REPORT
OF THE
STATE BOARD OF GEOLOGICAL SURVEY
OF MICHIGAN
FOR THE YEAR 1901

BEING THE REPORT OF
ALFRED C. LANE
STATE GEOLOGIST.

BY AUTHORITY

1902.
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THIRD ANNUAL REPORT
OF THE
STATE GEOLOGIST
ALFRED C. LANE
TO THE
BOARD OF GEOLOGICAL SURVEY
FOR THE YEAR 1901.

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, DEC. 31, 1901.

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

HON. A. T. BLISS, *President*.
HON. P. H. KELLY.
HON. DELOS FALL, *Secretary*.

Gentlemen—You have deemed it wise for me to make my annual report more full than usual this year,* and include therein reports of progress that shall give the chief results of the work, in regard to a number of scientific and practical matters which cannot be published in more final form for some time. Inasmuch as this involved more work and a start upon the report before the end of the calendar year the details of business and finance are placed at the end, to which they could be added at the last.

The work may be conveniently treated as heretofore by areas and by subjects, the units of area being in general counties. The counties upon which we are at work will be taken up in the order in which they have been taken in hand, but when we expect in the near future to have the report ready, the account of the state of the work will not be so full.

*My two previous annual reports were short, and contained not much matter of scientific interest, so that I did not recommend them to be printed by the State. They will be found, however, practically complete, in the Michigan Miner for February, 1900, and January and February, 1901, the publisher, Mr. C. B. Schaefer, furnishing 500 reprints to the Board.

TUSCOLA COUNTY.

Prof. C. A. Davis, of Alma College, who has been preparing the report upon Tuscola county, has been transferred to the chair of forestry at the State University, a place for which his knowledge of geology and botany, on the relation of which to forestry I elsewhere touch, especially fits him.

The necessary duties involved, and some brief but very fruitful studies on the origin of our marl deposits from a botanist's standpoint, showing the important part which Chara has played therein, have delayed his report. In its surface conditions Tuscola county consists of strips running northeast and southwest. The northwest corner is a fertile and recently emerged lake bottom mainly of clay with superficial sand ridges. Then from the northeast corner between Gagetown and Cass City there is a tongue of rolling till. Then the valley of the Cass is very largely sand and boulders washed from the ice, or deposited by the great stream which once occupied the Cass valley.* Finally in the southeast corner we come upon some deeply cut rough till country once more.

Recent explorations about Vassar, while showing that coal is there, have not found it in quantities enough to warrant mining.

The beet sugar factory at Caro has found a large flow of water in the Napoleon sandstone, as I told the driller he might expect. This sandstone comes next underneath the drift in the southeast part of the county and dips gently to the west. It will generally furnish a good supply of water but poorer qualities of water that sometimes occur above it will have to be cased out.

*See Report on Huron and Sanilac counties, Vol. VII.

SAGINAW COUNTY.

The preparation of the repeat on this county has been in my hands personally. I will not plead pressure of other duties for delay in its appearance though I have not been idle, but the reason why I allowed other matters to interfere have been as follows:

There are no outcrops of bed rock in the county, and therefore the geologist is dependent almost entirely upon information furnished him by exploring companies. Certain of the companies have been very generous in furnishing material, and others have been equally generous in promising maternal, which, for one reason and another, it has not been convenient to give as yet, while in the meantime records have been steadily accumulating. One of the things I am most anxious to do in Saginaw county is to prepare a map of the bed rock surface. This is of importance for coal mining, as the danger of mining into old channels is not inconsiderable.

It seemed wise to wait therefore for this material, so as to make the report on the county fairly complete, rather than to issue one which would be out of date before it could be released from the hands of the printer. But in the meantime I have tried to give publicity to some of the more important economic results. Much of the material regarding the coal of the county will be found in my coal report.*

It will be noticed that I find seven coal seams, three of them at least important enough to work. The two upper or Verne seams are higher in sulphur and volatile matter. The lower or Saginaw is higher in moisture, but very low in ash and sulphur, and there are likely to be lower seams.

In another place in this report under the head of prospects for oil and gas, will be found an account of the upward flexure of the Napoleon sandstone near Saginaw which seems to exist. This sandstone seems to have little if any rise when followed from north-northeast to south-southwest, but probably falls quite rapidly to the west.

The soil of the county is prevailingly clay. In some places patches of clay till are left bare and there are also areas of river silt and of sand, but the latter is not usually very deep. The sand is generally more than eighteen feet above lake level, and a large part of the county is below this.

Another reason for not pushing the publication of the county report, is that I found it would be well to wait until the contours of Bay county were adjusted before preparing the contour map. I have, however, studied carefully the altitude of the East Saginaw datum, and found it to be 582.3 A. T. (supposing that the United State Lake Survey Plane of reference at Milwaukee, known as Highwater of 1838, is 584.38 A. T.), with a probable error of only two or three hundredths of a foot, and no perceptible change in altitude (of two-tenths of a foot, say) in the past forty years. With the help of Mr. Charles Holmes, I have been able to refer all the levels about Saginaw, and the profiles of all railroads mining into it to this datum. This matter is treated of later under elevations.

*Part II of Vol. VIII.

BAY COUNTY.

The field work of Bay county, which, has been mainly in the hands of Mr. W. F. Cooper, is practically complete. In this county, which is also flat, over $10,000 worth of drain levels are said to have been run. Owing to political vicissitudes much of the work is said to have been repeated twice. To get the full benefit of the many miles of accurate levelling it was, however, necessary to run

some thirty-five miles of levels to tie the various system levels. For this we employed Mr. J. H. Blomshield, former city engineer, and the Mr. Cooper has been employed much of the time in adjusting these levels.

The soil map of the county is now complete. Mr. F. D. Owens, of the M. A. C., has made some special studies of the waters, and we have also assisted another Agricultural College student, Mr. G. M. Bradford, who is studying botany.

PRELIMINARY REPORT ON ARENAC COUNTY AND PARTS OF OGEMAW, IOSCO, AND ALCONA COUNTIES BY W. M. GREGORY.

Prof. W. M. Gregory has been at work on Arenac county, and has been assisted by F. D. Stone, C. H. Smith and W. F. Cooper. His work has been interrupted by an attack of varioloid. The following is his preliminary report of progress for the region:

CONTENTS.

§1. Introduction

These abbreviated notes on the formation and resources of the counties at the head of Saginaw bay are given as an aid to those seeking information to guide careful investigation that may lead to subsequent development. So many urgent inquiries have been received regarding resources of these counties that this advance summary of the facts regarding the location, importance and value of raw material suitable for working is prepared. Much matter of interest to the professional geologist has been entirely omitted and the matter presented in a manner to be of the most value to the prospector and business man.

This region while not a new country is still in various parts unsettled. The lands which supplied such abundant forests of pine and hardwood are now nearly bare and the country has been thought to offer no inducements to encourage settlers. To the average mind this region is supposed to be the worst part of Michigan's sand and swamp, but such is far from the actual fact. It is true that many have tried farming and failed, the failure being due to poor management. No better land exists in Michigan for general agricultural purposes than that found around Standish, West Branch, Harrisville, Au Gres, Whittemore, Prescott and Sterling. Small fruits, cereals, hay, potatoes, sugar beets and chickory yield abundant crops. Sugar beets average by test as high a percentage as those in Bay county. Each year brings an increase in beet acreage. For herding and grazing excellent opportunities are combined in cheap land, plenty of water and pasture. Several ranches of some extent have been established and their owners are realizing handsome returns.

Regarding the mineral wealth of the counties much can be stated in a few words. Continual rumors of copper and lead reach the newspapers when no foundations for such reports are at hand. The lead in Alcona county and on the Au Sable river is purely a myth as far as actual specimens produced, and copper in Arenac county is drift material of no significance. The rumors regarding coal are of such a character as deserve careful discussion and will follow in this paper. The true mineral wealth lies in extensive deposits of limestone, gypsum, building-stone, brine bearing rocks, marl and clay.

§2. *Limestone.*

The limestones of this region are of special interest to those desiring stone for burning, hydraulic cement, road ballast and beet sugar manufacture. The formations outcropping are the Upper Grand Rapids or Maxville limestone, and the Lower Grand Rapids of the Michigan series.

In Arenac county the point of contact of the Maxville limestone and the Lower Grand Rapids group is on the shore of Lake Huron, five hundred feet north of the northeast corner of Sec. 24, T. 20 N., R. 7 E., north of Harmon City. At this point the banks are fifteen to twenty feet high. The entire ledge shows the effect of lake action and the following section is well exposed:

4	feet clay or till.
3	feet red clay, with particles of lime.
1½	feet white clay.
3	inches cherty limestone.
5	inches cherty limestone and sandstone closely interstratified.
1	inch shale and brownish limestone.
8	inches limestone.
6	inches brown sandstone.
4½	feet bluish gray sandstone.
10	inches arenaceous limestone.
5	feet bluish sand, becoming hard in lower layers.

The strata are quite irregular as the thickness of the limestone varies and, as Winchell has noted, the dip from this point seems to be north and south.

Going north one-eighth of a mile on the lake shore from the above outcrop to the old Whittemore test shaft, we find the limestones are blended into brownish sandstones and the layer of bluish gray arenaceous sandstone increases in thickness. At the test shaft we find the first evidence of gypsum, which is directly underneath the lower layer of bluish arenaceous

sandstone in a stratum of 1½ feet thickness, which is crumpled and folded with thin seams of argillaceous limestones. From this point north on the shore to Alabaster the lake sand covers all evidences of outcrops. At the above shaft, a 10-foot bed of gypsum was found, but the project was given up, because the inflowing water was troublesome. On the lake shore near the county line of Arenac and Iosco are found numerous sink holes which are very indicative of a good gypsum bed beneath. Off shore from this point in fifteen feet of water are seen white beds of gypsum, being part of the lower bed worked at Alabaster and the one penetrated by wells at Au Gres and Turner.

Returning to Arenac county and following north line of Sec. 24, T. 20 N., R. 7 E., from lake shore one and a quarter mile west to the old quarry of Harmon and Crowell, this exposure is found:

6 to 12 inches of boulder clay.
6 inches arenaceous limestone.
9 feet bright grayish limestone, top of which is filled with flint nodules from 3 to 5 inches in diameter.

It is said that the number of nodules hindered the working of this stone. In 1888, Pollock opened a quarry 160 rods south and west of the first one and the following section is claimed to have been passed:

1 foot clay.
5 feet limestone, suitable for burning.
1 foot sandstone.
6 feet limestone, brittle and used for building purposes.

The hard flint nodules were absent from this quarry and some very fair building stone has been secured here.

Harmon and Crowell also opened a quarry in the southeast corner of Sec. 24, on the lake shore, here one and one-half feet of good limestone was secured, covered with greenish black shale. This is the White Stone Point limestone, covered with the shale which outcrops at Harmon City.

The limestone ridges in which the above quarries were opened, commence near the northeast corner of Sec. 13, T. 20 N., R. 7 E., and extend southwest into southeast corner of Sec. 14, and then southerly to the center of Sec. 23. Here the ridges are broken, for they do not appear again until we reach the north line of Sec. 26, where a few acres are exposed, and in Sec. 27 the same is again exposed in the southwest part of Sec. 27 at the house of W. M. Davis.

At White Stone Point an exposure of brittle grayish limestone occurs, which is in 6 inches of water and extends out into the lake for over 200 feet at a depth of not over four feet. A careful examination of this region, especially southwest of Harmon City, might reveal a ledge of fair thickness and quality suitable for hydraulic cement, building purposes or lime burning.

At Point Au Gres low calcareous ledges of an arenaceous limestone occur nearly half a mile in width along the water's edge. Nowhere is the outcrop over 8 feet above the lake. Here are exposed 5½ feet of arenaceous limestone with streaks of brownish sandstone. Calcareous concretions are found which closely resemble those found in the Griffin quarry at Omer. The lower bed is a brittle light gray limestone, containing some few flint nodules and mussel-like shells. Much stone has been removed from this place for building purposes, but none used for burning lime, as it is considered too sandy.

The above outcrop apparently goes to the northwest, for indications of its presence are found near the center of Sec. 36, and also on the west line of the same section. In the northeast corner of Sec. 27 a well-defined exposure occurs west of the schoolhouse. The beds are flat, only the top layers being exposed. The course is to the northwest from this place. The top bed is five inches of grayish brittle limestone, then a brownish sandstone, of three to four feet thickness, then seven feet of a dark grayish limestone. These sections are made from a well which passes into the rock at William Mackin's house west of the school.

Following to the northwest we find a large outcrop of eighty acres extent east of the center of Sec. 17, T. 19 N., R. 6 E. Mr. Omsted of Au Gres opened a small quarry in southwest corner of this section a number of years ago, and used the stone for the foundation of Mr. Grimore's house at Au Gres. It is believed that this stone is too arenaceous for burning. Mr. Omsted tried burning, but found that the lime was not suitable for use.

If the outcrop is traced still farther to the northwest, in Sec. 1, T. 19 N., R. 5 E., an excellent exposure exists. Starting east of the center of this section and running to the northwest corner, the limestone forms a distinct ridge of 25 feet height and one-eighth of a mile in width. At the east end of the ridge, Mr. Thomas Burt has had a small quarry opened for several years, and is burning a very satisfactory lime for general purposes. On the top of a six-inch layer of argillaceous sandstone are large angular blocks of limestone which are used for burning, and underneath the sandstone is a good limestone, which has been but little used. Near the west end of this ridge is Griffin's quarry, where material has been taken out for road ballast. The following section will represent the average formation of this quarry:

½ foot clay.
4 feet limestone of varying quality.
Many nodules, containing calcite.
Irregular pipe-shaped lime segregations.
2 feet argillaceous sandstone with many ripple marks.
1 foot brownish sandstone.
2 feet calcareous sandstone.

The lower beds are limestone, as has been shown by core drilling.

The following analyses of the Omer limestone have been made by Dow Chemical Company:

	Sample 1.	Sample 2.	Sample 3.
SiO_2	8.86	0.92	24.67
$(FeAl)_2O_3$	.94	0.43	.80
$CaCO_3$		96.74	
$MgCO_3$		1.05	

This ridge of limestone ends in Sec. 11, east of the Detroit & Mackinac railroad, on Mr. Parker's farm. Lime has been burned here for several years, and it is of an excellent quality. The limestone used seems to be from the lower beds of the Griffin quarry, which is east one-eighth mile and is 15 feet higher.

Continuing in a northwest direction to the center of Sec. 35, T. 20 N., R. 5 E, here limestone occurs in a larger raised area of 150 acres extent, with but few feet stripping in places. Only the upper beds are exposed and in many places large angular blocks of limestone occur. The quality of this stone for burning will compare favorably with that found in Burt's quarry. On several of the older buildings at Omer this material was used and is still in good condition.

There are rumors of outcrops in the region of Sec. 30, T. 20 N., R. 5 E. This is not improbable for one-half mile west rock is within 15 feet of surface. East of Arenac postoffice a field shows indications of a small extent of limestone near the surface. Mr. Stewart has made several small test pits and found the stone, but the wells of the near vicinity fail to show the stone to be of any considerable extent. A typical specimen from Arenac was analyzed with the following results:

Ca CO_3	94.8
Magnesia	1.1
Iron and aluminum	.9
Insoluble	1.7
Organic Matter by difference	1.5
	100.00

In Iosco county in Sec. 30, Burleigh township, at the old Keystone dam is an extensive outcrop of Maxville limestone. The following strata are exposed:

2 feet gray, brittle, hydraulic limestone, bottom layer filled with flint concretions.
3 feet arenaceous limestone, with lime concretions of irregular shape.
1 foot brittle, whitish limestone, with brownish streaks.
4 feet grayish free stone.

The upper layer has been analyzed with the following results:

SiO_2	6.32
Fe_2O_3, Al_2O_3	3.19
Ca CO_3	89.10
MgO	.71
H_2SO_4	.00
Loss on ignition	36.06

This would be quite suitable for general lime burning. Its low per cent of iron and magnesia would make it suitable for hydraulic cement in connection with some suitable clay.

The contact of the Maxville limestone and the Lower Grand Rapids is clearly shown at the junction of the Cranner creek and Johnson creek in Sec. 30, of Burleigh township.

The limestone found at the old Keystone dam extends across Sec, 29 at some 15 to 20 feet underneath the drift. Rumors of exposure in Sec. 27 and Sec. 34 have not been verified, but do not seem improbable. In this township, in section one, one-quarter mile north of Detroit & Mackinac railroad bridge, across the Au Gres river on the west bank, is a small outcrop of the brittle light-colored limestone, of six inches thickness, and underneath is 10 feet of bluish and brownish clay shales.

§3. *Gypsum.*

The northern part of Arenac, the adjoining territory of Iosco and the southeast part of Ogemaw furnish some excellent outcrops of gypsum. This is because the drift is not thick over the underlying rocks and then this region is the natural outcrop of the Grand Rapids group.

The most extensive exposures of the Lower Grand Rapids beds are at Alabaster in Iosco county. The beds comprise an available working area of over 480 acres and have an average thickness of 23 feet. In reality, two beds are present, as where this was worked in earlier years a layer of hard fossiliferous limestone and a small stratum of shale were between the two beds, but on working into the deposit the shale and limestone have entirely disappeared. The stripping is stiff boulder clay of 10 to 12 feet in depth. The face of the exposure has been opened for more than a quarter of a mile in length. The beds dip slightly to the southwest and the surface shows the small ravines due to solvent action of water. At the Alabaster quarry a large force of men are employed in quarrying, grinding and calcining.

The impure gypsum, which, is mixed with clay and colored with iron, is sold for land plaster. The variety which is streaked like castile soap, with irregular seams of clay, is shipped to eastern markets, where it is made into Mexican onyx. The purest gypsum is ground, heated and converted into familiar plaster of paris. The larger part of the staff material used for the World's Fair building and at the Pan-American came from this quarry.

A 90-foot shaft was sunk several years ago by the Alabaster Company to determine the condition of the lower bed's of their deposit. The underlying rock of the quarry is a bluish gray sandstone alternating with hard cherty limestone seams. At different depths several small beds of gypsum occur, the largest one nearly five feet thick, and at 85 feet depth.

At 90 feet a strong flow of water occurred, which stopped further work, and it is quite probable that this represents the bottom of the Grand Rapids group.

In Sec. 28, T. 22 N., R. 6 E., one-eighth of a mile north of the old Glendon dam on the east bank of the Au Gres river is a cut which exposes the following section:

One foot clay; four and a half feet gypsum, top layers very pink; three inches roughly foliated limestone and sandy limestone interstratified; two feet yellow shale; three feet bluish grayish arenaceous shale.

From the sink holes in the vicinity, and the fact that gypsum occurs on ridges, a careful test of this place with a drill might reveal a greater thickness than is shown in the cut.

On the Au Gres river, in Sec. 27, T. 22 N., R. 5 E., the river bottom in the southeast corner of the section is covered with a bluish gray arenaceous shale, which is so closely associated with the gypsum deposits of this region. Northwest, a quarter of a mile from the southeast corner of this section, a three-foot bed of gypsum occurs in bank of the Au Gres river. This is covered by two feet of sandy limestone and underlain by the blackish shales.

Following the Au Gres river through the sections of the southeastern part of the above township many small beds of arenaceous shales are found. A number of sink holes in section 36, outcrops in sections 24 and 12, are reported but have not been found.

At Whittemore, in Sec. 10 of 21 N., R. 5 E., is a well which penetrated several beds of gypsum at 50 feet and 170 feet. North of Whittemore, at Mr. Armstrong's house, beds of gypsum of five and seven feet thickness were passed at 90 feet and 130 feet in drilling for a flowing well.

In this same township, in section 20, southwest of Whittemore, on Cranner's creek west of its junction with Johnson creek, is a deposit of light rose-colored gypsum in the bottom of the creek. The masses are here exposed for 200 feet along the creek bottom and are covered by a bluish grayish shale with streaks of arenaceous limestone. Careful exploration of the high clay bluffs of this region might reveal a bed of sufficient quality and quantity for working.

Where the Detroit and Mackinac railroad crosses the east side of section 36 of this township, a large floater of gypsum occurs on the west side of the track. This did at one time show in the railroad cut, three feet from the surface. Some prospecting to the northeast might reveal the ledge from which this rock was brought by glacial action. A large sink hole occurs at this point and a small creek empties into the cavity. A drill test in this place might prove that the gypsum was from the underlying rock.

At Turner, in Arenac county, in digging surface wells large boulders of gypsum are found. In digging shallow wells of 25 feet depth it is not uncommon to take out of the solid clay nearly one-half of a ton of gypsum boulders. The water of a flowing well at the schoolhouse in Sec. 8. T. 20 N., R. 6 E., which is east of Turner, gives a strong test for gypsum. Near the corner of section nine, of the same town, Mr. Clukey drilled a 235-foot well and passed eight feet of gypsum at 95 feet. In Turner, near the Detroit and Mackinac depot, is a well of 300 feet depth and a very strong flow. The record of the well shows gypsum of five feet thickness at 64 feet. Mr. M. H. Eymer of this place has a well of 105 feet depth, and at 50 feet passed a 12-foot vein of gypsum.

Several years ago, Albert Hann opened a 36-foot pit east of Turner in southeast corner of section eight. The following section was passed:

25	feet clay.
3	feet bluish grayish arenaceous shale.
1½	feet gypsum.
5	feet hard, flinty limestone, with small seam of gypsum.

Mr. Hann did not continue the work because at this depth a large flow of water occurred and hindered further work.

At Twining, in drilling the flowing well of William Lilleberger, a vein of gypsum was found at 25 feet, but its thickness has not been carefully observed. In Mr. Barr's well, on section 25, which is south one and one-half miles, a 10-foot vein of this same rock was encountered at 20 feet, and the water of several wells in the near vicinity is very bitter, giving with Ba Cl_2 solution a strong precipitate of Ba SO_4, which is a proof of the presence of gypsum in the water. Mr. Barr states that the mineral comes to the surface 40 rods west of his house, but this outcrop has not been found. There is no question but what a bed of gypsum of fair thickness underlies the region of Twining, Turner and Turtle. Its value for mining can be determined by careful work with a drill.

In Au Gres, Mr. Bradley has a well through 10 feet of gypsum at 50 feet depth. On Mr. Grimore's farm, one and one-half miles north of Au Gres, the rock is found at 40 feet.

The outcrops of this formation have a limited area in this region and no evidence of gypsum of the Grand Rapids group outcropping have been found north of a line connecting Tawas City and West Branch and south of a line between West Branch and Au Gres. Gypsum is found in the deep wells of the Saginaw valley, but the above statement refers to a region in which a search might reveal the rock in suitable condition for practical working.

Judge Sharpe of West Branch is the authority for the statement that three and one-half miles east of West Branch on the Rifle river is an outcrop of gypsum, which several years ago caused much excitement from its size and purity. No careful exploration of this bed has been made and at present it is undeveloped.

§4. *Coal.*

Rumors of coal are very frequent from Arenac and occasionally from Ogemaw and Iosco. At present it is not doubted that these counties lie on the border of the Michigan Coal Measures and the Michigan Series. The location of the bottom of the coal measures is a matter of

commercial importance to these counties. The field has been carefully examined and these conclusions will aid those who desire to save expensive experiments in testing for coal. From Dr. Lane's examination of the coal in the Bay City and Saginaw region he has found that the coal lies in a large basin, in which the lower veins are less extensive than the upper seams nearer the surface. At the edge of the basin we would not find the deeper beds at all, for they extend only a short distance out from the basin's center. It is obvious that deep drilling at the rim would fail to reveal the lower beds of coal and would penetrate the Michigan series and Marshall sandstone.

The first reports of coal in this State came from the southern rim of the basin at Jackson and the northern edge at the Rifle river. Mr. Bennett, a Pennsylvania coal miner, was first to explore along the river. Bennett and Kinney prospected in 1875 and sold their claims to a Bay City company. This company sunk a test shaft, known as Bennett's shaft, in T. 19, R. 4 E., Sec. 3, N. W. ¼ of N. E. ¼ on the south side of the Rifle river.

In this shaft, according to reports, black shale and coal occurred at 18 feet. This is apt to be correct as far as the shales are concerned, for the shaft was located on a clay terrace 15 feet above river bed, which contains an outcrop of bituminous shale. The entire depth of this shaft was 27 to 29 feet. The upper 14 feet was a loose drift, then three feet of hard calcareous rock, then three feet of hard black slate, and lower seven feet all "cannel coal," which of course is incorrect, as shown by the way the coal burns. At 28 feet this shaft was drifted north 20 rods under the river and a large quantity of the hard black shale removed.

Many attempts were made to ship this coal, several car lots were drawn to Sterling and given a trial on the Michigan Central. It was found to have too much ash and smoke. A large raft was loaded with intention of shipping to Omer, but the project was hindered by the rapids in the river.

The coal taken from this shaft seemed to be of two kinds, one quite bituminous and breaking into blocks, the other a shaly coal of lighter color and more ash. After experimenting some time the company allowed work on the shaft to cease until McLean, of Bay City, in 1879 pumped out the standing water and after a careful examination sunk a shaft 60 rods to the southwest of Bennett's shaft on a high terrace south of river. After passing through 60 feet of sand the venture was given up and no coal was found. No work was done on the shafts until Mr. Sovereign, of Bay City, pumped the water from Bennett's shaft in the fall of 1899 and made a drilling in the bottom. Borings have been made on the north side of the river opposite Bennett's shaft and gave 25 feet of drift and 20 feet of sandstone, with no signs of coal. Mr. Ortman, of East Saginaw, made a boring on the north side in this same location and found 21 feet of drift, then sand rocks, blue shale and black shale to 190 feet, but no signs of coal.* In the southwest corner of Sec. 2, T. 19 N., R. 4 E., which is three-fourths mile southeast of Bennett's shaft, a test was made, rocks, sand and shales were found under 60 feet of drift material at 100 feet, and no positive signs of coal. Mr. James Ramsdell, of Bay City, tested in Sec. 10, T. 19 N., R. 4 E., and found:

75	feet sand.
10	feet clay.
7	sand rock.

And from this point to 200 feet—,shales, fire clay, and at last the underlying limestone. It may be that the shales found will prove small beds of coal, but no extensive beds are shown by the actual tests.

Mr. Stevens, of Omer, dug in river bottom, 14 feet through shales and slate to fire clay, and made a small shaft into the river bank some 25 feet in length. From these indications he sunk a test shaft on the south bank of the Rifle river in Sec. 8, T. 19 N., R. 5 E. This shaft shows the following strata:

12	feet clay.
12	feet shale.
6	feet fire clay.
5	feet shale, very hard.
1	foot coal (Cannel).
1	foot fire clay.
10	feet soft shale.
1	foot coal.
48	

The lower coal is block coal and is an excellent quality of steam coal.† Coal of the upper seam contains much sulphur and other mineral constituents and could not correctly be called cannel coal, as only very small seams of the highly bituminous coal occurs in the foot vein. The upper seam dips to lower seam, which is apparently horizontal; if the two meet a fair amount of coal would result. Mr. Sovereign pumped water from this shaft in spring of 1900, and an expert miner of Bay City made an examination. The coal of upper shaft was pronounced good; it was not possible to examine the lower vein. Mr. Stevens drilled in bottom of shaft 122 feet and passed the slate and stopped in hard shales, which is no doubt the limestone of the lower formations. A test drill hole was made 25 rods south of this shaft and no coal reported. Mr. Stevens' shaft is located south of Rifle river in N. W. ¼ of N. W. ¼ of Sec. 8, T. 18 N., R. 5 E., and the coal found here is evidently a pockety formation.

*Michigan Geological Survey, Vol. III, page 142.

†See Analyses in Vol. VIII, Part II.

At Deep River in 1875 Mr. Stevens, of Bay City, made a 120-foot test hole, and found such fair indications that he sank a 106-foot shaft, which gave:

20	feet drift.
10	feet clay.
53	feet sandstone.
20	feet shale.
1	foot coal.
2	feet shale.
106	

The abundance of water which flowed into the shaft from the top of the sandstone is said to have made the project a failure. The wells one mile east of Deep River station reach the sandstone at 10 feet to 20 feet, and the bed of Deep river two miles east is a white friable sandstone, full of small pieces of coal, and in places showing thin seams of black shale. To the northwest of Deep River station in Sec. 29 rock is reached at 75 feet, and in a test hole near the center of this section a small vein of black shale was reached. At Sterling it is 85 feet on the average to rock through the clay. At Culver, on the Michigan Central, Mr. John Dunn tried to secure a good supply of water for a mill and stock by deep drilling, but was unsuccessful. It was 300 feet to dark bluish shale, and going 200 feet into the shale gave no water. In Ogemaw county, T. 12 N., R. 1 E., three tests have been made, and in each case sections show plainly that the regions is well out of the coal basin. To try costly exploration for coal north of range 21 north would be a needless expenditure of time and waste of money. Dr. Lane suggests as the place for commencing preliminary explorations for coal 10 to 15 miles from the limits of the basin. This would make the region of Standish and Saganing quite likely to yield results.

At Omer a rich black bituminous shale is found in many of the drift wells. Mr. Sanderson's well west of the village is a fair example of this class of wells; shale was found in small seams on top of white sandstone. In excavating for the abutments of the Detroit & Mackinac railroad one-eighth of a mile below Omer some two feet of rich bituminous shale was found directly above the sandstone which covers the river bottom for some distance below Omer. No practical use can be made of shale without a roof. Mr. Gore drilled on the east bank of the Rifle river below the bridge at Omer and passed sandrock, shale and limestone. The flowing well near the postoffice in this town passes some 40 feet of shale down 50 feet. Mr. Menzer, in the southern part of town, reached a twenty foot vein of shale at 60 feet. None of the deep wells north of Omer reveal any positive sign of coal, although in some of the deeper wells at Tawas, Whittemore and Hale a shale is passed which belongs to the Michigan series, and has no relation to coal measures, and has led many to a strong belief in a rich deposit of coal. The strong ridge of limestone from Point Au Gres to the northwest (as described on pages 13 to 15) marks the northern rim of the coal fields.

§5. *Water Supply.*

At the present time one of the problems which confronts the manufacturers of this region is fuel for steam production. This was a question of no consideration in the days of abundant pine refuse from the mills, but today a supply of fuel will give a new lease of life to many of the small towns which were established during the period of a large lumbering business.

The development of coal mines has given encouragement to the manufacturing interests of Saginaw and Bay City. The regions north of the coal fields will eventually have to utilize the abundance of water power to be derived from the many creeks, lakes and streams of this region. At the present time long distance transmission of power has been so perfected that it is not impossible to utilize the power of all the rivers of a county.

The Rifle river is especially suited for furnishing abundant water power. For miles this river flows between high clay bluffs, which would render damming easy, and only a small area of land would be lost by flooding. In Ogemaw county, T. 21 N., R. 3 E., Sec. 9, the Rifle river flows over sandstone ledges for more than a mile. The remains of an old lumber dam exist one-eighth of a mile north of the iron bridge which is near the southeast corner of the above section. A head of 10 feet could easily be secured here, and with careful construction, for the river bed is sandstone and the banks solid clay, it would be possible to increase the head to at least 15 feet with an abundant supply of water.

Going down the river from this point to Isle Rapids, one-quarter of a mile west of the southeast corner of Sec. 28 of the above town, the fall is (771-720)* about 50 feet. In Sec. 28 occurs rapids three-quarters of a mile in length over beds of arenaceous limestone. The place would afford a head of at least 10 feet.

Where the abandoned line of the Detroit & Mackinac railroad crosses the Rifle river in Sec. 12, T. 20 N., R. 3 E., the elevation is 693* feet, making a fall of 27 feet from Isle Rapids. Wells creek flowing into the Rifle river in section 19 of the above township, brings in a constant volume of water. The river below the creek's mouth is 100 feet wide, averages three feet deep, and has a current of four miles per hour. Clay banks 40 feet high would afford solid anchor for dam. From the old railroad crossing down river to the mouth of this creek there is a fall of eight feet (693-685).

In T. 19 N., R. 4 E., east part of section three, a dam was built by a lumber company for flooding river. This is 250 feet long, solid clay banks with bed rock forming the foundations. A fall of 15 feet occurs and is the average for the year. Much trouble has resulted from spring freshets. The top of the dam has an elevation of 681 feet A. T., bottom 666 A. T. and a fall of 22 feet from the mouth of Wells creek. Rapids occur in river bed in many places below the dam. In the northeast corner of section one, near the town line, is a favorable site which would

furnish abundant power for a small flour mill which could draw on the region around Melita for flour, feed and custom work.

*Above tide line (A. T.); Lake Huron is 580 feet above it.

At Omer a saw and flour mill are operated by water power. A strong steady head of 13 feet is maintained for the year. The elevation of top of dam is 608 and the bottom is 595. The bottom of river is soft sandstone and shale. The old Rifle river canal in the west half of Secs. 36 and 25 of T. 19 N., R. 5 E., which extends from the river to Wigwam bay has a fall of 15 feet in one and a half miles. Mr. Chesbrough, a prominent lumberman of early days, cut the canal for log driving, and it was unsuccessful on account of the large amount of sand encountered.

Some of the larger creeks flowing into the Rifle river could be utilized for small power. Wells creek at Alger would afford sufficient supply for an overshot wheel for a small mill. Silver creek and Manfield's creek would yield power on small scale.

The west branch of the Rifle river could be relied upon for at least two dams of ten foot head and 75 to 100 feet in width. The east branch of the Rifle river near the north line of T. 22 N., R. 3 E., would provide power for several small mills.

Lake Ogemaw, a glacial lake which is two and a half miles northwest of West Branch and is 175 feet above the town, might at some future time furnish the place with a source of pure water supply and some power. In the basin of the Rifle river a large number of these glacial lakes are found with great variation in elevation. Power could be obtained in many cases by cutting canals.

The Au Sable river, in Crawford, Oscoda, Alcona and Iosco counties, from a short preliminary examination reveals an abundance of power. In the rapids in T. 24 N., R. 7 E., a fall of over 50 feet occurs in four miles. Several very advantageous sites for dams occur in the above township, and it is believed that places would yield 2000 horse power. The extent of the drainage basin, the number of tributaries, the constant volume and the average velocity with the high terraced clay bluff form a stream which will repay careful investigation by those interested in cheap power.

The Pine river, in Arenac county, while a small stream, of which not over 10 miles could be used for power purposes, has a fall of 44 feet between Standish and Saginaw bay. A point near the southeast corner of Sec. 5, T. 18 N., R. 5 E., where the Pine river receives its south branch, would supply power for a small industry, as a creamery. The water supply might fail during a part of the summer. At Deep River, on the Michigan Central, the north branch of the Pine river runs in a narrow valley, which affords an excellent location for a small dam with a head of at least eight feet. On the Pine river at Standish, Mr. Norn has a dam used for a log boom, and this has a head of eight feet, which could be increased enough to supply power for a small mill.

The Saganing creek, in the southern part of Arenac county, is rather deficient in volume to expect much power, although a dam northeast of Worth where the stream begins to pass out of the old lake shore would furnish several farmers with power for a small feed mill.

Tawas river, in Iosco county, with its source in a small group of glacial lakes near the southwest corner of Sec. 31, T. 23 N., R. 7 E., passes eastward through the township between high clay banks capped with sand at the southeast corner of Sec. 24. At this point it has an elevation of 666 feet A. T., or about 84 feet fall to Lake Huron level. Mr. Rodman has a water power saw mill in section 24 with a head of 15 feet and has an abundance of water the entire year. At Tawas City the river has a fall of three and a half feet in three-fourths of a mile, and a breast wheel at a narrow point would furnish power sufficient for small machinery.

In the northwestern part of T. 23, R. 5 E., lies a small group of glacial lakes very irregular in outline and each having a different elevation. The largest member of this group is Big Long lake, nearly two miles long and a quarter of a mile in width on the average. It is over 35 feet higher than Little Loon lake which is south a quarter of a mile. A connected channel would furnish power for a small feed and flour mill which the country needs.

The Au Gres river, of Arenac, Iosco and partly in Ogemaw, is fed by a large number of small tributaries and a few glacial lakes. The river rises in Styles lake; three-fourths of a mile southeast a dam on the outlet has a head of eight feet, and could be easily increased. At the junction of Hope creek and Au Gres river in Sec. 28, T. 22 N., R. 5 E., an average depth of one and a half feet of water and 20 feet width occurs. The banks are high and of solid clay. Much land would be flooded by a dam which would have a head of 10 feet. The river has an elevation of 655 feet at the Detroit & Mackinac railroad bridge, two miles east of Whittemore. In Sec. 18, T. 21 N., R. 5 E., a lumber dam was constructed and the location is an excellent one for a small mill requiring a 10-foot head. The river between the crossing of the railroad above and the main line north of Turner has a fall of nearly 30 feet (655-620). It would not be possible to utilize the lower course of the Au Gres river for power to any extent, for the low banks would allow too large a tract of land to become waste and swamp. At the junction of Whitney creek and Johnson creek, in Sec. 20, T. 21 N., R. 5 E., a head of 15 feet and a width of 100 feet could be obtained, but summer would lessen if not destroy the power for two months.

Near the center of Sec. 28, T. 22 N., R. 6 E., on the east branch of the Au Gres, the high banks and bed rock of the stream furnished a good lumber dam for flooding the river. The average width is 30 feet and depth one and a half feet, which could be made to give a head of 15 feet. Between this point and the crossing of Detroit & Mackinac railroad at East Branch station there is a fall of

31 feet (671-640); this would supply power part of the year at East Branch. Below this point the river banks are too low to ever allow much use of power.

The value of the water supply of this region lies not only in the abundance of power but also in the large number of flowing wells which may be obtained in many places by careful drilling. An abundant supply of pure water is essential for domestic purposes and is valuable in dairying, cooking and drinking.

The underlying rock formations in this district dip to the south and southwest. Some of the rock strata are more porous than others, which fact enables them to become the source of underground water. The impervious beds above and below a porous stratum hold the water to the level of the lowest outlet and when the beds are penetrated in drilling, if the head is higher than the well a flow results. Then again flows are formed by drilling through sand, gravel and clay on the slope of a moraine; the sand and gravel acting as the reservoir for the water. Wells of the last mode of formation are quite common near Tawas City and West Branch. Flows from the bed rock occur at Au Gres, Omer and Standish.

At Au Gres, Mr. Badour has a well which gives a strong flow; with traces of sodium chloride, calcium sulphate and some H_2S. The depth of the well is unknown, but it is probably nearly 200 feet, and is near the bottom of the Michigan series. At one time a large bath house and hotel was supplied with the water. At present it is flowing freely and ought to be checked, because water having a strong flow will in time destroy or lessen its head. Flowing wells are easily obtained in the Au Gres country, and some of the enterprising farmers are taking advantage of the quality and quantity of water for dairy and stock purposes. The water is well suited for cooking and cooling purposes, having on an average a temperature of 50 degrees. Small flows are obtained at 150 and 175 feet. These yield a higher percentage of salts and the quantity of water is much less.

At Omer a well of 315 feet depth serves the purpose of the town pump. It gives an abundant supply of water and did supply two small hotels. This well is into rock, and it is quite probable that it reaches the Marshall. The shallow wells of 35 to 50 feet are in the white sandstones and black shales which furnish poor water in small quantity. Mr. Squires had a well near his store which contained so much H_2S and sulphates that it was abandoned.

At Standish the public schools and court house are supplied with wells which vary in depth from 50 to 230 feet. At present time only one well at the primary school building is flowing, although when these wells were seen all were flowing with a strong head. The deeper wells having no flow now had the stronger in 1899. The Wooden Ware Company has a 75 foot well which flows and gives water of the following composition:

$CaCO_3$=2.52 grains per U. S. gallon,	0.043 parts per thousand.
$MgCO_3$=1.74	0.030
$CaSO_4$=2.52	0.043
Na_2CO_3=3.04	0.052

Mr. Norn, of Standish, owns a 1900-foot well drilled by Mr. Coryell, of Bay City. The flow at present is very strong from a depth of 400 feet. Abundant brine was found at 1000 feet to 1300* feet but was easily exhausted. This well seems to have passed into the Coldwater shales, as at 1900 feet the bluish shales were found, but this is only driller's record. Dr. Grigg, of Standish, believes this to be a good mineral water and has a number of cases on record which compare favorably with effects of some of the standard mineral waters.

At Turner and Twining flows are obtained at 90 to 105 feet. At the latter place Mr. Lilleberg has a flow at 90 feet which is medium soft water having a trace of sulphates and carbonates. South of Twining many of the farmers cannot obtain good water for domestic purposes; it is bitter and has an abundance of calcium sulphate which renders it unfit for cooking purposes. Mr. Eymer, of Turner, has a flow at 105 feet which is very hard water, coming from a sandstone layer in the lower Grand Rapids group.

*Salt Inspector S. S. Garrigues reports in 1880, that a 98 per cent brine was met at 1700 feet.

The large flowing well near the station in Turner serves the town for fire protection and is the strongest flow yet described. This well has a total depth of 250 to 280 feet. The water contains more sodium chloride than the shallow well and is similar in density and composition to deep Well water of Omer and Au Gres. The well if not allowed to waste itself will furnish abundant water for years. At the schoolhouse in this town a flow is found at 130 feet, and is stronger in calcium sulphate and has a greater density than the deeper well.

At Tawas City at least twenty flowing wells occur from 60 to 125 feet for the shallow flows and two deep wells at 700 feet and 800 feet. The shallow wells are on the "lake side of a water laid moraine" and do not reach rock. A gravel bed is the source of supply and the wells vary greatly in the quality of water, those at 90 feet being very soft, those at 50 to 75 feet showing much calcium sulphate and calcium carbonate. The rock is reached at 95 feet, and wells into the rock give hard water. The wells at the public school and the German school are very strong flows. The latter is the deeper and softer, the former is hard. At ten places within this village are strong flowing wells, and the majority of the flows are allowed to run with no check. Such a valuable water supply ought to be carefully protected from exhaustion and not allowed to run when unused. A more careful report of this region is to follow. This area of flowing wells extends south and north of Tawas City, and only a small distance east and west. At East Tawas the wells are very difficult to obtain and only a very few weak flows have been found by drilling shallow wells. The deeper wells of Tawas City were originally bored for salt, and at the present time these have strong flows on the sites of former extensive saw mills and salt blocks. Where the Gaus hoop mill stood south of Tawas City the well is very strong in chlorides, sulphides and hydrogen

sulphide. A similar well occurs a short distance west of Mr. Peter Evertz's store. The percentage of hydrogen sulphide is so high in this well that the characteristic odor is clearly recognized by those in the near vicinity. A combination of waters taken from different depths in this region might make a mineral water of commercial value and lead to the establishment of a sanitarium.

At West Branch a large number of flows exist at 60 to 80 feet for shallow flows and 200 to 240 feet for stronger flows. The deeper are in the bed rock and are very constant in volume, while those of the lesser depths are in gravel beds and quite irregular in quantity.

The value of this cheap method of water supply will undoubtedly lead many people to try for flows. Some regions are suggested in a brief way which might be made to yield a flow. In the vicinity of Glennie, Curtis and West Greenbush, of Alcona county; east of Prescott and south of Sage Lake, in Ogemaw county; in Arenac county west of Standish some four miles, and a four mile strip of country along Saginaw bay from Alabaster to Pinconning is more than likely to yield good flow.

§6. *Clay and Shales.*

The rapid increase of the hydraulic cement industry due to the abundance of marl, limestone and coal is creating a demand for clays, low in lime, magnesia and iron, and high in silicates. The surface clays of this region are directly or indirectly derived from glacial action which accounts for their great variation in composition and thus become a source of annoyance to large cement companies, for haying once located a clay bed the quantity may be unlimited but the quality is frequently unreliable.

The region under discussion has poorly drained areas which could be greatly improved by artificial means. A few large, well located drains are doing excellent service but the large part of the underdrained land remains to be improved by tiling. As the country is becoming more closely settled these conditions are slowly creating a market for homemade tile, which could be manufactured from some of the abundant clay deposits. Several good brick yards are in operation but the demand for bricks is not strong.

The clay from the Standish brick yard is taken from a four foot bed of slightly pebbly glacial clay which shows by analysis a small percentage of lime but still has many small limestone pebbles which prove deleterious to three per cent of the bricks made. In some of the finished product the lime on exposure to air and moisture slacks, in this manner softening and disintegrating the brick. Blowholes caused by escaping gases are also present. If the clay was carefully crushed and perhaps screened or washed as at Sebewaing to free it from all pebbles a much better product would be secured. More experience and a better demand for the brick will no doubt remedy all of the difficulties. The following illustrates the composition of clay from this brickyard which is north of Standish on the Pine river:

SiO_2	37.36	39.10
CO_2	17.16	16.38
Fe_2O_3	3.36	5.60
Al_2O_3	20.02	9.39
CaO	17.79	16.42
MgO	3.28	4.06
Organic Matter	1.03	9.14

At Alger, on the Michigan Central, a light sand exists on a heavy clay which is seen east of the station one mile, on the eastern part of Sec. 10, T. 20 N. and 3 E. This clay is high in Mg and very gritty. It is too calcareous for cement purposes. It might make a fair tile or brick material as the following analysis shows:

SiO_2	39.00
CO_2	19.82
Fe_2O_3	3.12
Al_2O_3	13.16
CaO	15.37
MgO	2.01
Organic	8.52

A clay deposit occurs one and one-half miles west of Sterling, which is in Arenac county on the Michigan Central. This is free of pebbles and has a high percentage of magnesia and silicon oxide. At Summit, which is northwest three miles on the railroad from Sterling, clay has been formed into a moraine and is very high in MgO.

An extensive bed of brownish colored clay constitutes the bed and parts of the banks of Manfield's creek at Shearer, which is on the abandoned line of the Detroit and Mackinac railroad. Several years ago an attempt was made to produce a suitable brick and from an examination of a large number which were burned from this clay it shows that a good brick was produced, but the lack of demand prevented further work. The clay is very high in aluminum and the first of this element produced in Michigan was manufactured from clay taken from this deposit.

A small brick and tile yard was started at Omer in Arenac county .and after a few trials has been inactive. The clay used was taken from near the Rifle river and east of the railroad bridge. This clay is of a fine quality for the above purposes and such an industry on a small scale might find a market for its output in Au Gres, Turner and Twining.

South of Tawas City in Iosco county, in Sec. 2, T. 21 N., R. 7 E., is a 40-foot clay terrace which is covered with sand. In some of the deep ravines of transversing creeks a solid bed of pebbly clay is exposed. The clay is slightly calcareous and contains a small percentage of sand. Over twenty years ago bricks were made here from clay taken from the side of the terrace and several house chimneys were built from these bricks and they have proved to be of excellent quality. Some trouble was experienced with lime. This might be a favorable place for investment of a small capital, for at present bricks would find a market.

North of Tawas City in Sec. 22, T. 22 N., R. 7 E., an attempt was made to build a schoolhouse from bricks made of clay obtained from northeast corner of this section. The clay is of medium quality but poor brick

have been produced by underburning and too much sand. At Harmon City in Sec. 24, T. 20 N. and 7 E., occurs a bed of very plastic clay which has been used by masons at Tawas City and Au Sable for lining the arches under boilers and serves the purpose of a medium fire clay. This deposit is low in lime and high in oxides of aluminum and silicon. This clay has the following analysis by F. S. Kedzie:

SiO_2	58.85
Al_2O_3	14.45
Fe_2O_3	7.60
$CaCO^3$	2.94
Mg O	.86
SO_3	1.73
K_2O	2.54
Water of combination	7.50
Organic matter	3.43

The following analysis of clay by H. & W. Heim, of Saginaw, represents a similar deposit:*

S_iO_2	54.5
Al_2O_3	24.85
Fe_2O_3	7.2
CaO	2.95
Mg_3O	1.75
SO_3	1.33
Loss on Ignition	6.5

*This clay occurs in connection with gypsum in the Lower Grand Rapids series and has a high shrinkage and would for brick take quite a little sand, but makes an excellent red brick, suitable for face and perhaps paving brick.

Experiments were tried with the clay for brick manufacture at West Greenbush in Alcona county. At the old pit the clay which was used is surface material of a brownish gray color, containing few pebbles of limestone and a large number of pure lime segregations. The bricks which were made contain too much lime and are easily weathered.

Several other regions might be mentioned which would serve as sources of supply for suitably manufacturing clays and road material. At many points on the Rifle river are 15-foot banks of solid smooth plastic clay, which is calcareous and in many places entirely free of pebbles. The only practical use made of these deposits as yet is for road material.

Many extensive clay deposits exist about Prescott, Lupton, Rose City, Styles lake and Edwards lake of Ogemaw county: Near Loon lake, Taft, Emery Junction, Vine and Tawas City are formations which would repay careful investigation.

§7. *Agricultural Resources.*

The real wealth of this region lies in the abundant fertility of the gently rolling country and the level plains of the old lake bottoms. The settlement of many districts has been delayed by the general belief that the land was worthless after the pine was removed. It might be safely asserted that land which has produced white pine or hardwood will meet the needs of agriculturists. Of course there are large tracts of sand barrens which have produced only the familiar jack pines, huckleberry bushes and sweet ferns. These jack pine plains are often so picturesque, entirely free of stone and stump, and so finely located on the banks of streams, that one is charmed. Perhaps in this way many settlers first chose such poor locations. The evidences of attempts made at farming years ago are found in many parts of these plains.

The sand of the jack pine plains is light and easily worked into a shifting powder which renders travel very difficult. Heavy frosts occur in every month of the year and precipitation is insufficient in dry time to keep alive any vegetation but hardy bush plants. The country south of the Rifle river to a line connecting Omer and Sterling is of this description and furnishes a serious obstacle to travel between Standish and the Maple Ridge country. The lands south of Wells creek and east of the Michigan Central railroad in Arenac county are perfectly level and covered with jack pine, huckleberry bush and sweet fern to near Dunham. In many places on all of the jack pine plains are small swamps with big growths of cedar, sedges and marsh grass.

In addition to the jack pine plains there are regions from which pine has been taken, its fertility depending upon its location and method of handling. On many of the old lumbering tracts the stumps offer a serious obstacle to the man who begins farming in a small way and many acres of fertile lands are idle because of the existence of a large amount of unpaid taxes and the cost of removal of pine stumps.

Old burnings-are regions over which the fire has swept and left the soil without its natural vegetable mould. Sandy lands are often rendered useless in this manner, while clay soils are uninjured. We also find in this region large tracts of sandy swamps, black ash swales, and cedar thickets along the rivers' banks.

Arenac county is supplied with an abundance of good lands but the northwestern part of Clayton township, parts of upper Whitney, northwestern corner of Arenac, northern section of Deep River, and parts of both Adams and Moffatt will furnish poor farms.

In Iosco county the jack pine plains have the following general distribution in townships—nearly all of Oscoda, which is the northern tier of townships in the county, parts of Wilbur, Plainfield, and north edge of Tawas. The territory adjoining the Au Sable river through the county is practically useless for farming, except that the river's flood plain furnishes excellent soil.

The entire southeast corner of Oscoda county is poor land, and Alcona county contains only small areas of jack pine plains.

To carefully locate the excellent land under cultivation and give the characteristics of the soil would require more space than this brief report allows. A few notes will be given of those places which, if given care, would make excellent farms. The first place to devote attention is the region north of Duck lake in Au Gres township of Arenac county. The drainage is imperfect and renders useless over fifteen sections of land which would make excellent hay or truck farming soil, for the material is a rich loamy muck. Duck lake is very shallow and its outlet

must be deepened or a ditch cut to the Rifle river. Along the entire course of the main stream and east branch of the Au Gres river are many acres of clay lands which would require stumping and draining, but would furnish excellent lands. Especially fine locations of state lands can be found here and for reasonable terms good places can be secured near railroad crossings of the river. The lands are so cheap that a few thousand acres fenced in for cattle grazing ground would be .sure to return handsome profits.

A large area of clay loam land is six miles west of Standish and is settling rapidly. The large swamp which is one mile west of Moore's Junction furnishes vast quantities of hay and an extensive tract of this with some of the adjoining sand plains would serve the purpose of a cattle ranch. Northeast of Alger in Moffatt township, the characteristic morainal country is present. This is furnishing fine land to a few settlers and the region would accommodate many more.

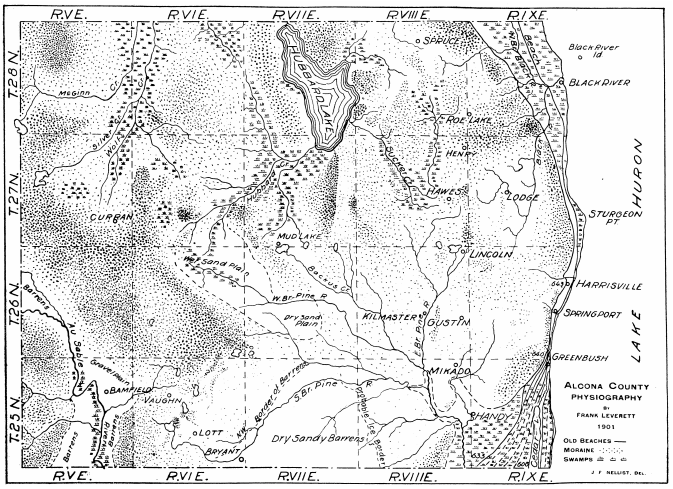

Plate I. Physiography of Alcona County, by F. Leverett.

Starting south of Melita is a broad strip of clay country, with morainal topography, which extends to Maple Ridge, where fine land has been well developed. This belt passes on north into Ogemaw county to Prescott, thence across the townships of Richland and Logan where the fertile belt turns into Iosco county, covering the southern half of Thompson township and the western half of Plainfield township. The belt appears on the north side of the Au Sable river in Alcona county at Vaughn. Here settlements are being rapidly made on the excellent clay loam soil. Alcona county is nearly three-fourths fair to good agricultural land.*

It is regretted that mention cannot be made of the sugar beet soil, the potato land, and various matters which would stimulate the settlement of lands which now lie idle. Only an attempt has been made to mention those lands suitable for farming, and waiting settlers, no reference has been made of the abundance of lands already under cultivation. It is hoped these brief notes will lead some to investigate and settle in a region whose fertility can no longer be questioned.

*About 300 square miles good farming land, 300 square miles good grazing land, 65 square miles jack pine land.

ALCONA COUNTY, MICHIGAN SURFACE GEOLOGY BY FRANK LEVERETT

SUBSURFACE GEOLOGY BY A. C. LANE.

Contents

ALCONA COUNTY.

During the year Mr. J. H. Killmaster of Alcona county wrote to the Survey, inquiring as to the possibility of a survey of that county. I pointed out to him that we were working that way, but that we had not money enough to take up that county, without dropping something of equal

importance. So he brought the matter before the Board of Supervisors with the result that they voted $200 to be expended under my supervision. This money was largely expended in employing Mr. Leverett, one of the most expert surface geologists in the United States, who was fortunately for us engaged on work for the United States Survey at West Branch and was courteously released for a time by them, so that no heavy bill for traveling expenses was incurred. Mr. Killmaster also, by giving the free use of his team of horses, saved the county many dollars. We also had made analyses of certain products. The report of the county was necessarily brief, and coming out of order in our studies, may need some revision when adjacent counties are complete. The report handed to the Board of Supervisors, which follows, is therefore necessarily incomplete.

REPORT ON THE SURFACE GEOLOGY OF ALCONA COUNTY, MICHIGAN. BY FRANK LEVERETT.

INTRODUCTION.

Situation and area. Alcona county is situated on the border of Lake Huron in the northeast part of the southern peninsula of Michigan. Its south border is near latitude 44° 30' and its north border about latitude 44° 50'. The border counties are as follows: Alpena on the north, Oscoda on the west and Iosco on the south. It embraces sixteen full and four fractional townships, the latter being along the shore of Lake Huron. Townships 25 to 28 N. and ranges 5 to 9 E., inclusive, fall within its limits. The area is about 690 square miles. The land surface is, however, somewhat less for there are several lakes in the county. The largest, Hubbard lake, has an estimated area of thirteen square miles, and the combined area of all the lakes probably reaches twenty-five square miles, thus leaving an area of about 665 square miles of land surface.

Alcona was organized into an independent county in 1869. It was attached to Cheboygan county from 1853 to 1857, to Alpena county in 1857 to 1858, to Iosco county in 1858 to 1859, and again to Alpena county from 1859 to 1869. From 1859 to 1866 it constituted but a single civil township of Alpena county, the township of Harrisville. Alcona township was cut off in 1866 and Greenbush in 1868. There were thus three civil townships at the organization of the county. At present there are eleven civil townships in the twenty land survey townships distributed as follows:

Curtis, in T. 25 N., Rs. 5 and 6 E.
Mikado, in T. 25 N., Rs. 7 and 8 E.
Greenbush, in T. 25 N., R. 9 E.
Millen, in T. 26 N., Rs. 6 and 7 E.
Gustin, in T. 26 N., R. 8 E.
Harrisville, in T. 26 N., R. 9 E.
Mitchell, in T. 26 N., R. 5 E., T. 27 N., Rs. 5 and 6 E., and T. 28 N., R. 5 E.
Hawes, in T. 27 N., Rs. 7 and 8 E.
Haynes, in T. 27 N.3 R. 9 E.
Caledonia, in T. 28 N., R. 6 E., and north half of T. 28, Rs. 7 and 8 E.
Alcona, in T. 28 N., R. 9 E., and south half of T. 28, Rs. 7 and 8 E.

Settlement and population. Situated as it is on the shore of Lake Huron, fishermen came to this county in advance of actual settlers. They wandered from place to place and built temporary dwellings or camped in the open air. The fishermen in some instances cultivated small garden patches, and one (S. M. Holden) started a cooperage business on the site of Springport, to supply barrels in which to ship the fish. There were fishing stations at the cove near Alcona postoffice, at the high banks where Springport now stands, and at Greenbush, which were thronged at an early date with fishermen. There seems to have been no other industry from the arrival of the first fisherman (thought to have been William Collins), about 1835, down to 1854, when the first sawmill was built. This mill was put up at Harrisville by two fishermen, Crosier Davison and S. M. Holden, but was soon sold to Benjamin Harris and sons, the persons after whom Harrisville was named. It utilized the power afforded by the small stream which enters Lake Huron at this village.

The first school was started in 1860, and was taught in the loft of the Harris store. The following year religious meetings were first conducted, the preacher being C. J. Merchant, a Methodist itinerary. The first physician was Dr. John Lyman, and the first lawyer, R. Z. Roberts. In 1866 the Harris firm, sold out its business to Weston, Colwell & Co., a firm with more capital, who gave the lumber business a fresh impetus and brought in a number of new families. The same year systematic efforts were made to induce settlers to clear up farms and develop the valuable agricultural resources. Roads were soon surveyed, stumps pulled and turnpikes constructed that aided materially in opening up the country to settlement.[1]

The lumbering industry was pushed so vigorously by several lumbering firms that the country was soon stripped of its rich growth of timber. The valuable agricultural lands were recognized as such by the woodsmen, many of whom have with profit abandoned lumbering and taken up farming. A population of less than 6,000 is now spread over a county whose soil will easily support two or three times that number.

The growth of population is shown in the following figures, taken from the United States Census reports: Population, 185 in 1860; 696 in 1870; 3,107 in 1880; 5,409 in 1890, and 5,691 in 1900. There are at present about eight persons to the square mile. Only four other counties in the southern peninsula have a thinner settlement and these are all far below Alcona in agricultural resources. The fact that the villages of Alcona county are very small should be considered in dealing with the subject of thinness of settlement.

Harrisville, the county seat and largest village, had in 1900 a population of but 403, and the combined population of the villages scarcely reaches 1,400, or about 25 per cent of the entire population. The decline of the lumber industry has affected the villages unfavorably, some of them having shown a marked decrease between 1890 and 1900. But the growth of farming has been such as to more than offset this decrease so that the population was slightly greater in 1900 than in 1890.

[1]For many of the facts concerning early settlement I am indebted to a pamphlet of 12 pages entitled "A brief history of the county of Alcona, Michigan" prepared by Charles P, Reynolds of Harrisville and published by the Harrisville Review Printing Office, in 1877. See also History of the Lake Huron Shore/II. R. Page & Co., Chicago, 1883.

Transportation facilities. The transportation facilities are excellent in the better settled eastern and southern parts of the county. There are docks and landings for steamers at convenient intervals on the shore of Lake Huron and a regular boat service in the summer months. The Au Sable & Northwestern railroad (narrow gauge) passes through the settlement in the southwest part of the county, and connects with the Detroit & Mackinac railroad at Au Sable. There is also an unobstructed river from where the Au Sable enters the county to its mouth at the village of Au Sable, which is extensively utilized for rafting timber. The Detroit & Mackinac Railroad Company has an old line passing from Black river southward to Au Sable through Lincoln and Mikado, and has constructed a new line along the shore the present year which gives Harrisville and Greenbush a much needed railway service.

During the lumbering period there were several lines running into the central and western parts of the county which were abandoned with the decline of the lumber industry. The graded beds are, however, easily changed into wagon roads by the removal of the ties, and in some cases they have been pressed into service without the labor of removing the ties. Such roads are, however, a torture to the traveler as the writer has had occasion to experience. In this connection it may be remarked that throughout much of the county improvement in wagon roads is needed.

Previous geological work. There being no outcrops of rock in Alcona county it has received but little attention from geologists. The county was explored to some extent by the first State geologist, Douglass Houghton, in 1838 or earlier, for he touches upon its salient topographic features in his second annual report, submitted in February, 1839. After discussing the general features of the region north of Saginaw Bay he remarks:

"An exception to the flatness of the country exists in an elevated district commencing in high hills a little south of Thunder Bay river and stretching in a southwesterly direction toward the head of Lake Michigan. This range at its commencement is usually known as the highlands of the Au Sable."

Attention is called by Houghton to ledges of limestone near the mouth of Thunder Bay river, which would be a barrier to the navigation of that stream, but he found nothing of the sort on the lower course of the Au Sable, and suggested the feasibility of navigating the stream unless it should prove to have too much shifting sand. The reconnaissance made by Houghton seems to have given him a false impression of the agricultural conditions of this region for he remarks that it is "ill adapted to the purpose of agriculture, being composed chiefly of sandy ridges with intervening swales, and rising so gradually toward the central part of the State as to leave the country extremely flat." This remark would apply only to a small part of the surface, but as that part is situated along the streams and the lake shore, that is, in places most accessible to the early explorer, it would naturally stamp the whole region unfavorably. In this connection it may be remarked that the prevalence of pine forests has tended to perpetuate the unfavorable name which this region so early received for it has been generally supposed that pine grows only on barrens. It remained for the settlers to demonstrate by abundant crops and the general evidences of thrift that this and other regions with pine timber really have a large amount of productive land.

[1]Senate Documents Michigan 1839, p. 267; also House Documents Michigan 1839, p. 383.

So far as known to the writer no geological work of note was done in this region from the time of Houghton's reconnaissance down to 1895, when F. B. Taylor made a trip along the shore of Lake Huron from Mackinaw to Saginaw Bay to determine the number and altitude of the old shore lines. He found two well defined beaches above the present one in the district north of the Au Sable river.[1] Taylor also found that higher beaches which are present in the Saginaw basin are not present in Alcona county and the county to the north, because this northern region was still covered by the great ice sheet.

State Geologist A. C. Lane made a trip through the southwest part of Alcona county in 1897, notes upon which are presented in a bulletin on the water resources of Michigan published by the United States Geological Survey.[2] These notes refer to water power on the Au Sable river, which is said to be excellent but unused, to the general topographic features and to the favorable conditions for obtaining flowing wells on the southern slope of the elevated tracts which traverse the western part of the county and extend southwest across Ogemaw and Clare counties.

Scope of the present investigation. An allotment having been made by the board of county supervisors in October, 1901, for an examination into the resources of Alcona county under the direction of the State Geologist, the present writer was engaged to proceed at once to the field and collect the necessary data for a report upon the character of the soils, the occurrence of marl or clay, of notable value, the conditions and prospects for flowing wells, and the general distribution of underground water,

and to obtain such data as the region affords that will bear upon the underlying rock formations. The investigation is similar to that already made in central and southern Michigan under the United States Geological Survey, but the present report enters more into detail concerning the resources of the county than is practicable in the more general and comprehensive report in preparation for the United States survey. The field work was done in October and the early part of November, and for its rapid and easy prosecution the writer is indebted to the several members of the board of supervisors and to a number of other citizens, notably J. H. Killmaster, Edward Chapelle, Charles Conklin, George Rutson, L. A, Colwell, E. M. Larson, D. W. Brooks and C. W. Goodsell. Indebtedness is also acknowledged to the Detroit & Mackinac and the Au Sable & Northwestern railroads for transportation over their lines and for valuable data.

Owing to the undeveloped condition and lack of roads in the western half of the county the examination was necessarily less detailed than in the more highly improved eastern part, but this deficiency has been partially filled by information furnished by supervisors and other old residents.

[1]For discussion of these beaches see American Geologist Vol. 17, 1896, pp. 253-257. Also Dryer's Studies in Indiana Geography, Inland Pub. Co., Terre Haute, Indiana, 1897, pp. 90-110.

[2]Water Supply and Irrigation Papers of the U. S. Geological Survey No. 30, Washington, Government Printing Office, 1899. See especially pages 20, 73-75.

CLIMATE.

The effect of the great lakes in modifying the climate of the bordering districts is a subject which has been thoroughly considered and ably discussed by one of the early State geologists of Michigan, Alexander Winchell, first in his report of progress for 1870, and subsequently in Harper's Monthly and in Walling's Atlas of Michigan, and in a separate publication entitled "Michigan." The subject is so complicated that space will not permit full presentation, and we can do little more than outline a few of the conditions prevailing in the particular region under discussion.

It is found that in winter the isothermal lines or lines of equal temperature are much farther south in the interior of the southern peninsula than on the borders by Lake Huron and Lake Michigan. It is no colder at Harrisville on the shore of Lake Huron and at Traverse City on a bay of Lake Michigan, each about latitude 44° 40', than at Flint and Owosso in the south central part of the State near latitude 43°. But the winter mean temperature at Harrisville is nearly three degrees warmer than at Grayling, a town in the same latitude in the interior of the State, as shown in the table below. In cold waves the contrast is often much more striking than that of the mean temperature. Thus the coldest wave that has been experienced in Michigan in the past 12 years was that in February, 1899, when the thermometer at Harrisville dropped to 25° below zero; but this was 16° warmer than the record at Lake City and Grayling, and 18° warmer than at Mancelona as reported in the United States Weather Review for that month. In the 12-year period just referred to there have been but three months in which the temperature at Harrisville has fallen lower than 20° below zero, but the interior of the State has experienced such a temperature in two or more months in nearly every winter. The following table of temperatures at Harrisville and Grayling for the four winter months, December to March inclusive, in the past five years, will serve to show the contrast between the shore and the interior, as well as the variations at each place. Grayling is in the same latitude as Harrisville and 70 miles west.

TABLE OF AVERAGE WINTER TEMPERATURES.

(Compiled from U. S. Monthly Weather Review.)

Period.	Harrisville.	Grayling.
	Deg. Fahr.	Deg. Fahr.
Winter of 1896–7	24.4	21.4
Winter of 1897–8	25.1	22.8
Winter of 1898–9	19.0	15.6
Winter of 1899–1900	21.2	19.1
Winter of 1900–1	21.4	19.2
Five year average	22.2	19.6

In summer the temperature, as indicated in Winchell's isothermal map, is as high in the interior of Michigan in latitude 44° 40' (that is the latitude of Harrisville) as it is at the southern ends of Lakes Huron and Michigan and decidedly warmer than at Harrisville or Traverse City. The map shows the mean summer temperature at Harrisville to be about 63 degrees above zero, while at the headwaters of the Au Sable, near the same latitude, it is 66 degrees. An examination of the Weather Review records at Harrisville and Grayling for the past five years (1897-1901, inclusive) shows the temperature at Harrisville to average 65 degrees for the summer months, while that at Grayling averages 66.4 degrees. The difference, therefore, is slightly less than Winchell's map indicates and is not so striking as that of the winter temperatures given in the table above. In spring and fall the climate is more equable on the borders of the lakes than in the interior of the State. Killing frosts are infrequent after crops are started in the spring or before they ripen in the fall. In the State Geological reports for 1839 to 1841 Douglass Houghton and his assistants made references to the fact that the Indians had grown corn successfully on the borders of the Great Lakes in several of the northern counties of the southern peninsula. Fruit growers have also found that the lake borders are the most favorable parts of the State for orchards. The thrifty apple orchards of Alcona county bear strong testimony to the favorable climatic conditions.

The following records of temperature and precipitation taken from the United States Monthly Weather Review for 1900 serve to indicate the ordinary conditions at Harrisville, except that precipitation is remarkably low for the month of June. As no station for weather observations has been established in the back part of the county or for some distance farther inland, the

departure from conditions at Harrisville in that part of the county is not known.

TABLE OF TEMPERATURE AND PRECIPITATION AT HARRISVILLE, MICHIGAN, FOR THE YEAR 1900.

(Compiled from U. S. Monthly Weather Review.)

Month.	Maximum Temp.	Minimum Temp.	Mean Temp.	Precipitation.	(a) Snowfall.
	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Inches.	Inches.
January	48	—14	22.8	1.24	8.5
February	55	—17	15.8	4.19	23.2
March	47	—5	22.1	2.05	20.5
April	75	20	42.2	1.36	.....
May	90	34	52.0	2.64	.....
June	96	37	61.2	0.53	.....
July	97	45	66.6	4.34	.....
August	98	52	69.8	5.23	.....
September	93	38	63.4	2.25	.....
October	79	28	56.7	2.90	.....
November	62	10	35.8	3.01	3.7
December	47	—3	25.4	1.37	9.5
Yearly	.....	.....	44.3	31.11	65.4

(a) The snowfall is included in the column showing precipitation.

The rainfall of this county is not more likely than temperature to be ill adapted to the needs of crops. The yearly precipitation is usually between 30 and 40 inches, and of this a sufficiently large part falls in the growing season to keep the soil in good condition for crops.

PHYSIOGRAPHY.

Topography.—A glance at the map of the surface features of Alcona county (Plate I) will serve to show that the northern and western parts of the county are largely occupied by hills or belts of rolling land, while the southeastern portion, mainly in the Pine river drainage basin, is a comparatively level district. An examination of the list of altitudes given below will bring out the heights which are found in various parts of the county. The datum to which points in this region are commonly referred is the surface of Lake Huron, whose mean elevation is nearly 580 feet above sea level. Referring to the altitudes, it will be seen that the highest point crossed within the county is, by barometric measurement, 1,260 feet above the sea, or 680 feet above Lake Huron. Possibly other points in the western part of the county rise a few feet higher, but it is doubtful if any exceed 1,300 feet. There is within the county an area of perhaps 40 square miles that stands above 1,000 feet, mainly in the western part. A large area, comprising probably three-fourths of the county, stands between 700 and 900 feet above the sea. There is but little low land along the edge of Lake Huron, for along much of the shore a rise of 100 to 175 feet is made in passing back a mile or less. On the north border, however, the low land extends three miles and on the south border fully five miles back from the lake. In general the highest land or backbone of the county constitutes the divide between the north flowing and south flowing streams, if we disregard Black river, and trends in a southwest course from the south part of T. 28, R. 9 E., to Lincoln and thence westward to the county limits. The hills in the south part of T. 28, R. 9 E., and those along the border of T. 27, Rs. 8 and 9 E., reach an altitude 300 to 325 feet above Lake Huron. Points in the east part of T. 27, R. 7 E., reach an altitude 400 to 425 feet above the lake, but with this exception the altitude in Rs. 7, 8 and 9 E. is less than 400 feet above lake level. With the exception of valleys and narrow strips of low plain bordering them, the western part of the county for a distance of eight to twelve miles from the west border rises more than 400 feet above the lake. This elevated part is shaded heavily on the map (Plate I) and the strength of shading is graduated to the prominence of the hills. In the Pine river drainage basin there is a gradual rise from the lake shore to the headwaters of the various tributaries.

The relief of the ridges and hills above the valleys and basins which they border or inclose seldom exceeds 300 feet and is usually 100 feet or less. Hubbard lake, which stands about 680 feet, is bordered by hills whose altitude ranges from 750 feet or less up to about 950 feet above the sea. The majority of the lakes stand much higher than Hubbard lake. Several near Vaughn are about 950 feet, Mud lake and others near it 875 to 900 feet and those near Lincoln about 770 feet. The hills near Vaughn lake and its neighbors reach about 1,100 feet, those near Mud lake 950 feet, and those around Lincoln 875 feet above the sea. A group of hills in Sec. 28, T. 27, R. 6 E., rises 200 feet above border districts, and Comstock hill in Sec. 25 of the same township is nearly as prominent. There are also some hills about 200 feet high in the southwest corner of the county, and the massive morainic tract forming the division between the Au Sable and Thunder bay drainage in Tps. 25 and 26 N., Rs. 5 and 6 E., has many hills and ridges which rise abruptly 100 to 200 feet above the bordering basins and sags. A very prominent mass of hills in the northwest part of the northwest township rises fully 300 feet above the valleys on the east and south.

Some of the hills and ridges in the northern and western part of the county are too steep to be easily tilled; but on the whole the slopes are so gradual as to be no hindrance to the cultivation of the land. In nearly every township there are plane tracts of considerable extent, as indicated in Plate I, while several townships in the southeast part of the county are nearly plane.

Table of Altitudes.—The following table of altitudes includes not only the points along the railroad lines which are determined by spirit level; but also a considerable number of barometric determinations. The latter are liable in some cases to contain serious errors, for there were some taken in the western and northern parts of the county which were carried through an entire day's drive, with no opportunity to check results. It so happened, however, that the weather conditions were somewhat steady at that time, so that the errors may prove to be unimportant. The barometric determinations in the eastern part of the county are probably not far from correct.

ALTITUDES ALONG THE OLD LINE OF THE DETROIT AND MACKINAC RAILROAD.

	Feet (above tide level) A. T.
Black River Station	585
Summit 1900 feet northeast of Roe Lake Station	822
Roe Lake Station	810
Summit 1400 feet south of Roe Lake Station	818
Henry Station	795
Summit 2400 feet north of Hawes Station	807
Hawes Station	790
Summit 700 feet south of Hawes Station	797
Summit 1500 feet north of Lincoln Station	798
Lincoln Station	779
Summit 6800 feet south of Lincoln Station	790
Gustin Station	693
Mikado Station	654
Top of grade 4000 feet north of Handy Station	640
Handy Station	624
County line Alcona and Iosco counties	631
Harrisville Junction (in Iosco county)	615

NEW LINE OF DETROIT AND MACKINAC RAILROAD.

Harrisville Junction (in Iosco county)	615
Greenbush Station	640
Summit about 1.8 miles north of Greenbush	648
Harrisville at Main street	625
Harrisville Station	622
Sturgeon Point	614.5
Alcona	602.5
Stony ridge 1.5 miles north of Alcona	621
Black River Station	585

BAROMETRIC DETERMINATIONS.

Bamfield Station on Au Sable and Northwestern Railroad	870* or 850
Au Sable river at bridge, near Bamfield	815* or 810
Vaughn Station, Au Sable and Northwestern Railroad	1023* or 1005
Hill at cemetery north of Vaughn lake	1100
Lott Postoffice	900
Bryant Station, Au Sable and Northwestern Railroad	852* or 835
Knoll cut by old railroad grade in section 7, T. 25, R. 7 E.	880
Swamp south of knoll in section 7, T. 25, R. 7 E.	820
Sand and gravel plain in section 3, T. 25, R. 7 E.	830

*Averages of two or three barometric determinations by A. C. Lane.

	Feet A. T.
Cross roads in northwest corner of T. 25, R. 7 E., near Tubbs' lake	850
Pine river at forks west of Mikado (bluff 640 feet)	620
A. D. McDonald's residence section 9, T. 25, R. 9 E.	675
Summit on State road near corners of Tps. 26 and 27, Rs. 5 and 6 E.	1290
Road intersection in N. W. part of T. 26, R. 6 E.	1070
Plain in Secs. 1, 2 and 3, T. 26, R. 6 E.	900-925
Ridge one mile west of Mud lake near postoffice	940
Mud lake, water level	860
Sand plain near center of T. 26, R. 7 E.	800
West branch of Pine river, Sec. 25, T. 26, R. 7 E., below dam	675
Township line east of dam	720
Killmaster postoffice	695*
Stream at Killmaster below dam	680*
Killmaster boring No. 1	702*
Killmaster boring No. 2	710
Killmaster boring No. 3, near postoffice	692*
Cross roads one-half mile west of Gustin	660
Pine river on State road, west of Lincoln	725
Upland west of Pine river, middle of line of Secs. 4 and 33	825
Upland near corners of Secs. 4 and 5, T. 26, and Secs 32 and 33, T. 27, R. 8 E.	875
Valley at Robinson's farm on State road west of Lincoln	810
Upland in east part of Lincoln	810
Summit in road in Sec. 5, T. 26, R. 9, E.	840
County infirmary	705
Mrs. Chapel's residence, one mile south of infirmary	750
Napoleon Sherbeneau's residence, one mile north of infirmary	750
Knoll near center of Sec. 19, Harrisville Tp.	710
West line of Sec. 19, at road intersection	695
Middle of line of Secs. 19 and 20, Harrisville Tp.	680
Stream near center of Sec. 20, Harrisville Tp.	660
Plain at line of Secs. 20 and 21, Harrisville Tp.	675
Low knoll near center of Sec. 21, Harrisville Tp.	700
Plain at line of Secs. 21 and 22, near jog in road	680
Summit in Sec. 22, Harrisville Tp., on E-W. road	700
Northwest corner of Sec. 34, Harrisville Tp.	700
Ridge 2 to 3 miles north of Greenbush	730-755
A. Atherton's residence, Sec. 26, T. 27, R. 5 E.	1010
Corner of Secs. 13, 14, 23, and 24, T. 27, R. 5 E.	920
Wolf creek, near corner of Secs. 1, 2, 11 and 12, T. 27, R. 5 E.	815
Plain in Sec. 2, between Wolf and Silver creeks	840
Dorr's camp in Sec. 34, T. 28, R. 5 E.	900
McGinn creek, near corners of Secs. 21, 22, 27 and 28, T. 2 S., R. 5 E.	870
Sandy plain north of McGinn creek in Secs. 21 and 22, T. 28, R. 5 E.	920
Hill near line of Secs. 8 and 9, T. 28, R. 5 E.	1200
Hill in Sec. 28, T. 27, R. 6 E.	1165
Nearly plain tracts in Secs. 23, T. 27, R. 6 E.	950-965
Range of hills in Secs. 14, 23 and 26, T. 27, R. 7 E.	975-1000
Hill on Sec. 24, T. 27, R. 7 E.	1000
Lowland between hills in Secs. 23 and 24, T. 27, R. 7 E.	875
Sheep ranch in Secs. 30 and 31, T. 27, R. 8 E.	875-925
Hubbard lake	680
Upland southeast of Hubbard lake in Sec. 7, T. 27, R. 8 E.	850
Sucker creek at line of Secs. 5 and 8, T. 27, R. 8 E.	700
Upland on line of Secs. 4 and 9, T. 27, R. 8 E.	820
Sucker creek on line of Secs. 2 and 11, T. 27, R. 8 E.	740
Upland in road one-eighth mile west of Henry Station	840
Upland at township line east of Henry Station	840
Hill in Secs. 13 and 24, T. 27, R. 8 E.	890
Cross roads at middle of line of Hawes and Haynes townships	800
Hill one mile north-northeast of Lincoln	850
Points near line of Secs. 5 and 6, T. 27, R. 9 E.	915
Summit in road on line of Secs. 5 and 8, T. 27, R. 9 E.	900
C. W. Goodsell's residence, east side Sec. 8, T. 27, R. 9 E.	800
Black river, in Sec. 3, near Frank Elmer's residence	675
Frank Elmer's residence in Sec. 3, T. 27, R. 9 E.	752* or 735
Summit in road on line of Secs. 17 and 20, T. 28, R. 9 E.	800
High points near center of Sec. 17, T. 28, R. 9 E.	825
Stream near corners of Secs. 17, 18, 19 and 20, T. 28, R. 9 E.	735
Till plain in Secs. 18 and 19, where road leads south	760
Middle of range line between Rs. 8 and 9 E. T. 28 N.	775
Stream on range line one mile north of last named point	690
Summit on line of Secs. 1 and 12, T. 28 R. 8 E.	840
Alexander McDonald's residence in Sec. 2, T. 28, R. 8 E.	860
Summit near middle of line of Secs. 2 and 11, T. 28, R. 8 E.	880
Spruce postoffice, corner of Secs. 3, 4, 9 and 10, T. 28, R. 8 E.	750
Cross roads one mile south of Spruce	770

BAROMETER DETERMINATIONS BY A. C. LANE.

	Feet A. T.
Flat Rock Station	860*
Au Sable, near Flat Rock	830
Gravel table lands near Bamfield	970
River, near Bamfield	812*
Terrace, near Bamfield	840
Bamfield Station	870
Faint river terrace back of Bamfield Station	900
Bryant, sand plains around	852*
Batton, edge of clay	900
Vaughn	1023*
Chevriers	990*

Drainage.—The drainage of Alcona county is nearly equally divided between the Thunder Bay river and Au Sable river systems, the north half being drained northward to Thunder Bay river and the south half southward and eastward to the Au Sable river. There is a narrow strip on the border of Lake Huron drained by Black river and other small direct tributaries of the lake.

The Au Sable river crosses the southwest corner of the county, but receives no important tributaries in that part of its course. Pine river, with its numerous tributaries, drains about six townships in the southeastern part of Alcona county, and enters the Au Sable in Iosco county. Its main forks are known as South Branch, West Branch and East Branch. Other important tributaries are McGillis creek, Backus creek and Van Etten creek. The South Branch, West Branch and McGillis creek all find their sources in the high belt of hills in range 6 in the western part of the county, and have a general eastward course across a plain in range 7 to the middle of range 8. Here, after receiving Backus creek and East Branch, the course is southward into Iosco county. Backus creek heads in Mud lake near the center of the county and flows southeastward across a plain in T. 26, Rs. 7 and S E., to join the West Branch in Sec. 33 of the latter township. East Branch, with its several headwater tributaries, drains the south part of T. 27 and the east part of T. 26, R. 8 E., and unites with the West Branch in Sec. 3, T. 25, R. 8 E. Van Etten creek drains the southwest part of T. 26, R. 9 E. and the adjoining parts of T. 25, Rs. 8 and 9 E., and enters Pine river in T. 25, R. 8 E.[1]

The principal tributaries of Thunder Bay river in Alcona county are Hubbard lake with its main affluents, Sucker creek and Hubbard creek, which drain much of T. 27, Rs. 6, 7 and 8 E., and T. 28, Rs. 7 and 8 E., and Wolf creek and its tributaries, McGinn, Silver and Wild Cat creeks. Which drain much of T. 27, Rs. 5 and 6 E., and T. 28, Rs. 5 and 6 E.

Black river has two forks, known as the North and South branches. The South or main branch drains much of T. 27, R. 9 E., and adjoining parts of Tps. 26 and 28, R. 9 E. The North Branch drains the northeast part of the county in T. 28, Rs. 8 and 9 E., and a small adjoining district in Alpena county.

*Average of at least two, one or more corrected by comparison with self-recording aneroid at a fixed point.

[1]This tributary of Pine River has received the same name which is applied by the residents to the main stream after it enters Iosco county, there being in that county an expansion of Pine river called Van Etten lake, which has led to the extension of the name Van Etten to part of the stream below Van Etten lake. This seems an unnecessary element of confusion which might be easily remedied by ceasing to call the lower course of Pine river Van Etten creek.

There are a few small direct tributaries of Lake Huron south of the Black river drainage basin, the most important of which is Cedar lake outlet, which discharges at Greenbush, and a small stream that enters the lake through the village of Harrisville.

The streams are in places bordered extensively by swamps. This is conspicuously the case in those tributary to Hubbard lake, and is a common feature on several other streams. Extensive swamps also occur in

the northeast and southeast parts of the county in the low plain, which has been at some time beneath lake level.

A large part of the swamp land, when cleared of logs and brush and properly ditched, may be drained sufficiently to become good farming land. This has already been done in a part of the Pine river drainage basin.

Lakes.—The lakes of this county are inadequately represented on any maps which have yet been made, and a special survey is needed to determine their position and extent. The plats of the government land survey show only those which were crossed by section and quarter lines, and but a few of these were meandered and accurately platted. The lakes which do not appear on the government plats are necessarily small, for each must fall within the quarter-line limit, but they form an important factor in determining the value of the grazing lands which border them and are so numerous as to supply the needs of much of the grazing district in the western and northern parts of the county. They usually constitute the head of streams, but a few are expansions of streams and a few have no outlet.

For attractive scenery, Hubbard is scarcely surpassed by any of the large inland lakes of the State. The body of water, seven miles in length and nearly two miles in average width, is bordered on all sides by ranges of hills with diversified outline and altitude, which at present are the haunts of deer and other wild game, but which may become valuable grazing lands. The body of water itself and its gravelly beaches will no doubt in time become one of Michigan's popular summer resorts. Already the building of an electric road to it from Alpena is being agitated, and the Thunder bay lowland, which extends back nearly to this lake, affords an easy line of access for such a road. For the variety and quality of its fish the lake already has a high reputation.

Other attractive lakes are those around Lincoln and the chain near Vaughn (Glennie postoffice), all of which are bordered by undulating uplands and gravelly or sandy beaches. But nearly every lake possesses attractive features and contributes to the pleasure both of resident and traveler.

THE GLACIAL DEPOSITS.

General Statement.—It is a well established fact that a moving ice sheet, such as now covers Greenland and gravitates from the interior toward the border of that great island, has in a comparatively recent geologic period covered eastern Canada and pushed southward across Michigan and adjacent states to the vicinity of the Ohio river. In the basal portion of the ice sheet there was a large amount of earth and stones which it had gathered along its path. The ice appears to have become overburdened with this load and to have dropped much of it as it advanced, building up a bed beneath it known as the ground moraine. The remainder it carried to the end of its course, and there heaped it up as a terminal moraine, similar in many respects to the moraines now forming on the borders of the Greenland ice sheet, or the glaciers of Alaska, or of the Alps. When the ice melted off from the country there was not a continuous and steady shrinking of the ice field, but places where the margin remained nearly stationary for a period sufficiently long to enable the ice to bring large amounts of material and heap up other terminal moraines inside the limits of those already formed. In this way several moraines were formed before the ice had melted off from Michigan.

The glacial history is not so simple as to be comprehended in a single great invasion and disappearance of the ice sheet with the halts made in its waning stage. Studies in the interior of the Mississippi basin in Wisconsin, Iowa, Illinois and Indiana have brought to light several distinct sheets of drift, each marking a great ice invasion, which differ much more widely in age than the successive moraines just mentioned. These sheets are not exposed to view in Michigan because the latest ice invasion extended over the entire State and left so heavy a deposit of drift as to effectually conceal any earlier drift sheets which may be present. It is, therefore, only in deep excavations and perhaps in a few valleys that the earlier sheets would be reached. Yet commingled with the drift of the last invasion there are copper nuggets and possibly other materials from the northwest, which must have been brought here by an earlier and independent invasion. As yet no separation of drift sheets has been made within the limits of Alcona county, and the earlier glacial history receives, therefore, only this passing notice.

The sinuous or looped course of many of the moraines serves to show that the movement of the ice sheet was greatly influenced by inequalities in the surface of the country over which it passed, there being more free and rapid movement through low districts, such as the basins occupied by the Great Lakes, than over the bordering higher land. This resulted in the production of ice lobes that have received names from the basins in which they deployed, as Lake Michigan lobe, Saginaw bay lobe, Huron-Erie lobe, etc. Probably the lobes were coalesced to a great extent when the ice was at its maximum, but they became very prominent in the waning stage and were presumably so also in the advancing stage or earlier part of the life of the ice sheet. Because of this lobation the moraines which were produced in the waning stage are looped around the basins and form sharp re-entrants between them. At these re-entrants a morainic belt is often projected some distance back from the point of junction, forming an interlobate moraine. This feature is well illustrated in northern Alcona county, as indicated below.

Moraines and Ice Borders in Alcona County.—Alcona county stands on the north side of the Saginaw bay ice lobe, for that lobe not only filled Saginaw bay but extended over a wide area on the north, west and south. Several moraines which are distinct ridges at the southwest end of the lobe become merged on its

northwest side into a single great morainic system, which bears northeastward from Clare county across the southeast part of Roscommon, the central part of Ogemaw, and southeast part of Oscoda into Alcona county. The ice movement was probably about at right angles to the trend of this morainic system, or northwestward from the central line or axis of Saginaw bay.

Upon crossing the Au Sable river in southwestern Alcona county, this morainic system makes a sharp turn to the northwest and constitutes the divide between the Au Sable and Thunder Bay river drainage in Oscoda and Montmorency counties, thus passing beyond the limits of the Saginaw bay lobe. But from this sharp tarn an interlobate moraine, or perhaps it may more properly be termed a morainic spur, extends eastward across the north half of Alcona and the south edge of Alpena county almost to the shore of Lake Huron. The ice appears to have been present on both sides of this spur while it was forming. That on the south was the Saginaw bay lobe, while that on the north may for the present be termed the Thunder bay lobe. Probably this spur was extended eastward with the withdrawal of the ice from the great morainic system toward the Lake Huron basin, and the greater part of it may have been formed during this withdrawal.

Between this great morainic system and the shore of Lake Huron there is, aside from the complicated spur just mentioned, but one well-defined moraine in Alcona county. This has been called by F. B. Taylor the Alcona moraine.[1] In the northern part of the county it is wrapped around the end of the morainic spur, but upon crossing Black river near the line of Alcona and Haynes townships a short distance west of Alcona postoffice, it becomes a separate or distinct ridge and leads southward across Haynes and Harrisville townships, with its eastern or inner border less than a mile from the shore of Lake Huron. Upon entering Greenbush township (T. 25, R. 9 E.) it bears away from the lake shore across Secs. 3, 9 and 17. It is ill-defined from Sec. 17, R. 9, to Sec. 26, R. 8, a distance of 2.5 miles, but has considerable strength in Secs. 26 and 35, R. 8, and enters Iosco county from the latter section. The moraine ranges in width from one-fourth of a mile up to nearly two miles, and rises from 25 to fully 100 feet above border tracts.

There are features in southern Alcona county west of the Alcona moraine that suggest an earlier ice border. Near the western edge of T. 25, R. 8 W. a sand plain sets in which rises about 100 feet above the country east of it with a rather steep ascent. The lower country to the east presents the ordinary topography of a ground moraine, and has drift of variable constitution such as would be expected in deposits made under the ice. The high sand plain is similar to the outwash deposits made by streams issuing from the ice. The only feature needed to make it certain of being an ice border is a terminal moraine, but this feature is wanting or at least is very obscure. It is, however, not uncommon in Michigan to find places where the outwash deposits stand somewhat higher than the moraine and it often happens that in passing from them through the moraine to the inner border district a great descent is made. This is conspicuously the case with the strong morainic system above outlined through much of its course from Clare to Alcona county. It is also not rare to find the terminal moraine becoming very weak while the outwash deposits continue prominent. In view of these conditions it may not be remarkable to find places such as this in southern Alcona county where the ice failed to build up a deposit beneath its edge that would resemble a moraine or approach in bulk that made by the waters in the outer border district. This bluff-like border is more conspicuous near the county line than farther north and becomes a gradual and inconspicuous slope at the north border of the sand plain in Sec. 2, T. 25, R. 7 E. As yet nothing has been noted by which the ice border can be traced farther north. It seems probable, however, that the ice held this position at a time not long previous to that in which it was forming the Alcona moraine. The continuation of the ice border in that case is likely to have been northeastward across Gustin township (T. 26, R. 8 E.) toward the east end of the great interlobate morainic tract of the north half of the county.

[1]Moraines of Recession: Journal of Geology, Vol. V, 1897, pp. 421-465, especially p. 459. Great ice dams of Lakes Maumee, Whittlesey and Warren: American Geologist Vol. XXIV. 1899, pp. 6-38, especially p. 20.

The outer border drainage.—The streams which issued from the ice margin during the development of the great morainic system above mentioned, found at first a southwestward discharge to the Muskegon river through the sand plains and swamps of Oscoda, Crawford, Ogemaw and Roscommon counties. But when the ice had shrunk to the inner border of that morainic system lines of discharge were opened along or near that border and the waters reached a lake known as Lake Saginaw in the western end of the low country bordering Saginaw Bay, instead of discharging through the Muskegon to the Lake Michigan basin. This lake, however, had a westward discharge through the Grand river valley into the Lake Michigan basin and thence on past Chicago to the Illinois and Mississippi rivers. One of these lines of southwestward discharge had its head on the flat topped gravel tablelands near Bamfield and after following the Au Sable southward about to the line of Alcona and Iosco counties it took a southwestward course to Lupton in Ogemaw county through a sand plain and swamp now drained northeastward by the Little Au Sable. From Lupton it passed southward through a sand plain which borders Rifle river to southern Ogemaw county and there, near Greenwood Station, entered Lake Saginaw.

As the ice melted the lines of discharge were shifted to the east. Lake Saginaw (or perhaps its successor, Lake Warren, see discussion of Lake History below) also became expanded with the retreat of the ice and covered wide areas in Iosco and Arenac counties as well as counties farther south and west, its limits being marked by beaches that are as a rule well denned and easy to trace. The lake may have extended into Alcona county at the level of the sand plain in T. 25, Rs. 7 and 8 E but no shore lines were noted north' of there above the Algonquin beach. It therefore seems probable that the lake occupancy was Very brief if it extended to that region at all.

The great sand plain which, as above rioted, covers much of T. 25, R. 7 E. in Alcona county, also covers several townships in Iosco county. It spreads out like a great delta on each side of the Au Sable river from near the point where that stream enters Iosco county, and covers all of T. 24, Rs. 6 and 7 E. and part of R. 8 E. also much of T. 23, Rs. 6 and 7 E. and extends slightly into bordering townships on the south and east. At the east, as noted above, it terminates abruptly as if prevented by the ice sheet from spreading farther. That the western part was built up largely by a stream flowing down the Au Sable toward the

ice is indicated by the slope of its surface, the altitude being about 50 feet higher in the north part of T. 24 R. 5 E. than it is in the southeast part of T. 24, R. 6 E., a distance of eight or nine miles down the valley. But there is very little descent between the east side of T. 24, R. 6 E. and the abrupt border about nine miles farther east. The level eastern part by barometer on train from Oscoda is found to be 830 feet above the sea. As above suggested it seems not improbable that this level corresponds to the highest stage of Lake Saginaw (or of its successor, Lake Warren).

There is a terrace along this part of the Au Sable standing about 40 feet lower than the sand plain. It terminates at the east in the abrupt border above noted as if the stream was still prevented by the ice from carrying material farther. This abrupt border at the point where the Au Sable and Northwestern Railroad strikes it is known as Seven Mile Hill and at that point it is the terrace and not the sand plain which is entered, the border of the sand plain being entered by the railroad west of Bisonette. It is thought that this terrace may also stand at a level of Lake Saginaw (or Lake Warren) but one that is correspondingly lower than the one correlated with the sand plain. The full connections have not been worked out in either case.

The glacial drainage connected with the morainic spur that covers the north half of Alcona county is very obscure. The low plains and swamps which occur among the hills and ridges or border the streams have not sufficient altitude to have given to streams that may have occupied them a southward or southwestward discharge into Lake Saginaw, and it is extremely doubtful if many of them represent lines of glacial drainage. A swamp leading south from the head of Sucker creek through Secs. 21, 28 and 33 T. 27, R. 8 E. to the headwaters of one of the tributaries of Pine river has the appearance of being a line of glacial drainage, though a weak one, for the valley it occupies is in places only one-eighth mile in width. It is thought that the large amount of sand and gravel in the hills and ridges of this morainic tract is an indication that the waters had considerable movement within the ice sheet and may have found discharge to a great degree without reaching the ground moraine under the ice. This being the case the valleys and low areas in this morainic spur may only represent places where the drift was too scanty to build up the surface there to a higher level, and may not be due to erosion either by glacial or postglacial streams.

Thickness of the Drift.—That the glacial deposits of Alcona county are of great depth is inferred from the fact that no outcrops of rock are found within the county even in the deepest valleys, and from the fact that rock has been reached only by very deep borings.[1] The valley of the Au Sable river, though about 400 feet below neighboring hills, carries no rock exposures within the limits of this county. Borings at Killmaster reached a level 150 feet below the level of Lake Huron before entering rock. There are wells 80 to 100 feet or more scattered over the older-settled parts of the county, and these all terminate in the drift. However, it is scarcely to be expected that the rock surface is as low throughout the county as at Killmaster, for in neighboring counties both on the north and south it stands in places 50 to 100 feet or more higher than the surface of Lake Huron. It seems to be below lake level in much of the shale areas on the border of the lake, but it is usually above lake level in the sandstone and limestone areas. If, then, as seems probable, the Berea Grit or other hard rock underlies a part of Alcona county, it is to be expected that the rock surface there will rise toward lake level, but judging from the outcrops in the neighboring counties there is little likelihood that it will reach an altitude much greater than 700 feet above tide. This leaves room for nearly 600 feet of drift in the highest ridges of the western part of the county, and the depth there may be considerably greater. But little more can be said at present concerning the thickness of the drift, as the data are too meager either to indicate the range in depth or the average thickness.

[1]There is a bare possibility that rock was struck at 60 feet in Sec. 3, T. 27, R. 9 E., and at 36 feet at Black river, as indicated in the discussion of wells.

Structure of the Drift.—The structure of the glacial deposits as here discussed involves not only the kind of rock or constitution, but also the mode of arrangement of the materials. The kind of rocks present in the drift of a given locality is a rude index as to the path over which the ice sheet moved, for fragments of rock from nearly every rock formation passed over are to be found in the material thrown down where the ice melted. The mode of arrangement of the materials is an index of the conditions under which the deposition took place. In some cases the dirt and stones from the melting ice were deposited in a current of water that was issuing from the ice margin; in other cases they were dropped in pools of quiet water, while in still others they fell directly on the ground. There seems, also, to have been considerable water action within the ice, by which the materials which it contained were more or less assorted before they left the ice. The conditions in a given part of the ice margin are liable also to have changed from time to time and produced corresponding changes in the structure. Indeed, such changes seem to have been very general, for one seldom finds a uniform deposit from top to bottom of a drift bank of much height.

In the deposits of Alcona county it is found that the rocks of sufficient size to be easily examined are composed very largely of Canadian crystallines, such as granites, quartzites and greenstones, together with a few red jasper conglomerates and other rocks of limited outcrop in Canada, and an occasional piece of native copper. The surface bowlders, especially, are of Canadian rocks, but these rocks also abound at all depths in the drift. It was noted throughout the county that the proportion of Canadian rocks is much greater than in the drift of the central and southern parts of Michigan. With these Canadian rocks there is a liberal supply of Devonian limestones from the Hamilton formation that outcrops along the west shore of Lake Huron from Alpena northward, and that probably forms the bed of the lake for some distance southeast from Alpena. There are also numerous fragments of Devonian shale. Sandstones are rather rare, especially in the northern part of the county, as is to be expected from the very limited occurrence of sandstone ledges to the northeast of this county. There appear to be two or more sandstones represented, but to what horizon or horizons they belong is riot yet known. In the southwestern part

of the county a few blocks of the Eo-carboniferous gypsum rock were recognized by W. M. Gregory, who is familiar with the outcrops of this rock formation in Iosco and Arenac counties. On a hill north of Vaughn lake, Gregory has found specimens both of Devonian limestone and of Eo-carboniferous gypsum rock. The former, together with the Canadian rocks which also abound in the same hill, indicate a south westward movement of the ice, while the latter indicates a northwestward movement. The copper indicates a movement east of south. The northwestward movement is in harmony with the moraines, as above noted, and was evidently the latest one. The movement which transported material southwestward probably took place while the ice sheet was very thick, and its movement was not controlled by the lake basins to such a degree as in its waning stage. The southeastward movement which brought in the copper may have been a still earlier one, and may also have transported the fragments of red sandstone that are present in this county and appear to he from the Lake Superior Potsdam.

The deposits of Alcona county range from well assorted, definitely bedded sand and gravel, through partially assorted and imperfectly bedded or partially commingled drift to a completely commingled deposit of materials of all sixes without assortment or bedding. The elevated parts of the county are as a rule composed of loose-textured material, but this material presents various degrees of assortment and bedding. In the low tracts there is a large amount of close-textured clayey material, but there are also strips of well-assorted sand and gravel traversing the low tracts. Hand and gravel are also found at moderate depths under much of the clay in the southeastern part of the county. The cause for the wide prevalence of assorted material there is not understood, though it seems probable that it was either an outwash from the ice, which was overridden by a fresh ice advance or the bed of an interglacial lake.

As indicated above, the loose texture and partial stratification and assortment of the material in the morainic tracts are thought to be largely due to the action of water within the ice, for had it occurred outside the ice the material could hardly have had its present irregularities of surface. Instead of a moraine there should be a plain of gravel and sand such as that in T. 25, R. 7 E., if the water action had been outside the ice. There are a few small tracts within the elevated morainic area where but little water action seems to have taken place, and in these places there is a somewhat clayey drift. The most extensive one is west of Curran in the south half of T. 27, R. 5 E., but there is nearly as much clayey drift in the elevated northwest half of T. 25, R. 6 E. Among the smaller tracts is one of three or four square miles in the west edge of T. 25, R. 5 E.; another of about the same area in the southwest part of T. 28, R. 5 E., and a third in Secs. 3, 4, 9 and 10, T. 27, R. 6 E. There is also a large amount of close-textured drift in T. 28, R. 8 E., and the northwest part of T. 28, R. 9 E., on ground less elevated than that of the tracts just mentioned.

The details concerning the surface portion of the drift are given below in the discussion of the soils and the wells. Very little is known concerning the lower portion of the drift. In the borings at Killmaster, which are the only ones which are certain to have reached the bottom of the drift, no notes were kept concerning the character of the deposits overlying the rock.

THE LAKE HISTORY.[1]

Predecessors of Lake Algonquin.—As soon as the ice sheet in the Huron-Erie basin had melted back from the rim of higher land which constitutes the continental divide, the waters from the melting ice became ponded between the ice margin and that divide and found discharge across the lowest point on the divide. This point was at Fort Wayne, Indiana, and the line of discharge is known as the Fort Wayne outlet, while the lake, from its occupancy of the Maumee basin, is known as Lake Maumee. Similarly the melting back of the Saginaw ice lobe resulted in a lake in the plain west of Saginaw bay, which is known as Lake Saginaw. This discharged westward past Pewamo, Michigan, into Grand river, and this outlet is known as the Pewamo channel or Grand river outlet. Lake Saginaw, however, did not begin its history so early as Lake Maumee.

After a time sufficiently long for a well-defined beach to be formed on the shore of Lake Maumee, the ice in the Huron-Erie basin became melted back far enough for the waters of that lake to extend to Imlay, Michigan, where there is another place on the divide which was as low as the head of the Fort Wayne outlet. A double line of discharge then followed, and the level of Lake Maumee was lowered a few feet. It remained at the lower level long enough to form a second beach.

By a further recession of the ice, the waters of Lake Maumee reached the vicinity of Ubly, Michigan, and there found a lower line of westward discharge than the Fort Wayne and Imlay outlets. The lake level was lowered about 30 feet, and the other outlets were abandoned. Because of this change in outlet the lake has been given a different name from its predecessor and is called Lake Whittlesey, in honor of Charles Whittlesey, one of the earliest students of these old beaches. By the time Lake Whittlesey began its history, Lake Saginaw had come into existence, and Lake Whittlesey discharged into it. The Ubly outlet entered Lake Saginaw near Cass City, and from there westward into Saginaw county there was only a narrow strip of water along the south edge of the ice sheet, which then had its southern limits at a moraine that follows the north side of Cass river.

[1]The following references will enable the reader to consult the papers and reports which treat of the lake history here so briefly outlined. Papers which treat only of the beaches of the Superior, Michigan and Ontario basins are not here listed, because of the remoteness of application to this region.

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By a farther recession of the ice on the "Thumb" of Michigan, a wide opening was made from Lake Whittlesey to Lake Saginaw at a level as low as Lake Saginaw, and the two lakes became united. Because of this lowering of level and union of the two lakes a new name, Lake Warren, has been applied in honor of G. K. Warren, a pioneer student of lake beaches. Lake Warren discharged through the Grand river outlet down to a time when the ice at the eastern end of the great basin occupied by Lake Erie and Lake Ontario had melted back far enough to permit the discharge of its waters eastward to the Mohawk river. The lake then ceased to exist as a single large body, but was succeeded by three lakes: Lake Algonquin, which occupied much of the area of Lakes Superior, Michigan and Huron, and the low land on their borders; Lake Erie, in the Erie basin, and Lake Iroquois, in the Ontario basin. It is only with the first of these lakes that we are here concerned.

Lake Algonquin.—The name Lake Algonquin was applied by J. W. Spencer in 1888 to a body of water which occupied the basins of the upper Great Lakes and discharged through the Trent valley in Ontario into Lake Iroquois in the Ontario basin.[1]

The shore or bench of this lake was first discussed by Spencer in 1891, attention being called chiefly to the part of its shore southeast of Lake Huron and Georgian Bay.[2] The presence of the beach on the west shore of Lake Huron was inferred but not observed by him. The tracing of the part of this beach in Michigan has been done by F. B. Taylor, who in 1895 carried his studies from the Straits of Mackinac southward on the shore of Lake Huron and of Lake Michigan far enough to determine the extent of Lake Algonquin in each of these basins. He has also extended his studies some distance into the Lake Superior basin. The results of his work have only been briefly outlined in a communication to the American Geologist in 1896[3] and in his "Short History of the Great Lakes" in 1897[4]. He found that Lake Algonquin had at first a southward discharge through the St. Clair and Detroit rivers into the Erie basin, for it came into action before the ice had withdrawn from Balsam Lake at the head of the Trent valley in Ontario. When the ice uncovered Balsam Lake the discharge of Lake Algonquin shifted to the Trent valley. It is his opinion that the head of the Trent outlet was not much below the level of the St. Clair outlet at that time so that the change produced but a slight lowering of the lake. He has also found that Lake Algonquin had Its discharge shifted back to the St. Clair outlet through an uplift of the region occupied by the Trent outlet. Its history has, therefore, been more complex than was anticipated by Spencer.

These investigations by Spencer, Taylor and others have shown that the Algonquin beach on the borders of Lake Huron and Lake Michigan is inclined upward in a north-northeast direction, but that in the eastern half of the Superior basin it is practically horizontal. It was of course horizontal throughout when formed except perhaps at its northeast end on the immediate border of the ice sheet where ice attraction may have held the water a little higher than the general level of the lake. The departure from horizontality here in Michigan may, therefore, be taken as a measure of the amount of uplift that has occurred. The level of the Algonquin beach at the south end of Lake Huron as interpreted by Taylor, is about 25 feet above the surface of Lake Huron. The rise is very gradual between there and Alcona county for the beach at Greenbush Station on the new line of the Detroit and Mackinaw railroad is about 60 feet and at the court house at Harrisville 63 feet above Lake Huron (as determined by hand level from railway track on Main street in Harrisville). But on Mackinac Island the beach is 170 to 205 feet above Lake Huron. Taylor reports that there is a heavy well-developed beach at an altitude about 170 feet which is the lowest of a series of four or five similar ridges which rise by successive steps to an altitude of about 205 feet above Lake Huron.[5]

According to Spencer the Algonquin beach rises on the east shore of Lake Huron from 18 feet below Lake Huron at Tort Huron to 134 feet above the lake at Southampton, Ontario, which is nearly opposite Greenbush in Alcona county. This part of the east shore is nearly along the line of uplift while the west shore departs from it 45 to 60 degrees or more. It is, therefore, not surprising that the beach stands markedly higher at Southampton than at Greenbush.[6] The rise from Port Huron to Southampton, allowing it to be 25 feet above Lake Huron at Port Huron, is about one foot per mile, while from Port Huron to Greenbush it is about 3.5 inches per mile.

The Algonquin beach is a strong one in Alcona county and has been recognized by many of the residents as an old lake shore. It has been cut back in places about one-fourth of a mile into the slope of the Alcona moraine, and presents in such places a steep bluff, which may be 30 to 50 feet in height. The average height from Greenbush northward to the north line of the county is more than 20 feet. South from Greenbush the lake did but little cutting. Instead it built a series of low gravelly bars 3 to 6 feet high and 50 to 100 yards or more wide, which are separated by narrow swamps or sloughs. These fill in much of that interval between the Alcona moraine and Cedar lake.

[1]Proceedings American Association for Advancement of Science, Vol. 87, 1888, p. 199.

[2]Deformation of the Algonquin beach and birth of Lake Huron: American Journal of Science, Vol. 41, 1891, pp. 11-21.

[3]Preliminary notes on studies of the Great Lakes made in 1895: American Geologist, Vol. 17, 1896, pp. 253-257.

[4]Dryer's "Studies in Indiana Geography," pp. 102-105.

[5]The highest old shore line on Mackinac Island: American Journal of Science, Vol. 43, 1892, p. 210.

[6]American Journal of Science, Vol. 41, 1891, p. 14.

In front of the old lake bluff bowlders are in places so numerous as to constitute a pavement. They abound for a distance of one-fourth to one-half mile east from the old shore. They are probably in large part a residue from the glacial deposits which the lake eroded as it was cutting back its shore, but some may have been shoved up toward the shore by rafts of ice in the spring. There are also deposits of cobble and gravel along the base of the lake bluff at numerous points. In the village of Harrisville the gravel stands in a double crested ridge or bar with a swamp back of it and a rather steep bank along the front. The court house is built on the front or eastern crest. It is probable that the bar is a storm beach and stands slightly above the mean level of the old lake. This may account for the cutting of a bank on its front. In this connection it may be remarked that the base of the bluff is generally a few feet lower (5 to 10 feet) than the highest part of the gravel bars along the old shore. This is perhaps an indication that the lake had dropped to a slightly lower level before it had completed the cutting of the bluff. The solution of the question should be reached as studies become more extended.

The Nipissing Great Lakes.—When the ice sheet had melted away from the lower end of the St. Lawrence valley a direct eastward outlet for the three lake basins which had been occupied by Lake Algonquin was opened, and the waters fell nearly to the level of the present lakes. They were connected by straits almost as narrow as at present, and hence may be considered independent water bodies. Taylor has given them the name Nipissing Great Lakes, from the Nipissing outlet or pass through which the waters discharged from the east end of Georgian bay into the Mattawa-Ottawa channel that led to the St. Lawrence. The lakes which we have

been considering were glacial lakes whose extent and altitude were more or less dependent upon the ice sheet, but the Nipissing Great Lakes were post-glacial and independent of the ice sheet.

The Nipissing beach formed on the west shore of Lake Huron was found by Taylor to intersect the shore of Lake Huron near Harrisville. To the south from there it is below the surface of Lake Huron, while to the north it rises gradually, reaching an altitude of about 45 feet above the lake at Mackinac Island and about 100 feet at the Nipissing outlet at the east end of Georgian bay. The city of Alpena is built on this beach, and it forms a conspicuous sandy belt in the northeast part of Alcona county along the east side of the north fork of Black river. It comes to the shore of Lake Huron about a mile south of Black River village, and is not well displayed farther south except perhaps in the low sandy ridges at and back of Sturgeon Point light-house. These were probably formed by Lake Nipissing rather than by Lake Huron, though they stand so near the level of the high stages of Lake Huron that it is not an easy matter to settle their relationship to Lake Nipissing.

The strength of the Nipissing beach and the size of its outlet channel indicate that the lake lasted through a considerable period. Taylor thinks that its beach is stronger than the Algonquin. Its history was brought to a close by the shifting of the outlet to the present one, through the St. Clair river, as a result of the uplift of the northern part of the country.

Lake Huron.—The fluctuations of Lake Huron, the probable length of time it has existed, and the various phases of its shore, have been discussed at some length by State Geologist A. C. Lane in his report on Huron county in Vol. VII of this survey. It is his opinion that the work accomplished by the Nipissing lake and Lake Huron, which he thinks have a level very nearly coincident in that county, is greater than that by Lake Algonquin in about the ratio of 3 to 2, and that the work accomplished since the beginning of Lake Algonquin is somewhat greater than that by Lakes Whittlesey and Warren. The records of lake fluctuation for the 100 years 1800 to 1890, together with the rainfall data from 1857 to 1800, are set forth graphically in a diagram. It appears that there is a rude correspondence between the extreme stages of the lake and the wet and dry periods, as well as an annual cycle dependent upon the rainfall, evaporation, etc., at the various seasons of the year. The extreme fluctuation is nearly G feet and the annual about 1.34 feet.

Aside from the fluctuations which are due to variations in rainfall, there is thought to be a gradual emergence of the land on the border of Lake Huron as the result of an uplift now in progress. This matter has been investigated by G. K. Gilbert of the United States Geological Survey, and he calculates that the rise of land at the Straits of Mackinac is at the rate of 6 inches per century, and diminishes to zero between there and the outlet at Port Huron.[1] Concerning the length of time Lake Huron has existed, Gilbert remarks as follows:[2]

"The deduced mean rate of change—0.42 foot to the 100 miles In a century—depends on assumptions which are convenient rather than probable. These are: (1) that the whole region moves together as a unit being tilted without Internal warping, and (2) that the direction of its present tilting is identical with the direction of the total change since the epoch of the Nipissing outlet of the upper lakes. What we know of the general character of earth movements gives no warrant of such assumptions of uniformity, but no better assumptions as to this region are now available. * * * * * I am disposed to ascribe only a low order of precision to the deduced rate of change, and regard it as Indicating the order of magnitude rather than the actual magnitude of the differential movement.

"If we assume that the rate of 0.42 foot per 100 miles per century is uniform and secular, and project it backward to the time when the drainage of Lake Huron was shifted from North Bay to Tort Huron, we obtain for the period since that change about 10,000 years. From studies at Niagara. Taylor has estimated the same period as between 5,000 and 10.000 years; (Bull. Geol. Soc. America, Vol. IX, 1898, p. 83) and the comparison Indicates that the rate of modern change is of such magnitude as to accord well with the idea that it continues the geologic change."

In the last 16 years the land is said to have made 10 rods abreast of the life saving station at Sturgeon Point. At the beginning of the period it was cutting right up to the fence lines of the light-house enclosure. Thence all the way to Harrisville there seems to be a strip 200 feet wide of recent growth, and at Harrisville the report is that from 1884 to 188G the lake was cutting the bluffs, which are now about 380 feet from the lake front.

[1]Eighteenth Annual Report U. S. Geological Survey, part 2. pp. 639-640.

[2]Loc. cit. pp. 637-639.

ECONOMIC RESOURCES.

Soils.—Alcona county presents wide variations in the character of its soil, there being a range from the most productive clay and clay-loam soils to the most barren sand. There is also considerable swampy land with peaty soil. The clay and clay-loam soils usually contain enough water to supply the needs of plants. The sandy and loose-textured soils vary greatly in the moisture contained in them, in some cases being sufficiently damp to be productive, and in some cases dry and barren. The following classes of soil may be readily distinguished: 1, clay; 2, clay-loam; 3, sandy loam; 4, wet sand; 5, dry sand; 6, peaty or organic soil. There are parts of the county where a single class of soil prevails over a wide area, and parts where a single farm may contain two or more classes. In the latter case the soil is referred to as mixed or variable. The descriptions of the soil below are given by townships, beginning at the lowest number and working to the highest; and should be used to supplement the map, Plate II.

In T. 25, R. 5 E., situated in the southwest corner of the county, there is a strip of productive land with clay-loam soil occupying the west border in Secs. 7, 17, 18, 10, 20, 30 and 31. There is also clay-loam on the east border in Secs. 1, 24 and 25. The remainder of the township is

mainly sandy barrens, the principal exception being a narrow strip of wet land along the Au Sable river valley.

In T. 25, R. 6 E., there is a tract of productive clay and clay-loam soil embracing fully 25 square miles. The poor land lies around the edge of the township, there being a narrow strip on the south edge that is sandy, and parts of the north and west borders that have a sandy loam of poor quality and too broken for easy cultivation. A portion of the productive land in the north and west parts of the township has a very hummocky topography, and is therefore difficult to cultivate, but makes excellent pasture land. Several lakes in this broken area add to its value for pasture or grazing.

In T. 25, R. 7 E., there is only a narrow strip of productive land situated on the north and west borders, mainly in Secs. 1, 4, 5, 6, 7, 18 and 19, and embracing perhaps 6 square miles. It has a mixed soil with spots of clay, with wider areas of sand and sandy loam. The remaining parts of the township are dry, sandy barrens.

In T. 25, R. 8 E., there is a large amount of wet land mapped by the land survey as swamp, but which when cleared and ditched is found to be a good farming district. In the northeast part of the township in Secs. 1, 2, 11, 12, 13 and 14, there is a heavy clay soil. The remainder of the township carries a mixed soil with abrupt changes from sand to clay and a predominance of sand. With the exception of a narrow strip of dry sand on the west border, which is barren, the sand of this township is generally productive, and several good farms have already been cleared in the central part of the township.

In T. 25, R. 9 E., there is a heavy clay soil in Secs. 5, 6, 7 and 18, and considerable productive land from these sections eastward to the shore of Lake Huron. A part of the moraine in Secs. 4, 8 and 9 has a rather light sandy loam soil. The south half of the township is largely swamp land interspersed with sandy and gravelly ridges formed by Lake Algonquin. Some of the wet land in the southwest part of the township has been brought under cultivation and proves to be very productive. It embraces a bay of Lake Algonquin and has a soil of fine sand or loam.

In T. 26, R. 5 E., there is a very broken tract of sandy loam. The same is true of T. 26, R. 6 E., except about 12 square miles in the northeast part, which is a level tract of wet sand. Both townships are much better adapted to grazing than to farming. There are several lakes in the hilly portion and several small streams in the flat portion, which afford an abundant supply of water for herds.

In T. 26, R. 7 E., there are a few square miles of sand and sandy loam with rather light soil, but much of the township has a productive soil of clay and clay-loam. The most barren soil is found in Secs. 18, 19, 20, 21, 22, 27 and 28, being largely dry sand. Secs. 1, 2, 3, 4, 12 and 13 have much sandy land but are well watered and adapted to grazing. The remainder of the township has a mixed soil with patches of clay and much clay loam and a moderate amount of sandy loam. Nearly all can be brought under cultivation except the sandy sections above mentioned. In T. 26, R. 8 E., there is a tract of productive clay land in the eastern part, in Secs. 11, 13, 14, 23, 24, 25, 26, 35 and 36. The northern third has a sandy loam and is adapted to grazing rather than agriculture. The remainder of the township has a mixed soil with a sufficient amount of clay and clay-loam to justify bringing it under cultivation, and a large part is already cleared and farmed.

The greater part of T. 26, R. 9 E., is productive farming land. There are a, few farms with sand and sandy loam along the Alcona moraine in the eastern part of the township. The northwest part in Secs. 5, 6, T, 8, 17 and 18 also has a sandy loam soil, but it is fair to good farming land. The narrow lake plain is in places very stony and is on the whole less productive than the upland back of it.

In the southeast part of T. 27, R. 5 E., there is a tract of about 15 square miles which has a productive soil of clay and clay-loam. The western and northern portions have a lighter soil, adapted to grazing rather than farming. The northeast part is level, and there is considerable swampy land in Secs. 1, 12 and 13.

In T. 27, R. 6 E., there is a tract with productive clay-loam soil extending northeast from the productive tract in T. 27, R. 5 E., from Secs. 18, 19, 30 and 31 to Secs. 3 and 4. It is very hilly in Secs. 17, 18, 19, 20, 30 and 31, and difficult to cultivate, but in Secs. 3, 4, 9 and 10 there is an undulating surface easy to farm. The remainder of the township is adapted to grazing and well watered, but the soil is rather light for farming.

In T. 27, R. 7 E., there is very little productive farming land. The northwest quarter is largely swamp and part of it covered continually with water. It opens into Hubbard lake at the northeast end. The remainder of the township has a rather light sandy loam soil that can be best utilized for grazing land.

In T. 27, R. 8 E., the productive land is largely situated in the southeast quarter, there being considerable clay-loam soil in Secs. 23, 24, 25, 26, 27, 34, 35 and 36. There is a swampy tract along Sucker creek, which when cleared up and ditched may become productive. The uplands in the northern and western parts have some clay-loam, but sandy soil predominates and grazing would probably be more profitable than agriculture.

In T. 27, R. 9 E., there is a large amount of productive farming land, which is nearly all under cultivation. The western and northern borders have a, sandy loam, and the moraine and lake plain that lie between Black river and Lake Huron have a sandy or sandy loam soil, but in the remainder of the township clay-loam greatly predominates over the lighter soils.

In T. 28, R. 5 E., in the extreme northwest part of the county, there is but little land adapted to agriculture, and this is in a belt of hardwood timber in the southwest part,

covering parts of Secs. 29, 30, 31, 32, 33 and 34. The eastern edge of the township is fiat and rather wet. The remainder is dry and largely rolling land with light soil.

On the west border of T. 28, R. 6 E., there is a strip of flat and rather wet sandy land. There is also a large swamp in the northeast part in Secs. 1, 2, 3, 11 and 12. The remainder of the township is rolling land with rather thin soil. The wet land may be brought under cultivation after it is cleared up and ditched, but the uplands are scarcely suitable for farming.

In T. 28, R. 7 E., there is scarcely any land under cultivation and much of it has a light soil. Hubbard lake occupies about one-third of the township. It is doubtful if the uplands west of the lake will be worth settling, but northeast of the lake the soil is better, though it is a very hilly tract.

In T. 28, R. 8 E., there is a large amount of productive land. At least 80 per cent of the land is a rich clay or clay-loam. The only tracts worth mentioning that are too light for agriculture are small areas in the northeast and southeast corners and in Secs. 21 and 28. There is a large swampy tract at the headwaters of Sucker creek in Secs. 25, 20, 27, 34 and 35. There are also swamps in the southwest and northwest parts of the township.

In T. 28, R. 9 E., which is the northeastern corner township, there are a few square miles of productive land in Secs. 6, 7, 8, 17, 18, 19, 20, 21 and 22, with considerable clay-loam soil. There is a very broken tract south of these sections in the southwest part of the township with a rather light soil. The remainder of the township is a low. swampy tract bordering the lake.

Wells.—It is only in the thickly settled eastern portion of the county that wells have been put down in sufficient number to test the supply of underground water, and even there it has usually been tested only to very slight depths. Throughout the thinly settled western and central portions, springs and surface water are generally adequate to the needs of the residents, though the quality of water is in some cases very poor.

The wells are usually between 15 and 30 feet in depth and obtain a moderate supply of water of fair quality. They appear to be supplied largely by seepage from the clay which prevails in that part of the county. The deep wells present less uniformity than the shallow ones, some being strong while others are so weak as to be pronounced failures. Some are entirely through clay, while others are largely through sand, and still others pass through alternations of sand and gravel with clay. The wells indicate that there is a widespread and thick bed of sand under the surface clay in the eastern part of the county. It is often dry for a few feet, but is charged with water farther down. In such wells there is little or no rise of the water above the level at which it was struck. Wells which enter water-bearing sand immediately under the clay are liable to have a head considerably higher than the top of the sand bed.

It is probable that flowing wells may be obtained by sinking to a depth of 100 to 150 feet or less in several localities within the county, for the situation is very similar to that in flowing-well districts in neighboring counties toward the southwest. The eastern slope of the prominent moraine from Lott postoffice northward across Tps. 25, 26 and 27, R. 6 E., seems a very favorable place for flowing wells, the conditions being similar to those at Rose City and West Branch, in Ogemaw county. Possibly flows may be obtained in the southeast part of T. 27, R. 5 E., and northwestward from there past McCollum lake. If the ice sheet pushed up into that region from the northeast, as seems probable, the waters which soak in along the elevated moraine that constitutes the divide between the Au Sable and Thunder Bay rivers are likely to be working down the slope toward Thunder Hay river and may have sufficient head to overflow in the comparatively low tracts at the head of Wolf, Silver and McGinn creeks, and for some distance down these streams.

In the eastern part of the county, flowing well prospects seem good all along the lake shore on the east side of the Alcona moraine. Flows may also be struck in low ground both north and south of the divide between tributaries of Hubbard lake and the headwaters of the east and west branches of Pine river. One flowing well has already been obtained near a branch of Pine river in Sec. 11, T. 26, R. 8 E., at the moderate depth of 65 feet, which is at least an encouragement to prospect for others in similar situations along each side of this divide.

At Harrisville and Springport and for some distance north and south from these villages there are strong springs issuing along the border of the lake, which supply the needs of residents to such an extent that but few wells have been made.

At Black River village water is hauled from the lake and delivered in barrels to the residents, the lake water being of far better quality than that obtained in shallow wells in that swampy tract. W. B. Smith made a boring in this village which struck a hard material, possibly bed rock, at 36 feet. A second boring a few feet distant struck a similar material at the same depth.

At Greenbush wells 25 to 30 feet deep furnish a good quality of water. They are largely through sand and gravel.

In the vicinity of Lincoln the wells are 30 to 40 feet in depth, largely through sand. In this village the lakes are used to a great extent for watering horses and cattle.

In and near Mikado several wells are about 30 feet in depth, and are largely through clay. William Dolson has a well 64 feet deep on his farm south of the village which was all clay except thin sand beds at 45 and 50 feet. It was of a yellow color to a depth of 12 feet, the remainder blue. There is a good supply of water in this well, but one 20 rods south at John Butterfield's reached a depth of 70 feet without obtaining a supply of water.

At Killmaster there is abundance of water at various depths, as shown by the three deep borings made in prospecting for oil. The water overflows from the base of the drift. Records of the borings appear in Dr. Lane's discussion of gas (pages 65 to 67 of this report).

At Vaughn Station, Hartwell Hayes bored 80 feet through clay and found very little water, but several wells in the vicinity of this station obtain a good supply of water at about 30 feet.

The following records of farm wells in the eastern part of the county illustrate the variable depths at which water is found, and to some extent the beds penetrated:

A boring in Sec. 4, Greenbush township on land of James McClelland was sunk 95 feet entirely through sand and gravel without obtaining water. It is on the crest of the Alcona moraine at an altitude about 160 feet above Lake Huron.

John R. McDonald has a well in Sec. 6, Greenbush township, 44 feet deep, which passed through a blue-black clay in its lower part but obtained a good quality of water. Some wells in that vicinity have a water with a bad odor, obtained in the blue-black clay.

A. D. McDonald has a well in Sec. 9, Greenbush township. 44 feet deep, which has only two feet of water, but is a strong well. It penetrated 14 feet of clay at top, below which was dry sand to the water near bottom of well. Mr. McDonald has dug a number of wells in that vicinity on other farms which enter sand below a few feet of clay.

Adolphus Lovlett in Sec. 34, Harrisville township, bored 60 feet without obtaining water, but, a well across the road obtained water at 30 feet. It is, however, of poor quality with offensive oder.

Charles Clayton has a well in the northwest part of Sec. 34, which obtained a good supply of water. The depth is 57 feet; for 40 feet there is a loose textured material below which is a hard clay.

Mrs. Dean made a boring 105 feet at her residence in Sec. 22, Harrisville township, which struck a water-bearing fine sand at 45 feet and did not reach the bottom of that deposit. The pipe has been drawn up to the top of the sand bed because the sand screens better there than in the lower part.

James Clemens bored 110 feet at his residence in Sec. 20, Harrisville township,* and obtained but little water. There are, however, several good wells near by with a depth of only 20 to 30 feet.

Frank Spencer has a well in Sec. 18, Harrisville township, 66 feet deep that has 40 feet of water. It penetrated 47 feet of dry sand, and then wet sand to the bottom.

Mrs. Chapel, 2.5 miles west of Harrisville, has a well 95 feet, but wells in that vicinity are usually shallow.

Thomas Stone has a well in Sec. 15, Harrisville township, 56 feet deep, which struck a weak vein of water in fine sand near the bottom.

Mrs. B. Culver's well about a mile southeast of Lincoln is 68 feet deep and water rises 17 feet.

The flowing well at Frank Blong's residence, two miles southwest of Lincoln, in Sec. 11, T. 27, R. 8 E., is 65 feet, with the head five feet above the surface. It penetrated: (1) clay 18 feet; (2) gravel and weak water vein, 8 inches ; (3) clay with hard crust at about 30 to 35 feet from surface and softer clay below, 44 feet; (4) gravel with flow of water, 2 feet. Altitude of well about 120 feet above Lake Huron.

John Clarke, in Sec. 27, T. 27, R. 8 E. has a well on high ground that is 65 feet deep and has very little head, though a strong well. It penetrated: (1) loamy soil 3 or 4 feet; (2) yellowish clay 30 feet; (3) dry sand, becoming wet near bottom, 30 feet. Mr. Clarke made a well on low ground in the northwest part of this section which has some oil on the water and an offensive smell when boiled.

Arthur Close has a well 53 feet deep in Sec. 34, T. 27, R. 8 E. that has only a few inches depth of water yet: is strong. Edward Burge has another in the same section, 40 feet deep, with but little head, and D. W Brooks has one in Sec. 36, that is 36 feet in depth. In this well there are 24 feet of stiff clay below which are thin beds of sand and clay.

Napoleon Sherbeneau made a well 117 feet deep in Sec. 34, Haynes township, which is in sand and gravel at bottom, but passed through much clay. It has considerable head. His neighbor, James Barber, in the same section has a well 104 feet which also has considerable head. Another neighbor, Mr. McIntyre, in Sec. 4, Harrisville township, has a good well 56 feet deep. Each well is about 170 feet above Lake Huron.

Frank Elmer, near center of Sec. 3, Haynes township, sunk a well 64 feet, 2 in. deep, which is reported to have entered a white material near the bottom that contains some mineral thought to be lead. The beds passed through are said to be: 20 feet clay, 4 feet sand where first well caved, 3 feet boulders, 4 feet blue clay hardpan, 10 feet quicksand, then hardpan and sticky stuff to the water gravel. The water is hard, but free from chlorine or sulphates. Mr. Leverett was told that the well went through 40 feet clay and 20 feet gravel before striking the white material. Other deep wells in the north part of Haynes township are as follows: James. Martin's, east side of Sec. 10, depth 104 feet; Joseph Miller's in southwest part of Sec. 11, about 80 feet; Fred Otto's, in southeast part of Sec. 5, 56 feet. None of these wells struck the white material which was found in Mr. Elmer's well.

Alexander McDonald's well, in the southeast part of Sec. 2, T. 28, R. 8 E. is 103 feet. It penetrated 20 feet of clay at the top, below which was dry sand, becoming wet near bottom. The altitude is about 280 feet above Lake Huron. A neighboring well in Sec. 11, is 80 feet. West from there on the low tract near Spruce postoffice wells are obtained at shallow depths.

*Near the east branch of the Pine, 640 A. T.

MARL.—LEVERETT.

Marl deposits in Alcona county, so far as examined, were found to be too thin to be utilized in the cement industry. There is from 6 to 10 feet of rather impure marl in the lake on the township line a mile west of Lincoln. About 6 feet of marl, apparently of good quality, was found on the border of Tubb's lake in Sec. 31, T. 20, R. 7 E., forming a platform 10 or 12 rods wide. Marl deposits 1.5 to 2 feet thick are exposed in a railway ditch in a swamp one-half mile north of Harrisville Station, and a similar depth in railroad ditches south of Greenbush on the west side of Cedar lake.

MARL (BOG LIME).—LANE.

Deposits of what is popularly known in Michigan as marl, but is nearly a pure calcium carbonate, occur at a

number of points at Springport (South Harrisville), Kirk Ludington's, Shabno's, four miles south of the Presbyterian church in T, 27 N., R. 9 E., etc.

A very interesting deposit in some ways is one that is crossing the lake road about three miles and a half north of Harrisville. It covers probably not less than 20 acres. I do not know how deep it is, though it has been tested. The interesting tiling, however, is its mode of occurrence, which is directly in front of the bluffs worn by the lake at a higher level, with no ridge or barrier between it and the present lake. It is wasting away, but the upper part is redissolved and precipitated and passes into a firm and hard calcareous tufa, while as one goes down it becomes granular and then soft. It appears to be a genuine Chara lime formed by the precipitation of lime by the lake weed known as Chara, but it can hardly be supposed to have been found in such purity directly on the beach of a great lake, and we are forced to assume that it is the relic of a small lake, the rest of which has been eroded away.

There is enough, perhaps, for lime kilns, but hardly, I think, for a cement plant; and, beside, it is so hard and granular on top that the advantage of marl, its fine sludgy character suitable for mixing, would be lost.

CLAY.—LEVERETT.

In general, clay deposits of fine and uniform texture are rather rare in Alcona county, but in the southeast part there is considerable clay that carries but few pebbles, an area of several square miles being-found around Mikado and northward from there between Gustin and Killmaster. Although an unsuccessful attempt has been made to burn a kiln of brick at Mikado, it seems probable that the surface clay will in many cases prove suitable for brick or tile. It will at least be worth while to experiment further with the clay, for that part of the county would be greatly improved by underdraining with tile, and it will be an advantage to manufacture the tile where it is to be used.

CLAY.—LANE.

At South Harrisville, Sec. 32, T. 26 N., R. 9 E., some brick has been made of glacial clay. It is not entirely free from pebbles, effervesces somewhat and makes cream-colored brick. Some brick has been made also at Mikado (West Greenbush) of a similar quality. All the clays of the county are Pleistocene or surface clays, and it is the almost universal rule that such clays have more or less calcium and magnesium carbonate. Generally the top of the bed is free from carbonates, which have been leached out.

Just at Harrisville the stream falls over a smooth, well-bedded clay, apparently an old lake clay free from pebbles. If not, it could easily be washed free by the stream.* Back of Sturgeon Point, on Sec. 25, T. 27 N., R. 9 E., are fields where a similar clay appears to be present, but it is particularly well exposed where the Black river opens out from the hilly moraine country to the swampy land of the old lake bottom on Sec. 3 of the same township and See. 34, just north. Here a calcareous clay is extremely well exposed in the bed of the stream, appearing almost as though it were lied rock. But probably the same bed of clay also appears in the bluffs of the outer valley above the flood plain and at least 10 feet above the river. Here it is light reddish in color, does not effervesce with acid, lies close to the abandoned track of an old logging railroad, and could be readily worked. I should think it would make unusually good brick and tile (see analysis below), though it is quite possible that farther working and testing with auger would show that in going deeper more lime was encountered. Still it is quite likely that an important top layer may have been leached free.

*As at Sebewaing, see Vol. VIII., Part I.

There are indications that similar clays occur all the way along, but somewhat below and nearer the shore, the highest former shore line of Lake Huron (645 to 655 A. T.).

The Au Sable river also flows at several points over firm, well-bedded pink clays, apparently free from pebbles but full of lime. A good place to observe them, however, is in a little side stream at Bamfield's, Sec. 11, T. 25 N., R. 5 E., where they are well exposed.

Three typical samples of the clays were sent to the McMillan Chemical Laboratory, Albion, for analysis, and the following reports were received from Prof. Delos Fall:

	910.		911.		912.		Millbury, Ohio.
Free sand	13.98		11.53		38.55		
Combined silica	27.60		25.71		22.73		
		41.58		37.24		61.28	61.03
Alumina	12.58		7.08		16.37		
Oxide of iron	3 59		3.99		5.59		18.10
							6.65
Calcium oxide	13.04		17.70		2.33		1.29
Carbonic oxide	16.26		21.00		.....		
		23.28		31.60			
Calcium carbonate							
Sulphur anhydride	0.41		0.41		0.67		1.55
Magnesia *	6.44		6.52		1.21		
							.53
Organic matter	3.72		3.46		9.14		9.20
	98.62		97.40		96.59		
Difference, principally alkalies	1.38		2.60		3.41		
	100.00		100.00		100.00		

No. 910 is the ordinary calcareous clay or marl of the district from Black river near the water level, and is free from pebbles or grit. It will be seen that it is composed of about ⅓ very fine sand or rock flour, ⅓ clay proper, and ⅓ dolomite. It may be used for making brick, but will yield a light brick that will not stand hard burning.

Samples of clay from the Au Sable valley appear to have similar composition.

*There is not enough CO_2 to combine with all the lime and magnesia. Hence there is probably some hydrous magnesian silicate present.—L.

No. 911, from the old brickyard southeast of Harrisviile, is a typical tile clay and contained some small limestone pebbles. It will be seen that it contains even more lime, nearly half. Neither of the clays appear to be suited to the higher uses for clay.

No. 912, the third clay, which lies over No. 910 and may be derived from it by solution of the calcareous material; is of an entirely different character. If the silica is finely divided enough, and I think it is, it would make an

excellent clay to mix with Portland cement for the manufacture of marl. I have given an analysis of the Millbury, Ohio, clay, which is largely used in the state for cement manufacture, for comparison.

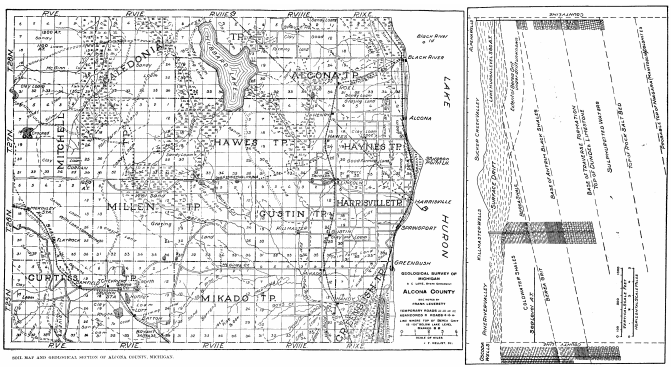


Plate II. Soil map and geological section of Alcona County.

It would also make an excellent grade of red brick, and very probably also paving brick. It remains to be seen by a series of borings how much of this clay there is, but in all probability field tests showing whether it effervesces with muriatic acid will be sufficient to show this.

WATER POWER.

The following data concerning the water power in Alcona county have been furnished by J. H. Killmaster of Harrisville, who has a, general acquaintance with the conditions throughout the county:

"Generally speaking, dams of 10 to 14 feet head could be maintained on the south, west and east branches and main stream of Pine river, with horse power from 40 to 200, according to location, the farther down the stream the larger the volume. The same thing may be said of the streams flowing into Hubbard lake and of Black river. The portion of Wolf creek in Alcona county carries but a small volume, but in Alpena county it becomes a stream of considerable volume.

"On Pine river there is a dam on the east branch at Killmaster village with 12 feet head and an average of about 40 horse power for the season. There is a 48-inch turbine wheel here, but the volume is not sufficient to supply the wheel except during the spring freshet. In the summer the wheel will exhaust the water in about 4 days, so that the stream will not furnish the wheel more than 4 days a week.

"The other tributaries of Pine river have about the same volume as the east branch at Killmaster, at corresponding distances from their sources. A dam could be constructed at the junction of the east and west branches in Sec. 3, T. 25, R. 8 E., that would give a head of 10 or 12 feet, and the supply of water would probably supply a 60-inch turbine wheel, for the power should be at least 150 horse power.

"There is a dam on Sage (McGillis) creek in Sec. 33, T. 26, R. 7 E., with 12 feet head. The stream is small and the power of no consequence.

"A dam at the head of the south branch of Thunder Bay river, just below the point where it leaves Hubbard lake, has 6 feet head, and there is probably about 200 horse power.

"A dam on Sucker creek in Sec. 5, T. 27, R. 8 E., has 10 feet head, with power about the same as at Killmaster.

"On Hubbard creek, in Sec. 24, T. 27, R. 6 E., there is a dam with 12 feet head and a power about the same as at Killmaster.

"There is a dam with similar head on Wolf creek, in Sec. 31, T. 28, R. 6 E., with a greater volume than at Killmaster.

"The dam at Black river has 10 feet head and probably there is 50 horse power.

"The dam at Harrisville is on a stream which would furnish perhaps 15 or 20 horsepower. There is an abandoned dam beside; between them there may be 20 feet fall."

In his report on the Water Resources of the Lower Peninsula of Michigan, State Geologist A. C. Lane notes that the Au Sable river has splendid unused water powers, especially through the stretch from Mio in Oscoda county to T. 24, R. 6 E., in Iosco county, which embraces the portion of the stream in Alcona county.*

*Where the south branch of Black river reaches the old line on Sec. 3, T. 27 N., R. 9 E., it is flowing rapidly, with clay bottoms and banks. It has something like 25 miles of drainage area, with numerous springs and would make a good dam site. Thence to Black river is practically dead water, until close up to the mouth where there are two dams, one ten feet and one six feet, both now used more for lumbering operations than anything else. Such powers as we have mentioned ought to make nice electric light stations for small towns if nothing more.

Of a very different character is the Au Sable. This is a large stream fed with numerous springs. At many places along its banks bluffs rise from 60 to over 100 feet high, and in such cases often the upper two-thirds or so of the bluff is sand, the lower clay, and at the base of the sand are extensive springs. It is a remarkably meandering stream for a stream of such a, rapid flow and fall. Betwen Flat Rock, near the south line of Sec. 38, T. 26 N., R. 5 E., and Bamfield's place, there is about 20 feet fall. Thence to Sec, 16, T. 24 N., R. 16 W., the river drops about 200 feet, 55 feet of it in the stretch known as the rapids, which lie in Iosco county. The drainage area, above where it enters the county is not far from 1500 square miles. From a rough estimate of velocity and size I should think that it was discharging in November, 1901, about 1100 cubit feet per second, while in summer the discharge may fall to half that. Gagings upon this stream at the Tucker farm bridge say, or somewhere above the in-flow of the Pine river and also of the Pine and Black rivers, would easily give us more definite ideas, and an application should be made to the U. S. Geological Survey for a gaging station.—L.

SUBSURFACE GEOLOGY. BY A. C. LANE.

Search for rock exposures along the shore and the Au Sable river, the two regions most likely to show them, has been fruitless, and no rock exposures have been met incidentally. Nor has inquiry led to any authentic exposures. Along the rapids of the Au Sable, however, there are blocks of sandstone apparently belonging to the Marshall series, which may indicate that sandstone

is not far beneath. The drift at Bolton, Sec. 35, T. 25 N., R. 6 E., shows abundant Marshall sandstone fragments, and it is conceivable that some of the streams may show rock exposures. But none of the places that we examined proved to be such, merely hard, very clayey till of the ground moraine.

We are mainly dependent, therefore, for our knowledge of the rocks beneath upon borings in this and adjacent counties and upon our knowledge of the general geology, checked somewhat by certain facts as to the character and arrangement of the surface deposits.

In regard to the general lay of the county, we may note that the rocks of the Lower Peninsula of Michigan, as has been long ago pointed out by geologists, lie in a basin whose center is somewhere near Midland county. Thus, for instance, the limestone formation which appears in the Griffin quarries three miles northeast of Omer can be traced southeast to the lake shore, over on the Charity islands, at Bayport in Huron county, and so down to Jackson county, and thence curving northwest past Bellevue to Grand Rapids. Not only do its outcrops lie in this great curve, but the formation is found in borings beneath Midland.

All the coal of the State will be found practically within the basin made by this limestone formation. Thus no coal in commercial quantity will be found in Alcona county, as it lies outside the basin, and the rumors of coal are mainly founded upon the occurrence of black shale, as will be later described.

Moreover, since Alcona county lies in the northeast of the center of the basin, we may expect that the rocks, if there is no irregularity, will dip, and any particular bed will be found deeper, to the southwest.

The exact direction of the dip may not always be the same. The directions at right angles to it, known as the strike, are given approximately by the course of the north side of Thunder bay, and the rock ridges north of Alpena, and seem to be very close to northwest and southeast, though if the reef[1] about 7 miles off Harrisville in 14 fathoms of water is a solid reef of limestone, it may be more nearly N. 37½° W.

Now there is but one set of wells to bed rock in the county, those at Killmaster, and they are so near together that it is not very safe to infer dips from them. So in estimating what kind of rocks a section down into the earth would show we have taken into account wells immediately north around Alpena, south around Au Sable and Oscoda.

A few words as to the names of the rocks may not be out of place.

The unconsolidated deposits are known as surface or drift, and are either sand, gravel, stratified clay, or a stony or bouldery, poorly stratified clay known as till. Aggregates of vegetable matter known as peat or muck, and of calcareous matter known as tufa or marl, also occur.

A consolidated sand is known as a sandstone. Other rocks, when they or their drillings are granular or crumbly in texture, are sometimes called, mistakenly, sandstone.

A fine-grained sandstone, the individual grains of which are angular with good cutting edges, is known as a grit.

A consolidated clay which easily splits, is known as a shale. They may be of various colors, most usually blue, also white (often called fire-clay), red (especially near salt water), green or black. The black shales are often mistaken for coal, but though they contain some combustible matter, in the region of which we are talking it is but 20 per cent or less, and they have no commercial value. Limestone is composed mainly of carbonate of lime. When magnesia takes the place of the lime largely, it is known as dolomite. A blue color generally indicates more or less animal or vegetable matter or clay. A limestone with clay is said to be argillaceous, with sand, arenaceous.

The record of the wells must be taken from reports, as samples have not been preserved, but only in a few cases indicated do I suppose the description to be seriously wrong.

[1]Fishermen bring up pieces of honeycombed limestone in their nets and say that the cavities are used by trout to lay their spawn where it is protected from other fish. The same phenomena are reported by Bell from the Manitoulin Islands on the opposite shore of the lake; Bull. Geol. Soc. Am., Vol. 6, p. 297. It also occurs off Sand Beach and Charlevoix.

KILLMASTER.

At Killmaster three wells were put down, one about 10 rods from the bridge on the east side of the stream and about 500 paces N. 1000 W. of the south line of Sec. 22, T. 26 N., R. 8 E. Its elevation is near that of the Gustin Station, i. e., about 670 A. T. It was the last put down[1] and the deepest (1530 feet). It is said to have had 150 feet of 10-inch casing, 240 of 8-inch to bed rock, and 614 feet of 5⅝-inch to case off salt water, the hole being dry the balance of the way. There is said to be 600 feet of casing in it still, not now to shut off the brine, for it is put in with a perforated screen at the bottom, but so as to ensure that the brine pump which was once planned should draw the brine from the bottom. However, this inside casing is now stopped up at 306 feet, as that was as far as I could let a thermometer down. Moreover, when it is bailed out it remains for some time at a different level from the water between the two casings, which rises to the top of the inner casing and slowly flows into it. It is a strong brine, a little from the top giving a specific gravity of 1.105 and 40.6 ounces of it yielded 6.5 ounces of salts, i. e., 15.9 per cent.[3] The temperature at 302 feet is about 50° F. The record is as follows:

Surface Deposits:		
Sand, then till, no gravel at the bottom.....	240	240
Coldwater Shale Series:		
Sandstone	4	244
Gray shale	6	250
Sandstone	4	254
Gray shale	276	530
Berea Shale:		
Red shale	20	550
Black shale	20	570
Berea Grit:		
Sandstone: Gas in top of sandstone, and a very small quantity of oil, which was overcome by salt water in the sandstone below the gas. However, bubbles of burning gas (not H_2S or CO_2) are now coming up continually in the water, which analyzes as given....	40	610
Devonian (Antrim[2]) Shales:		
Gray shales (compare Bedford shales).....	150	760
Dark shales (compare Cleveland shales).....	150	910
Gray shales (compare Erie shales).....	25	935
Dark shales (compare Huron shales).....	65	1000
(The top of the Traverse may be here.)		
Gray shale and limestone.....	32	1032
Black shale (compare Huron shale).....	58	1090
Limestone, color varying from light to dark....	440	1530
Traverse (i. e. Hamilton):		
The first few feet are—		
Hard limestone	8	
Soft limestone	80	
Hard limestone	90	
Hard limestone	4	
Soft limestone	20	

[1]1892 by Hawes & Woodward, of Findlay, Ohio, with cable tools costing about $5,000.

[3]These gave Prof. F. S. Kedzie on analysis:

$CaCl_2$	11.53% of the salts, i. e. 1.821% of the brine		
$MgCl_2$	3.56	.562	
$FeCl_2$	.20	.032	
Water of crystallization	6.14		.971
K	0		
Br	0		
NaCl (salt)	72.21	12.514	
	100.64	14.929 solids.	15.9

A brine of this strength should have sp. gr. of 1.111, according to Winchell's table, but this is avowedly not very accurate, and neither are my weights on common country scales.

The brine is remarkably free from sulphates and would give a very high grade of salt, and I think it more than probable that the sample taken was somewhat diluted.

[2]Term introduced to replace St. Clair, which had been elsewhere used in another sense. It covers the strata from 2306 feet to 2585 feet in the well of Plate VI, Vol. V, of our reports.

Hole No. 1 is about 80 rods from No. 3, nearly south, but a little east of it, and was the first put down. It is 10 feet by hand level above No. 3. It went only 600 feet, stopping on a hard bed which was supposed to be limestone at first but was afterwards thought, and doubtless rightly, to be the hard upper crust of the bed encountered at 570 feet in No. 3. A dip to the south of between 30 and 40 feet is thus indicated.

The formations were similar to those in No. 3, except that there was a bed of gravel at the bottom of the drift, which served as a reservoir for gas. This showed a registered pressure of 103 pounds (apparently the direct water pressure). This gas was overcome by a large flow of fairly fresh water, which was encountered when the 6-inch casing was driven through the gas vein into the sandstone rock. The well was bored wet with pole tools. At first the water gushed up with 40 feet head or so, but now it barely flows. It still yields, however, a considerable quantity, converting the neighboring land, though 20 feet above the stream, into a cat-tail marsh. The water has a Sp. gr. of 1.005, gives strong reactions for calcium and chloride, but practically none for sulphates. The temperature of this slowly-flowing water is 47° F., about 3° less than the temperature at 307 feet in hole No. 3, and 3° F. more than spring water.

The deep hole, No. 3, was dry below the Berea Grit.[1] At 1000' or 1090' the black shales occur which are so widely diffused in the drift and outcrop at Partridge Point and Thunder Island. The base of these black shales is shown in two wells, put down by the Alpena Business Men's Association.

[1]Accordingly it did not read the Corniferous or Dundee limestone.

ALPENA COUNTY WELLS.

The wells just mentioned were one on the north line of Sec. 22, T. 29 N., R. 8 E., and the other on the east and west center line but a few feet from the water and a few feet above it. I have seen samples from the wells, and the base of the black shale appears to come shortly below 63 feet in No. 1, below 76 feet[2] in No. 2. This would indicate a, drop of more than 32 feet per mile to the south or 45 feet per mile to the southeast, for the northernmost well is the more westerly. These wells are almost directly north of Killmaster, and supposing the black shale in the Killmaster well to be at 1090 feet, we have a dip from the No. 2 well to the Killmaster No. 1 of[3] 38.4 feet per mile, or 53.7 feet per mile to the southwest.

Comparing holes Nos. 1 and 3 at Killmaster, we found a similar dip, and the same rate is indicated from the exposures of the base of the black shale on Partridge Point, just north.

The dip around Alpena is reported by Mr. A. W. Grabau as also about 30 feet to the mile to the south, i. e., 42 feet per mile to southwest.

At Alpena there are three wells over 1000 feet deep, from which we may obtain an idea of the strata which may be met from the black shales down to the rock salt. The record of the Churchill well was as follows:[4]

RECORD OF THE CHURCHILL WELL.

1891.	Character.	Feet.	Total.	Per day.	Hours.	Remarks.
Oct. 29	Sand.....	39	39	39	6	Struck light vein of fresh water.
30	Boulders...	2	41	2	12	Surface pipe to rock.
	H. w. l*.....	7	.....	7	6	
Nov. 2	"	8	.....	8	12	
3	"	5	.....	5	12	
4	"	5	66			
	Shale	9	75	14	12	
5	H. w. l.....	16	.....	16	24	Rock very hard.
6	"	16	.....	16	24	1 hr. lost callipering.
7	"	17½	124½			
	Shale	2½	127	20	24	
9	H. w. l.....	18	145			
	Granite.....	3	.....	21	24	Extra hard gray limestone.
10	"	5	153			
	H. w. l.....	14	167	.....	.....	Delayed 35 minutes on account of bit.
	Shale.....	5	172	24	24	
11	Shale.....	15	187	.....	.....	Working in blue shale.
	H. w. l.....	13	200	28	24	
12	H. w. l.....	21	221	24		
	Shale.....	3	224	.....	.....	3 men in each watch.
13	Shale.....	15	239			
	H. w. l.....	10	249	25	.....	Shale, 7 ft. white—Slimy shale.
14	"	13	262			
	Shale.....	7	.....	20	.....	Very sticky nature.
16	"	20	289	.....	.....	Blue.
	H. w. l.....	15	304	35		
17	"	17	321	20		
	Shale.....	3	324			
18	H. w. l.....	15	339	15	.....	Extra hard.
19	"	11	350	11	.....	Extra hard.
20	"	13	363	19		
	Shale.....	4	367			
21	"	20	387	.....	.....	Shale blue.
	H. w. l.....	5	.....	25		
23	Shale	25	417	25	.....	Lost 6 hrs. by stripping pin from top of jars.
24	Shale (blue).	25	442	25		
25	"	2	444			
	H. w. l.....	10	454	12	.....	Extra hard.
26	"	7	461	7	.....	Extra hard.
27	"*	6	427	.....	.....	Light vein flowing Water now flowing.
	H. g. l.....	5	469	8	.....	Extra hard.
28	"	5	474	5	.....	6 hrs. lost by sickness of one man.
30	"	10	484	10	24	
Dec. 1	"	10	494	10	.....	Strong flow of mineral water at 489 ft.
2	"	10	504	10	.....	Flow still continues shale caving in.
3	Granite*....	6	510	6		
4	"	7	.....	7	.....	Flow shows stronger.
5	"	6	.....	6	.....	Flow unabated, rock very hard.
7	"	7	.....	7		
8	"	6	.....	6		
9	"	7	543	7	.....	Increased flow at 570, shows connection with Harrington well.
10	Shale.....	25	568	25	.....	At 590 fresh flow struck which exceeds in strength anything ever struck in Alpena, much stronger of sulphur. At 598 struck another vein of water which shows stronger traces of Mg.
11	H. g. l.....	20	588	20		Put in 588 ft. of casing. At 588 ft. hole reduced to 5⅛ in.
12	H. w. l.....	13	601	13		
14	"	20	621	20	.....	At 605 another vein of sulphur water struck.
15	"	20	641	20		
16	"	20	661	20	.....	670 shut off now.
17	"	10	671			
	Shale.....	20	691	30	.....	698 perforated pipe.
18	H. w. l.....	20	711	20	.....	Volume of H_2O somewhat stronger.
19	"	12	723	12		
21	"	20	743	20		
22	"	13	756	13		
23	"	16	772	16		
24	"	5	777			
	Sandy lime.	5	782			
	Shale.....	5	787	15	.....	(800 ft.).
25	H. w. l.....	10	797	10		Shut off 790.

* H. is hard, w. is white, g. is gray, l. is limestone. The driller's "granite" is really very hard cherty limestone of the Dundee or Corniferous.

1891.	Character.	Feet.	Total.	Per day.	Hours.	Remarks.
Dec. 26	"	12	809	12	.....	
28	"	18	827	18		
29	"	18	845	18	.....	Shut off 794.
30	"	15	.....	15		
31	"	10	.....	10		
1892.						
Jan. 1	"	15	.....	15		
2	"	10	.....	10		
4	"	10	.....	10		
5	"	7	.....	7		
6	"	13	.....	13		
7	"	12	937	12		
8	"	8	954	8	.....	At 936 ft. reduced to 5 in.
9	"	17	989	17	.....	Somewhat softer.
11	"	15	989	15		
12	"	20	997	20		
13	"	8	1,015	8		
14	"	18	1,036	18		
15	"	13	1,056	13		
16	"	20	1,048	20	.....	10 ft. very soft jack, struck what seemed to be the water.
18	"	6	.....	6		
19	.....	.....	.....	.....	.....	12
20	.....	.....	.....	.....		9½ Put in 601 ft. 2-in. pipe, 4 men.
21	.....	.....	.....	.....	.....	Put in 400 ft. more pipe, 4 hours.
22	H. w. l.....	.....	.....	.....	.....	Spent 14 hrs. pulling out 1,000 ft. pipe.
23	"	10	1,072	10	12	
25	"	6	1,078	6	12	
26	"	10	1,088	10	20	
27	"	13	.....	13	24	
28	"	13	.....	13		
29	"	10	.....	10		
30	"	12	.....	12		
Feb. 1	"	10	.....	10		
2	"	12	.....	12		
3	"	12	.....	12		
4	"	10	.....	10		
5	"	12	.....	12		
6	"	12	.....	12		
8	"	13	.....	13		
9	"	12	.....	12		
10	"	12	.....	12		
11	"	15	1,256	15		
12	"	15	.....	15	.....	Struck salt rock; went into rock salt about 20 ft.

[2]At 76 feet is black shale, at 81 to 83 feet is green shale, the rest is limestone.

[3] $\frac{(590 - 73) - (670 - 1060)}{24} = 38.4$

[4]A summary is also given by Mr. Grabau later in this report.

There seem to have been casings at 800, 1062 and 1278 feet.

The end apparently corresponds to the rock salt bed, which at St. Clair and all along the St. Clair river occurs 800 feet and more below the top of the Dundee beds.

A number of other wells by Fletcher, Moench and others do not go so far, but go through the shale above into the Dundee limestone for water.*

*Which has been analyzed. U. S. G. S. Water Supply Paper No. 31.

AU SABLE AND OSCODA WELLS.

These points are as much south of the county as Alpena is north, and yet since there are no outcrops and but one group of wells to bed rock in the county, we are obliged to take them into consideration. Some 11 wells have been put down here within a distance of a mile. We may distinguish in order from north to south three groups, which we may call the Pack group, the Smith group and the Loud group.

Unfortunately, we have no detailed log of any of these wells, but from various recollections, letters and allusions in reports of the salt inspectors we may compile the following account, upon which we may rely with some confidence:

The Pack wells are 20 to 25 feet above the lake, the Smith wells about 15, the Loud wells from 6 to 8 feet.

There are 90 to 100 feet of surface deposits, mainly sand. Then down to some 200 feet is a series of sandstones and shales, which yields in the less elevated wells of the Louds a flow of slightly saline water containing from ½ to 1 per cent of salt, at a temperature of about 48° to 50°.

Then blue shales, and occasionally red, predominate, and toward the bottom black shale, the Berea shale, until at 950 feet in the Park wells, 960 in the Smith, and quite likely a little deeper in the Loud wells, they strike the Berea Grit. This holds a strong brine, 90° to 98°, of good quality, as the analysis of Smith Kelly and Dwight's brine shows.[1] But the sandstone is fine-grained and split with, and passing into, shale and does not yield brine freely, though the quality, in its low percentage of sulphates and ratio of earthy chlorides, is that of the Berea brines generally. According to Mr. E. F. Holmes, the sandstone in going north runs out and yields less and less brine.

We And also in Alma, Grayling and western wells that there is little trace of the Berea. Comparing the Oscoda wells and their elevations, it is clear that the sandstone must dip 30 to 40 feet per mile to the south. Beneath this Berea Grit one well of Pack's was drilled to about 1800 feet depth, and is said to have been 1761', 1785', 1850' deep according to various reports, and dry all the way, encountering only blue and black shales with thin streaks of limestone. It is reasonably certain that it could not have penetrated the Dundee (Corniferous) limestones, whose hardness, light colors and mineral

waters could hardly fail to be remembered. But it must have gone pretty near to the top of it, and the black shale, in which Mr. Elliott, the driller, says they left off, may have been the Bell[2] or Marcellus shale. This, according to Mr. Grabau, follows the trough of Grand lake north of Alpena, some 50 odd miles north of Oscoda, and accordingly the dip thence to Oscoda would average between 30 and 40 feet per mile.

If the strike of the rocks is supposed to be S. E., the Pack wells in Sec. 34, T. 24 N., R. 9 E., should have the rock at about the same elevation above sea level as Sec. 34, T. 25 N., R. 8 E., near the south line of Alcona county, and we have so assumed in constructing the section (Plate II). According to this the dip from Killmaster would be,[3] measuring on the top of the Berea Grit, about 50 feet per mile to the south. But if the strike is nearer east than south the true dip will be less than 50 feet, but cannot be less than 26 feet per mile, which it is in the direction from Killmaster to Oscoda.

It is unfortunate that we cannot identify the top of the (Hamilton) Traverse in the Oscoda wells and thus be able to compare dips on this horizon with Killmaster and the strata about Thunder bay.

[1]U. S. G. S. Water Supply Paper No. 31-No. 291:

$CaCO_3$	tr.
$CaCl_2$	42.1
$CaSO_4$	tr.
$MgCl_2$	19.8
NaCl	179.5
	241.9 grams per kilogram.

[2]Defined by Grabau In his paper in this report.

[3](670 — 570) — (25 + 580 — 950) ÷ 8 = 395 ÷ 8 = 49.

ECONOMIC GEOLOGY.

Oil and gas possibilities.—The Eo-carboniferous series to which the Marshall sandstones and Coldwater shales[1] belong contains a number of "oil sands" in Pennsylvania, but the first horizon which seems hopeful in this State is the Berea Grit. This rarely fails to show some signs of oil or gas. On the west shore the salt wells of Muskegon and Ludington encountered more or less gas at this horizon. So did the wells at Bay City (at 2090') and Blackmar (at about 1632').

It is a well-known oil sand in other states, and the Killmaster wells show that it may yield oil or gas in the county if other conditions are right.

The quality of the oil is much better than that from the Canada horizons, which is a heavier oil with more sulphur. The Petrolea oil seems to come from beneath the black shales in the limestone of the Traverse and Dundee beds. The deep Killmaster and Oscoda wells seem to show that the Traverse is not only dry but free from oil or gas. The Dundee or Corniferous, however, has not been struck in the county, though the section shows at what reasonable depths it should be found.

There are other oil and gas horizons underlying the county. The Niagara has one and the top of the Trenton also is a well-known place, which has a great reputation among drillers, but the depth is so great,[2] and the chance of finding anything of value, unless something is found higher up, so small, that for the present they may be dismissed from consideration.

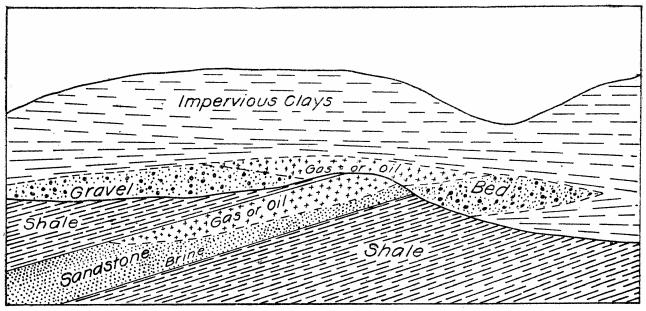


Figure 1. Illustrating possible occurrence of gas or oil. Compare the section on Plate II.

The source of oil and gas is supposed to be animal or vegetable matter buried with the rocks when they were formed, and slowly decomposed, very likely in the presence of salt water. The vegetable matter is supposed to make the lighter oils, which are free from sulphur. The same vegetable matter gives the dark coloring to the black shales which we find both above and below the Berea Grit.

[1]There are beds of shale in the sandstone, and sandstone in the shale.

[2]The Niagara very likely begins not more than 200 or 300 feet below the Alpena rock salt horizon, is liable to be 800 feet thick, and will be succeeded by a series of red, blue and black shales, 600 feet thick or so, beneath which will come the Trenton.

Now the first place in which we might find oil or gas is in the surface deposits. It may occur in these in one of four ways.

(a) In the first place, fragments, stones and boulders of the oil and gas generating strata may be scattered in the surface gravels or till, and the oil and gas slowly collect in pockets or pools under beds of clay, which may serve to hold it down. This may be in part the source of the gas in Killmaster well No. 2. Such gas may occur anywhere in the county and is probably the source of most of the gas of the surface gas springs, but is not likely to be of much value.

(b) In the second place, a porous inclined bed which holds or generates gas may be covered by a gravel bed, and this in turn by clay, as shown in the sketch just given.

In that case the gas and oil may work out from the outcrop into the gravel bed. Part of the Killmaster gas might thus have worked out of the little bed of sandstone below, and accumulated in the gravel.

Now it seems quite probable that accumulations of oil or gas of value might thus have been formed beneath Alcona county. The coating of surface deposits is thick enough to give a good pressure, and usually is clayey and impervious enough to hold the gas down well.

In particular it would seem quite possible that, especially where the Berea Grit comes directly beneath the surface

deposits or the black shales above and below it, gravels occurring at the base of the same might be full of oil and gas under good pressure.

If we assume the dip southward of 38.4 feet per mile found above, the Berea Grit will be as high as the rock surface of Killmaster at a point about 8.6 miles north of Killmaster and should be at an equal elevation along the line of strike, that is, a northeast-southwest line* through this point. It is worth noting that Mr. Leverett has not found the white sandstones, such as the Berea and Marshall are, north of a point two miles south of Lincoln, though red sandstones resembling the Potsdam sandstone occur all over the county. Wells along this line would be desirable to test the possibilities of oil and gas in this way.

It must be remembered that the chance of striking moderate quantities of oil or gas enough to supply a few houses are very much more than those of striking very large quantities, such as would warrant starting a new town, so that in planning such wells they should be placed where they would be of use.

(c) In the third place, it is possible that there might be cracks in the earth's crust made by earthquakes, or otherwise extending down into lower reservoirs of oil or gas and allowing them to work toward the surface.

This is a very popular theory of the origin of oil and gas in springs and has caused many thousands of dollars to be thrown away in exporations. There are no indications of such faults and fissures, however. The gas springs around Killmaster are not in a line. The strata of Lower Michigan are not usually much disturbed, and even if they were, a leaky reservoir is no sign of great and valuable accumulations.

(d) A certain amount of illuminating gas, marsh gas, is often generated in swamps directly from the decay of recent vegetable matter, and is of no economic importance.

*Compare the line BB of Plate II.

Attention was called to the possibilities of gas in the county by a number of springs, which either yield inflammable gas continuously or when stirred with a pole. The following notes on them are compiled from notes by Mr. Leverett and myself.

Near the center of Sec. 26, T. 26 N., R. S E., there is a boiling spring on the land of the Gustin Land Company which has such a large amount of gas that it led to the Killmaster borings. The gas wall blaze two or three feet high when lighted as it issues from the water, without being confined in a pipe. It is at least 10 feet below the level of Killmaster well No. 1, and the temperature of 44° F. one bitter, freezing cold day in November is close to the probable mean annual air temperature, and may indicate that the water comes from some depth. The water is hard and has a little chlorine,[1] but not enough salts to affect its gravity.

In Sec. 14 of the same township there is a gas spring on B. Anger's land in the north part of the section and on Mr. Gunther's land in the west part.

In Sec. 32 of the same township there is a gas spring on land of the H. M. Loud Company. In Sec. 34 there is one on the land of Simpson & Henry. In Sec. 15, T. 25 N., R. 8 E., that is the township south, there are two gas springs on the land of Ambrose Thompson. Aside from the above noted springs, there are said to be numerous places along the east branch of Pine river where gas bubbles up in the bed of the stream.

Mr. Killmaster has also noticed oil in the well of Angus Cameron, Sec. 12, T. 28 N., R. 5 E.

The next place we might expect gas or oil is in the sandstones, and particularly the Berea Grit. They would tend to accumulate in larger quantity here:

(a) Where there is an upward bend or anticlinal in the bed. Of a complete anticlinal or dome there is no evidence. In fact, as we have seen, the indication is of a fairly steady dip to the southwest.

But in a basin like that which is formed by the rock beds of Michigan there are liable to be flutings around the side, folds pitching toward the center of the basin. In such case the strike would veer now to one side and now to the other of its mean course. Now the fishermen bring up on their nets about 7 miles off Harrisville, in about 14 fathoms of water, fragments of peculiarly-honeycombed limestone, over the reef, similar to that described by Bell.[2] If this limestone reef is a real outcrop of bed rock, which is by no means certain, it would probably represent the limestone at the top of the Traverse formation. But in that case the strike from the reef to Partridge Point in Thunder bay would be north of northwest.

Again we may see, comparing the Killmaster and Oscoda walls, that if the dip is no greater than that farther north the strike must be considerably to west of northwest. Thus it is possible that there may be such flutings. In order to find them out, however, it would be needful to have more wells, put down to some recognizable stratum and arranged in a northwest to southeast line, so as to find out accurately the course of the line of strike. Then the points where it is most to the southwest of its mean course will be the tops of bends which may collect oil and gas.

[1]Ca is strong; SO_4 trace; Cl. low. Sp. Gr. 1.001?

[2]Ante, p. 65.

(b) In the second place the gas and oil might collect in the upper parts of the oil and gas-bearing beds where they were overlain by clay. This is also illustrated in the section of Plate II, as well as in the sketch on p. 71.

In this case we have practically one-half of the anticlinal, the rest being cut away, and its place taken and the escape of gas prevented by the clay. The best places to test this would be the same as those to test previous possibilities,—a belt parallel to the strike and about

where the Berea Grit will lie directly under the surface materials. Just where that will be cannot be told, for we do not know how deep it is to bed rock; but if we suppose the elevation of the extreme limits of the Berea Grit to be between that at Killmaster and that of the exposures and wells north, the Berea Grit will extend to somewhere between Harrisville and Sturgeon Point, extending thence northeast and reaching as far as a point about eight miles north of Killmaster. And near this line explorations will be not only cheapest, for the depth will be comparatively slight, but most likely to be fruitful.

Drilling may well be on low ground at first, and valuable flowing wells may very likely be obtained, though of course any flows of water would have to be shut off temporarily in testing for flows of oil or gas.

(c) The Berea Grit is rather an uncertain element, sometimes present and sometimes not, and if areas where it is present and porous are isolated by erosion with a covering of shale and clays, or merely pass by transition into shalier and less porous beds, it is possible that the more porous parts might become reservoirs for gas and oil. For instance, the Berea Grit around Killmaster seems to have been much more porous than at Oscoda.

Areas of this kind might, of course, occur anywhere the Berea Grit occurred; that is, anywhere except in the northeast corner of the county. Here, as the new railroad cuts, for instance, of the "Stone Ridge" on Sec. 35, T. 28 N., R. 9 E., show by the abundance of slabs of black shale and total absence of the Berea Grit, the underlying rock is the Antrim black shale of the Devonian.

I would suggest as appropriate places for test wells for oil or gas, Harrisville very particularly; some point in the Black river valley near the south line of T. 27 N., R. 9 E.; the neighborhood of Lincoln; the valley of Sucker creek, and the eastern shore of Hubbard lake.

If bed rock surface was found unusually high, and the backward curve in the moraines which indicate the ice margin suggest the possibility of such a thing, it might be worth while to explore farther north. But a few wells in the regions suggested, not over 300 feet deep probably, would be very instructive. In particular would I recommend the sinking of a well at Harrisville, not only to see what the oil and gas prospects were, but also with a city water supply in view. It will not be safe to use water from Lake Huron and let sewage go into it also.

Salt.—There are two sources of salt manufacture, natural brine, and rock salt, which is dissolved by pumping down upon. The disadvantage of brine is that it is liable not to be so strong, and to contain so much earthy chlorides (Ca, Mg) Cl_2, that a large amount of the bittern must be thrown away. On the other hand, the Berea Grit is generally remarkably free from calcium sulphates and not likely to cake, and at 550 feet and lower in Huron county, at White Rock, Port Huron, Port Austin, etc., proved a satisfactory brine and made remarkably pure salt. The sample from Killmaster is not as strong as could be wished, but may have been diluted somewhat with rain water. No doubt south of Killmaster it would be stronger, and if the Berea Grit were porous enough to yield the brine freely would be very satisfactory for salt manufacture.

the brines of the Dundee are too strong of sulphur and other salts than sodic chloride to be good for making salt. But the rock salt at Alpena ought not to be more than about 1750 feet deep at Black river, about the depth it is along the St. Clair river. Moreover, if from the salt one wished to make soda—a great and growing industry of the State—limestone, which is the other chief raw material, can easily be obtained by rail or boat from Alpena county.

As the section shows, the rock salt would soon be quite deep as one went south, and to test for rock salt at Black river or north, one should plan for a well 2000 feet deep.

Water and mineral water.—The county is well watered at present, yet some of the best farming lands are the lands originally marked as swamp lands. These often turn out to be fairly heavy clay lands, as around Gustin and the lower valley of the Pine. Here deep wells will first be needed.

The well water is hard and the stream water is not very soft. The character of the Killmaster water has been already described.

The drift is thick and usually ample supplies of water for domestic use will be encountered in it. Water from bed rock will usually be scarce or slightly brackish, except perhaps in the southwest corner of the county, where wells into rock may strike the Marshall sandstones and find plenty of good water.

The slightly saline waters have a stimulating effect on the kidneys, and waters of the same general type as those first struck at Killmaster and Oscoda when well advertised, as the Apollinaris or Attapah, often have considerable repute. It would be possible to obtain strong saline and sulphureted waters, such as are widely exploited for bathing in the southeastern part of the State.

Peat.—There have been a number of inquiries regarding peat in my office lately. This is now compressed and manufactured into blocks for fuel in Ontario. It has been used for nursery packing, and is the soil for celery, mint, cranberries, etc. There were large areas of swamp originally in the county, but many of these have cleared up into good land and the depth of the peat was not great.

One area not yet touched, however, extends from just north of Alcona in Sec. 2, T. 27 N., R. 9 E., and follows the Black river to the junction of the two branches and up the other one. Here are extensive areas of cranberry bog and tamarack swamp with some sand ridges, which are convenient to the railroad. I do not think the peat is very thick, but do not know, and it would be convenient to develop.

Rumors of coal and lead.—Rumors of the existence of coal in the county may be ascribed to the boulders of bituminous black shale, which will burn pretty well. In fact in Scotland a similar shale is distilled for the oil in it. It has, however, no commercial value. Fragments of this bituminous shale are abundant throughout the county in the coarser deposits. About a mile north of Alcona the railroad makes a cut which exposes great boulders of shale.

There are also reports of the discovery of lead in the county, but I was not able to find, either in the hands of anyone or in the drift, any lead ore.

The fishermen off Sturgeon Point are said to have brought up lead on their nets and used it in marking barrels. Mr. Perley Silverthorne is said to have done so. Native lead is hardly ever found and the ordinary lead ores cannot well be used for marking, so that I am tempted to believe that it was some substance like black lead, perhaps a black clay, which was thus found.

The Indians are also said to have found lead up the Au Sable river. An investigation of similar rumors in Huron county led me to imagine that they might have sprung from the Indians claiming to have found lead for bullets, for the honest possession of which they could not otherwise account. When later plied with liquor that they might divulge the secret in their cups, they found the process so agreeable that they kept up the illusion. But no amount of liquor could ever reveal the secret, for the simple reason that there was none to reveal.

ALPENA COUNTY.

In the summer of 1900 Mr. A. W, Grabau, then of the Massachusetts Institute of Technology but now of Columbia University, an accomplished paleontologist, whose "Scientific Guide to Niagara," issued by the New York State Survey, must make his name widely known, visited Alpena for us. My object in sending him was in particular to study and call attention to the high-grade limestones of that region. The account of his field work, in which he was assisted by W. F. Cooper, arrived too late for inclusion in my last annual report and was printed in the American Geologist.

Last summer he spent another month on his way back from the summer school of Columbia University in the Upper Peninsula. Some samples collected by him were very thoroughly analyzed by W. E. Brady of the Illinois Steel Co., and we have also a suite of analyses of the Bolton quarry, for which we have to thank Mr. M. J. Griffin.

The results of his studies will be found elsewhere incorporated in a preliminary study of the economic value of the limestones of the State.

Although Alpena county is very interesting in more respects than one, we can hardly prepare an elaborate report until we have a better topographic base. It is, however, one of the best places in the State to collect fossils, and a guide illustrating them for popular and school use should be prepared. A good detailed county report would, however, be worth all it would cost if the topographic base were ready.

KENT COUNTY.

As stated in my last annual report, I seized the opportunity offered by Mr. Nellist's interest to arrange for contour map of Kent county, which would be of immediate service and could later serve as a base for a detailed county report. Unfortunately, I have not had funds to pay him enough to justify his devoting his whole time to it. The map is, however, practically complete as to field work and will, I hope, be ready for publication with this report. In the meantime his notes have been of service to Mr. Frank Leverett of the United States Geological Survey, who has been making studies of the surface geology. Miss Emma J. Cole of the high school has recently published an elaborate list of the plants near Grand Rapids, and Dr. Burton E. Livingston of the Hull Botanical Laboratory of the University of Chicago, basing his studies upon the work of Nellist, Leverett and Cole, has prepared the appended very interesting study and map of the plant societies of the county, a study of the connection of the botanical distribution with the soils and surface geology.* It is valuable in itself, for it is practically a map of the soils of the county, but it is even more valuable as an excursion into a field lying between geology and botany, agriculture and forestry, and showing the problems which should be studied and solved by judicious cooperation.

Of great importance, if verified, to forestry is his suggestion that it is chiefly the capacity of the soil to retain moisture that determines the distribution of the different societies of trees upon the uplands, and that in this respect humus accumulated by dead leaves, etc., may replace clay, so that little by little even upon a light sandy soil, the jack pine may be replaced by the white pine, and that in turn by the maple and beech.

It will however be essential to study not only the surface distribution of the sand and clay, but also, as has been suggested, the depth of the same.

*This department has been quite active lately in studies of the kind to interest Michigan folk. See the references which Dr. Livingston gives, and also, "In Urwald," a lecture by E. Desor, published in the volume of Oeffenttiche Vorträge, in Basel, 1881. (Boston Public Library.)

THE DISTRIBUTION OF THE PLANT SOCIETIES OF KENT COUNTY, MICHIGAN. BURTON EDWARD LIVINGSTON.

INTRODUCTION.

1. A New Field for Research.—It is a matter of common knowledge that the vegetation of any extensive area is made up of a greater or less number of plant species mingled and growing together. It is also

generally known that these different species naturally fall into a number of somewhat distinct groups, giving to certain tracts of country an entirely different aspect from that of other tracts nearby. One who has traveled about the Southern Peninsula of Michigan can hardly have failed to notice, for instance, the differing vegetations of the pine plains, the oak forest, and the beech and maple forest. There is hardly a single plant found common to the first and last of these groups. They are as distinct as would be so many human commonwealths composed of different races of people. It is with the study of such plant groups that the present paper has to deal.

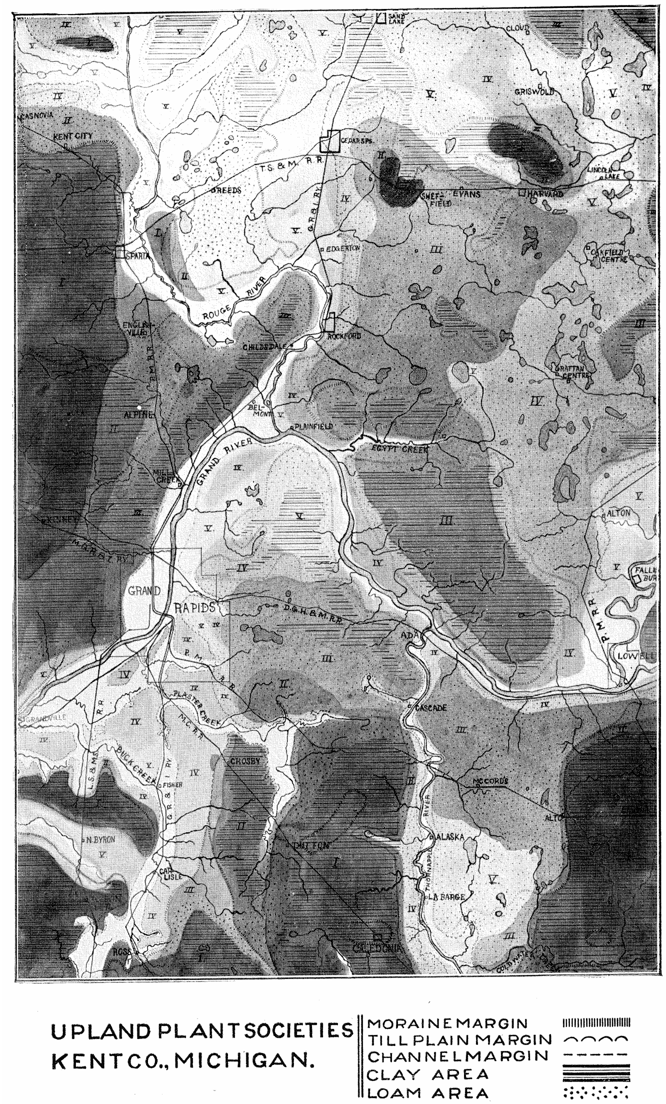


Plate III. Plant Societies of Kent County, by Burton E. Livingston.

In some instances the study of these groups of plant forms has been undertaken by geologists, and their part in the work has been marked by the frequent use of the geological term formation to designate the groups. The word is still in use by many students of the subject, especially with reference to the larger and more comprehensive complexes. Among botanists the term *plant society* to mean the same thing has been suggested and quite largely used within the past few years. It seems somewhat more appropriate than the other word, on this account, at least, that it implies the idea of an organism and organic unity rather than that of a unity of mere juxtaposition in time and space. The latter word will be used throughout this paper.

A plant society, then, is a group of several or many species growing together over some more or less extensive area, and characterized by an apparent congeniality and community of interest, such that all thrive under the same general conditions. Since for any large area the ground will be occupied, not by a single society but by several, which will alternate with each other in some irregular manner, the next logical step after the determining of the societies themselves, will be to attempt the formulation of whatever principles may underly their arrangement or distribution over the surface of the region. How far success or failure has attended the attempt here made to determine some of the principles which underlie the distribution of the plant societies of Kent county, can be judged better at a later day, but it is hoped that this paper may stimulate and aid the prosecution of similar studies in related regions. Another more special reason for this research is this, that if the flora of these more thickly settled counties is ever to be studied and recorded, this work must be done soon; the present vestiges of the former primeval flora are fast disappearing.

Plant distribution has been a common subject for discussion among botanical authors for over a century, but (aside from the discovery of a few broad climatic factors which seem to determine the distribution of great vegetation types over world areas) little of a definite and satisfactory character has been attained. This is perhaps in great part due to the fact that species and not societies have usually been studied, thus causing general principles to be lost sight of in a mass of detail whose organization proved well-nigh impossible. It may also be due, in part, to the broad areas chosen for investigation, and the hasty and superficial study which of necessity resulted. Perhaps this general birds-eye viewing had to be done to prepare the way for more exact work, but it seems that enough of it has now been accomplished. What is needed now, if there is to be formed even an acceptable working hypothesis of the principles of plant distribution, is the careful and exhaustive study of areas of limited extent. Once having these studies at hand, comparisons between the different areas may be instituted, and thus, perhaps, some sort of a universe may be forthcoming from the present chaos.

2. Literature.—On account of the comparative newness of what may be termed the *society method* of study, as contrasted with the older species method, there is very little literature which can have any bearing on the present work. By far the most valuable paper which has come to my notice is that by Dr. T. G. Chamberlin,[1] of the University of Chicago, on the native vegetation of eastern Wisconsin. But the development of the society method of study for limited areas has, so

far, been almost entirely due to the work of Dr. H. C. Cowles and his students. In his recently published account of the plant societies of the Chicago area[2] Dr. Cowles has given an excellent review of the most important articles upon the general subject of plant societies. It will therefore be unnecessary to enumerate them here, espcially since they have no direct bearing upon the flora of the region here studied. In this paper the author makes an attempt to classify the plant societies of the Chicago area according to the physiographic stage of the land which they occupy. For instance, the life history of the flora of a typical ravine in a clay moraine is here traced out in some detail, from its beginning as a small gully in the hillside, through all the physiographic changes accompanying the progress of erosion, to its temporary culmination in a broad flood plain. The thesis of the article is briefly this: that as the physiography of the land surface changes, so must the vegetation clothing it change also. Other papers having a very close bearing upon the historical aspects of our problem are another one by Dr. Cowles,[3] and the still more recent one by Mr. H. N. Whitford.[4] The bearing of these papers upon the conclusions here brought out will be introduced in connection with the development of the present work.

[1]Chamberlin, T. C.: Native Vegetation of Wisconsin. Geology of Eastern Wisconsin. 2:176. 1873—1877.

[2]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. of Chicago, 2:1-76. 1901.

[3]Cowles, H. C.: The physiographic ecology of Northern Michigan, Science 12:708, 709, 1900.

[4]Whitford, H. N. The genetic development of the forests of Northern Michigan; a study In physiographic ecology. Bot. Gaz. 31:289-325, 1901.

3. Kent County, its Climatology.—Kent county is so situated that it is traversed both by the southern boundary of the pine forest region and the eastern boundary of the so-called Michigan peach belt. It is also crossed by the Grand river valley, the line of one of the great main channels by which the melting ice of the glacial period reached the Mississippi system and the Gulf, and also the line marking the farthest northern extension within the peninsula of many typically southern plants. The county embraces-a rectangular tract of land 24 miles by 36 miles in extent, its western boundary is a meridian averaging about 23 miles east of Lake Michigan at its widest part. The lacustrine influence upon the climate is probably felt throughout the county. Owing to the comparatively small extent of area, differences in climate between its different parts could hardly be pronounced enough to cause any marked difference in its vegetation. Also on account of the great distance apart of the stations for meteorological observations, if there were lesser differences between the climates of different portions of the county, such would not be brought out by any records which have been made. Therefore a study of these meteorological data will give no clue to the principles underlying plant distribution within our area. The following tables are given here, not that they may be of any use in the present report, but that they may be on hand when this area is to be compared with another. They give the data by months for such stations as lie within or near the county:

AVERAGE TEMPERATURE BY MONTHS FOR THE KENT COUNTY REGION.[5]—DATA ARE IN DEGREES FAHRENHEIT.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
White Cloud	.....	.....	.....	44.6	55.9	65.9	72.0	67.8	61.0	51.6	39.4	27.5
Stanton	23.6	22.6	25.9	.....	54.9	65.6	69.7	65.8	60.5	47.0	33.9	19.3
Muskegon	24.2	21.7	30.2	44.7	55.2	65.5	69.8	67.9	62.1	49.9	36.9	28.2
Grand Haven	24.2	25.0	30.6	43.6	53.7	64.4	68.8	67.0	60.9	49.6	37.1	26.4
Ionia	.....	.....	32.0	46.0	.....	68.2	72.0	69.4	61.2	50.8	37.4	26.1
Grand Rapids	24.8	24.9	31.2	47.2	59 0	68.2	72.3	69.2	62.3	49.0	37.4	30.9
Waverly	.....	21.2	31.8	.....	55.6	.....	.....	69.3	61.6	49.4	37.0	27.1
Hastings	23.4	25.0	31 6	46.0	57.7	67.7	71.2	68.7	61.6	49.4	37.4	29.6
Allegan	23.7	24.2	33.8	47.7	.....	68.6	72.2	69.3	63.1	49.1	37.5	30.2

[5] These tables are compiled from the reports of the Michigan section of the U. S. climate and crop service.

AVERAGE PRECIPITATION BY MONTHS FOR THE KENT COUNTY REGION.[5]—DATA ARE IN INCHES.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
White Cloud	.....	.....	.....	2.40	7.15	2.09	2.96	1.32	2.52	3.00	1.37	1.99
Stanton	.....	.....	.....	1.98	.....	.....	.....	1.93	3.34	2.36	2.47	2.65
Muskegon	4.36	2 32	1.85	1.61	2.59	1.48	2.55	1.30	3.27	2.32	2.20	1.76
Grand Haven	2.66	2.21	2.29	2.53	3.42	3.87	2.71	3.67	3.55	3.22	2.99	2.65
Ionia	.....	.....	.....	1.67	.....	2.02	1.94	1.17	2.84	1.97	1.99	2.36
Grand Rapids	2.87	2.76	2.18	2.74	3 34	4.53	2.82	2.56	3.12	2.91	3.15	3.09
Waverly	.....	1.94	3.18	.....	2.58	.....	.....	1.22	4.20	2.13	3.11	2.59
Hastings	2.60	2.03	2.12	2.68	4.02	4.06	2.26	2.74	3.12	2.62	3.11	2.98
Allegan	2.42	2.22	.....	2.66	4.50	2.67	2.73	2.33	3.07	2.47	2.77	2.98

4. Geology of the County.—The bed rock of the area is almost entirely covered to a great depth by glacial drift, only a few small outcrops being found within its limits. A small portion at the northeast angle is underlain by the Jackson coal-bearing strata, a correspondingly small area in the extreme southwest is underlain by the Marshall sandstone, and all the intervening drift rests upon the formations of the Grand Rapids group.[6] The drift is so deep throughout the county that the underlying rock layers have apparently no influence upon the vegetation.

The drift itself presents some very interesting features[7] and, since these have an important bearing on the problem of vegetational distribution which confront us, it will be necessary to describe them in some detail.[8] The land consists, in general, of two great blocks of till upland lying on either side of a much lower gravel and sand plain of varying width, which extends in an irregular line from about the middle of the northern boundary (see map, Plate III) southward through Cedar Springs, Rockford, Plainfield, Grand Rapids, Fisher, Carlisle and Boss, and cutting the southern boundary about three miles east of the southwest angle of the county. This plain traces the path of the outflowing water as the Michigan ice sheet retreated northward at the end of the last glacial epoch. An indentation or embayment in the southern ice margin during this retreat marked the junction of the two lobes of the glacier, the eastern lobe coming from the region of Saginaw bay, the western from that of Lake Michigan. It was naturally into this embayment that much of the water was discharged

during the melting process, and the line of sandy plains just traced marks, from Carlisle northward, the path of this gradually retreating notch in the edge of the ice. Southward of Carlisle the Green lake sand and gravel plain (in Allegan and Barry counties) originated in the same way.

[5]These tables are compiled from the reports of the Michigan section of the U. S. climate and crop service.

[6]See Geological Map of Lower Michigan, compiled by A. C. Lane, Mich. Geol. Sur. V, 1893.

[7]For aid in interpreting the glacial topography I am indebted to Mr. Frank Leverett, of the U. S. Geological Survey.

[8]A brief description of these features, by Dr. A. C. Lane, will be found in the introduction to Miss E. J. Cole's Grand Rapids Flora. Grand Rapids, 1901.

Three well marked terminal moraines lie partly within this area. The one earliest formed merely bends across the southern boundary, lying south of a line drawn from Ross to a point about two miles east of Carlisle, and thence out of the county in a southeasterly direction to Middleville and Hastings (Barry county). When this material was deposited, the embayment between the two glacial lobes had its head north of Green lake (Allegan county), and its outflowing water found its immediate outlet southward. It formed by its outwash the great triangular plain—which I have designated by the name *Green lake*—bounded on the north by a line drawn from Green lake to frying (Barry county), and on the west by one from Green lake to Bradley (Allegan county). This plain and its margins being the only regions studied south of the Kent county line, it was thought unnecessary to include it on the map. The highest point of the moraine just mentioned is just east of Corinth. This is the junction point of the two moraines formed from the Saginaw lobe on the east and the Michigan lobe on the west. Thus the high land lying to the east of a line joining Green lake and Corinth is composed of materials from the region of Lake Huron and farther north, while that to the west is composed of drift from the Lake Michigan and Lake Superior region.

The second moraine passes through the middle of the county. Its southern edge is marked by the Grand river valley, its eastward termination being the margin of the plain of Flat river. The escaping water, at the time of its formation, found its way out to Lake Michigan apparently by two channels, one being the present valley of the Grand from Grand Rapids westward, the other extending directly southward to Ross, where it also began to bend toward Lake Michigan. The highest point, marking the junction of the two lobes, lies north of Plainfield.

The northernmost moraine has its highest point northeast of Cedar Springs. The sand plain formed by the outwash here extends from a point about three miles north of Cedar Springs south through Edgerton to Rockford. Its width north of Edgerton is from four to live miles, but near this village it begins to narrow rapidly and is joined by the Rouge valley. South of here the outflow of water cut a deep channel about one-half mile wide through the last moraine described, from a point about a mile and one-half north of Rockford to Childsdale. There the glacial stream entered the plain of the previous outwash. Following the old line of flow it cut a new channel in the already existing plain. Where the old plain divides, south of Grand Rapids, the newer channel is found to do the same. One of the branches follows the present Grand, being, of course, much wider than the flood plain of that stream and extending from the moraine margin about two miles farther to the southeast than the line of the Holland division of the Pere Marquette railroad. This railroad roughly traces the marginal line of the present flood plain. The other channel extends from the point where the Michigan Central railroad leaves the Grand! Rapids & Indiana railroad, southward to Ross, thence southwest to Lake Michigan.

Besides the plains just described, there are very pronounced though narrower sand-gravel plains forming the valleys of the Rouge and Thornapple rivers, and a broader one through which the Flat river meanders.

Most of the surface soil throughout the country is predominantly sandy. There is so much sand in the till that almost every creek valley is a miniature sand-gravel plain. Especially is this true of Plaster creek; southeast of Grand Rapids, and of the larger creeks in the northern portion of the county. In classifying soils and designating them on the map, no attempt has been made to distinguish the different gradations between clay and sand. All which could not be termed either clay or sand have been bunched together as loam,—in the broadest sense of that word,—and denoted on the map by dots. More accurate records were made, but it was found that these minor differences of soil bore no apparent relation to the nature of the societies recorded, and it was thought best not to encumber the map with unnecessary details. Clay is denoted on the map by horizontal lines, sand by an absence of any marking. It will be noticed that moraine and till plain margins are not always the boundary lines of soil areas. This is explained by the fact that the sandy soil almost invariably borders and faces whatever escarpment there may be along a moraine or till plain edge; indeed, it often extends back from the edge for several miles on the higher level. This is true for even slight depressions. Anyone who has ridden a bicycle through Michigan must have noticed that where the road is on a higher level it may be hard clay, but where it descends to cross a creek the slopes and bottom of the valley are usually sandy. This illustrates the fact just stated. The process of erosion by which this condition of things is brought about is going on rapidly at present; the creek valleys are becoming more sandy rather than less so. On account of their small area, no attempt has been made to map these sand .and gravel deposits. They are to be understood as existing along most of the creeks and about many of the lakes.

METHODS.

The studies here reported were begun at the suggestion of the State Geologist, Dr. A. C. Lane, in the autumn of 1900, and were completed in the summer of 1901. The author's previous botanical study in the vicinity of Grand Rapids, although not made definitely for this purpose, has been of value in the present work.

Owing to the large proportion of cultivated land in the county, and the correspondingly small proportion which is in an approximately natural state, a study of the natural plant societies is necessarily a difficult one. In the middle of a section, and hence farthest away from the roads, is usually quite a stretch of wooded land, and throughout much of the county these wood lots at the rear of the farms have been the field of observation. From these areas, taken here and there,—samples of the original vegetation, as it were,—an attempt has been made to reconstruct, as accurately as possible, the plant societies which occupied the region at the time of settlement. The effects of pasturing in these wood lots have been allowed for as far as possible. Information has been gathered from local residents as to the nature of the forest which was removed in making certain fields ready for the plow, and has been of great service in some instances.

The vegetation of the area falls naturally into two groups, that growing on what is commonly termed dry ground and that found in moist or swampy places. Each of these groups can be separated into several societies, which often merge gradually into one another so that in some localities it appears that we have a mixture of several of them. But in general the division is sufficiently well marked. In the following discussion the two primary groups will be taken up separately.

THE UPLAND SOCIETIES.

1. *The Societies Characterized*.—The range of altitude over the whole county is less than 400 feet; so that absolute altitude itself, with its concomitant variations in climatic conditions, is not a factor in the distribution of the flora. Differences in relative level, however, produce marked variations in the drainage, and hence in the water content of the soils. This is an important factor in plant distribution.

The vegetation of the upland falls into five societies, which may be characterized as follows:

I. Beech-maple Society, comprising as predominant and characteristic the following plants: Beech, sugar maple, enchanter's nightshade (Circæa), wild licorice (Galium lanceolatum), wood nettle (Laportea), catnip (Nepeta), pokeweed (Phytolacca), rich weed (Pilea), nightshade (Solanum nigrum), and red-berried elder.

II. The Maple-elm-agrimony Society, comprising: sugar maple, American and rock elms, agrimony, spikenard (Aralia racemosa), honewort (Cryptotænia), spice-bush (Lindera), moonseed (Menispermum), black snake-root (Sanicula), and wild black cherry.

III. The Oak-hickory Society, comprising: white and red oak (*Quercus rubra-coccinea*), shag-bark and pig-nut hickory, false Solomon's seal (Smilacina racemosa), northern bedstraw (Galium boreale), Aster lævis, and panicled cornel. This society is much the same as the following, but with the addition of the two hickories. It also has many plants in common with the previous society, and may be regarded as an intermediate type between II and IV, both of which are much more distinct. Owing to the difficulty of distinguishing sharply between *Quercus coccinea* and *Q. rubra*, these two forms have been brought together under the name *Q. rubra-coccinea.*

IV. The Oak-hazel Society, comprising: the white and red oaks, Aster lævis, A. macrophyllus, New Jersey tea, hazel, spurge (Euphorbia), Helianthus occidentals, Solidago cæsia, and hoary pea (Tephrosia). The spurge found in this society is the broad-leaved form. In the following society this plant is just as common and characteristic as here but there it has much narrower leaves. The individuals of the broad-leaved form appear stronger, greener, and more robust than the others.

V. The Oak-pine-sassafras Society, comprising the white and red oaks, white pine, sassafras, plantain-leaved everlasting (Antennaria), wormwood (Artemisia), sand bur, spurge (narrow-leaved form), huckleberry (Gaylussacia), lupine, sweet fern, braken, and Solidago nemoralis. This includes the dryest and most open form of "oak openings" together with the country which was once quite well covered with pine. They are put together here, because aside from the now partially extinct white pine the floras are practically the same.

To one who knows the woods it will be apparent that in these five societies we have a gradation from the close, compact formation of the beech and maple forest, where the sunshine seldom reaches the ground, to the very open and sunny oak openings and pine plains. It would naturally be supposed that the denser societies are living under more favorable conditions for growth than the more open. This, indeed, we shall find to be the case.

A more extensive list of plants is given in the following table, which shows almost graphically the distribution of the enumerated plants throughput the five societies. The nomenclature is that of the sixth edition of Gray's Manual.[9] The Roman numerals heading the five columns at the right of the names indicate the societies by number, the same method of indication being also adopted on the accompanying map. The letters opposite the plant names show in what societies the plant occurs, the relative abundance in that society being denoted by the letter itself. C denotes common; F, frequent, and R, rare. An asterisk accompanying the letter expresses the fact that the plant is one of those to be regarded as characteristic of that society. Our *rare* has not the meaning given the word by the systematist; plants which he would consider rare are not sufficiently

abundant to be considered at all in such a list as the present.

A very complete list of the Pteridophytes and Spermatophytes of Grand Rapids and vicinity has been recently published by Miss Cole.[10]

[9]Gray, Asa: Manual of the botany of the Northern United States, 1889.

[10]Cole, E. J.: Grand Rapids Flora. Grand Rapids, Mich., 1901.

Table of the Upland Plant Societies

TABLE OF THE UPLAND PLANT SOCIETIES.

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Acalypha Virginica	Three seeded mercury	F	F			
Acer rubrum	Red or swamp maple	R	F	R		
Acer saccharinum	Sugar or rock maple	C*	C	R		
Actæa alba	White baneberry	F*				
Adiantum pedatum	Maidenhair fern		F			
Agrimonia Eupatoria	Agrimony		C*	F		
Andropogon furcatus	Beard grass					C*
Antennaria plantaginifolia	Plantain-leaved everlasting					C*
Aralia racemosa	Spikenard		C*	F		
Artemisia caudata	Wormwood					C*
Aspidium acrostichoides	Christmas fern	F*				
Aster cordifolius		F	C	C		
Aster lævis				C	C*	
Aster macrophyllus				F	C*	
Boehmeria cylindrica	False nettle	C*	F	R		
Carpinus Caroliniana	Blue or water beach		C*			
Carya Alba	Shag-bark hickory		F	C*	R	
Carya porcina	Pig-nut hickory		F	C*	R	
Ceanothus Americanus	New Jersey tea			R	C*	F
Cenchrus tribuloides	Sand bur					F*

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Chimaphila umbellata	Prince's pine			R	R	F*
Circæa Lutetiana	Enchanter's nightshade	C*	R			
Cornus alternifolia	Alternate leaved cornel		C	C		
Cornus florida	Flowering dogwood		C	F		
Corylus Americana	Hazel			F	C*	F
Cryptotænia Canadensis	Honewort		C*	F		
Cynoglossum Virginicum	Hound's-tongue	F*	R			
Diervilla trifida	Bush honeysuckle				F	C*
Dracocephalum parviflorum	Dragon head	F*				
Echinospermum Virginicum	Beggars lice	C*	R			
Epigæa repens	Trailing arbutus					F*
Epiphegus Virginiana	Beech drops	C*				
Euphorbia corollata	Spurge			F[11]	C*[11]	C*[12]
Fagus ferruginea	American beech	C*	R			
Galium boreale	Northern bedstraw		F	C*		
Galium circæzans	Wild licorice	F*	R			
Galium lanceolatum	" "	C*	R			
Gaultheria procumbens	Wintergreen				F	C*
Gaylussacia resinosa	Black huckleberry				F	C*
Gerardia quercifolia	Smooth false foxglove			F	F	F
Geum album	Avens		C*	R		
Hedeoma pulegioides	American pennyroyal	F*				
Helianthus divaricatus	Sunflower		R	F	C	C*
Helianthus occidentalis	"				F	C* F
Hepatica acutiloba	Liverleaf	C	C*	C		
Hepatica triloba	"			C	C*	
Hieracium scabrum	Hawkweed			F	F	C*
Juglans cinerea	Butternut		F	R		
Juglans nigra	Black walnut		F	R		
Laportea Canadensis	Woodnettle	C*	F			
Lechea minor	Pinweed					C*
Lespedeza polystachya	Bush clover				F	C*
Lespedeza Stuvei intermedia	" "					C*
Liatris cylindracea	Blazing star					C*
Liatris scariosa	" "					C*
Lindera Benzoin	Spice bush		C*			
Lobelia inflata	Indian tobacco	C*	R			
Lupinus perennis	Wild lupine				R	C*
Medeola Virginiana	Indian cucumber root	F*				
Melampyrum Americanum	Cow wheat				F	F*

[11] Broad-leaved form.
[12] Narrow-leaved form.

2. Distribution of the Upland Societies.—This is shown by the map (Plate III). From the darkest to the lightest of the live shades used a gradation is shown corresponding to that in the societies from I to V. The sixth and lightest shade denotes deeply-eroded channels occupied chiefly by lowland societies. In these channels the areas occupied by the different societies are so limited that any satisfactory representation of them on the scale of the present map was deemed impossible. Therefore they are left unshaded. Also the lowland societies along the margins of smaller streams and lakes and in swamps among the hills are omitted entirely from the map. The reason for this is in part the same as the one given for the larger channels, and also in part this, that although some of the swamps are large enough to map well on the present scale, yet to trace their margins accurately would require more time than it would be worth, and to map them inaccurately would not be true to the instinct of the work.

Steep slopes where erosion is at present rapid, as along the margins of the many stream valleys and along old glacial channels, are occupied by societies III, IV and V. The character of the soil seems to make no difference here, the drainage being quite complete and the accumulation of humus impossible. It has also been found impracticable to indicate these very narrow areas upon the map.

In the southern tier of townships, all the heavy clay soil, whether it be rolling moraine or level till plain, was originally occupied by the beech-maple society (I). In the lighter loamy soils are usually found the oak-hickory society (III), with transition zones between it and (I) held by the maple-elm-agrimony society (II). The very sandy loam bordering the deep narrow valley of the Thornapple river and spreading eastward from Alaska and Labarge nearly to the Elmdale till plain, is occupied by the oak-hazel and the oak-pine-sassafras societies. This loam is in many places as sandy as the soil of the Grand river sand plain; it might almost have been denoted as sand.

Within the "big bend" of the Grand river is an area of decidedly clayey country occupied by the oak-pine-sassafras society (V), although here the pine is not at all prominent. It appears as though this area were well on the way toward society IV at the time of clearing. But the marked presence of sassafras, wormwood, sand bur, Solidago nemoralis and other forms of society V, make it impossible to classify it elsewhere.

The Grand Rapids sand plain (reaching from Rockford, through Plainfield and Grand Rapids to Grandville and Ross) is generally covered with societies IV and V. The foundation soil is apparently the same throughout, being a gravelly sand, but the areas of society IV have

undoubtedly more surface humus, thus giving the soil a darker color and a more loamy texture. The higher parts of the plain, and hence the portions which have been out of water longest, are generally those to show this condition. The lower portions where violent water action probably continued after the main stream receded, and where, owing to the slope, erosion is even now well marked, bear little surface humus and are characterized by society V. Here, at the time of clearing, the pine was usually present. Transition areas between IV and V were covered with "oak openings," however. Of course much of these channel areas is swampy and hence thrown out of the present discussion.

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Menispermum Canadense	Moonseed		C*	F		
Monarda fistulosa	Wild bergamot, horse mint, balm			F	F	C*
Monarda punctata	Horse mint					F*
Myrica asplenifolia	Sweet fern					C*
Nepeta Cataria	Catnip	C*				
Onoclea sensibilis	Sensitive fern		F*			
Ostrya Virginica	Ironwood		C	C		
Phlox subulata	Moss pink					F*
Phryma Leptostachya	Lopeed		F*	R		
Physalis Virginiana	Ground cherry					C*
Phytolacca decandra	Pokeweed	C*				
Pilea pumila	Richweed	C*				
Pinus Strobus	White pine				F	C*
Polygonatum giganteum	Solomon's seal		C	F		
Populus grandidentata	Large toothed aspen					C*
Prenanthes alba	Rattlesnake root		R	F	C*	
Prunus serotina	Wild black cherry		F*			
Prunus Virginiana	Choke cherry			F	C*	
Pteris aquilina	Braken				F	C*
Pyrola elliptica	Shinleaf					F*
Quercus alba	White oak		R	F	C*	C*
Quercus ilicifolia	Black scrub oak					F*
Quercus rubra-coccinea	Red or black oak		R	F	C*	C*
Rhus copallina	Dwarf sumack				R	F*
Ribes Cynosbati	Gooseberry	C*	F			
Rudbeckia hirta	Browneyed Susan			R	R	C*
Sambucus racemosa	Red berried elder	C*	R			
Sanicula Marylandica	Black snake-root		C*	F		
Sassafras officinale	Sassafras			R	R	C*
Smilacina racemosa	False Solomon's seal		C	C		
Smilax hispida	Greenbrier		F	R		
Solanum nigrum	Nightshade	C*				
Solidago bicolor concolor	Goldenrod			F	F	C*
Solidago cæsia	"			F	C	C
Solidago nemoralis	"					C*
Solidago rugosa	"		C*	F		
Tephrosia Virginiana	Hoary pea			R	C*	C
Tilia Americana	Basswood	C	C	F		
Ulmus Americana	White or American elm	R	C*	F		
Ulmus racemosa	Rock elm	R	C*	F		

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Vaccinium Canadense	Blue berry			F	C	C
Vaccinium Pennsylvanicum	Dwarf blue berry			F	C	C
Vicia Caroliniana	Vetch		F	C*	C	
Vitis cordifolia	Frost grape		C	C		

North of Grand river it is only in the western column of townships that the heavy clay is characteristically covered with society I. In other portions of the region the clay is covered with society III, IV or V. It will be noticed that clay bearing the oak-pine-sassafras society is common in the extreme north and becomes less common southward. Societies III and IV approach each other in character as we pass northward. The hickories become less frequent and the general aspect of III becomes more that of IV. It needs to be remarked here also that the stretch of society III reaching from the Rouge river southward and lying west of Grand Rapids is a curious mixture of II and IV. Judging from the trees alone, the southern part of it would be placed in society II, but the presence of New Jersey tea, Solidago cæsia, etc., seem to place it in the oak-hazel group. Sassafras is present here to a remarkable extent and in many places, especially to the north, white pine also. The northern part of this stretch contains much pine. Altogether, the area can better be classified under III than elsewhere. In the general discussion to follow the possible reasons for the mixing will be considered.

In the bit of beech-maple society in the extreme northwestern part of the county is found the only marked instance of the presence of hemlock. This tree belongs typically with the hard wood group in northern Michigan.

In the northern part of the county white pine was almost universally present in the uplands at the time of settlement. This can be proven by stumps which are still in place or have been used in the construction of stump fences. There are pine stumps and a few trees still standing even in the beech-maple group upon areas north of an east and west line drawn through a point about midway between Cedar Springs and Rockford. South of this line the pine disappears in society I and becomes very rare in all but IV and V.

3. *Generalizations on the Upland Flora*.—Any sort of generalization upon a study of such a limited area as the present must necessarily be a hazardous undertaking. I shall venture to call attention to the following points, however, all of which must be looked upon as merely tentative suggestions:

a. The Soil Factor.—It appears that the general distribution of the upland societies is based primarily upon the nature of the superficial soil. This must be so since the roots of the smaller plants never penetrate very far into the soil, and since in the case of trees and shrubs, seed germination and the growth of seedlings is conditioned by these surface layers. If seedlings cannot develop it is clear that there can be no mature plants.

Surface soils may be classified either according to their chemical or according to their physical nature. The usual soil analyses show the relative amounts by weight of the different chemical constituents. Now it is very probable that the original till material covering Kent county was reasonably uniform in chemical constituents. That it was thoroughly mixed by the movement of the ice sheet is shown by the wealth of different minerals to be found in any small region. But the till has been more or less sorted by water action in many localities, so that in some few cases, almost pure silica is all that remains on the surface. However, in spite of this washing, the most sandy soils contain a considerable amount of other minerals.[13]

But the plant can make use of the soil constituents only after they are in aqueous solution. Now the great bulk of the soil is practically insoluble in water, and it makes no difference to the plant what may be the chemical nature of these undissolved substances. Thus it would be much more to the point to make analyses of the soil water, for it is this which effects the plant directly. Such analyses were not made in connection with the present work; the distribution of the vegetation seemed not to demand it. It is hoped that they may be made at some future time, either for this region or some similar one. It is very probable, however, that soil waters from the surface soil in different parts of this area will be found to he very nearly uniform in their salt content. We are led to this conclusion by two considerations: First, the chemical nature of the soluble part of the surface soil itself is probably very nearly uniform throughout the county. Secondly, the washed soils are usually comparatively shallow, and upward diffusion of dissolved substances probably takes place with comparative rapidity, especially when aided by the soil currents produced by changes of temperature, etc. The only localities where it is at all probable that a paucity in soluble salts would occur in the soil water, are the deep sand plains. There is some rather questionable evidence from the vegetation that such is the case in these localities. More work needs to be done before any definite decision can be made in this regard.

In classifying soils according to their physical nature, the only question which has any direct bearing upon plant growth is that of the ability of the soil to retain water by capillarity, so called. Primarily, this ability depends upon the size of the soil particles. Thus sand will retain less water than loam, and loam less than clay. The three grades of surface soil shown on the map have been indicated with this in view.

Sandy soil may be made to retain more water in two different ways, either by the addition of clay or by the addition of humus. The physical effect of the humus is very well marked. Of course the humus also adds some nitric acid and certain organic materials which are of benefit to the plant, and it also increases the amount of soluble salts at or near the surface; the humus is formed mainly from leaves, and in these organs the mineral part of the plant body is concentrated. This is perhaps an important fact in the growth of hard wood upon deep sand which is well covered with humus. Where drainage is complete and rapid, as in sand, and oxidation is also rapid, humus does not readily accumulate; but where it does accumulate as a surface layer, the ability to retain water approaches that of clay.

[13]Kedzie, R. C.: Analysis of soil of jack-pine plains near Grayling, Michigan. Annual report Mich. Board of Agriculture, 27, p. 211, 1888; also Bull. 99, 1893.

From the present study it appears that the most import ant soil factor in the distribution of the flora of Kent county is this one of the relative ability of the superficial layers to retain water. In other words, the controlling soil condition is one of drainage.

Throughout the southern half of the county, soils which retain much water are covered with society I, II or III. The only exception to this is the small clay area within the bend of Grand river. The soil of this area is apparently as good as that farther south, but it is very dry in dry weather. There is no marked humus covering. Perhaps the proximity to the well drained valley on either hand has an influence through underground drainage, but this was not looked into and the question must be left for the present unanswered.

Within the sand plain area of the southern half of the county there are several small stretches of societies I and II. Owing to the fact that at one time a much larger stream than the present one flowed through the valley of the Thornapple river, that valley has a well marked terrace between the country level and the present flood plain. This old flood plain is sandy and corresponds in manner of formation to the Grand Rapids sand plain. But in very many places this terrace is covered with societies I or II. Some of the finest "sugar bushes" which I have seen are here. The sandy soil is thickly covered with a layer of humus. These strips of hardwood are so narrow that they could not well be shown upon the map. The same condition holds on the rather high part of the plain lying west of Crosby. This is indicated upon the map. Also at the base of the escarpment forming the margin of the deeper glacial channel in the Grand Rapids sand plain there are several instances of societies I and II upon humus-covered sand. Notably is this true near the southwest corner of Grand Rapids and on the margin of the Buck creek valley near the Lake Shore & Michigan Southern railroad. In this connection it is interesting to note that beech trees are found quite commonly upon the humus-covered established dunes along the east shore of Lake Michigan.[14]

In the northern half of the county west of the Rouge river we find the heavier soils still retaining societies I, II and III. East of the valley of this river we find the country is much cut up. The clay areas are small and pretty well drained. They may be occupied by any society from I to V. That they can support society I is well shown by its occurrence in several places. Its general absence from this region is perhaps due to another cause, to be mentioned later.

East of Sparta and northeast of Cedar Springs are perfectly typical examples of society I growing upon light soil, the former without trace of pine. In the western part of the Sheffield area I was told by a resident that the clay was at least twenty feet below the surface. But in these areas the soil is deeply covered with humus. What the conditions are which cause the accumulation of the humus in one place and not in another apparently similar place, I was unable to make out. This phenomenon most often occurs in a rather low region where the sand would normally remain moist longer than elsewhere. It has been suggested that the beech cannot grow to perfection in the absence of humus, because of the symbiotic relation of its roots with certain humus fungi. The maple-elm-agrimony society, however, grows to

perfection on heavy soil with little or no true humus. It is also found on lighter soil which has a humus covering.

[14]Dr. Cowles tells me that lie has seen these beech covered dunes as far north as Frankfort, and Mr. Whitford has observed them on Manitou Island.

In the southern half of the county it seems fairly clear, then, that societies I and II will grow on rather deep sand if that be covered with humus, and that when society V is found on clay it is well drained and usually with little or no humus. Throughout the county there is an obvious difference in humus content between the areas occupied by societies IV and V, the sand of the former being mixed with vegetable debris. The intermediate society III is found on the loamy soils and on the dryer and better drained clay areas.

b. The Historic Factor.—Besides the factor of relative water content in the soils there is another which may be active in this region. I refer to what may be termed the historic factor.

As the ice sheet retreated slowly northward at the end of the last glacial period the portions of Kent county first uncovered were, of course, in the southern part. And the first parts of the sand plains to be uncovered lay also at the south, although these areas were probably under water long after the ice itself had disappeared. It is probable that the pine-heath[15] group which today reaches farthest north, reached well toward the glacier front during the ice age. And at the end of that age, the ice in its retreat was probably followed northward by vegetation, the pine-heath society leading the way. Near the ice margin the soils were probably raw, absolutely without humus, subject to great drought in summer and to extreme cold in winter. These are just the conditions in which we find the pine-heath group today in northern Michigan. It is probable that at one time they occupied all of Kent county, but the climate became warmer and more equable with, the farther retreat of the ice, and the growth of the hardy pines, etc., produced a little humus. Their roots fixed the soil so that erosion was less rapid, and perhaps the sassafras and the white and red oaks and the whole of our society V gradually crept in, occupying the better part of the ground along with the pines and heaths. Then as the soil improved the oaks became more and more numerous and the pine seedlings could not develop on account of the shade.[16] The pines thus became fewer in the south and the oaks at last predominant. This would be the stage of our society IV. But the process of working over the soil continued,—though perhaps the ice-sheet had shrunken by this time nearly to its present size,—and humus continued to accumulate in favored places; the hickories, maples and beeches of Ohio and Indiana spread continually northward over every suitable stretch of soil, as fast as it was made fit for them. When the maples and beeches reached maturity in the richest parts of the oak and hickory forest the oaks and hickories probably ceased to mature. Seedlings of these trees fail to develop well under maples and beeches, possibly on account of the dense shade. Thus we have reached the stage of our society I.

[15]This group comprises, besides several pines, two species of juniper, bearberry, hairbell, braken and several of the other forms found in our society, V. Cf. Whitford, H. N.: *loc. cit*. p. 298 *et seq*.

[16]It is known that pine seedlings fail to mature in the shade of healthy deciduous trees.

In such a northward advance, the plant societies would not progress in uniform lines, like a inarching army, regiment after regiment, as might be supposed at first thought; on the contrary, there would be many mixed areas, and the advance would often be almost imperceptible, like that of a ragged line of skirmishers. Here and there in a sterile, perhaps in a well drained portion, would be left a detachment of the advance guard, like the patches of societies V and IV in the southern townships of our county. And these would be surrounded by the later comers as they crowded on, occupying all soils in which they could come to maturity, and preventing the development of new generations of the forms previously in possession. With these thoughts in mind, a glance at the map will suggest much more than was seen before.

The beech and maple societies (considered by Cowles and Whitford[17] to be the climax society for temperate North America) extend northward along the lines of soil richest in water content, and reach farthest north in the western part of the county. This latter fact may be due to the lake influence. Chamberlin states[18] that in Wisconsin the beech is limited to regions near the lake. He believes its distribution to be determined by lacustrian climate. This is perhaps partly true here, at any rate the advance of society I has been much greater a long-the side of the county nearest the lake.[19]

Also the other societies,—II, III and IV,—are each a little in advance of the previous one, and each is apparently advancing into the area occupied by the next hardier one. In the extreme north we find almost: the entire area occupied by societies IV and V.

According to this line of thought, the reason for the predominance of the pine groups in the north is simply that sufficient time has not yet elapsed since the glacial period for these areas to be reached by the societies found predominant farther south. Along a wavy east and west line passing through Rockford lies the "zone of tension" between societies I, II and III on the one hand and IV and V on the other. This line bends far northward at the west, following the western edge of the Rouge valley as far as Kent City and Casnovia. It also bends northward to Sheffield and Harvard on the other side of the Rouge valley. Perhaps a climatic factor is operative in producing this zone of tension, perhaps the beech-maple-hickory society cannot occupy large areas to the north of it . But it seems more probable that the climate,—somewhat colder as we pass northward,—has acted only as a retarding factor, assisted by the fact that a good portion of these northern townships have a

light surface soil, which seems unsuited for the hard wood societies in the absence of humus.

[17]Whitford, H. N.: *loc. cit.* p. 302.

[18]Chamberlin, T. C.: *loc. cit.* p. 180.

[19]But Dr. Cowles tells me that in the neighborhood of Chicago beech is found almost exclusively on areas quite far removed from the lake.

The strongest point in favor of the idea just expressed is found in the fact that at the time of settlement practically all of societies I and II in the northern part of the county were well mixed with pine. In some places the pine stumps are so numerous as to raise the question whether the hard wood is not an entirely recent affair. It is probable, however, that scattered maples and beeches were mingled with the pine and that on the removal of the latter their seedlings simply took possession of the ground and shut out the pine seedlings.[20] Also in societies II and III, west of Rockford and as far south as Mill Creek the pine is still pronounced, and in many small spots society IV, or even V, still retains its hold. As has been noted before, this is a mixed group and is hard to classify. There are no traces of pine in the hard wood forests to the southward. It may well be, however, that a further extension of this study will show that this hypothesis of the historic factor is utterly untenable.

Another line of evidence seeming to throw some light upon the historical development of this flora, is that obtained from a comparison of the several sand plains of the region. As was stated in our introduction, there is a well marked sand plain just south of the boundary of Kent county, which we have termed the Green lake sand plain. The soil here is like that of the higher part of the Grand Rapids plain, shown on the map, very sandy, but with a good admixture and coating of humus so that at the surface it appears loamy. The vegetation is made up of all five of our societies. In general the type is that of society III, but there are many spots, especially on the margins of the numerous ponds and lakes where societies IV and V hold the ground. In slight depressions along the margin of the plain the humus is deep and society I is common. There are also many rather large areas of societies I and III well out in the plain. Usually these are in slight depressions, not low enough to be swampy, but well covered with humus. We may say, then, that in the most southern of the three sand plains which have been studied,—and therefore the one which has been out of water and fit for vegetation the longest,—the predominant society is III, but I and II are not uncommon, while IV and V occupy a relatively small portion of the area.

In the Grand Rapids sand plain we have seen that society IV is predominant, with a good part occupied by V and comparatively very little by I, II and III. And in the plain which extends from Rockford northward, the only upland society found is V. Of course the last plain has been out of the water a much shorter time than the other two. In fact, a great part of it is at present swamp and is occupied by lowland societies.

In these three plains we seem to see successive stages of vegetation occupying successive stages in the formation and accumulation of humus. Of course the extensive destruction of the natural vegetation which has taken place since settlement of this region began, will make it impossible for the natural course of events to continue here, even if the above hypothesis be the correct one. Often clearing and burning has reduced the soil from a condition suited to society II or III to one only fit for society V. This is probably also true on the moraines in the northern part of the county. It will probably be impossible ever to trace the history much farther than it had gone at the time of settlement.

[20]Beal has shown that oaks, maples, etc., can reach a considerable age in dense forests without any marked growth. An oak may thus be twenty-five years old and yet have a height of only a few inches. If the shade-producing plants are removed these dwarfed trees will set up a renewed growth. For figures of such dwarfed trees see Beal, W. J.: Observations on the succession of plants in Northern Michigan. Annual report Mich. State Board Agriculture, 27: 74-78, 1888.

THE LOWLAND SOCIETIES.

Under this heading will be briefly considered three groups of societies, the pond-swamp group, the lake-river group, and the spring-brook group. In the first I shall include those aquatic societies which are found in small ponds together with those marsh societies whose habitat is undrained swamps either on the margins of such ponds or elsewhere in swampy depressions. The second group will consist of the aquatic societies of the large lakes and of flowing water,—whether in creeks or larger streams,—together with marsh societies which occupy the drained marginal swamps along these lakes and streams, and also the moist ground societies of the river and creek flood plains. The third group will comprise the societies of the spring-brook and its margins. I have been unable to observe any variation in these lowland societies corresponding to variations in the nature of the soil. It seems to make no difference whether the soil be sand or clay, if it contain sufficient water to cause it to be classified as lowland, it will always bear certain types of vegetation. These various types depend, apparently, upon the *amount* of water so retained and upon the nature of the water as a solution.

1. *Definition and Distribution of the Lowland Societies*.—In the following paragraphs the definition and the distribution of the several lowland societies will be presented together. My study of the lowland has not been as thorough as that of the uplands and the discussion will not be as complete. The societies will be numbered consecutively in the same series as those of the upland.

a. The Pond-Swamp Group.—Throughout the county, but especially in the northern and northwestern part, depressions which reach below the water line are numerous. They vary in diameter from a few hundred feet to several miles, and their margins are of course sinuous and very irregular. They may be found on almost any sort of topography, but especially in morainic

areas and in sand plains. In the former situation these deep hollows among high clay hills are often almost impossible to drain, even artificially. The great accumulation here in the form of peat, of which we shall speak later, has led cultivators to drain these swamps wherever practicable. Sometimes ditches for this purpose have to be twenty or thirty feet deep and take a sinuous course for several miles, following the depressions in the topography. Thus in morainic regions these swamps are naturally undrained; there is no circulation of water through them, it is lost almost entirely by evaporation.

In the sand plains these depressions occur principally along the margins. The margin of the Grand Rapids plain is in some places almost a continuous line of such swamps and ponds. They also occur out in the middle of the plain, notably so in the Green lake plain, south of the county line. These sandy basins are apparently as poorly drained as those in the clay; it is probable that the deeper clay holds the water. The vegetation is the same whether the basin is in sand or clay.

VI. The Chara-Nymphæa (Aquatic) Society.—Where these undrained depressions are small, and at the same time deep enough to contain standing water throughout the year, we have a pond. The water is usually .shallow and filled with aquatic growth. The presence of water prevents in some way,—perhaps by limiting the supply of oxygen, —the total decay of dead plant materials, and debris accumulates upon the bottom of such a pond, forming black peat. This may be intermixed with calcareous material from Chara[21] and from mollusc shells. The calcareous deposits may be quite pure, as sometimes in the larger ponds and lakes, so that they may be used for marl. Generally, however, an undrained swamp has a bottom of fine silt-like peat or muck, which,—being thoroughly saturated with water so as to furnish almost no support to a person or animal, and being of unknown depth,—gives to many ponds the name of bottomless. The vegetation of such a pond is characteristic. The white and yellow water lilies (Nymphæa and Nuphar), the alga Chara, which often forms great masses, the duckweeds (Lemna, Wolffia, Spirodela) and the bladderworts (Utricularia), are the predominant types throughout the county.

VII. The Sedge-Sphagnum-Tamarack (Bog) Society.—It is obvious that as an undrained pond is filled up by peat deposit its margin will be built out into the water. This process has been going on since the close of the ice age, and thus many ponds are surrounded by a broad belt of characteristic *undrained swamp* or *bog*. In many cases the pond has been entirely obliterated by this encroachment of the marsh upon the standing water. These marshes, whether they have a true pond in the center or not, always show a zonal arrangement of plants. Thus several distinct societies might be made out of what is here brought under one head. An admirable discussion of these zones of plant life in the Chicago area is presented by Cowles (loc cit.). The facts are the same in Kent county as there. Along the margin, in shallow water, are found sedges (Carex), the bulrush (Scirpus lacustris), Scirpus atrovirens, S. polyphyllus, the buck bean (Menyanthes), and the swamp cinquefoil (Potentilla palustris). Farther back these give way to the true peat-bog flora, comprising cotton grass (Eryophorum), peat moss (Sphagnum), leather leaf (Cassandra), Calapogon, Pogonia, Cypripedium candidum, C. spectabile, the tall blue-berry (Vaccinium corymbosum), cranberry, poison sumac (Rhus veninata), pitcher plant, sundew, Elodes campanulata, Woodsia, shrubby cinquefoil (Potentilla fruticosa) and the tamarack tree. The black spruce, which is common in such localities northward,[22] is rare here. In one extensive swamp crossed by the right of way of the Detroit, Grand Haven & Milwaukee railroad about five miles east of Grand Rapids, and bearing the name of Saddlebag, there were originally many of these trees. They were first practically all killed by burning. Now the swamp has been artificially drained and I think no spruces remain. The margins of the undrained swamp are often occupied by a characteristic margin flora of which the winter berry (Ilex verticillata), hardhack (Spiræa salicifolia and S. tomentosa), and the Osmundas (O. cinnamomea, O. Claytoniana, and O. regalis) are perhaps the most typical. Or the margins may have a vegetation resembling that of the dryer parts of the drained swamp, the elms, swamp oaks, asters, etc., forming a transition to the adjacent upland societies. Where the latter are of the type of IV and V, however, the transition zone is apt to be omitted. The margin flora just mentioned may be developed in such a case, or the swamp society may break off abruptly at the sandy slope which marks the original shore line of the pond from which the swamp has been formed.

[21]Davis has shown that Michigan marl is mainly from Chara. See Davis, C. A.: A contribution to the natural history of marl. Jour. Geol. 8: 485-497, 1900. Also: A second contribution to the natural history of marl. Jour. Geol. 9: 491, 1901.

[22]Whitford, H. N.: *loc. cit*. p. 314.

b. The Lake River Group.—The societies along the shores of the lakes and along the rivers and larger creeks are quite similar, no matter whether they be in sand or clay. Perhaps the wave currents of the large body of standing water and the better opportunity for saturation with oxygen and hence for oxidation, simulate the stream currents and prevent the existence of stagnant water conditions, whatever these may be. It is true also that most of the large lakes have outlets so that there is a constant, or at least intermittent changing of the water. In embayments and quiet places along the margins of such bodies of water the aquatics take on more or less the character of pond vegetation and the shores of such places are apt to develop the aspect of an undrained swamp. The vegetation here is often intermediate in character between that of the drained and of the undrained swamp.

VIII. The Potamogeton-Myriophyllum Elodea (Aquatic) Society.—This occurs in lakes and the larger rivers. Besides species of the three genera mentioned it includes Vallisneria, Ceratophyllum, the water shield

(Brasenia), water buttercup (Ranunculus aquatilis), and numerous green algae, such as Cladophora, Spirogyra and Hydrodictyon.

IX. The Willow-Ash-Elm Society.—This occurs on the margins of lakes and rivers. The aquatic society (VIII) grades into the willow belt through a grass-arrowhead zone wherein wild rice is often predominant. In open places in the marginal willow thicket are often pickerel weed (Pontederia), cat-tail, Sparganium simplex and androcladum, and the like, or these may mingle farther out with the grasses and arrowheads. The sedge-bulrush zone is not nearly as pronounced here as in the case of the pond, though these plants occur often in great numbers. On the beach of Grand river, outside the willow zone, there is often a zone of rag weed (Ambrosia trifida) and other annuals.

But back of the willow margin, on the river and on the lake, we usually find a very characteristic drained swamp area. This is the richest in species of all our societies. It occurs along the margins of streams and lakes, but some of the finest examples of it are in the ancient channels of the glacial streams. The channel followed by the Grand Rapids & Indiana railroad from Grand Rapids to Ross was, at the time of settlement, almost one continuous stretch of drained swamp, although in some places there are patches of society VII marked by groups of tamarack. The same is true of the broad creek valleys in the northwestern part of the county. The vegetation here is a great complex of species, its *tout ensemble* remaining quite uniform but the component plants varying through a wide range. Only a few samples can be given. We may select the following: Black ash (Fraxinus Sambucifolia), elder (Sambucus Canadensis), Lobelia cardinalis, L. syphilitica, Polygonum lopathifoliurn, P. hydropiper, P. acre, P. dumetorm scandens, bittersweet (Solanum dulcamara), red osier (Cornus stolonifera), Epilibium coloratum, bugle-weed (Lycopus Virginieus), skull cap (Scutellaria), hedge nettle (Stachys), Solidago ulmifolia, panicled cornell (Cornus paniculata), sour-gum (Nyssa sylvatica), green brier (Smilax), arbor-vitæ, swamp oak (Quercus bicolor), red maple (Acer rubrum), slippery elm (Ulmus fulva), and alder (Alnus incana). The list might cover a page. Of course in any one place one will not find all of these plants, but they are pretty sure not to be far distant. Bugle weed is sure to be found everywhere. The Polygonums are the characteristic herb forms in the dryer parts of these swamps, and often in all parts, some ten or twelve species of this genus occurring there. Along the Rouge river, in the northern part of the county, the red maple is apt to be mingled with the willows in the margin zone.

X. The Basswood-Hackberry-Phlox-Lungwort (Flood Plain) Society.—This is the typical river flood-plain society. It contains many of the plants of society II. Here, as well as in society II, occur most of the spring flowering herbs, bloodroot (Sanguinaria), Trillium, Indian turnip (Arisæma), etc. The cork elm (Ulmus racemosa) is common, and the American elm frequent. Butternut and walnut (Juglans cinerea and J. nigra), the bur oak (Quercus macrocarpa), and the pig-nut hickory (Carya porcina), also occur here. Back from the lake or river this society merges gradually into the upland society which occupies the adjoining upland.

c. The Spring-Brook Group.—Here will be included a single society, that which forms ribbon-like stretches along the margins of the smaller brooks and broader patches on the springy hillsides, where the brooks have their sources. The little streams usually possess a well marked aquatic flora, which consists, however, of but few species. The algæ Vaucheria and Cladophora are found fastened to stones at the bottom, and the watercress (Nasturtium),together with water purslane (Ludwigia palustris), often forms great masses which well nigh stop the flow of water.

XI. The Lobelia-Chelone Society.—The trees of this society are either the same as of the upland through which the brook flows, or are like those of the drained swamp. But the herbs and shrubs which follow the brook are quite characteristic. Among these are the blue and red Lobelia (L. syphilitica and L. cardinalis), the turtle-head (Chelone glabra), the gentians (Gentiana Andrewsii and G. crinita), swamp milk-weed (Asclepias incarnata), beggar's tick (Bidens), tear-thumb (Polygonum arifolium and P. sagittatum), Aster puniceus, several Eupatoriums, alder (Alnus incana), and several low willows. Many of the plants found here also occur in the drained swamp society (IX), but they exhibit a better development here and are quite closely massed together in a narrow strip along the margin of the streams and in rather broad areas of springy ground at the stream's source, so that the society as a whole is quite distinct from IX.

2. *Generalizations on the Lowland Flora*.—From the possibility of such a classification of these lowland societies as the one just given, it seems probable that the main factor in determining their distribution is water. But the amount of water is practically the same in an undrained and in a drained swamp and on a brook margin; yet the floras are dissimilar, especially the first two. It has been suggested that the great amount of organic materials in the solution of the undrained swamp may effect the plants physically or chemically and thus exclude those which occur in the drained swamp. If these substances effect the plants physically it must be through osmotic pressure. By this means a concentrated solution might withhold water from the plant. A few tests of the water from swamps whose flora was of the bog type seem to show that the osmotic pressure of the water is no greater than of that from a spring or river. Enough work along this line has not been done, however, to decide the question.

There remains the other suggestion, that the undrained swamp owes the peculiar character of its flora to the chemical nature of the soil solution. It may be lack of oxygen in the soil which shuts out the plants of the drained swamp. The question is to be solved by experiment, and not by observation. Perhaps, in the

case of a brook, the more uniform. How of a solution of rather uniform constitution occasions the development in the margin of such a stream as different from that in a drained swamp. This question must also be attacked experimentally.

CONCLUSIONS.

From the present observations it appears that we are entitled to retain as a broad general hypothesis, the physiographic idea advanced by Cowles (loc. cit.), namely that physiography determines vegetation. But this hypothesis is not getting us very near to the ultimate factor upon which depends the distribution of the plant societies. The ultimate cause of all this varied vegetation must be something more particular, something which will affect the individual plant. For such a region as this, this *something* must exist in the nature of the soil; climatic factors cannot explain differences in such a small area; and the historical factor is broad and general like the physiographic one, and hence is not ultimate. That local differences in vegetation are due to soil factors has been as good as proved before this, and the proof is strengthened by the present study. The physiographic hypothesis explains how it is that various soils may be physically and chemically different. But after this is explained, the question with which we have to deal lies still untouched: What is it *in the nature of the soil which determines the distribution of our plant societies?*

Now, by "nature of the soil" we can denote two things, and only two, i. e., the *physical* nature and the *chemical* nature. But we have seen that neither of these can influence the plant *per se*. (See page 43). Either one of the features may, however, be effective through soil water. Water is the only feature of the soil which comes in direct connection with the vitality of the plant. The chemical nature of the soil may be effective through the nature of the dissolved substances which enter the plant, indirectly, through osmotic pressure, its physical nature may be effective through the retention or non-retention in the soil of the water itself.

So far we may go *a priori*; beyond this tests must be made. The nature of the soil water from various soils in various positions must be carefully determined. From these determinations we shall know how much truth or falsity there is in the explanation here offered, that the nature of the soil water is not usually a decisive factor for such a region as this. Also, by careful tests the ability of various soils to retain water must be determined, and these determinations recorded with the vegetation found growing where the tests were made. Thus, and thus only, can the hypothesis offered in the present paper be tested, i. e., the hypothesis that *the decisive factor in plant distribution over a small glaciated area is, in most cases, the moisture-retaining power of the soil.* Comparisons and observations can neither destroy this hypothesis nor establish it.

On the other hand, the present series of observations seems to show that the historic factor is a very important one in the distribution of the plant societies of Kent county, and the test of the hypothesis offered in this connection is to be obtained through observation and comparison, and through them alone; we cannot get the ice-sheet back and have the whole history worked out before our eyes.[23]

It may not come amiss to suggest some areas which it would be well to study for comparison with the present one. First, the study should be carried westward to Lake Michigan; along its shores we find much more primitive types of vegetation than anywhere in Kent county. Also, by this means the present area would be brought into better connection with that of Cowles' work. Secondly, an area should be studied in the center of the State and another bordering on Lake Huron or Lake St. Clair. With these at hand we might feel that we were free from the danger of drawing conclusions from a peculiar and exceptional area. Thirdly, there are needed studies and maps of several typical areas, scattered from the present one northward to Hudson's bay.

It is hoped that in the future such studies may be made and the results carefully mapped and published. Emphasis is here laid on the map, for by it alone can a satisfactory comparison be instituted. Photographs are apt to be too superficial to be of any accurate use, though they would undoubtedly be valuable in connection with the map.

I wish to thank Dr. H. C. Cowles, to whose writings I have had occasion to refer so often, for suggestions which have changed for me the whole aspect of the problem of plant distribution in this region, from that of a problem impossible—or at least hopeless—of solution, to that of one whose solution is apparently a question of time and of careful and accurate work.

[23]Similar conclusions to the ones here expressed have just been published. The paper appeared too late to be referred to In the main text. Bruncken, E.: Studies In plant distribution. 1. On the succession of forest types In the vicinity of Milwaukee. Bull. Wis. Nat. Hist. Society, 2:17-28, 1902.

MUSKEGON COUNTY.

Prof. C. D. McLouth of the Muskegon high school has put in a little of his summer time very intelligently and industriously in collecting data as to the soils as well as to flowing wells, and the deep wells which have recently been drilled. His assistance in the latter matters I would gratefully acknowledge while incorporating his help into my notes on the prospects of oil in that region given on a later page. But he has also prepared a nearly complete series of township maps, showing the distribution of the soils, and has helped Mr. Leverett in his work. I append his general notes.

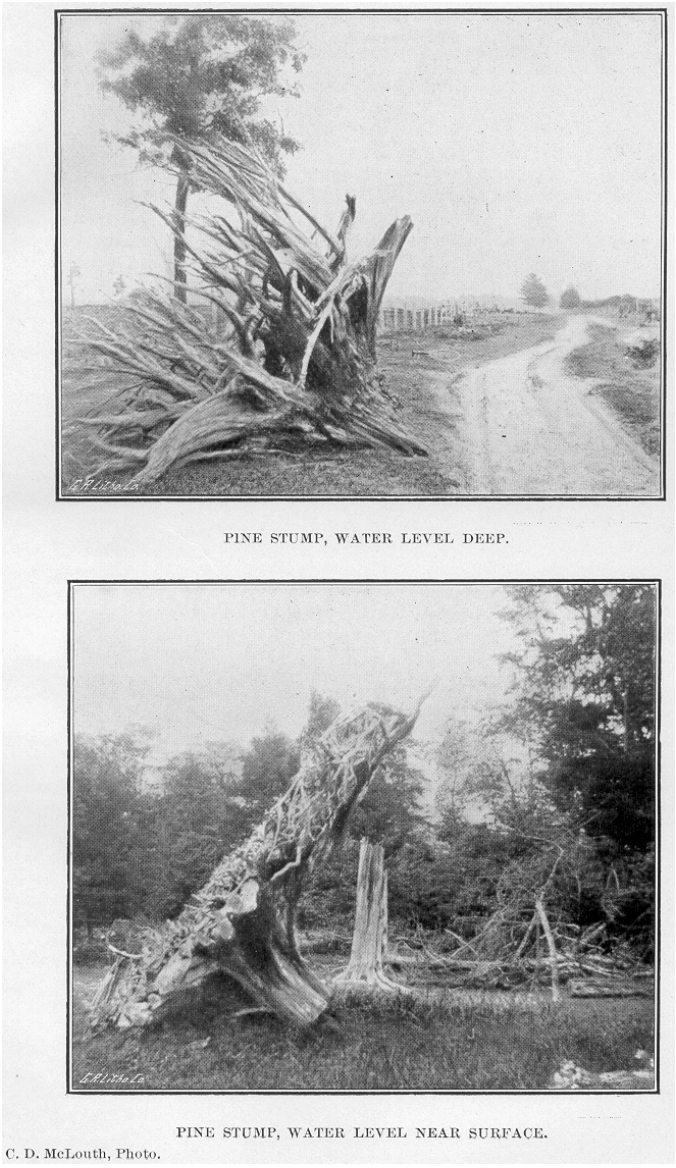
SOME GENERAL REMARKS ON THE TOPOGRAPHY, SOILS, WATER SOURCES, FLORA, ETC., OF MUSKEGON COUNTY. C. D. MCLOUTH.

Surface.—A large portion of the surface is a sand sheet covering nearly the whole county, the principal exceptions being portions of the townships of White River, Whitehall, Montague, Casnovia, Ravenna, and perhaps the northern part of Holton. A belt of this sand area some 10 miles wide and having its middle line approximately along the course of Muskegon river has the general appearance of a plain, but slopes considerably from the point where the river passes the county line to the shore of Lake Michigan, also it becomes shallower and apparently lower northward and southward from the river, that is, the river seems to run nearly along its deepest part. In Cedar Creek and Blue Lake townships sand dunes are conspicuous but of undetermined extent. Similar but slighter hills, knolls and ridges of sand occur in various parts.

The northwestern part of White River township presents a surface of clay approximately 100 feet above Lake Michigan. Southward and eastward loam and finally sand become the dominant soils. Casnovia, eastern Moorland and northern and eastern Ravenna constitute a hilly region in which morainic ridges are prominent, loamy soil abundant and deposits of boulders and gravel frequent. A moraine traced by Mr. Leverett winds northward through Fruitland township from near Muskegon through Whitehall and Montague, thence northwestward to the limit of the county.

Coast.—Along the coast the land height, exclusive of dunes, falls from an elevation of probably more than 100 feet at the northern end to nearly the level of the lake at the southern end. Clay is visible on the beach only at and near the northern limit. Cobblestones and gravel are noticeable in the vicinity of White lake. Sand, with a slight sprinkling of pebbles, is the feature along the remainder of the line. Dunes are highest at the south and form an unbroken line about one-half the entire distance northward, beyond which there are considerable portions along which the level land surface extends to the slope of the bluff. A mile or so below the northern line of the county the sand dunes begin to diminish gradually but rapidly, lying against the face of the clay bluff instead of upon the bluff, and within two miles north of the boundary no traces of dunes are to be found. Black and reddish magnetic sands are conspicuous in many places along the beach and are sometimes separated by action of the waves into layers an inch or more in thickness.

Lakes and Lakelets.—The lakes along the coast are of course confined within slopes corresponding in height and abruptness with the general land elevation previously mentioned. Little Black lake in the extreme southwest drains into Lake Michigan by a shallow ditch. It is practically level with the receiving lake and has been lowered somewhat by the ditch. The land rises away from its borders with very slight ascent except where low sand ridges seem to indicate former confines gradually moving toward the coast.



PINE STUMP, WATER LEVEL DEEP.

PINE STUMP, WATER LEVEL NEAR SURFACE.

C. D. McLouth, Photo.

Plate V. Pine stumps in dry and wet ground.

Wolf lake, in the interior, lies in the high sand plain near Muskegon river. Its banks are steep, entirely of sand, somewhat more than 80 feet above the water level, which is 67 feet above Lake Michigan. Carr lake or Five lakes, a few miles south and westward, consists of a series of shallow, receding ponds lying in hollows on the north margin of an undulating tract of sand that seems to be an area of old dunes. Twin lake, in Dalton township, lies but little below the general land level. Some of the lakelets northward have deeper basins.

Speculations on the Geological History.—Evidently in successive stages of recent times less and more of this region has been covered by Lake Michigan than at present. White lake, Duck lake, Muskegon lake, Lake

harbor, are infillings of the lower valleys of the several streams that formerly flowed farther out to reach the great lake; this is shown by the fact that the bluffs now confining these lakes are exactly continuous with the bluffs now lining the valleys of the streams for miles inland. Numerous sand ridges, dunes and swampy tracts indicate former presence of water of considerable depth.

Various present conditions seem to indicate that the water is now or recently has been in quite rapid recession, considerably extending the land area. A large portion of Moorland with small portions of several adjacent townships is a recently reclaimed marsh (although considerably above Lake Michigan). Much of Sullivan township was a desolate swamp which extended into Fruitport and Norton townships, appearing to the eye as an unbroken plain and but a few feet above lake level at the coast.

In the southwestern corner of Fruitland township is a swampy tract extending back from the lake several miles. This swamp is bounded on the east by an irregular sand ridge reaching a height of 120 feet perhaps in places. Eastward from this ridge for something more than a mile extends a swamp that has been denuded of a fine growth of arbor vitæ and other trees. This second tract merges into higher land at the east, where it is more or less plainly demarked by low ridges and knolls of sand. This tract has been partially reclaimed and subjugated to the plow. Eastward still farther the land is mostly under cultivation, but distinct traces of a swampy character remain. Again, in the eastern row of sections in Dalton township and extending for some distance into Cedar Creek is a low, moist, loamy and sandy area. The north branch of Bear creek runs along the western limit of this tract, its bed but little depressed below the general land surface. Close to the creek on the west rises an irregular dune-like ridge of sand clearly determining the southward direction of the stream. This ridge (which has been viewed only at a distance of about half a mile) seems to be the dune line of an older border of the lake. It is quite evident then that these several areas extending some twelve miles from the lake into the central part of the county are successive reclamations from the lake.

The high sand plain along Muskegon river is thought to have been a delta formation when the lake extended far inland. This is suggested by the fact that it seems to be highest near the present course of the river, sloping very gradually southward, northward and towards the present shore.

Springs and Wells.—Springs are of course numerous along the streams and in the hilly regions of the east and northwest. Near the lake shore many streams have cut deeply into the underlying clay and springs gush out from the banks many feet above the streams. In the so called delta region there is very little water found at the surface, but so far as known wells are not very deep, 20 feet often being sufficient to find good water. In the low and level tracts previously mentioned water may usually be found by very shallow digging. Wells from 4 to 10 feet deep are the rule. In Casnovia many wells are more than 100 feet deep and often water is not found even at a greater depth.

Flowing wells are quite common near the shore, ranging in depth from 35 feet at Montague to some 250 feet at the south line of the county.

Soils and Minerals.—The character of the soils has been suggested in various ways by what has preceded. The high sand plain covering most of Muskegon township and more or less of Egelston, Cedar Creek, Laketon, Norton, Dalton and Fruitland is a particularly barren region. Away from the immediate vicinity of Muskegon the settlers are very scattering; few signs of prosperity are visible in their homes; frequent deserted buildings and clearings show where the struggle to get a living and establish a home has been abandoned. In traveling over the region along nearly the whole course of the river in the county no public road has been found except at the head of the lake from which the stream could be viewed. Blue Lake township is a most desolate region, supporting the least population of any township in the county. The low and level regions before described are mostly of a sandy soil more or less mingled with clay and having clay or "hardpan" (the latter a ferruginous sandstone approaching bog ore) lying but a few inches or feet below the surface. The low sands are more or less dark and may be finer than the high sands, and are always moist because of the impervious material underlying. These lands are said to have been easily cleared of stumps because of the horizontal direction of the roots. The rolling lands of Casnovia and parts of Ravenna and Moorland, with the similar lands in the northwestern part, are perhaps altogether the most valuable for general farming.

A large deposit of magnetic sand within a few miles of Muskegon is known to certain persons. At Twin lake the surveyor's compass is unreliable because of deflections. A deposit of diatomaceous earth lies somewhere in the northwestern part of Laketon township, probably not many chains distant from the coast.

Orchards and Other Crops.—Near the city considerable gardening and growing of small fruit is done even on the high sands. In Egelston township, between Wolf lake and Muskegon river, a man is surprisingly successful in raising melons on a high sand slope, using no fertilizer. Moorland has been famous for an immense production of peppermint oil, but low price has reduced the production to a small fraction of the former amount. Sugar beets are being grown with success on the swamp lands of Sullivan and Ravenna, the yield being high in tonnage and quite satisfactory in per cent of sugar. It is noticeable however that the acreage in beets yearly moves toward the loamy slopes bordering the swamp. Peach orchards in Casnovia township and in the vicinity of Whitehall village are thrifty and yield fine crops.

Native Flora.—Presumably the high sandy region was formerly occupied largely by pine and hemlock. The characteristic trees now are oaks, *Q. alba* and *Q. tinctoria*. These are usually of a scrubby character, but some good timber occurs. *Q. rubra* is scarce. *Pinus resinosa* is very scarce, only a few trees have been noted in Fruitland township. *Pinus Banksiana* is somewhat more common. *Pinus strobus* is seen everywhere, unless in the extreme east and northwest portions. Slocum's grove, occupying some half dozen sections adjacent in Casnovia, Moorland and Ravenna, is a splendid mixed forest containing perhaps 30 species of trees such as beech, maples, basswood, elms, oaks, hemlock, yellow birch.

On the moist low plains that have been recently cleared the characteristic tree growth seems to be the trembling aspen, *Populus tremuloides*. This seems to spring up quickly and profusely wherever such soil is left exposed.

The accompanying plate V shows the contrast between the roots of the pine in low places, where they have only a short way to go for water, and on the sand plains where they have to run down deep.

WASHTENAW COUNTY.

For some time the scientific departments of the State University have needed and asked for a topographic map of their neighborhood. Upon several occasions Prof. Russell has appeared before the legislature in behalf of such a topographic survey, not only of the neighborhood but of the State, and the following quotation from a letter from Prof. Spalding shows its importance in another department:

"I would like to reiterate and emphasize with all my power what you say regarding the necessity of a topographic map. This is so great a need with us in Ann Arbor that important work already begun will have to" stop unless we can have the region mapped. I have already had some conversation with Prof. J. B. Davls, our professor of surveying, etc., in regard to a map of the Huron river at Ann Arbor. Some of my students have been constructing preliminary maps of some of the glacial lakes near here, and they serve for purposes of study to some extent, but they are not sufficiently accurate for a scientific piece of work and could not be published. Prof. Reighard feels the same need; so does Prof. Runel. We must, by one means or another get truthful maps of the State just as soon as may be. You may be sure of the hearty cooperation of all of us on that score, for it is a 'long felt want.' The right way, as you suggest, is for the State to do its share towards paying for it and then get the U. S. Survey as soon as possible to go ahead."

In consequence I entered into an arrangement with the United States Geological Survey, a copy of which is found in another place, for a topographic survey which will nearly cover Washtenaw county and also portions of adjacent counties on the north, east and south, and will, I trust, be of use in many ways to the large number of students that come to the State University and Normal College, particularly in illustrating to them the utility of such a map, as well as the residents of the region.

When this map is finished I hope to arrange for a careful geological survey of the county. Mr. F. Leverett, Prof. Sherzer and Prof. Russell already have many notes on the surface geology and two deep wells recently put down, that at Milan and at the university, help to give us more exact knowledge of its deeper structure and mineral waters.

The samples preserved at the university of the well were put up wet and have so cemented that I have been able only to give a cursory examination. An abstract of my examination and correlation, combined with newspaper items, may not be useless, pending further details or in case the samples should be in any way destroyed, and will be found in connection with my discussion of the prospects for oil and gas in a later paragraph.

It is to be regretted that the university has not made all that it might in addition to science from this boring. The rate of increase of temperature, the magnetism excited by the earth in the casing, and the character of the mineral waters and their gases, are as worthy of study as the mere succession of the strata. This well might be an important part of the equipment of a geological laboratory.

LAPEER COUNTY.

This is one of the counties the rocks beneath which are probably rather monotonous, the sandstones and shales of the Marshall and Coldwater series. It is, however, one where we are very uncertain of the dips and where anticlinals suitable for the concentration of oil and gas may occur, so that every item of information by wells is of exact value.

Mr. J. J. Mason informs us that he put down a well at Columbiaville 1500 feet deep, the last 90 feet thereof being a brine-bearing sandstone, presumably the Berea. The well was plugged at 700 feet in order to use fresh water, which comes in probably from the Marshall at 300 to 400 feet depth.

Mr. F. B. Taylor began to work up the surface geology of this county in the summer of 1900. But his work is not entirely finished, and I cannot tell how soon we may be able to finish a report uniform with those of Vol. VII. I prefer, therefore, to publish here his preliminary report, which has already been given to the residents of the county through the courtesy of the Lapeer County Clarion, March 8 and 15, 1901.

SURFACE GEOLOGY OF LAPEER COUNTY, MICHIGAN
SUMMARY OF REPORT OF PROGRESS.
BY F. B, TAYLOR,

The field work upon the surface geology of Lapeer county is still in an incomplete state. The month of May, 1900, was given to this work and the results so far attained are summarized below.

Work upon a topographic map with contour intervals of ten feet is well advanced and is nearly complete for the southern two-thirds of the county. The northern third will require some further barometric work. Borne of the rougher parts in the central portion of the county will need some further study, especially in Arcadia, Mayfield, Deerfield and Oregon townships. The extremes of surface relief range from about 750 feet above sea level on Flint river in northwestern Oregon township to about 1275 feet above sea level in southern Dryden and Metamora. The highest point of the region is in section 6 of Addison township, Oakland county, about three-fourths of a mile south of the county line. This point is close to 1300 feet above sea level. Belle river in northeastern Almont is down to about 780 feet above sea level, that is 200 feet above Lake Huron. The central part of the county has several clusters of rugged, irregular, steep-sided gravel hills. Dryden, Metamora and Hadley are mostly high and hilly, while the eastern border and Burnside, Burlington and Rich townships are mostly flat and close to the level of 850 feet above sea level. On sections 21 and 28 of Burnside is a sharp isolated hill commonly called Burnside mountain, which rises about 300 feet above the plain to the east. The topography of the county is characterized by a series of ridges and valleys. In the eastern half they trend southeast and northwest, but in the western half they run northeast and southwest.

The bed rocks of Lapeer county are entirely covered by glacial drift, in most parts to a relatively great depth. So far as known they do not protrude at any point. The depth of the drift and the configuration of the buried rock surface beneath can be learned only as it is revealed in well borings and other excavations. Within the limits of Lapeer county there are so few such borings so far as learned which reach the rock surface that very little is known respecting it. In Dryden and Metamora townships, which comprise the highest parts of the county, the drift is known to be very thick, not less than 300 to 400 feet, and probably more. So far as learned, the drift does not appear to be much less than 100 feet deep in any part of the county.

The entire surface of the county is therefore composed of loose, unconsolidated sediments. By far the greater part of it is clay, but with a considerable admixture of sand, gravel and stones, large and small. With but few exceptions the day has stones and boulders scattered promiscuously through it; clay of "this sort is called "boulder clay" or "till," and by well-drillers "hardpan," and is well recognized as a characteristic glacial deposit. It is the normal deposit of slowly-moving massive bodies, or streams of ice, and its heterogeneous character readily distinguishes it from sediments laid down in water, whether still or in motion. Almost the whole of the great mass of softer sediments which covers the bed rocks of Lapeer county is composed of this boulder clay or till. But here and there through it and upon its surface are occasional beds of sand and gravel and bouldery places and sometimes beds of clay horizontally bedded in fine layers free from all coarser sediments. These distinctly classified sediments are the deposits of water, the coarser ones in running water and the finer ones in quiet or still water. They are all comprehended under the general term of modified drift, that which was laid down by the glacier without the intervention of water action being designated as unmodified drift. The entire mass of the drift deposits is made up of an exceedingly complex mingling of these two classes of sediments. But while the main constituent of the drift is boulder clay or till, almost every well or other deep excavation shows more or less extensive and irregular masses of modified drift, usually sand or gravel, embedded in or lying under the till. These more porous layers often become great reservoirs for the accumulation of rainwater, and when they lie in an inclined position and are overlain by an impervious bed of till they are likely to become the reservoirs for artesian wells and perennial springs. There are a number of artesian wells and springs of this kind in Almont township. Before the completion of the work, it is desirable to make some further collection and study of well records with a view of learning as much as possible concerning the conditions of natural water storage and supply.

The study of the surface features and deposits of the county is also well advanced. Incidentally to the study of the topography and the distribution of the different kinds of soil, much has been learned concerning the history of the development of the surface. Inasmuch as the topography and soil distribution of the county as we find them are almost entirely results of the particular processes by which the drift was originally fashioned, it seems desirable to present a brief sketch of the history of that development. The data for this sketch and for the map of the surface features which should go with it are nearly complete. The accompanying map (Plate IV) presents a rough sketch of these features so far as made out, but is lacking in accuracy of detail in some parts, especially in the northern and northwestern parts of the county.

The general facts required for this historical sketch are at hand and may be briefly summarized. As its maximum the continental ice sheet of the glacial period overspread the whole of Michigan, and it reached far to the south over Ohio and Indiana. At that time a solid mass of ice filled the basins of Lakes Michigan, Huron and Erie and covered all the intervening and surrounding country. Southern Michigan was then deeply buried under the ice to a depth measured perhaps by thousands rather than hundreds of feet. As it retreated northward by gradual melting, its margin frequently halted, probably periodically, and at each halt a more or less well defined ridge of drift was formed at and under the edge of the ice. These ridges are known as moraines. A numerous and intricate series of them has been traced out and mapped in Ohio and Indiana and southern Michigan, and their distribution shows that when Lapeer county first began to be uncovered by the retreating ice the glacier was still occupying the Saginaw valley and the basins of Lakes Huron and Erie. The glacier moved forward most rapidly in the valleys and lagged behind on the higher

ground, with the result that the higher parts of the country were uncovered first as the ice retreated. The thumb of Michigan forms a broad ridge projecting northward between the Saginaw valley on the west and the valley of the St. Clair and Detroit rivers on the east. Lapeer county may be said to lie upon the basal portion of the thumb. As the glacier retreated, its margin formed in two great lobes, one projecting southward in the Detroit valley and the other in the Saginaw valley. Between these projecting lobes was a sharp re-entrant angle running northward on the intervening high ground into Lapeer county. Thus, through all the time that the ice-front was retreating across this country, the apex of the re-entrant angle between the lobes was within its area. Strong drainage usually issues from such angles in the glacier, and its magnitude is roughly proportioned to the magnitude of the lobes that bound it. In Lapeer county the rivers that drained the glacier were large and they made a strong impress upon the surface deposits. Although some further investigation will be required on the relation of the moraines and the associated drainage in the central, northwestern and northern parts of the county, enough is known to show that in its retreat northward the ice-front halted five times, the moraine of the last halt barely touching the northern fringe of the county. In each position, except the last or most northerly one, a river of considerable size flowed along the edge of the ice and was fed by streams issuing from the ice itself.

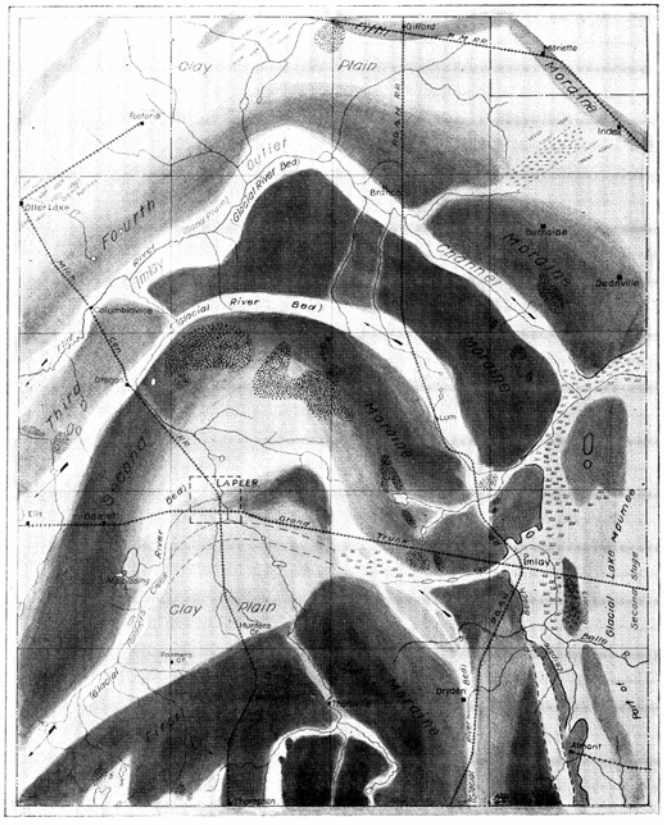


Plate VI. Lapeer County, Surface Deposits—F. B. Taylor.

Moraines are not merely dumps of detritus falling from the steep front edge of the glacier, but are also largely accumulated upon and under the ice near its margin. Such a moraine forms a belt varying usually from two to five miles wide, though sometimes much wider. The first moraine formed in Lapeer county covers the western half of Dryden township, the southwest corner of Attica, the southeast corner of Lapeer, nearly all of Metamora and the southeast half of Hadley townships. This is a very hilly district and forms the highest part of the county. The earliest glacial river bed in the county is associated with this moraine and lies in Dryden and Metamora townships. It turns an entire semicircle, starting north across the county line south of Whigville and turning gradually around to west and south and passing out of the county about a mile and a half east of Thomas.

This river bed has peculiarities which are hard to explain. There is some evidence that it did not flow along the ice-front, but under the solid ice-mass itself, and that it issued from under the ice at a point about two miles south of the county line. The ice-front at the time of this moraine appears to have been a little south of the county line, and the relation of this channel to it remains for the present somewhat problematical.

The next later moraine in Lapeer county passes north through the west half of Almont township, runs north-northwest through eastern Attica and central Arcadia, where it turns west across northern Mayfield and thence runs south-southwest through eastern Oregon, central Elba and northwestern Hadley townships. This moraine is quite irregular in character. It has a high rolling topography in southwestern Almont, is so weak as to be almost unrecognizable in southeastern Attica, but in northeastern Attica and in Arcadia and Mayfield it is very rugged and has many high, steep-sided knolls of gravel associated with it. In some parts it is chiefly made up of these.

The drainage at the time of this moraine went northward in eastern Dryden, northwest across Attica and, after crossing Lapeer in a course not yet clearly made out, it ran southwest up the course of Farmer's creek, across eastern Elba and central Hadley.

The next later or third moraine is a faint feature running north-northwest through central Almont and western Imlay and Goodland, becoming a strong feature in the latter township. Thence it passes northwest through North Branch to the northeast corner of Deerfield, where it turns southwest and, following the south side of Flint river, passes out of the county.

The drainage of this stage is not yet made out continuously. The long flat depression west of Almont suggests a line of drainage, but seems to lack specific characters of a river bed. It seems to fade away within three miles north and nothing representing a river bed appears until a point is reached about two miles northwest of Imlay City. Here a wide channel opens rather abruptly and runs northwest past Lum, King's Mills and north of Five Lakes. Beyond this its course is not yet made out, but there is a river course running across

the center of Oregon township from northeast to southwest which is probably a part of the same. Between Almont and Imlay City it may be that a readvance of the ice filled up a channel that existed there and pinched it out.

The next and fourth moraine runs north-northwest through eastern Almont in very faint form and passes northward about a mile and a half east of Imlay City in broken fragments. In Goodland township it becomes a strong feature and turning northwest crosses southwestern Burnside, northeastern North Branch and southwestern Burlington townships. On the flat plains of Rich township it seems to have no representation. But in southwestern Rich and running southwest through central Marathon it is well developed along the north side of Flint river. This moraine and the two preceding ones are crowded together two or three miles south of Imlay City into a breadth of four or five miles.

At this stage the drainage took on a new relation. As the ice-front drew back to this position the water of Lake Maumee flowed in over a part of the ground uncovered and it found a free passage across a low divide in northern Goodland township and down Flint river. Thus an outlet for the lake was established instead of a river carrying only the drainage from the immediate ice-front. Lake Maumee was a lake which gathered in front of the receding margin of the continental glacier and it filled the valley of the Maumee river and had its principal outlet at Fort Wayne, Ind., and thence down the Wabash. One arm of this lake reached nearly to Cleveland in Ohio and another to Imlay City, Mich. But the new outlet through Lapeer county did not carry the whole discharge, for the Fort Wayne outlet continued to be active. A beach composed of gravel and sand was made by the waves of this lake where it dashed upon its shore. This beach, known as the Leipsic beach, has been traced northward through Almont and Imlay townships to the northern part of Goodland, where the outlet narrowed up and began to flow as a river in which wave action was not so powerful. At Imlay City this beach is about 850 feet above sea level, but it declines somewhat southward. From the center of Goodland the river ran directly northwest to the southern part of Rich township, where it turned southwest and followed the course of Flint river, passing out of the county in the northwest part of Oregon township.

The last and fifth halt of the ice-front in Lapeer county made a moraine which barely touches the northern edge of the county. A faint morainic ridge passes north of Silverwood and runs west-southwest into the northwest part of Rich township. Another runs east and west north of Clifford and another runs southeast a little south of Marlette in Sanilac county. The course of this last one probably carries it across the northeast corner of Burnside township. But the northern townships of the county have not yet been fully studied.

So far as known, this moraine does not appear to have had a river along its front. This moraine and the preceding one are both rather faint in the northern part of the county and there is no well marked valley between them, but an almost level plain. All these moraines have well developed courses of transverse drainage, that is, at right angles to the course of the moraine and the ice border. The streams that made these seem to have flowed out from under the ice. Belle river follows one of these in Attica and Imlay townships to where it joins the lake outlet north of Imlay City. Mill river follows others through the second, third and fourth moraines across Attica and Goodland townships. Another runs south-southwest from northern Burnside to the lake outlet in North Branch. Flint river passes through one at Thornville, and again in eastern Oregon and Marathon it follows two others. There is a good one also in western Oregon running northwest to Flint river. This one has an esker in it. It some instances these lines of drainage appear to be associated with large accumulations of gravel and sand, which were laid down by the streams as they came from under the ice. The greatest gravel accumulations, however, such as those in the northwest part of Arcadia and in northern Mayfield, do not appear to be associated with such transverse river courses. The transverse courses through the fourth moraine seem to have carried off the drainage of the firth directly away from its front.

There was, presumably, a soil covering the rock surface of Lapeer county before the advent of the continental glacier. That was a soil of disintegration, produced by the decay of the rock surface as it lay in place. Probably most of that soil was swept away by the first advance of the ice, but a considerable portion of it may have been mixed in with the other ingredients which make up the till. So far, however, there has been no certain recognition of the preglacial soil.

The character and distribution of the present soil of Lapeer county is very intimately related to its glacial history. The drift which the glacier left behind, with all its variety of topographic form and composition, has been the basis of soil formation. The weather, animal and vegetable life, and chemical action have all contributed to the final result. Mechanical forces of disintegration have resulted from frost and sunshine, from wind and running water, and from the action of both vegetable and animal life. Chemical decomposition results from oxidation and from the dissolving power of water aided by carbonic acid gas and the humic acid of decaying vegetation. The contribution of humus or decaying vegetation to the surface soil is perhaps the most efficient of natural agencies for its enrichment. Steep slopes and high ground generally are well drained and their principal sources of vegetable enrichment are derived from leaf mould and the decay of roots and fallen trees. But some part of these materials are always carried off in solution by surface streams to lower ground. Ponds and swamps, including especially in this county the old river beds, have poor drainage, and they receive a considerable contribution of enriching matter from the surrounding higher ground. A number of the ponds and swamps of Lapeer county contain deposits of

marl and most of them contain more or less muck and peat, a few in considerable quantities.

The morainic areas of the county have for the greater part clay soils, and so have the flat till plains of the northern townships. There is, however, a considerable variety among these soils. They are heavier or lighter according to the proportion of clay they contain. The soil on the earliest or first moraine of the county comprising the high ground in the southern part, is in most parts rather more gravelly and sandy than the common run of the till in the other moraines and the soil is therefore a shade lighter. Some of this moraine, however, is purer clay and has a slightly heavier soil, notably in eastern Hadley and northwestern Dryden. The till plains of the northern and northeastern townships have in the main a still finer clay soil and are correspondingly heavier. Much of Rich and Burlington and Burnside, with the eastern parts of Goodland and Imlay, are of this heavier clay variety, sticky when wet and more or less inclined to harden on drying in the sun. There are sandy streaks, however, across Burnside township which contribute somewhat to ameliorate the toughness of the clay and turns it into sandy clay loam. Through the middle, southern and western parts of the county the clay soil is usually described locally as "clay loam."

There are a great number of knolls and scattering beds of glacial sands and gravels associated with the several moraines, and these of course have lighter soils. They are frequently devoted to fruit culture. Many gravel knolls are covered with orchards.

The old glacial river beds are mostly poorly drained. In consequence of this they are to a large extent swampy, although they all contain more or less sand and gravel in the form of bars formed by the currents of the glacial rivers. Some of these bars are flat and wide and furnish excellent light soil areas for small fruits.

The old lake outlet, or "Imlay Channel" as it is called, is mainly floored with muck and peat as far north as the north side of Goodland township. From that on it is partly occupied by sand bars to the bend in the south part of Rich township. Southwest from this there is an extensive sand plain bordering Flint river, narrowing at Columbiaville, but widening again below that and passing into Genesee county. This sand forms a very light, barren soil.

Dune sand is scarce, so far as seen, being found only in northwestern Mayfield and the adjacent part of Deerfield townships.

There are some large areas of muck (peat and celery) soil in Lapeer county, especially in the townships of the eastern and northern border. Some of these have been drained recently and are coming into use, notably those near Imlay City and along the course of Mill river in Goodland township. There are also many smaller areas in the central and western parts of the county.

Lapeer county has so far made but little progress in the development of industries based on its economic geological resources. These resources are, however, so far as now known, comparatively few. There is a considerable quantity of marl in the county and localities so far determined are shown upon the map. None of them, so far as learned, are of large enough extent to form a basis of cement works in the present stage of this industry. No beds have yet been found having an extent of over one hundred acres. Because of their present unavailability mainly, the marls found have not been tested thoroughly to determine their suitableness for cement. The largest swamps in the county, in the eastern and northeastern parts, appear not to yield marl. Marl was formerly burned for lime in several parts of the county, most notably in southwestern Hadley and southeastern North Branch townships.

Clay suitable for brick and tile manufacture may be found in several places, but so far as known none are now worked for these purposes. None, however, of the best quality and free from pebbles is known at present.

Gravel and sand are very generally scattered in patches over Lapeer county. For the greater part, however, it furnishes but indifferent road metal because it is too sandy. It remains loose and unpacked when put upon the roads. In many places the composition of the material is in large part too fine, and also in part too coarse. Such metal makes a road soft when new and rough after it has become settled or worn. The tendency of the sand to remain loose even where it does not appear to be too fine seems to be due chiefly to two causes: to the hardness of the pebbles and sand grains and to their roundness. Too few of the grains crush under the wheels to form any cementing material and the metal is generally very free from anything like clay as it comes from the pits. The grains are almost all of the hardest crystalline rock brought by the glacier from Canada, and their roundness and smoothness is such that they will not knit together and pack without the aid of some cementing material. Clay is sometimes put on sandy roads for this purpose, but this method, while it works well in many cases, is too commonly overdone. Too much clay is used to attain the best results. By a little judicious screening of the gravel and a proper use of clay for cementation, there is every reason to believe that the generally too sandy road metal of the county can be utilized to good advantage.

It may be remarked again in closing that this sketch of the surface geology of Lapeer county is prepared upon an incomplete basis of observation. Three or four weeks more ought to be given to field work before the final report is written.

BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY, 1901.

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