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.

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BOARD OF GEOLOGICAL 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.

ILLUSTRATIONS.

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ERRATA.

Page 38, line 13 from top, G. K., not C. K. Gilbert.
Page 5, line 2 from top, C. A., not A. C. Davis.
Page 25, foot note 3, the reference should be to "recherches sur le rôle physiologique," etc.
Page 37, line 1 at bottom, Pt., not Pl.
Page 74, line 21 from top, 534 feet, not 634 feet.
Page 106, after Na, line 13, insert NO_3.
Page 208, figure 8 should be figure 9.

FIFTH ANNUAL REPORT

OF THE

STATE GEOLOGIST

ALFRED C. LANE

TO THE

BOARD OF GEOLOGICAL SURVEY

FOR THE YEAR 1903.

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.

Geological Survey of Michigan.

Annual Report for 1903. Plate II.

Wooded Areas of the Ann Arbor Quadrangle (in green).

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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.

The accompanying map (Plate III) shows all of Roscommon county and the southern half of Crawford county. Careful study was made of

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.

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.

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.

[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.

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%.

The nature of the soil particles themselves often plays an important part in determining the water-retaining and water-lifting power.

[1] Warming, E., 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.

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.

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	33.00
	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....	6.31	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	0.06	0.01
	H_3PO_4.....	0.49	0.44	0.14	0.28	0.14	0.08
	Nitrogen...	0.22	0.12	0.07	0.11	0.04	....
	Organic matter....	7.48	2.97	2.20	4.73	1.22	2.16

[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 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	0.32
	Mg	0.12	0.17	0.15
	K	0.20	0.33	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	0.02	0.05	0.01
	Organic matter	1.61	2.50	2.25

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]

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

[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.

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 (70. + ?)

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.

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 (Gaylussacia 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 blueberries 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."

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

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

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.

II. THE DISTRIBUTION OF 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

[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.

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, H., Die Waldungen von Nordamerika. Munich. 1890.
[2] Warming, E., Bot. Tid. 21, 1897. For a résumé of this paper I am indebted to one of my students Mr. G. H. Jensen.
[3] Wollny, E., 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.

1. *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.

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.

[1] For early papers on this subject see:
Thurmann, J., Essai de phytostatique appliquee á la chaine du Jura. Berne. 1849.
Nägeli, C., Sitzungsber. Akad. Wiss. München. 1865.
Unger, Ueber den Einfluss des Bodens auf die Verteilung der Gewächse. 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, E., Action de l'eau du sol sur la végétation. Rev. Gen. Bot. 7: 16-26, 17-84, 123-137, 1895.

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 cul-

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

[2] See footnote, p. 6.

[3] Gain, E., 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.

ture experiments with plants the author is convinced that the vegetation of the worst soils here discussed does not suffer from want of salts.

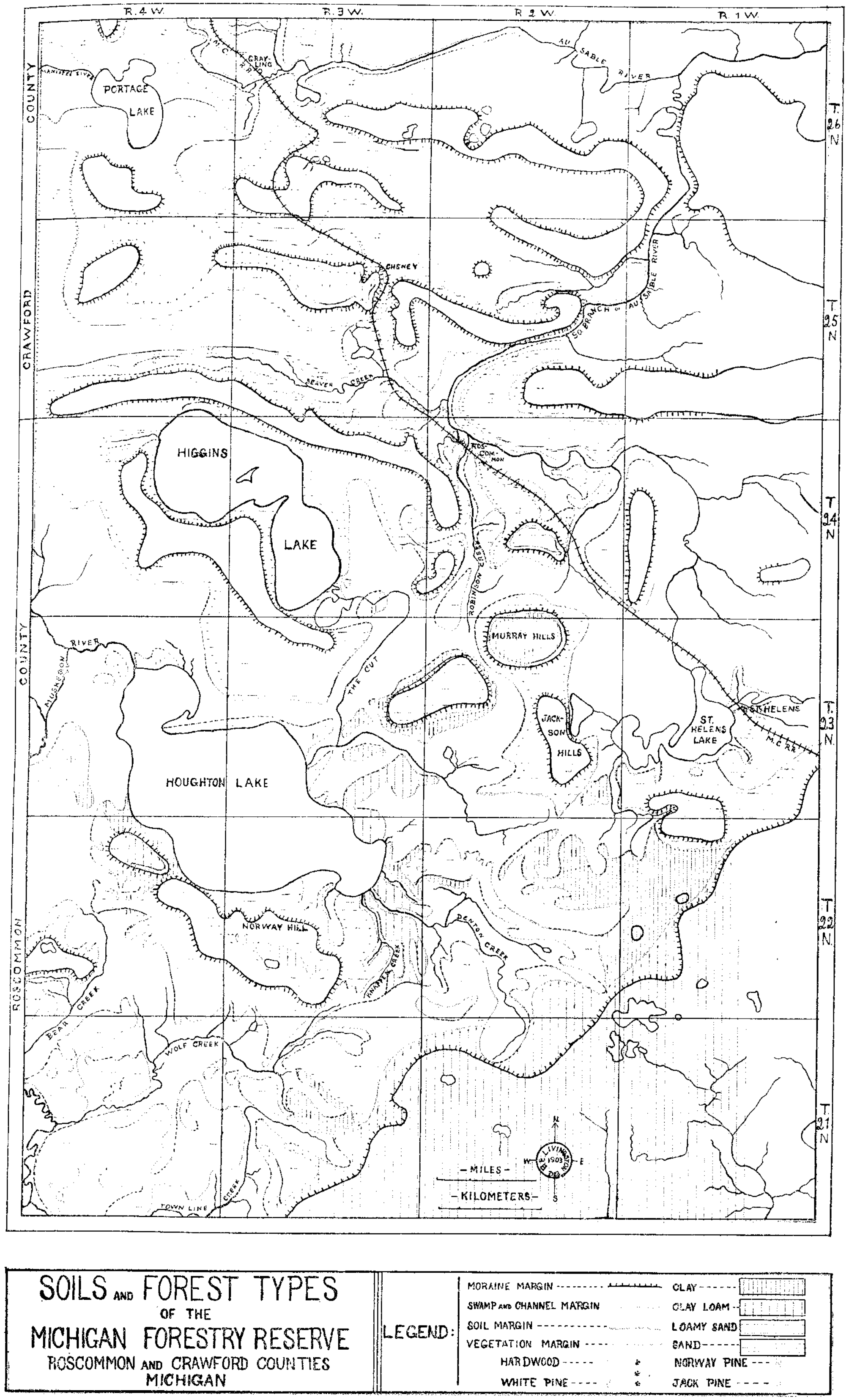
It appears here, as in Kent county, that the hypothesis of Cowles[1] that the nature of the vegetation depends upon the physiographic stage, will hold in a general way. The physiography of the Southern Peninsula of Michigan depends very largely upon glacial topography, however, so that if we wish to 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.

(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

[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.



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.

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.

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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.

RELATION OF THIS REGION TO KENT COUNTY.

The predominance of the pines in the region under 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

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

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.

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.

BY FRED EUGENE WRIGHT.

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

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

hills that many important points which are valuable in the structural investigation, can be deduced from a good topographic map alone.

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. G. 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 S. W. Cor. Sec. 36, 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. 42 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 off 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 Secs. 9, 16 and 15 and over ridge into 22 of T. 51 N., R. 43 W. The White Pine road along the E. range line 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 60 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. Górdon, 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 Secs. 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 in-

[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.

land is not over 10 feet above lake 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.

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

[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.

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.

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

[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.

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.[1] 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.[2]

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

[1] Especially noticeable on the escarpment S. W. of the Carp lake mine.
[2] Michigan Geological Survey, Volume VI, part 2, pp. 86-96.

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).

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.

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

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

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 molluscs 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 country 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

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

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 Lenawee 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 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 63½ 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 all 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