Geological Survey, Vol. IV., pp. 01-71), Prof. Calvin discusses these formations under the name of Oneota limestone and St. Peter sandstone. He says (p. 63-64):—

"The last fifty or sixty feet in ascending towards the St. Peter sandstone are characterized by the presence of beds of sand and shale inter-stratified with the Magnesian limestone. The sandstone layers, as already noted, differ as to number and position in different localities, and it is not possible to recognize any one as sufficiently constant to mark a definite horizon. It is in the last 50 or 00 feet that the Iowa equivalents of the New Richmond sandstone and the Willow River limestone of Wisconsin, or the New Richmond sandstone and the Shakopee limestone of Minnesota, are found."

On page 68, Prof. Calvin states that there can be little doubt as to the essential equivalence of the Lower Magnesian (Oneota) limestone and the Calciferous sandrock of New York and Vermont, both on stratigraphical and paleontological grounds. He says:—

"The relations of the Calciferous sandrock of the Champlain valley are paleontologically more intimate with the overlying Trenton than with the underlying Potsdam. The formation belongs to the Ordovician or Lower Silurian, and not to the Cambrian, and the same statement may be made with respect to its equivalent, the Oneota limestone in northeastern Iowa."

Concerning the taxonomic relations of the St. Peter sandstone, he states that Sardeson gives a list of fossils from the St. Peter sandstone near Minneapolis, in the Bull, of Minn. Sci., Vol. Ill, No. 3, p. 318. He says:—

"The collection embraces casts of Gasteropods and Lamellibranchs belonging to the genera Maclurea, Murchisonia, Cypricardites and Modiolopsis. The fauna of the St. Peter, as indicated by Sardeson's collection, is closely related to the Trenton, if not identical with it, and lends support of the views of those geologists who would correlate the St. Peter of the Upper Mississippi with the Chazy of New York."

In Wisconsin but few fossils have been found in either formation. I have never seen any except a fragment or so in the Lower Magnesian limestone.

From the stratigraphic relations, it has seemed to me that the Lower Magnesian limestone was more closely connected with the Potsdam than with the overlying formations. There is no real break between the formations, the Potsdam sandstone grading into the bottom of the limestone above. Between the limestone and the St. Peters there is, however, evidence of an erosion interval in the well marked unconformity in the region where I have worked in the S. E. Dr. Chamberlain and his associates of the earlier survey noted the unevenness of the Lower Magnesian surface, but, in part, at least, this unevenness was referred to an intraformational break, i. e., they supposed that condition occurred by which the newly deposited beds of limestone were somewhat broken up and heaped up into mounds by the waves, and over these more continuous beds were deposited, covering the ridges and hollows. On the uneven surface thus produced, the St. Peter sandstone was deposited with consequent varying thickness.

It appears to me, however, that this unevenness of the surface of the Lower Magnesian limestone is, in large part, at least in the area where I have been working, due to the erosion of the rock beds during an interval of emergence as land. At Albany, southwest of Madison, a street cut shows eight feet or more of loose fragmental chert overlying a weathered surface of the Lower Magnesian limestone, and upon this loose material are the basal beds of the St. Peter sandstone. There is a little conglomerate here composed of sandstone enclosing somewhat worn fragments of the chert. I have found this bed of chert developed at intervals over quite a widespread area, as shown by exposures and well records. This seems to me clearly to indicate an erosion interval. The emergence of the Wisconsin land at this time does not, however, seem to have extended so far as northeastern Iowa, for there deposition seems to have been continuous. It is noted, however, as indicated above, that in northeastern Iowa there was sufficient shallowing of the water to cause the deposition of considerable sand in the upper part of the Oneota (Lower Magnesian group), such as would be expected if the land in Wisconsin emerged.

At the top of the St. Peter sandstone, again there are transition beds indicating a gradual change to the limestone-depositing conditions of the Trenton. This gradation usually takes place within a thickness of 10 feet or less.

There is no indication of a later interval of erosion during which the St. Peter sandstone could have been eroded so that we must conclude that its absence at certain places, as shown by exposures and well records, is due to the fact that its deposition did not overtop all the Lower Magnesian hills. The drill may thus pass from the Trenton right down into the Lower Magnesian limestone with no intervening sandstone, as Dr. Chamberlin explained for the well at Oshkosh.

On the other hand, there are places where the pre-St. Peters erosion entirely cut away the Lower Magnesian limestone and the St. Peter sandstone was there laid down upon the Potsdam sandstone with no intervening limestone. Mr. F. M. Gray, a driller of Milwaukee of wide experience, informs me that this was the case in many of the wells at that place, and at Wauwatosa. The log of the well at Lake Park, Milwaukee, as I Interpret the data furnished by Mr. Gray, is as follows:

Lake Park Well, Milwaukee.

Hamilton group—		
Soapstone	80	feet
Cement rock	12	"
Soapstone	30	"
Waterlime? Brown limestone	30	"
Niagara limestone	320	"
Cincinnati shale	180	"
Galena and Trenton limestone	330	"
St. Peters sandstone	958	"
Potsdam sandstone		

The well at the E. P. Allis works in Milwaukee showed a like condition as far as the absence of the Lower Magnesian is concerned, but a bed of "red marl" occurs lower down, probably at the Mendota horizon. This latter condition occurs in other wells in the city. The Lower Magnesian is also absent at Wauwatosa.

The Lower Magnesian limestone is absent here and not included in the 330 feet referred to the Galena and Trenton, with the St. Peter absent, is shown by the fact that on going still farther west to Elm Grove and Waukesha, the Trenton (including the Galena) shows thickness of 320 and 300 at the two places, with both the St. Peter and Lower Magnesian present below.

This will explain things at the Sheboygan well referred to by Mr. Lane. (See Plate XIII, Vol. II, Geol. Wis., p. 335.) The thickness of limestone referred to the Trenton and Galena is less at Sheboygan than at the old city well at Milwaukee, and this latter thickness is less than that shown by the Lake Park well just referred to. In neither this old Milwaukee well or the Sheboygan well is the thickness of the sandstone penetrated below great enough to indicate surely that the Lower Magnesian limestone may not be present below, though it may be absent. Where the Lower Magnesian is absent, there is no means of drawing a line in the log of a well between the base of the St. Peter and the top of the Potsdam. It is reported to me that the well at Union Grove in Racine county penetrated more than 1,400 feet of sandstone below the base of the Trenton with no limestone beds at all. I do not know whether later and deeper wells at Sheboygan found any Lower Magnesian present at a greater depth than in this old well cited by Chamberlin or not.

It may really be, in the Oshkosh well, that it is the Lower Magnesian that is absent, with nothing to cut off the St. Peters sandstone from the Potsdam below, instead of the sandstone being absent and the Lower Magnesian and Trenton both being included in the 208 and 240 feet of limestone, as interpreted by Dr. Chamberlin. The local conditions, however, may warrant his interpretation.

As a general thing, however, in southeastern Wisconsin, the St. Peter sandstone is present, though varying greatly in thickness, so that the Trenton and Lower Magnesian is usually distinguishable.

The following is my interpretation of the well records sent by Mr. Lane, on the basis of the formations in eastern Wisconsin. There may, of course, be local conditions which, if known, might change this somewhat.

LOG OF WATER WORKS WELL AT MARINETTE.

Interpretation of Wm. C. Alden, Asst. Geol. U. S. G. S.

Pleistocene.

		Thickness.
1-70 feet.	Red sand and gravel	
70-85	? ?	85 feet

Galena limestone.

85-144 feet.	Round chipped limestone	59 feet

Trenton limestone.

144-196 feet.	Blue shales.	
196-240	Chipping limestone coarse.	
240-250	Chipping limestone.	
250-320	"Slate" light blue and white	176 feet

(Base of Trenton uncertain.) (St. Peter sandstone absent.)

Lower Magnesian limestone.

320-450 feet.	Chipping limestone coarse.	
450-550	Coarse chipping limestone light colored, and dolomite.	230 feet

Potsdam group.

550-560 feet.	White sandstone, very white, mealy-looking.
560-560	?White sandstone.
560-670	White and greenish, calcareous sandstone.
670-685	White sand.
685-712	Rounded white sand.

Huronian or Archean.

712-716 feet.	"Granite" (broken and lost).
716	Dark red quartzite.

LOG OF ST. P. & STE. MARIE WELL, GLADSTONE.

Location ?

Interpreted by Wm. C. Alden, Asst. Geol. U. S. G. S.

0- 87 feet.	Pleistocene	87 feet
87-326	Galena and Trenton limestone	234
325-404	St. Peters (probably), lime and sandstone in mixed layers	89
404-642	Lower Magnesian limestone	228
642-743	Potsdam, shell sandstone	101
743-	Hard rock, possibly Archean	
	Total depth	743 feet.

Altitude about 605 feet.

NOTE.—Comparing this with the log of the well at Marinette, the elevation of whose curb is, I suppose, somewhere about 600 ft., it is seen that the two wells are very much alike except for the St. Peters, which is absent in one and 89 ft. thick in the other. The elevation of the base of the Trenton not far from 280 ft. in each and the thickness of the Lower Magnesian is about the same in each. If these beds are really St. Peters their absence at Marinette may be due to the higher elevation of the Lower Magnesian surface at that place, which the St. Peter deposition did not overtop. It is not possible for me to say, however, that this mixed sandstone and limestone is not a part of the Lower Magnesian group as in northeastern Iowa,

LOG OF THE WAGNER WELL.

The data below the Utica shale cannot be very satisfactorily correlated with the typical Wisconsin formations because of the discordance in the character of the beds. The following grouping is suggested, but the dividing lines might be moved up or down in each case:

Pleistocene.

0- 9 feet.	Gravel and clay	9 feet

Hudson River (Lorraine).

9- 54 feet.	Blue shale	45 feet
54- 67	Fossiliferous shale	13
76- 95	Brown shale	28
95-115	Blue shale	20
115-123	Brown shale	8
123-193	Gray shale	70
193-201	Light gray shale	8
	Total	242 feet

	Utica shale	251 feet
201-251 feet.	Bituminous shale	50

Galena Limestone.

251-334 feet.	Limestone	83 feet
334-389	Fossiliferous limestone	55
389-397	White limestone	8
397-406	Dark limestone	9
407-412	Quartzite (?)	6
412-456	Limestone	44
456-457	Quartz	1
457-481	Limestone	24
	Total Galena (possibly some Trenton)	230 feet

Trenton shale and limestone.

481-485 feet.	Blue shale	4 feet
485-499	Black limestone	14
499-518	Limestone	19
518-522	Blue shale	14
	Total	51 feet

St. Peters group, possibly including some of Trenton and Lower Magnesian groups.

522-560 feet.	Sandstone, soapstone, limestone	38 feet
560-561	Red clay shale	1
561-562	Sandy shale	1
562-628	Limestone, soapstone, sandstone	66
	Total	106 feet

628-640 feet.	Lower Magnesian, very crystalline limestone	12 feet
	Total depth	640

I have gone into this considerably at length, possibly more so than is necessary. I shall be glad, however, if this is any assistance in understanding the relations of these formations.

You might send this letter to Mr. Lane, with any suggestions you wish to add. I shall be glad to be of any further assistance to him or to hear from him directly. I should like, myself, to have a better understanding of the real relations of these formations.

Respectfully,
(Signed) WM. G. ALDEN,
Asst. Geol. U. S. G. S.

We have at this point introduced a compilation of the Eastern Wisconsin section, from Chamberlin's report in the second volume of the Wisconsin Geological Survey reports. We find, coming up the Lake Michigan shore, a series of wells,—at Kenosha 1805 feet deep, at Racine 1600 feet deep, at Milwaukee 1700 or more, at Sheboygan 1475 feet deep, and at Manitowoc 1263 feet deep, all flowing and all ending in a sandstone of which the question arises whether it is the St. Peters, the Potsdam, or both combined. In this matter the letter of W. C. Alden is of interest, which is given above. But the practically important matter is, without question,—that along the Lake Michigan shore at from 1500-2000 feet plenty of water can be obtained in the sandstone, and that this water is distinctly mineral, but not very hard. Flows are likely to occur up to about 100 feet above the lake.

Back of the other side of the ridge made by the Niagara is another belt of flowing wells illustrated by Oshkosh, where there is standstone from 714 or 680 to 961; Appleton, where wells are 600 to 790 feet deep, and Marinette, where, as we have just seen, the sandstone still comes in at from 600 to 700 feet depth, and the depth of the Archean is still from 700 to 900 feet, which is continued up into Michigan.

Both these belts undoubtedly may be extended into Michigan, though I do not know as yet of any wells on this outer lake shore belt. The Manistique flows are not so deep.

Continuing the Oshkosh-Appleton-Marinette-Menominee line of wells we find others of various depths along the lake shore, as at Ford River, Escanaba, Gladstone, and Rapid River. All these wells start in the Trenton. The only one that begins above it is opposite Escanaba at the place of H. Wagner, of which I insert a record below, which differs somewhat from that given in the 1901 report (p. 228):

H. Wagner, Delta County, S. W. ¼ of N. W. ¼ of Sec. 8, T. 39 N., R. 21 W.

Drift.		
Gravel and clay	9	
Lorraine (Hudson R.)		
Blue shale	45	54
Fossiliferous shale	13	67
Brown shale	28	95
Blue shale	20	115
Brown shale	8	123
Gray shale	70	193
Light gray shale	8	201
Utica.		
Bituminous	50	251
Trenton.		
Galena—		
Limestone	83	334
Fossiliferous limestone	55	389
White limestone	8	397
"Upper blue" of Wisconsin, Trenton?		
Dark limestone	9	406
"Upper buff"?		
Quartzite (? geodes)	6	412
Limestone	44	456
Quartz (? geodes)	1	457
Limestone	24	481
"Lower blue."		
Blue shale	4	485
Black limestone	14	499
Limestone	19	518
Blue shale	4	522
"Lower buff."		
Sandstone, soapstone and limestone (perhaps in part St. Peters)	38	560
St. Peters.		
Red clay shale (weathered surface of Lower Magnesian?)	1	561
Sandy shale	1	562
Calciferous.		
Limestone, soapstone and sandstone	66	628
Crystalline limestone	12	640
Depth of hole		640

As complete samples have not been seen it is not certain that the record is correct, but the probabilities are that the lower part of the well extends into the Calciferous or beds below the Trenton. I was, however, informed that upon re-measurement, the well proved not as deep as was supposed. In a recent well near by at 860 to 900 feet a broken formation, either the conglomerate of the Archean quartzite, was apparently struck, with a good body of sandrock above. We can see in the beds from 481 feet to 562 feet down about where the shale comes in, which appears in the records at Menominee and other points. Around Maple Ridge there was a well which went through 30 feet of limestone and then, as reported, 150 feet of soft blue shale, which may correspond to and represent some of the blue beds of the Trenton. At Flat Rock, near Escanaba, a flowing well is said to be 800 to 900 feet deep. But not all flowing wells need to be this deep. At the charcoal furnace north of and near Gladstone, there are a group of flowing wells that belong to the Cleveland Cliffs Co., described below.

At Rapid River, Section 19, T. 41 N., R. 21 W., or nearby, there are eight or nine flowing wells which are supposed to go through 270 feet of the Trenton rock and strike sandstone below. One is 270 feet deep, rises three or four feet above ground and the temperature of the flow is constantly 45.8° F. by measurements July 12, 1902, and Aug. 26, 1903. Another opposite Dillabaugh's is 275 feet deep and has a 10-foot head. Seven miles north and two miles east of Rapid River there was a well put down for oil on Sec. 34, T. 42 N., R. 21 W. A set of samples were to have been kept for me, but were said by Mr. M. D. Kelley to have been stolen from him. As near as I can judge, there was about 300 feet of more or less oily Trenton and below that, down to within 20 or 30 feet of the bottom, was very largely white sandstone. The extreme bottom was apparently decomposed schist of the iron bearing series. At 170 feet or more above was sandstone, some of it a very clear white sand. The flow outside the casing, which is 800 feet deep, was very strong; the temperature being 47.3° F., and the amount over a quart a second. It probably works around the casing from about the same level as the Rapid River wells or somewhat deeper. Assuming, however, that certain samples which I found left in the boxes were arranged inversely from the bottom up each 10 feet, which seemed to be the system they were working on, we have the following record which harmonizes with what might be expected. The papers have recently[1] had many accounts of flows of oil from this well, or one near it, but while there is little doubt but what there is a strong flow and some oil the relative proportions of oil and water are quite possibly reversed.

[1]Saginaw Evening News, 10/25/1903; Marquette Mining Journal, 12/2/1903; Gladstone Delta, 12/5/1903, and 10/31/1903; Detroit Tribune, 11/13/1903; Iron Mountain Press, 11/5/1903; Crystal Falls Drill, 11/28/1903; Chicago Record-Herald, 11/1/1903.

RAPID RIVER OIL WELL, HYPOTHETICAL RECORD.

200 paces W., 505 S. of N. E. corner Sec. 34, T. 42 N., R. 21 W.

Surface.

Swamp peat and muck	3 to 6	6
Marl	10	16

16 feet 10 inches casing.

Trenton.

Dolomite with geodes lined with fine dog-tooth spar calcite and filled with oil "gum"	264	?280

St. Peters horizon?

Signs of oil. Strong flow of water, over 1 quart a second. Temperature 47°3 F.

An old well 300 feet west was 202 feet deep	350	630

Calciferous?

S. at 620 box 380 a dolomite.

Potsdam.

"White sandstone comes in 600-700 feet down." Clear white glass sand (Upper Potsdam of Rominger).

Samples, boxes 300 to 370	80	710
Reddish sandstone coarse.		
Sample, box 290	10	720
Coarse red sandstone.		
Sample, boxes 250 to 280	40	760
Feldspathic sandstone.		
Box 290	10	770
Coarse mixed very micaceous red sandstone.		
Box 210-230	30	800

Last samples, large fragments of decomposed chloritic schist, like Archean rocks.

This should be compared with a record of a well put down for water at the station of the Minneapolis, St. Paul & Sault Ste. Marie R. R. at Gladstone, elevation 605 A. T., which according to letters of Mr. P. Swenson of the company, and J. F. McCarthy, the contractor, mast be about as follows:—

Pleistocene.

	Thickness.	Total.	Dates and Remarks.
Old dug well (in sand)	13	13	Began May 9.
Quicksand	38	51	
Till (clay and hard pan)	10½	61½	
Sand and gravel	15	76½	
Clay and limestone	10½	87	
Boulders	4	91	

Trenton.

Limestone	234	325	
Lime and sandstone in mixed layers	89	404	

St. Peter's horizon? Some water at 400 feet.

Calciferous.

Limestone	228	642	At 580 Sept. 15. Compare Rapid River 630.

Sample 632 is crystalline magnesian limestone.

Potsdam.

Shell sandstone.

Sample at 742 feet, white, round sand, like Rapid River, 630 to 710. At 690 feet Oct. 1. Main water flow, 150 gallons a minute. Hardness only 5.°86. Finished Oct. 9.

Hard rock, not Archean granite at the end.

Average progress 5 feet a day, but from Sept. 15 to Oct. 1, and Oct 1 to Oct. 9, 7 feet a day.

It is a pity that we cannot have analyses of each water separately, yet the low hardness is significant. Though drawing from a deeper source, it is less hard than the Marinette, and one of the Menominee wells, and the Escanaba waters, including one of the shallower artesian wells given below.

ESCANABA WATERS.

ANALYZED BY VICTOR C. VAUGHAN.

Number	243.[3]	244.	296.[1]
Date	12/8/94	12/8/94	11/30/95
Reaction	alkaline	alkaline	alkaline
Hardness	6°	8°	11°
Total residue	240	140	290
Inorganic residue	180	80	270
Organic residue	60	60	20
Cl as NaCl	11.55	11.55	3.30
Sulphates	trace	trace	trace
Free ammonia	0.069	0.075	0.028
Albumenoid ammonia	0.33	0.39	0.165
Nitrates	trace	trace	....
Nitrites	trace	trace	....
Bacteria in 72 hours	250	quefaction.	120

[1]Artesian well, microscope shows small deposits.
[2]Slightly milky, stale odor, no reaction; unicellular plants and animal water fleas, vegetable debris and organic matter.
[3]Dirty yellow color, stale odor, no reaction; Algae, desmids, unicellular, plants and animals, vegetable debris inorganic matter. This and No. 244 are probably from the bay.

An important practical deduction, therefore, is that by going to the deeper waters in the Potsdam and casing off the waters from the limestone a softer water can be obtained. In explanation of this it must be remembered that there is an upward pressure and circulation which will prevent the limestone waters from working down into the sandstone to any great degree, while the Potsdam and Archean normally contain soft waters. The wells at the furnace, two miles north of Gladstone, deserve a moment's attention here, for there appears to be an exception, but it is not. There are at least five flowing wells here.

1. The one on the mainland, at the south end of the row of tenements flows a quart or more a second with a temperature of 45.5° to 46°. It is housed; there are two

casings, the 8-in. comes one foot above ground, and the 4-in. two feet more, and there is a curved neck of inch pipe 21/2 feet long,

2. At the north end of the tenements has a similar but fluctuating flow as though affected by the pumping of the wells at the plant. Temperature, 44.9°.

3. Is the most southwestern of the plant wells, put down in the winter of 1900-1901, said to be 174 feet deep in sand and gravel. Temperature, 47.7° to 47.8°.

4. The northern of the three wells at the plant was put down deeper, i. e., to 500 feet for more water, and did not get it, but got more lime. Temperature, 49° to 49.3° F. This, however, evidently did not go deep enough. It should be put down 200 feet more.

5. Inaccessible; capped.

Before passing to the waters of the Archean area, we will include a few more notes on those of the sedimentary or eastern end of the Upper Peninsula. Over at Brampton, west of Rapid River, the wells go through 20 feet of hard pan and then find water in the limestone. A little north of the station on section 21, T. 41 N., R. 22 W., is a spring with a strong flow of over a quart a second and a temperature, July 12, 1902, of 48° F. Three miles north, at Perkins, there are wells from 150 to 250 feet deep through rock all the way, and wells of the same general type occur at Maple Ridge and Lathrop. Similar wells have been put down near the Wisconsin line at Ingalls by James Lucas.

At Talbot there is a drilled well close to the station. At Daggett there is a well, put down by W. H. Dolan, which at 40 feet was in a hard, white non-effervescent clay shale that might be valuable. At 45 feet it passed into a dolomitic sandstone. At 60 feet the sandstone was still calcareous, but at 80 feet it was almost pure quartz sand. This well must be in the Calciferous, possibly finishing in the Potsdam.

A short record of a well at Neebish Island down into the Potsdam sandstone, is given in the annual report for 1901. Mr. Alden suggests as a possible correlation for it:—

"?No samples	111	
Trenton limestone	112	223
St. Peter's sandstone	161	384
Potsdam	33	417
?Pre-Cambrian shale and quartzite	110	527"

I think that the bottom is conglomeritic Potsdam, and the limestone in part, at least, Trenton, yet I am not sure but that the Lower Magnesian is wholly gone and the white, sugary sandstone is St. Peter's. At any rate the top of the true Potsdam seems to be similar at times.

The drillers' full record is as follows:—

Drillers' "Log." [1]*Neebish Well.*

	Thickness.	Total.
Clay, boulders, and sand	33	33
Limestone, hard	1	34
Limestone, vein water, soft	1	35
Limestone, hard	14	49
Limestone, gritty, softer	40	89
Limestone, darker in color, not so gritty but harder [111-138 light colored]	17	106
Limestone, softer	13	119
Limestone, shale	2	121
Limestone, hard	3	124
Limestone, softer	3	127
Limestone, hard	7	134
Limestone, softer	6	140
Limestone, shale	2	142
Limestone	7	149
Limestone, hard [148-158 light colored]	4	153
Limestone, softer	5	158
Limestone, shale [bluish, thin chips]	5	163
Limestone, brittle [bluish, chipping, 163-200]	22	185
Clay	1	186
Limestone, brittle	4	190
Shale; cased here for first time	8	198
Limestone	2	200
Shale, [large chips, thin bedded]	5	205
Limestone, darker in color [sandy dolomite]	9	214
Limestone, shelly, full of little seams	9	223
White sand rock	10	233
Shale	2	235
White sand rock,[1] got first flow water at 250 feet, and more in several places in going through the sand	176	411
Sand; harder, looks like granite boulders pounded up	8	419
Sandy shale;[2] sand pumpings look red but when washed out are black	87	506
Sand rock	21	527

[1]Matter in brackets are notes on samples, the rate of effervescence with acid varies, being greatest at 123 and 190 to 200 feet, least at 138 and 211-223 feet.

Average, about 10 feet per day drilling. Worked just day time.

Reported by A. W. Palmer, Jan. 16, 1900.

Location, across the west channel on the mainland opposite Trombleys and about 1,000 feet south of north line of Trombleys; about 100 feet from water in the Sault Ste. Marie river and 6 or 7 feet above level of river about 11/2 miles below the rapids in the river.

The St. Ignace flowing wells have been reported in the annual report for 1901. The temperature is about 51°.

At Manistique flowing wells are from 200 to 800 feet deep. At 800 feet in the Hiawatha House well a flow was struck, which lifted the drill and had 30 to 40 feet of head, occurring in a "not hard shell rock" (Trenton ?). John Luce is in charge of 30 wells which furnish city water and are also used for fire protection. They are cased from 30 to 40 feet down and range in depth from 250 to 500 feet; the latter going through the seam of water and not gaining in depth. This was put down for salt, but the tools were lost in the bottom of the hole. Near the level of the main streets the water comes within a foot of the ground, others have head up to 16 feet. The character of the water is hard, for it is in limestone. The surface rocks of the quarries are limestones of the Niagara.

[1]Clean white glass sand rock 223-384, light red 384-411.

[2]Coarse red conglomerate, grows coarser, 417-506; at 430 red le of Huronian quartzite; 506-51 510-527, material mainly Huronian.

At the Burrell Chemical Co. is a well 300 feet deep all the way through limestone; temperature of flow, 46° F. They used to pump this heavily, but at the time of my visit they were stopped by fire and all other flows had increased very much. This well is out at the end of Cedar street. Across the river is another well with a strong flow. One of the city wells at the corner of Geer street and Houghton avenue, 280 feet, has a temperature of 45° F. (July 14, 1902) to 45.5° (Aug. 26, 1903) and a strong flow. During the summer of 1903 a number of new city wells were put down by Kenney and Coleman, as follows:—

1. Corner Garden avenue and Potter street, 6-in. pipe and a two foot pipe horizontal; just finished Aug. 26. There is a good flow of clear hard water at a temperature of 45° F., not more than 15 feet above Jake, 226 feet deep, a very little water was struck at 140 feet but no head. Mr. Coleman gives the following notes of the hardness:—

0 to 80 feet, hard drilling.

80 to 140 feet, soft drilling.

140 to near end, hard drilling.

Then softer, but just over the water hard drilling, as almost always the case.

The record is as follows:—

Sand		
Dolomite, light buff, massive	2	2
Light dolomitic limestone	2	4
Bluish white dolomite (harsh feel)	11	24
Above beds probably belong to Rominger's[1] third or uppermost member of the Niagara, and to the Racine or upper Coralline of Wisconsin, corresponding to the surface section and that in the quarry as follows:		
Cherty dolomite bluffs (Pentamerus)	10	10
Solid dolomite	5' 4"	15' 4"
Bluish dolomite	10	25 4
Blue clayey seam of partition which at points is full of small *Pentamerus oblongus* not over one inch in diameter.		
Brownish crystalline granular beds with Favosites and other corals	3	28 4
With open druses, lined with calcite	3	31 4
Fine grained bluish dolomites with Syringopora	5	36 4
Open grained brown dolomite with purple cavities	4	40 4
Open grained brown dolomite	4	44 4
Brownish crystalline dolomitic limestone.	16	40
Compare quarry beds from 25 feet to 44 feet.		
Light bluish dolomitic limestone	12	52
Buff crystalline cherty limestone	13	63
White limestone	7	70
Buff crystalline dolomitic limestone	10	80
White limestone	27	107
Mottled gray dolomite	18	125
Buff dolomite	11	136
Yellow dolomite	22	158
Gets harder and a little water, no flow at 140 feet.		
Yellowish limestone	30	188
Yellowish dolomite	12	215
This may be base of coralline, top of Byron beds of Wisconsin, Rominger's lower division.[2]		
White thin banded lithographic dolomite	10	225
Compare outcrops on sections 24 and 25 to the north.		
At bottom white limestone	15	240

[1]Vol. I, Part 3, p. 37.

[2]Volume I, Part 3, p. 37.

2. Mackinaw avenue and Elk.

3. Cedar street, near L. Rice.

4. Garden avenue and Potter.

In this rock with a 30-foot string of 4-in. tools they made 15 to 20 feet a day.

The same contractors put down a well 240 feet deep at the Burrell Chemical Works, while across the river, i. e., on the northwest side of the town, are a couple of wells put down 208 and 210 feet.

North of Manistique, on the Manistique and Northern R. R., on sections 24 and 25, T. 41 N., R. 16 W., very white, hard limestone is exposed showing by bandings that weather out, that it was a limestone mud.

Apparently the well begins in the uppermost of Rominger's three fold division of the Niagara, and goes through the middle or coral beds of the Wisconsin Survey, and it is worth noting, showing some beds of real limestone, low in magnesia. The bottom appears to be in Rominger's lowest division, or the Byron beds of the Wisconsin geologists. If we suppose the top to be at 426 of the St. Ignace well No. 2, the bottom layers with water might compare to the water found there at 680 feet. The bottom beds may correspond with those found on sections 24 and 25 of the township immediately north.

It seems to me it would be desirable to put one well down into the Potsdam, that is over 1,400 feet deep—and see what kind of water could be obtained there. I don't consider the bare possibilities of oil in the recommendation, but the water might be softer than in the present, and if not it would be pretty sure to be a valuable and probably palatable mineral water. One would expect it to be of the same class as the deepest wells of Chicago, Milwaukee, Manitowoc and Sheboygan.

All of the present wells, except perhaps the Hiawatha House 800 feet well, which may be from the Trenton, are in the Niagara and the strata may be compared with samples which have been saved from St. Ignace. Probably the sandstone struck at 897 feet, the bottom of the first well there (pl. 63 of Vol. V), may be the horizon of many of these wells. The record of the second well is given on page 228 of the 1901 report and we notice that there are strong flows of water encountered in the Niagara from 575 feet, that is, 65 feet, below its top, down. On page 227 of that report is given the record of a flowing well on Neebish Island, Mr. Alden's correlation of which is given above; the sandstone near the bottom being like those near the bottom of the Rapid River well.

As I have said, flows and springs are found or may be expected for a good ways back from the Lake Michigan shore, as at Newberry. The surface deposits of the drift are commonly not very thick over the Niagara. Over the Lorraine and Utica shales they seem to be thicker. There are extensive swamps; there is a good deal of surface sand, and it is not difficult to get surface wells. Over on the north side of this region at Grand Marais, T. 49 N., R. 14 W., a well was put down in 1899-1900, 1,200 feet deep. It tapered from 8-in. to 6-in. in diameter and was cased for the first 100 feet. It is about 100 rods from Lake Superior and about 30 feet above the lake level. It was started on the strength of artesian wells at Newberry,—citizens thinking that the same flow might be struck there and not appreciating that they were on the other side of the divide. It seems to have found some 1,100 feet of Potsdam, under 100 feet of drift. The well was 8 to 6 inches in diameter, cost $3,500, and the water did not flow. There was 100 feet of casing, but it has now been abandoned, and though the water was reported as extremely hard we cannot now tell its nature. Mr. Arthur D. Wood writes:—

"The Grand Marais well is located about 100 rods from Lake Superior, about 30 feet above the lake level. It was started on the strength of the Newberry artesian wells, the citizens of this city thinking that the same flow might be struck from here.

"The drill went through sand for the first 100 feet and then came in contact with hard pan of a sandstone nature of different colors. In some places this was harder than in others. During the drilling of the 1,200 feet several hardheads were met with, otherwise it was principally sandstone. The water in the well never flowed, but at times would rise to within a few feet of the surface and then it would not be seen again for a week at a time.

"The well is a thorough test that 1,200 feet will not strike a flow in the section.

"(Signed) ARTHUR D. WOOD.

"Grand Marais, Mich., 7/30, 1900."

The only reliable analysis of a well in the Potsdam sandstone is of the one put down by the Calumet & Hecla Company, near the Calumet & Hecla stamp mills at Lake Linden. They have drilled wells 1,500 feet deep, all the way through a monotonous series of sandstone strata. One has been analyzed. The same company have at their smelting works (section 7, T. 55 N., R. 32 W.) another well which goes down 500 feet, beginning 8 feet above the level of (Torch lake) Lake Superior. Water is usually quite clear, but occasionally brings up some red sand. There was much surface water cut off by a 10-in. casing for 30 feet. There was 90 feet of 8-in. casing down into the solid rock; 104 feet of solid sandstone followed. There is 200 feet of 4-in. pipe inside the 8-in. casing and 50 feet of 3-in. pipe below that; 200 feet of the well now having filled up with sand. When not pumping, the water stands at 25 to 30 feet below the surface, but can be pulled down with a pump to about 150 to 180 feet. It was drilled in 1887. The analysis by Mr. G. L. Heath, is as follows:—

C. & H. Stamp Mill Well.

	Grams per ton.
Silica	10.87
Carbonate of iron ($Fe CO_3$)	5.90
Sulphate of lime ($Ca SO_4$)	10.90
Carbonate of calcium ($Ca CO_3$)	43.59
Carbonate of Magnesium ($Mg CO_3$)	27.92
(Salt) Chloride of sodium ($Na Cl$)	52.69
Traces of chloride of potassium and nitrate of sodium.	
	151.87
Loss on ignition, organic matter and carbonic acid of bi-carbonates	32.33
Total solids	184.20
Parts in 1,000,000, by weight, taking Sp. Gr. of this water as unity.	

Compare the analyses on pages 163 and 164.

It is interesting to contrast this with the well at Freda, on the other side of the copper range, not so deep and also all the way through red sandstone, of which we will speak a moment later. In discussing the water of the copper country, we may give a group of analyses, showing the character of the surface waters and shallow mine waters. Most of these were made by Prof. Geo. A. Koenig or under his direction, and I owe them to him or the mine officers for whom they were made. The collection will be found valuable, I think, as showing what kind of boiler waters may be expected from various classes of water.

Water from Old Estivant Property, Copper Harbor.[1]

	Grams per ton metric.
Calcium carbonate	206.0
Magnesium carbonate	107.2
Magnesium chloride	36.
Sodium chloride	26.4
Sodium sulphate	52.4
Sodium carbonate	41.6
Silica	83.2
Organic matter (humus)	166.0
Total	718.8

[1]Sent by Osgood to test for boiler use, figures raised from 250 cc.; strongly carbonated and low in chlorides, upper type. L.

Well at Arcadian Mine location, Aug. 23, 1898.

		Grams per ton metric.
Sodium chloride		2.15
Sodium sulphate		9.76
Sodium silicate		15.00
Calcium carbonate		41.90
Ferrous carbonate		1.40
Magnesium carbonate		2.40
Na_2O	6.99	
K_2O	1.70	
	8.69	
$C_{60} H_{24} O_{27}$		20.90
		93.51

This has about the same hardness as the Boston Pond, not far off, upper type.

The following are some figures of analysis of the water at the Tamarack dock.[1]

Tamarack Dock.

Total solids	177.2
Organic loss by ignition	22.8
Inorganic solids	154.4
Sodium chloride (from silver chloride precipitated)	9.6
Sodic sulphate	24.0
Iron and aluminium oxide	1.0
Silica[2]	16.7
Balance probably mainly calcium and magnesium carbonates	103.1

What the undetermined balance consists of is shown by the next analysis.

Filtered Portage Lake Water.[3]

	Grams per ton.
Calcium carbonate	63.7
Calcium chloride	30.7
Magnesium chloride	2.35
Magnesium sulphate	6.45
Sodium chloride	14.45
Sodium silicate	7.9
$H_2 Si O_4$	15.7
	139.75
Albumenoid ammonia	.06

[1]Computed from figures per fourth litre.

[2]Silica, iron and alumina in two litres .0354 gr.

[3]Feb. 17, gave 279.5 mg. in 3 litres and by analysis.

Portage lake should, of course, be intermediate between Lake Superior and various other waters, except so far as it might be affected by the mine drainage of the Isle Royale, Quincy, and other mines and the towns and metallurgical operations. These introduce the earthy chlorides.

Here is an analysis of the water of Thunder River, near the Wolverine mill, which, however, does not affect it:—

Thunder River.

	Grams per metric ton.
Calcium carbonate	27.3
Magnesium carbonate	8.51
Ferrous carbonate	2.03
Sodium chloride	1.70
Sodium sulphate	2.84
Sodium silicate	14.48
	72.49

This has about the same amount of mineral matter as the Houghton water supply or the tank that used to supply the College of Mines, gathered from shallow springs, from the top of the hill back of the school.

College of Mines.[1]

	Per million.
Alumina	1.82
Calcium carbonate	16.25
Ferrous carbonate	.49
Magnesium carbonate	15.82
Magnesium sulphate	4.69
Silica	8.20
Sodium silicate ($Na_2 K_2(Si O_3)_2$).	3.90
Sodium chloride	trace
Free ammonia	.03
Albumenoid ammonia	.15
Humus (organic)	27.06
	78.40

The small artificial pond for the boilers of the Franklin Junior Mine,—Boston Pond, is about equally soft.

[1]Tank. Shallow springs from the top of the hill back of the school, analyzed by A. Formis.

Franklin Junior.[1]

Calcium carbonate		29.00
Ferrous carbonate		1.16
Magnesium carbonate		9.50
Sodium silicate		1.16
Sodium sulphate		2.75
Sodium chloride		2.21
Na_2O	1.32	
K_2O	0.60	
Humus (organic)		37.60
		83.38

[1]Small artificial pond.

Some analyses of water near the Winona mine are: —

Winona.

(1) Yellow, with an unpleasant smell and color.

	Grams per metric ton.
Calcium carbonate	66.60
Magnesium carbonate	24.15
Calcium sulphate	14.55
Silica	3.25
Sodium chloride	31.50
Potassium chloride	7.50
Humus (organic matter)	25.05
Free ammonia	1.00
Albumenoid ammonia	3.40
Total directly	177.00

(2) Turbid with salt, but no smell nor color; pleasant taste.

	Grams per metric ton.
Calcium carbonate	131.25
Magnesium carbonate	26.45
Ferrous carbonate	20.40
Sodium chloride	9.65
Free ammonia	.05
Albumenoid ammonia	.29
	188.09

(3) A spring gives the following analysis in grams per metric ton :—

Calcium carbonate	45.06
Magnesium carbonate	11.76
Ferrous carbonate	0.153
Sodium chloride	3.41
Sodium sulphate	.28
Sodium aluminate, $Na_6 Al_2 O_4$	.322
Silicate, $Na H SiO_4$	20.980
Ammonium nitrate, $NH_4 NO_3$	.108
Albumenoid ammonia	2.22
Organic matter	5.02
Sum	89.313
Total directly determined	93.4

The analyses of the pond at the Tamarack, and that by G. L. Heath on page 68, show the kind of contamination produced by the deep waters of the copper mines, one with earthy chlorides.

So far as the hardness goes, the amount of calcium, magnesium, and ferrous carbonates, does not fall below that in Lake Superior, say about 50 grams per ton and is not often more than double that, i. e., there should be from 3° to 6° of hardness. With this, agrees analysis 156 of the Hancock water by V. C. Vaughan, while No. 326 is extra high.

HANCOCK.

ANALYSES BY V. C. VAUGHAN.

Number	156	326
Date	9/20/92	7/29/96
Color		
Odor	(1)	(2)
Reaction		
Hardness	4°	7°
Total residue	[1]12	150
Inorganic residue	[1]10.5	110
Organic residue	[1]1.5	60
Na Cl	2	4.95
Permanganate reduced	3	2
Free ammonia	.07	0.098
Albuminoid ammonia	.40	0.136
Nitrates	Distinct trace	trace
Nitrites	0.0	trace
Bacteria in 72 hours	525	Liquefied

[1]Slight offensive odor and markedly acid reaction; microscope shows indeterminate granules and a few fresh water algæ. Figures returned for inorganic residue, etc., are all ten times too small.
[2]Trace of sulphates and small deposit of vegetable debris.

We have had an analysis of Teal lake ice. It will be fit now to give analyses of this and other lakes of the iron bearing rocks. First near Ishpeming and Negaunee.

	Ishpeming lake.		Negaunee—Teal lake.
Number	153[1]	191	179[2]
Date	7/14/92	7/8/93	9/22/98
Hardness	2°		
Total residue	42.85	33	
Inorganic residue	28.52	25	
Organic residue	14.33	8	
Na Cl	0.75	2	0.75
Permanganate	3.5	4	
Free ammonia	0.68	.03	0.6
Albuminoid ammonia	0.09	.10	.49
Nitrates	Distinct trace	traces	trace
Nitrites	0.0	traces	trace
Number of bacteria in 72 hours	575	300	2,400

[1]Microscope shows indeterminate granules and bacteria.
[2]Reaction of inoculation positive; vegetable debris.

Compare analyses and remarks on page 51.

These are very soft. At Iron Mountain, on the other hand, the waters are hard and the Randville dolomite occurs around there. There may be mine water contamination.

IRON MOUNTAIN ANALYSES OF PUBLIC WATER SUPPLY.

Location.	Outlet of lake Antoine.	Waterworks well.	City hydrant.	Lake
Number	84[1]	82[2]	83[3]	120[4]
Date	6/10/90	6/10/90	6/10/90	6/24/91
Color				slight sediment
Odor				
Reaction				
Hardness	13°	13.2°	12°	11°
Total residue	120	150	164	125
Inorganic residue	69	69	118	58
Organic residue	51	81	46	67
Cl as NaCl	4.125	4.95	4.95	6.93
Permanganate reduced	29.402	32.149	25, 34.9	28.331
Free ammonia	00.358	0.388	0.502	0.11
Albuminoid ammonia	0.342	0.444	0.57	0.322
Nitrates				
Nitrites		very faint trace	faint trace	
Bacteria in 72 hours	3	6	6	2

[1]Algæ diatoms, *Draparnaldia*, *Diatoma vulgare* Foraminifera.
[2]Colorless amorphous matter, Dark colored amorphous matter, algæ, crystals, *Crenothrix*, *Diatoma vulgare*, *Zooglœa*.
[3]Colorless amorphous matter, yellow amorphous matter, algæ, a few diatoms.
[4]Microscope 100 and 500 diam., Diatoms, colorless amorphous matter, monads.

IRON MOUNTAIN.—CONTINUED.

Location.	Lake.	Well.
Number	134[1]	135[1]
Date	1891	1891
Color		
Odor	faint	
Reaction		
Hardness	8.6°	1
Total residue	150	260
Inorganic residue	100	140
Organic residue	50	120
Cl as NaCl	1.3	1.0
Permanganate reduced	7.584	10.428
Free ammonia	.15	.08
Albuminoid ammonia	.24	.106
Nitrates		trace
Nitrites	trace	strong trace
No. of bacteria in 72 hours	4	2

[1]Trace of sulphates.

IRON MOUNTAIN.—CONTINUED.

Location.	Public water supply.	Water works.	Water works.	Public water supply.
Number	131[1]	128[2]	67	182[3]
Date	1/28/92	11/23/91	4/14/90	8/25/93
Color				
Odor				
Reaction				alkaline
Hardness	13.7°	13.2	8.5°	
Total residue	130	220	210	
Inorganic residue	88	150	130	
Organic residue	42	70	80	
Cl as Na Cl	0.42	2.	4.5	0.2
Permanganate reduced	7.9	0.15	7.8	
Free ammonia	0.7	0.008	0.26	.008
Albuminoid ammonia	0.05	0.025	0.27	.04
Nitrates				
Nitrites		trace	trace	
Bacteria in 72 hours	4	13	9	250

[1]Microscope shows indeterminate granules.
[2]Microscope shows fine grains of sand. Trace of sulphates.
[3]Microscope shows a few vegetable fibres.

IRON MOUNTAIN.—CONTINUED.

Location.	
Number	189[1]
Date	7/98
Color	
Odor	
Reaction	alkaline
Hardness	
Total residue	
Inorganic residue	
Organic residue	
Cl as Na Cl	0.2
Permanganate reduced	
Free ammonia	.068
Albuminoid ammonia	.05
Nitrates	
Nitrites	
Number of bacteria in 72 hours	3,500

[1]Microscope shows a few vegetable fibres.

IRON MOUNTAIN.—CONCLUDED.

Location.	Lake.	Water works.
Number	121[1]	122[2]
Date	6/24/91	7/2/91
Color	slight sediment	Contain much floc'lent matter
Odor	....	....
Reaction	....	....
Hardness	11.2°	11°
Total residue	143	120
Inorganic residue	67	72
Organic residue	76	48
Cl as NaCl	7.09	4.0
Permanganate reduced	35.522	20
Free ammonia	0.092	0.03
Albuminoid ammonia	0.314	0.15
Nitrates	....	....
Nitrites	....	....
Number of bacteria in 72 hours	2	4

[1]Microscope—Diatoms—Colorless amorphous matter. Monads.
[2]Microscopic appearance—Vegetable fibres and bits of decayed wood.

Norway is very similarly located to Iron Mountain and the analyses of wells and other sources are similar, but a shade less hard, from 10° to12°.

NORWAY.

Number	124[1]	125[2]	126	183[3]	184[3]
Date	7/2/91	7/2/91	11/8/97	8/16/98	8/16/98
Color	....	sediment	....	....	....
Odor	....	....	....	....	....
Reaction	....	....	....	feebly alkaline	feebly alkaline
Hardness	10°	12°	10°	9°	11°
Total residue	120	126	101	280	340
Inorganic residue	111	111	95	220	270
Organic residue	9	15	6	60	70
Cl as Na Cl	1.0	3.0	0.5	1.6	1.4
Permanganate reduced	3.2	3.5	1.2	3	3
Free ammonia	0.01	0.02	0.005	0.005	0.005
Albuminoid ammonia	0.03	0.15	0.01	0.10	0.08
Nitrates	....	....	....	0.05	0.06
Nitrites	....	....	....	0.0	0
No. of bacteria in 72 hours	3	5	2	480	150

[1]Microscope—Deposits.
[2]Bits of vegetable fibres.
[3]Sulphates 2, microscope shows only indeterminate granules.

Number	185[7]	277[8]
Date	8/16/98	11/19/97
Color	....	Milky
Odor	....	Ammoniacal on warming
Reaction	feebly alkaline	alkaline
Hardness	11.5°	9.2
Total residue	240	430
Inorganic residue	160	255
Organic residue	80	175
Cl as NaCl	1.2	16.5
Permanganate reduced	3.5	3-
Free ammonia	0.02	1.4400
Albuminoid ammonia	0.30	trace
Nitrates	1.0	....
Nitrites	0	....
Number of bacteria in 72 hours	300	liquefaction

[7]Trace of sulphates. Microscope shows specks of vegetable matter.
[8]Some sulphates present—considerable amount of amorphous material, probably a salt of ammonia.

There was a flood of water in the Vulcan mine, near Norway, in the fall of 1903; which almost drowned them out (did drown two mules), and analyzed as follows, in grains per metric ton:—

Insoluble matter, clay and SiO_2	4.4
Solid solubles	340.00
Organic matter	52.3
Carbon dioxide	37.3
Non volatile solids	250.4
In solution.	
Silica	5.8
Alumina	4.4
Ferric oxide	trace
Calcium oxide	84.4
Magnesium oxide	62.8
Sulphur anhydride, SO_3	36
Chlorine	61
Potassium	trace
Sodium present not determined, very small.	
Strontia and lithia	0
Total by addition	254.4

We may consider this combined as follows:—

$Ca\ SO_4$	61.2
$Ca\ CO_3$	85
$Ca\ Cl_2$	26.6
$Mg\ Cl_2$	73.3
$MgO,\ SiO_2$	9.7
$MgO,\ Al_2O_3$	6.2
MgO representing bases combined with organic matter	30.6
	292.6

E. E. Ware, laboratory of E. D. Campbell, Ann Arbor.

Compare non-volatile solids and CO_2=250.4 plus 37.3=287.7. The hardness of 308 grams per metric ton would be equivalent to about 18°.

The water is not unlike Vaughan's waters 183 and 184 in hardness and inorganic residue, but has a comparatively large amount of chlorine, and yet a very small amount of sodium, which is very peculiar, but reminds one of the deeper waters of the copper country much diluted.

The temperature of the water at the 12th level, 1,000 feet from the surface, was: at the shaft, 57.°2 F.; at the first winze, about 100 feet west of the shaft, 60.°6; and the west end, almost 300 feet west of the shafts, 58.2°.

See annual for 1901, p. 246. According to the observations there, the mine water at 1,210 feet was 56°, and at 270 feet, 45.°8. This water is then, abnormally warm,—either from working up(?) or the heat from casing, friction, and decayed timber.

The question arose whether it had any immediate surface source, and accordingly, analyses were made of the surface waters.

1 is from Lake Hanbury, into which the mine water drains.

2 is from water in the gravels at Norway, from the Aragon mine sand shaft, used for city supply.

3 is from Pine creek.

Comparing them with the deep mine water, there is a large amount of carbonates, a variable amount of sulphates, and much less chlorine than in the mine water, which, therefore, is probably not derived from any of them.

Feb. 19, 1904.

	Lake Hanbury.		Sand shaft.		Pine creek.	
Total solids	301.4		762.5		205.2	
Inorganic solids	268.1		668.1		172.7	
Carbon di-oxide	82.8	1.88	160.5	2.98	56.2	1.28
Lime	63.9	1.14	195.2	3.48	57.6	1.022
Magnesia	52.5	1.335	88.0	2.2	38.4	.835
Chlorine	3.6	.1019	3.8	.1074	1.0	.028
Sulphuric anhydride	33.6	.42	245.8	3.07	9.5	.118
Alkali chlorides	13.8		14.0		3.4	
Potassium oxide	....		1.7		....	
Sodium oxide	....		6.7		....	
Total	280.2		653.7		160.1	
Silica, iron and alumina by difference	17.9		12.4		12.6	

Examination for potassium, showed its presence in all three waters. Determined as grams per ton.

(Signed) L. KIRSCHBRAUM.

Made at the Chemical Laboratory of the University of Michigan, E. D. Campbell, supervising.

An Ishpeming mine water, coming out of a diamond drill hole at a depth of 825 feet, gave the following results, which are quite different from the Vulcan mine water, and more nearly like surface waters:—

1.	2.	3.	4.
Lime as carbonate	55.8	(Oxide determined)	31.3
Magnesium as carbonate	17.0	" "	8.1
Iron and alumina carbonate	.5	" "	.7
Requiring CO_2 .... 33.2		" "	34.3
Total encrusting solids	73.3		
Chlorides as sodium chloride	56.2	Chlorine determined	34
Sulphates as sodium sulphate	67.0	SO_3 "	33.4
Total corrosive solids	123.2		
Silica	10.5		
Water of crystallization[1]	3.2		
Excess of CO_2	1.1		
Combined CO_2	33.2		
Sodium chloride	56.2		
Organic matter by difference from ignition loss	19.9	19.9. Ignition loss	113.6
Total by computation	229.1		
Total by evaporation at 100° C.	232.2		
Difference (minor errors, extra weight of potash over soda and undetermined)	3.1		

[1]The sulphates are probably in large part calcium sulphate, etc., and the soda correspondingly carbonate, reducing the amount of crystallization water.

Analysis by Kirschbraum, computation by Lane.

IRONWOOD.

From Ironwood, Dr. Vaughan has tested three kinds of water. The Montreal river, which is the public water supply, Nos. 130,180; Pine Lake, 181, and various wells, 153, 188, etc., as follows:—

(The inorganic residue is probably, in part, silt.)

IRONWOOD.

Location.	Pine lake.[1]	Well.	River.[3]	River.[4]	Well.[5]	Well.[6]
Number	181	153[2]	130	180	188	194
Date	9/1/93	4/29/90	1/25/93	9/20/93	8/8/93	6/29/93
Color	yellowish	....	....	yellowish	....	....
Odor	musty	....	....	....	....	musty
Reaction	....	....	....	....	feebly alkaline	....
Hardness	9°	4°	6.5°	7°	8°	6.5°
Total residue	550	117.5	190	540	212	850
Inorganic residue	470	70.0	100	490	200	350
Organic residue	80	40.5	90	50	12	500
Cl as Na Cl	1.0	9.9	5.6	0.50	3.0	44.58
Permanganate reduced	....	....	46.136	12.5	12	....
Free ammonia	0.018	0.176	.103	0.08	0.10	0
Albuminoid ammonia	0.30	0.248	.116	0.35	.20	.066
Nitrates	....	2.315	trace	....	traces	large amount
Nitrites	....	2.687	trace	....	traces	.90
Number of bacteria in 72 hours	500	12	960	250	600	450

[1]Microscope shows vegetable fibres and algæ.
[2]Duplicate number in Vaughan's list—Microscope 100 diam.—Brownish algæ and particles of inorganic matter.
[3]Sulphate trace—Microscope—Fresh water algæ.
[4]Microscope shows vegetable debris.
[5]Indeterminate granules; bacteria.
[6]Microscope shows vegetable fibres, Diatoms, etc.

IRONWOOD.

Location.	Waterworks.		Waterworks.	Filter.	Well.
Number	199[1]	200[1]	201[2]	223[3]	229[4]
Date	6/17/93	6/10/93	6/4/93	7/27/94	8/23/94
Color	brownish red	brownish red	brownish red	slightly yellowish	slight milkiness
Odor	....	....	....	....	....
Reaction	slightly acid	slightly acid	slightly acid	alkaline	slightly alkaline
Hardness	2.5°	2.5°	2.0°	5°	6°
Total residue	75.0	75.0	75.0	90	170
Inorganic residue	12.5	12.5	12.5	64	100
Organic residue	62.5	62.5	62.5	26	70
Cl as Na Cl	5.0	5.0	5.0	1.98	7.42
Permanganate reduced	....	0.0	....	....	....
Free ammonia	0.052	0.075	0.0084	0.33	0.018
Albuminoid ammonia	0.10	0.18	0.0528	0.51	0.200
Nitrates	0.70	0.6	0.6	....	trace
Nitrites	1.80+	8.0	trace	....	faint trace
Number of bacteria in 72 hours	....	384	231	liquefaction	1,600.

[1]Microscope shows bacteria—Diatoms—Monads.
[2]Microscope shows Diatoms—threads of bacilli and Desmids.
[3]Microscope shows vegetable debris and bacteria.
[4]Microscope shows small deposit of inorganic matter, vegetable debris, and a few Infusoria.
In Nos. 199 and 200 the reaction was positive,—the water dangerous. The brownish red color is due to swamp water, and humic acid, as the reaction shows.

IRONWOOD.

Location.	Well.	Well.	River.
Number	231[1]	232[2]	233[3]
Date	8/24/94	8/24/94	8/27/94
Color	milky	sigt. milkiness	brown
Odor	stale, musty	....	....
Reaction	feebly alkal'e	slightly alk'e	slightly alk'ne
Hardness	1°	6.5°	3.5°
Total residue	200	210	120
Inorganic residue	150	140	30
Organic residue	50	70	90
Cl as NaCl	4.12	4.95	1
Permanganate reduced	....	....	....
Free ammonia	0.18	0.01	traces
Albuminoid ammonia	0.191	0.12	0.18
Nitrates	trace	traces	faint trace
Nitrites	large amount	large amounts	....
Number of bacteria in 72 hours	800	200	120

[1]Trace of sulphates. Vegetable debris, diatoms, algæ, infusoria. Inorganic matter.
[2]Microscope shows inorganic matter, bacteria, algæ.
[3]Microscope shows inorganic matter, a few algæ. Desmids.

Location.		Well.[2]
Number	223[1]	
Date	2/7/93	4/29/90
Color	....	....
Odor	....	....
Reaction	alkaline	
Hardness	15°	4°
Total residue	400	117.5
Inorganic residue	340	70.0
Organic residue	60	47.5
Cl as Na Cl	3.30	9.9
Permanganate reduced	....	....
Free ammonia	0.005	0.176
Albuminoid ammonia	0.04	0.248
Nitrates	trace	2.315
Nitrites	....	2.687
Number of bacteria in 72 hours	....	12

[1]Trace of sulphates. Microscope shows deposit chiefly inorganic matter.
[2]Microscope shows algæ, Infusoria, vegetable fibres, and inorganic matter.

SAULT STE. MARIE.

Location.			
Number	99[1]	100[2]	101[3]
Date	10/28/90	11/17/90	11/17/90
Color	....	....	....
Odor	....	....	....
Reaction	....	....	....
Hardness	3°	5°	4.9°
Total residue	89	153	107
Inorganic residue	21	117	59
Organic residue	68	36	51
Cl as NaCl	3.30	6.6	8.23
Permanganate reduced	0.632	5.99	5.322
Free ammonia	0.224	0.058	0.05
Albuminoid ammonia	0.168	0.104	0.12
Nitrates	very faint trace	0.27	0.965
Nitrites	0.1065	....	very slight trace
Number of bacteria in 72 hours	2,500	7	12

[1]Sulphates 5. 46. Microscope 100 diam.: Colorless amorphous matter, yellow amorphous matter, crystals,—algæ.—Desmids. 500 diam.: Colorless amorphous matter, yellow amorphous matter, crystals of Na Cl. Diatoms. Sciadium. Compsopogon.
[2]Microscope 100 diam. Colorless amorphous matter. Fibres, algæ 500 diam. Colorless amorphous matter, fibres. Draparnaldia.
[3]Microscope 100 diam. Algæ, germs, animalculæ. yellow amorphous matter. Draparnaldia and other algæ. Zoogloea, Paramecia, red spores of algæ, yellow amorphous matter, positive reaction.

AMASA.

Number	158[1]	159[2]	160[3]	161[4]	162[5]
Date	11/3/92	11/3/92	11/3/92	11/3/92	11/3/92
Color	....	slightly turbid	....	....	yellowish
Hardness	8.8°	9.7°	13°	7.5°	9.50
Total residue	100	200	190	420	110
Inorganic residue	75	170	150	295	80
Organic residue	25	30	40	125	30
Cl as NaCl	12.5	6.7	1.1	1.1	1.2
Sulphates	....	trace	....	heavy traces	trace
Permanganate reduced	20.54	25.28	31.60	18.96	28.5 / 48
Free ammonia	0.016	0.032	0.036	0.016	0.02
Albuminoid ammonia	0.112	0.36	0.15	0.21	0.23
Nitrates	....	heavy traces	....	....	....
Nitrites	....	heavy traces	....	....	....
Number of bacteria in 72 hours	44	liquefied	liquefied	liquefied	liquefied

[1]Microscopic appearance: Pigment granules, carbonate of lime, vegetable detritus.
[2]Mass of pigment, inorganic crystals, diatoms
[3]Microscope shows pigment granules, woody fibre. Bits of cotton fibre.
[4]Woody fibres. Pigment granules. Fresh water algæ.
[5]Under microscope. Pigment granules. Diatoms.

AMASA.

Number	163[1]	164[2]
Date	11/3/92	11/3/92
Color	....	....
Hardness	9°	10.2°
Total residue	460	170
Inorganic residue	270	120
Organic residue	190	50
Cl as NaCl	7	2.9
Sulphates	....	faint trace
Permanganate reduced	28.62	44.08
Free ammonia	0.026	0.03
Albuminoid ammonia	0.24	0.24
Nitrates	....	....
Nitrites	....	....
Number of bacteria in 72 hours	countless	innumerable

[1]Cotton fibres. Indeterminate granules. Carbonate of lime.
[2]Pigment granules, algæ, woody fibre, reaction with inoculation positive, the previous analyses negative.

The Upper Peninsula being as yet a comparatively undeveloped region, there are many wells which are very shallow and superficial. The Amasa analyses are probably of this character. The hardness, like that of Iron Mountain, is noteworthy, and suggests that the surface deposits may have come largely from the east rather than the north.

At times, however, the surface deposits and wells in them, are quite deep.

At Sidnaw, wells go through 100 feet of quicksand. Schwartz Brothers at Pentogan, T. 42 N., R. 34 W., put down a well 4 feet by 4, 43 feet deep, through till (stone, gravel, and loam), at 32 feet a two foot seam of coarse sand was dry, at the bottom a quicksand was encountered, and drilling to a depth of 195 feet encountered nothing but quicksand.

On the other hand, at the Mass City brickyard, a well over 200 feet deep encountered nothing but clay. The surface deposits of the Upper Peninsula are quite irregular in distribution. On the Copper Range, just north of the Tamarack mine there is a large deposit of irregular gravel, with marked kettles, a sort of kame deposit, probably in an angle in front of the continental ice sheet. The same phenomena are repeated at Wheal Kate south of the Atlantic mine, and for a long ways south on the crest of the range, while the country not over 600 feet above the lake has been more or less worked over by the former extension of Lake Superior, and is liable to be clay with streaks of gravel or sand along old terrace lines. The areas of Laurentian rocks are large areas of bare knobs with pocket swamp between. On the whole, large areas of the Upper Peninsula and many of its streams have very soft water, which is an important item in many manufactories.

About 3° to 4° hardness is as soft as is to be expected.

I have previously remarked that the structure of the Lake Michigan shore belt is favorable to flowing wells, and that there is a probability that such wells drawing from the Potsdam sandstone will have fairly soft water. The structure of the Lake Superior shore, on the other hand, is not favorable to flowing wells east of Marquette. From Marquette around to Pequaming some should be obtained in the sandstone that skirts the Huron mountains. Thence to the end of Keweenaw Point, flowing wells need not be expected, though they may perhaps, be obtained in the low belt of land marked by the Sturgeon and Otter, Torch lake, Gratiot lake, and Lac Labelle.

We may insert here appropriately the following analyses:—

WATER ANALYSES NEAR CALUMET AND HECLA SMELTER, TORCH LAKE.

	2	3	4
Suspended sediment slight			
Silica	3.7	9.5	24.8
Iron oxide (exists as carbonate) and alumina	2.7	1.1	1.5
Calcium sulphate	5.8	7.0	2.0
Calcium carbonate	47.7	79.8	79.1
Magnesium carbonate	30.5	31.2	21.2
Sodium chloride	21.3	10.7	4.8
Potassium chloride	trace	trace	0.8
Nitrates	trace	.085	K_2CO_3 1.3
Difference (organic or undetermined matter)	34.1	9.0	1.4+
Loss on ignition direct	(23.1)	(14.3)	
Total solids	145.8	149.3	137.0

Parts per million.

These three analyses were all by G. L. Heath.

2. 10/1/1900, from the outside casing, down into solid stone, in parts per million.

3. Water from 80-foot wells at the C. & H. smelting works, Sept., 1900, driven just to sandstone, through the following strata:—

	Thickness.	Depth.
Soil and reddish sand	6 to 10 ft	6 to 10
Red hard pan	6 to 10 ft	16 to 20
Clear white beach grit, some pebbles and boulders	50 to 60 ft	78 to 88
Gravel and red sandstone	2 ft	80 to 90

Wells from the base of the drift are characteristically harder and have less salt, the total solids being about the same, yet this water though about twice as hard as Lake Superior, is only about half as hard as a normal Lower Peninsula water.

4. A driven well sunk in the beach near the Calumet & Hecla Mining Co.'s pumping station, on the west shore of Keweenaw Point, is evidently not at all Lake Superior water, but much like No. 3 and drift water. The water must come from the land side, and in fact, has a head of one foot above the lake. It illustrates the same principle as that of the well known fact that fresh water can often be found by digging down into a salt water beach. Outside the casing of the 500-foot well, comes a water very similar but with slightly less salt. The 1,500-foot well, it is said, never struck salt water, or indeed, very much water anyway, at the bottom. This 1,500-foot well, is, however, now filled up several hundred feet, so that it is now pumped (air lift or Pohlé system), the water coming from the first 500 feet. There was also a well at Mills, 500 feet deep, furnishing water of the same composition as that from the deep one.

Beginning from the end of Keweenaw Point, however, the conditions of strata dipping toward the lake are once more favorable to flowing wells clear to the Wisconsin line. I accordingly favored putting down a well near the lake shore at Freda, the stamp mill site of the Copper Range Company, Sec. 25, T. 35 N., R. 35 W. The results were disappointing. It was 18 feet to bed rock, and the well is said to have flowed slightly in the first 100 feet,—possibly from the surface deposits. The strata were red all the way down, sandstone but more or less basic, calcareous and much cemented, and this feature probably accounts for the relatively poor yield of water, and more or less shaly. In particular, from 910 to 950 feet, the beds were shale, making a regular red mud under the drill and underneath this the water was decidedly brine. The record is given below. It is obvious that this well is important in many ways. It indicates that, as was long ago held by [1]Irving, the sandstones east and west of the Copper Range are not of the same character, the character of this Freda water being much more like those of the deep waters of the Copper Range than like that of the Lake Linden well.[2]

[1]Copper Bearing Rocks, chapters V and VII.

[2]Above, pp. 143. 163.

RECORD OF FREDA WELL.

Drilled by Chas. Coryell for Champion Mine.

Surface, muck, sand, etc., thickness, 18; total, 18.
Temperature of strong spring near by, 45° F.
Surface puddles, 50° F., June 22, 1902.
Top beds, dark maroon sandy shales, with much basic matter.
Water ever since, surface water not entirely cased off, water came to surface one day, in first 150 feet, but only once.
Temperature at top of water, 45.5° F., at about 100 feet.
March 5, at 150. Cased.
Water level about 50 feet down at 500-600 feet after stopping the drill over Sunday, March 28, at 400.
Temperature observed by Sheldon 51°, at 480; thermometer, 9111.
Temperature observed by Sheldon 51.5°, at 550.
Temperature observed by Sheldon 51.5°, at 636.
Alternate hard and soft streaks at 600.
Temperature after 12 hours suspension of work, 50°, at 730.[1]

Temperature after 8 days suspension of work, 49°, at 730.
Red shale, 40, 950.
Average speed, 1 foot in 3 hours.
June 22, finished at 970 to 950 feet.
Water level at 100-150 feet below ground on Monday, and bailing 18 to 20 times made no appreciable difference in the height.
Temperature, 49° at 730 feet.
Temperature at bottom, 55° (950), by 9109 Greene's thermometer.
Temperature 55.6° at bottom by 9111.
The temperature observations are not satisfactory, but the increase of 4° to 4.6° in 950—480=1° in 80 feet, to 1° in 87 is about equivalent to the total increase of 55.6° to 55°—45° to 43=1° in 85 feet to 1° in 80 feet.
The water from the bottom June 22, was found to have a sp. gr. of 1.07, and the sample taken for analysis a week or two before gave Dr. Koenig: sp. gr. 1.0511.

	Grams per kilogram.
$Ca\ Cl_2$	44.51
$Na\ Cl$	19.29
$K\ Cl$	0.56
$Mg\ Br$	0.24
Mn	0.57
	65.47

The Midland Chemical Co. also tested the same (Jan. 23, 1903) and found sp. gr. 1.049, Br .35 grams per kilogram, equivalent to $Mg\ Br_2$ .40.

This relative to the specific gravity is about as strong as the Midland water, and reminds one at once of the waters from the Tamarack and Quincy mines given above.

[1]Observed, by driller, perhaps warmed too much, in putting in and out. Thermometer at those low temperatures must be handled very promptly as the drill house is very hot often.

To compare with the Freda water, the Quincy water, and the Tamarack water, we have the following interesting analyses of the water from the bailer of the Vertical or Whiting shaft of the Calumet and Hecla, 4,960 feet deep. The water pumped from the Hecla end of the mine at much less depth, is "even more saline." These waters are in contrast with the shallower carbonated waters, say those of the Winona or Arcadian. It is noteworthy how small is the percentages of sulphates, as well as carbonates. That, to my mind, militates against any theory of origin of these deposits from sulphides. The minute quantities of nickel, copper and zinc with iron, point rather to olivine, or some such ferro-magnesian (ferine) silicate as the original source.

Details of probable compositions in sediment.	Mine water, C. & H. Vert. shaft.		Atlantic ocean.
	Grams per liter.	Grains per U. S. gallon.	Grains per U. S. gallon.
Insoluble silica	.0222	1.29	....
Insoluble oxide of iron	.0127	.74	....
Dissolved silica (SiO_2)	.0033	.19	....
Dissolved chloride of iron	.0045	.26	....
Zinc chloride (with trace nickel)	.0290	1.69	....
Copper chloride ($CuCl_2$)	.0045	.26	....
Magnesium chloride	.0875	5.10	276.5
Sodium chloride (salt)	1.88	109.37	1,591.85
Potassium chloride	.074	4.31	58.25
Potassium bromide (in ocean only)	....	....	33.65
Calcium chloride	3.138	182.87	90.10
Calcium sulphate	.0555	3.23	....
Sodium sulphate (in ocean only)	....	....	261.30
Calcium carbonate (dissolved by free carbonic acid)	.248	14.46	....
Loss on ignition (actual determination)	1.13	63.0	....
No lithium. Undetermined balance traces carbon, etc.	....	....	....
Sum of all constituents	6.65	386.77	2,237.65
"Total solids" on evaporation as weighed {354+ / 383+}	6.32	368.5+	2,238.72

G. L. HEATH.

While, therefore, there is a possibility of artesian wells along the Lake Superior shore of Keweenaw Point and the Porcupines, unless they are not deep the water is likely to be a mineral water,—perhaps even valuable for the manufacture of bromine and other salts.

WATER POWER.

In regard to the question of water power, that subject has been in the hands of Mr. R. E. Horton of the U. S. Geological Survey, to whom I have given various assistances at different times. Mr. W. M. Gregory and W. V. Savicki have also aided him. The result of his work in this state will be found in the U. S. Geological Survey Water Supply Papers, No. 30, No. 49, pp. 239-260; No. 65, p. 315; No. 75, p. 111; No. 83, pp. 241-297; and the Michigan Engineer for 1901. In an official letter, correcting No. 83, we have the following discharge measurements on the Au Sable river at the gauging station at Bamfield, Michigan:—

Date.	Hydrographer.	Gage height (feet).	Discharge (sec. ft.).
August 14, 1902	Horton & Gregory	....	1,133
August 26, 1902	W. M. Gregory	0.82	1,026
September 17, 1902	W. M. Gregory	.80	998
October 7, 1902	W. V. Savicki	0.72	981
March 6, 1903	Horton & Roundy	1.10	1,176
March 13, 1903	E. P. Roundy	2.00	1,999

BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY, 1903.

EX OFFICIO:

THE GOVERNOR OF THE STATE,
HON. A. T. BLISS, *President.*

THE SUPERINTENDENT OF PUBLIC INSTRUCTION,
HON. DELOS FALL, *Secretary*.

THE PRESIDENT OF THE STATE BOARD OF EDUCATION,
HON. L. L. WRIGHT.