REPORT
OF THE
STATE BOARD OF GEOLOGICAL SURVEY
OF MICHIGAN
FOR THE YEAR 1908

GEOLOGY

ALFRED C. LANE
STATE GEOLOGIST

MAY 18, 1910

BY AUTHORITY

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1909

REPORT
ON THE
GEOLOGY OF TUSCOLA COUNTY MICHIGAN

BY
CHARLES A. DAVIS

PUBLISHED BY THE BOARD OF GEOLOGICAL SURVEY AS PART OF THE ANNUAL REPORT FOR 1908

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

GOV. FRED M. WARNER, President.
HON. D. M. FERRY, Jr., Vice President.
HON. L. L. WRIGHT, Secretary.

Gentlemen—I beg to present herewith for publication a report prepared by Prof. C. A. Davis on the Geology of Tuscola county. This continues the work of the Huron and Sanilac counties, and connects them with the report on Bay county. Its preparation has been delayed somewhat by the preparation of the report on peat, which seemed of more immediate use to a wider circle.

Very respectfully,
ALFRED C. LANE,
State Geologist.

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CHAPTER I. INTRODUCTORY.

Geographical position. Tuscola county is located at the base of the broadly triangular projection formed by the entrance of Saginaw Bay into the otherwise regular outline of the Lower Peninsula of Michigan, and which is commonly called the "Thumb." Carrying out the simile of a mitten or hand, Tuscola county, is located on the palm side of the base of the thumb, and has for its boundaries, Huron county upon the north, and a small portion of the east, (in the extreme northwest corner, along the line of a small projection of Akron township); to the east are Sanilac and Lapeer counties, on the south Lapeer and Genesee, and on the west, lie Saginaw and Bay counties, while Saginaw Bay cuts off the northwest corner of the county, and gives it a coast line twelve or fifteen miles long.

History. Lying as it does, adjacent to Saginaw Bay, where the shores are low and reedy, Tuscola county was favorably situated for hunting and fishing, and hence was a favorite dwelling place for the Indians, long before it was visited by white people, the more so, perhaps, because the stretches of light, sandy soil which exist along the bay shore and throughout a considerable portion of the Cass river valley, gave them sufficient easily tilled ground for their simple agriculture, while the marshes undoubtedly were visited for wild fowl and fish, and also for the wild rice which was probably very plentiful upon them, especially before the lowering of the water level caused it to be displaced by other plants.

It is not, however, the purpose of the writer to speculate concerning that early time, since the frequent occurrence of Indian names, the name of the county itself, the fact that abundant relics of the former occupancy by the Indians, in the shape of stone implements, old camping sites, fields and battle-grounds, are even now found and pointed out, and are evidence that there was a considerable Indian population in the region, long previous to the time before history, as we understand it, began. The records of the Indian tribes which lived in the county from the time when white men began to go into this region, up to the time of its settlement and the removal of the Indians, have been gathered together and preserved in the annals of those early days and published in various State and county publications. These are after the manner of the histories of the times, and mark the constant warfare between tribes already upon the ground and those retreating before the ever-increasing pressure of the white men who were encroaching from the west and south. It is perhaps sufficient to say that it was not until 1835 that the first permanent settlement was made in the southern part of the county, in what is now Tuscola township, and, because the difficulty of establishing roads, and the peculiar relation of the best agricultural lands to those not so good, of which more will be said in a subsequent chapter, prevented rapid development of the county, it was not until 1850, that it was organized into a separate county, having, with certain minor exceptions, nearly its present boundaries. The county seat was at first established, by act of legislature when the county was organized, at Vassar, where it remained until 1866, when, after much discussion, it was removed to its present location.

Former Geological Work. The fact that there are relatively very few outcrops of rock in the county, has prevented to a large degree geological and other forms of scientific exploration within its boundaries, until recently. Except for brief visits of the distinguished former State Geologists, Professor Alexander Winchell and Dr. Carl Rominger, both of whom studied the rock formations of the lake shores in Huron county, and made causal investigations of the rock outcrops in the bed of the Cass river, no geological work of which there is any printed record, has been attempted until lately. Indeed, the work of these earlier investigators, especially that of Dr. Rominger, who visited the outcrops in 1873-6 was so thoroughly done, that but little can be added to the record which he made concerning the structure, stratigraphic position and the fossils of the rocks represented in these outcrops. Mr. W. F. Girty of the U. S. G. S. has visited the outcrops since.

In the summer and fall of 1896, the region was studied by Dr. Alfred C. Lane, the present State Geologist, and Mr. F. B. Taylor, of the U. S. Geological Survey, and the broader relationships of the glacial deposits and the shore lines of the higher levels of the glacial and post-glacial lakes were worked out and roughly correlated with those of adjoining regions, while all of these features have been more recently examined by geologists working in adjoining counties.

Maps. The only geological maps of Tuscola county issued up to the present time, are such as have appeared as parts of the general, geological maps of the State, which have been published from time to time.

The earliest map of this sort was published by Professor Alexander Winchell[1] in 1878.

Soon after this map appeared, Dr. Carl Rominger,[2] then State Geologist, published another similar map. Later, in 1892, still a third general geological map of the State was compiled by Dr. Alfred C. Lane,[3] in which was embodied much additional data obtained by a careful study of well records collected chiefly by Mr. Charles E.

Wright, who had been for a number of years State Geologist. The same author[4] again published a revision of this map in 1906, in which the latest available information was embodied, and several other revisions on a small scale had also been published in the meantime.

The early surface maps of Tuscola county have not been carefully examined and but little need be said here regarding them except that those published before the Land Office Surveys in 1845 and 1848 are inaccurate as to the location of streams and of the shore lines, as but little was known of the then swampy region.

[1]Winchell, A., in Walling's Atlas of Michigan, 1873. Republished by R. M. and S. J. Tackabury, 1883.

[2]Rominger, C., Geology of the Lower Peninsula, Geol. Sur. Mich., Vol. Ill, Lansing, 1876.

[3]Lane, A. C., Geol. Sur. Mich., Vol. V.

[4]Lane, A. C., Plate II, in Flowing Wells and Municipal Water Supplies of the Southern Peninsula of Mich. W. S. and I. Paper, 182, U. S. Geol. Sur., Washington, 1906.

Various state maps after this Survey, were based more or less carefully upon the plat books of the General Land Office, and were more accurate, but even such maps are not without errors, although published after the county was well settled, and the first railroad was built.

One of the county maps, without date, but showing all of the present towns of the region, and the Detroit and Bay City Railroad, shows Squaw creek crossing the hills just east of Wahjamega P. O. and connecting Cass river with Saginaw Bay; this error was perpetuated on some State maps until quite recently.

The Walling's Atlas, referred to above, had a small map of this county. In 1888, an atlas[1] of the county was published by local surveyors. This was a compilation of township plats, showing the ownership of the land as well as the location of streams, roads and towns. The edition of this useful publication having been exhausted, a second work[2] of the same sort was issued in 1902.

Reprints of the township plats of the first of these publications were used as field maps, and, with some additions and corrections made from personal observations, were used in preparing the base map used in the various plates accompanying this report.

[1]Atlas of Tuscola county, Michigan. Published by H. S Hadsall, Vassar, and E. R. Cookingham, Caro, 1888.

[2]Atlas of Tuscola county, Mich. The Monarch Publishing Co., Philadelphia, 1902.

The Present Survey. This was begun in the summer of 1897, by the writer acting under instructions from Dr. Lucius L. Hubbard, then State Geologist, and Dr. Alfred C. Lane, Assistant State Geologist, in charge of the Geological Survey of the Lower Peninsula. The work was undertaken in accordance with the plan outlined some years before, of having a series of counties in the Lower Peninsula carefully studied with a view to pointing out undeveloped mineral and other resources, and also to continue the investigations already begun upon the water resources of that portion of the State, and to define as exactly as possible the boundaries of the coal basin, then not fully known.

Tuscola county was particularly interesting from these points of view, because it had been early prospected for coal by many drillers, and because drilled wells were the chief sources of water supply in that part of the county adjacent to Saginaw Bay. The work of prosecuting the survey proceeded slowly, because of the numerous enquiries which were made, and it was not until the year 1900, that the field work was completed and work could be begun in digesting and reducing the immense mass of field notes collected. Pressure of other work still farther delayed the study of these notes and the preparation of the final report and accompanying maps, until the present time.

Acknowledgments. The writer wishes to acknowledge in this place the great assistance received by him in the preparation of his work, from numerous citizens of the county. The residents of both town and country districts were uniformly helpful and courteous, and furnished whatever information was asked, cheerfully and. most graciously. To Mr. Charles Montague arid Dr. Graves of Caro, Russell Brothers of Unionville, Mr. Henry Bush, Jr., now of Caro, former County Drain Commissioner E. Hover, and many other officials and citizens of the county, the writer wishes to express personal thanks for their assistance and interest in his work. Thanks are due to Messrs. F. B. Taylor and

Frank Leverett of the U. S. Geological Survey, for assistance in correlating the old shore lines, and to Dr. Lane, State Geologist, for field notes, assistance in many ways, and for much helpful suggestion in preparing this report and accompanying maps.

CHAPTER II. PHYSICAL GEOGRAPHY.

Temperature and Precipitation. An examination of the tables prepared from the monthly reports of the "Climate and Crop Service" issued under the direction of C. F. Schneider of the State Weather Bureau with headquarters at Grand Rapids, gives Vassar a mean annual and monthly temperature of 46.2° F. and Arbela near the southwestern corner of the township of 46.7° F. At Harbor Beach the annual average is given as 44.4° F. and at Hayes in the northwestern part of the same county as 46° F.[1] In the report on Bay county[2] the mean temperature of Bay City is given as 46.3° F. or only slightly more than for Vassar. The annual averages for Vassar as far as determined vary from 45.4° F. to 47.6° F. and at Arbela from 44.1° F. to 48,6 ° F. from more complete information. At Vassar the monthly averages vary from 18° in February to 70.4° in July; at Arbela from 18.6° to 70.8° during the same months. Arbela is approximately nine miles south of Vassar which would perhaps account for the increase in temperature, in the same way that the average temperature of Saginaw is found to be nine-tenths of a degree greater than for Bay City regardless of the fact that this city is at times tempered by the breezes of Saginaw Bay to a greater extent than Saginaw is.

[1]A. C. Lane, Huron county, Mich. Geol. Sur., Vol. VII, Part 2, pp. 33, 34.

[2]Annual report for 1905, p. 356.

AVERAGE TEMPERATURE AT VASSAR, MICH.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.	State average.
1898	24.4	23.9	36.0	42.3	56.4	67.1	70.6	68.8	63.8	50.0	34.0	25.1	46.0	46.0
1899	21.2	16.6	24.8	48.8	57.4	67.7	69.0	68.0	57.4	53.2	41.5	27.0	46.0	44.9
1900	27.8	19.0	23.2	46.0	59.2	66.2	70.6	73.6	63.9	57.2	36.7	25.0	47.6	46.0
1901	21.9	13.0	30.8	46.1	55.7	66.0	73.8	68.6	61.8	49.8	33.8	23.5	45.4	44.6
1902	21.3	18.4	......	......	53.2	58.5	71.2	64.0	58.6	50.6	45.8	26.8	46.8	45.2
1903	23.8	24.8	43.0	47.1	60.0	62.1	71.9	65.6	62.9	......	39.2	20.4	47.1	44.2
1904	12.6	10.0	29.9	......	57.6	65.8	69.4	......	......	50.4	40.7	23.0	......	41.9
1905	16.6	14.8	24.7	45.2	56.9	66.8	70.1	69.0	64.4	50.4	36.2	20.7	46.4	44.2
1906	31.8	22.4	21.8	48.7	55.0	......	67.0	......	67.0	49.0	38.6	28.0	......	45.9
1907	23.8	17.8	......	35.5	51.0	......	......	......	62.8	44.9	......	......	......	42.8
1908	23.8	......	31.8	......	......	......	......	......	......	......	40.2	......	......	45.9
Mean	22.4	18.0	31.8	45.0	56.2	65.0	70.4	68.3	62.4	50.6	38.4	25.8	46.2	44.7

AVERAGE TEMPERATURE AT ARBELA, MICH.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
1898	25.6	24.6	36.2	42.6	56.6	68.4	71.8	69.8	64.0	50.4	34.6	25.4	47.6
1899	22.0	17.0	24.1	41.9	56.8	67.9	67.0	68.0	45.8	51.5	42.8	28.4	45.8
1900	26.7	17.2	24.0	41.4	57.7	65.2	70.0	73.4	64.8	56.8	36.4	27.2	47.2
1901	22.0	15.2	30.6	46.4	55.8	68.0	74.1	......	62.2	50.4	33.5	24.2	43.8
1902	22.0	21.3	37.8	45.6	58.0	61.8	71.2	65.2	61.1	51.6	47.3	25.2	47.3
1903	22.6	23.2	29.4	44.0	59.4	62.2	70.2	65.1	62.8	52.2	35.2	20.8	45.4
1904	13.4	11.0	31.0	40.0	58.2	66.2	70.2	67.2	62.2	48.6	38.0	23.0	44.1
1905	17.8	15.0	34.0	43.6	56.6	67.0	70.2	70.0	64.4	50.9	36.2	30.8	45.4
1906	31.8	23.4	27.4	47.6	57.6	68.0	71.6	74.6	67.5	50.4	37.4	26.0	48.6
1907	23.2	18.6	37.4	38.0	50.2	65.0	70.4	67.1	62.0	45.0	36.7	27.3	45.1
1908	22.6	18.6	33.8	45.3	57.8	66.6	71.9	68.4	68.2	52.8	38.7	25.8	47.5
Mean	22.5	18.6	29.8	44.2	56.8	66.0	70.8	68.9	62.3	50.9	38.0	25.8	46.7

MAXIMUM AND MINIMUM TEMPERATURE AT VASSAR.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.	Amount.	State.
1898	47, -18	50, -13	65, -1	69, 16	79, 27	93, 41	96, 36	95, 39	97, 28	87, 27	68, 8	49, -5	75, 15	60	100-31
1899	49, -11	54, -25	56, -1	87, 10	82, 34	94, 42	95, 43	97, 37	94, 27	83, 21	67, 22	57, 5	70, 17	59	100-49
1900	49, -5	63, -22	44, -10	79, 24	85, 33	90, 38	95, 41	99, 45	91, 32	88, 21	75, 8	52, 2	70, 17	59	100-38
1901	45, -7	32, -13	64, -6	83, 21	81, 32	92, 35	94, 42	91, 45	89, 31	77, 23	61, 13	49, -10	72, 17	55	108-28
1902	37, -5	44, -6	—, 8	—, 21	72, 30	83, 30	90, 43	85, 41	85, 30	74, 23	70, 18	49, -6	69, 19	50	98, -31
1903	47, -7	46, -10	74, 5	80, 17	86, 23	86, 40	91, 45	84, 39	87, 29	—, 22	70, 11	40, -6	72, 17	55	99, -39
1904	38, -21	42, -20	54, 5	......	85, 30	90, 39	97, 35	88, —	85, —	78, 31	72, 4	50, 28	71, 15	56	99, -41
1905	42, -14	40, -17	78, -5	78, 25	82, 28	89, 40	94, 47	92, 45	90, 32	84, 15	65, 10	49, 10	74, 18	56	100-40
1906	60, 10	57, -12	52, -1	75, 20	90, 28	87, 37	90, 40	......	92, 40	75, 25	55, 15	45, 5	71, 18	53	99, -36
1907	48, -10	45, -14	68, —	64, 19	82, 32	92, —	90, —	94, —	83, 35	63, 18	......	......	73, —	......	100-42
1908	45, -21	......	55, 23	......	......	......	......	......	......	......	65, 10	......	......	......	101-41
Mean	46, -10	47, -15	61, 17	77, 19	82, 30	90, 38	93, 41	91, 42	89, 32	79, 22	67, 12	49, 3	73, 17	56	100-38
Amount of difference	56	62	59	58	52	52	52	49	57	57	55	46	56	56	138

MAXIMUM AND MINIMUM TEMPERATURE AT ARBELA.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.	Amount.
1898	48, -11	50, -8	65, 7	69, 13	79, 29	93, 41	96, 39	95, 42	97, 33	87, 27	68, 9	49, -1	74, 18	56
1899	48, -10	54, -24	55, 5	85, 11	81, 32	91, 42	93, 40	96, 36	90, 23	81, 22	66, 22	62, -10	75, 16	59
1900	47, -7	64, -15	45, -6	78, 22	84, 27	89, 40	94, 44	96, 40	90, 36	88, 28	68, 12	50, 2	74, 19	55
1901	44, -10	35, -12	63, -5	82, 23	82, 32	94, 34	96, 48	......	88, 31	78, 24	60, 8	58, 10	71, 15	56
1902	40, -6	54, -10	65, 6	82, 22	89, 27	87, 40	92, 45	88, 44	83, 34	75, 25	73, 18	46, 2	73, 20	58
1903	49, -5	45, -11	73, 12	79, 18	87, 23	85, 42	93, 43	85, 40	88, 34	77, 24	73, 11	40, 5	73, 19	54
1904	37, -17	43, -17	58, 7	75, 11	85, 26	91, 41	95, 43	91, 41	85, 30	77, 25	65, 8	48, -7	71, 17	54
1905	42, -8	38, -15	78, 4	77, 23	84, 25	88, 41	93, 47	91, 48	86, 34	83, 19	63, 11	47, 11	72, 20	52
1906	60, 9	55, -20	52, -2	75, 22	85, 27	95, 34	95, 45	96, 46	94, 29	76, 23	57, 16	48, 3	74, 21	53
1907	62, -10	43, -8	70, 8	68, 16	82, 26	92, 38	93, 44	93, 38	90, 32	78, 20	55, 16	48, 7	73, 19	54
1908	48, -17	46, -14	68, 0	75, 17	85, 26	93, 36	97, 47	99, 40	96, 32	83, 19	69, 3	56, -6	76, 16	60
Mean	48, -8	48, -13	63, 3	77, 18	84, 28	91, 39	94, 44	93, 38	90, 33	80, 23	65, 13	50, 1	73, 18	55
Amount of difference	56	61	60	59	56	52	50	55	57	57	52	49	55	55

An examination of the annual maximum and minimum temperature averages at Vassar shows a constant decrease in extreme of variation of from 60° in 1898 to 50° in 1902, thence rising to 55° in 1903, 56° in 1904 and 1905, and dropping to 53° in 1906. At Arbela the more satisfactory data give an average extreme amount of fluctuation of 55° for the 11 years ending 1908, the annual average varying irregularly from 58° in 1902 to 60° in 1908, or 3° less than for Vassar for a somewhat lesser period. During the 11 years ending 1908 the highest temperature recorded at Vassar with a slightly incomplete record especially for 1908, was from 99.45° in August, 1900, down to 25° below zero, February, 1899. At Arbela the highest temperature recorded during the period 1898-1908 was 99.40° in August, 1908; the lowest 24° below zero in February, 1899. This would make the maximum amount of temperature change for Vassar 124.45° and for Arbela 123.40° as far as the data go. At Vassar the average amount of change indicated by the monthly extremes of variation is from 46° for December, 1898-1906, the month of least variation to 62° in February, 1898-1907; at Arbela the least amount of greatest monthly change also takes place in December where the record amounts to 49°, or 3° greater than for Vassar, likewise the greatest amount of change also comes during February when there is 61° of variation, this being 1° less than for Vassar. The record at Arbela is quite complete for the 11 years ending 1908.

PRECIPITATION AT VASSAR.

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Amount.	State.
1898	2.42	2.74	2.79	1.23	2.15	3.42	2.30	2.93	1.29	3.64	1.80	1.23	28.03	32.29
1899	1.95	1.12	4.80	0.93	3.94	1.68	4.11	0.27	1.90	5.25	......	1.69	27.05	28.90
1900	1.34	2.80	1.88	1.92	4.26	2.29	2.29	5.70	1.43	2.51	4.82	0.66	31.90	32.31
1901	2.72	1.38	1.78	2.25	3.41	0.37	9.69	4.63	0.92	2.44	1.15	1.94	32.07	28.06
1902	0.36	0.91	6.22	0.92	1.78	4.99	4.60	1.71	4.83	1.06	1.37	1.89	31.45	32.53
1903	1.70	2.21	1.15	2.40	2.76	3.70	1.12	5.66	1.95	2.35	1.55	1.38	27.93	32.72
1904	1.85	2.50	3.10	......	2.11	2.20	1.91	1.55	2.60	......	0.42	0.75	18.98	29.78
1905	1.92	1.07	2.75	2.15	4.95	4.38	2.48	1.16	3.61	2.32	1.61	0.80	29.18	33.32
1906	3.95	1.25	3.45	2.35	3.35	3.09	1.25	2.50	1.08	5.50	2.50	2.40	33.87	31.41
1907	6.80	0.95	4.20	1.90	1.55	1.60	1.05	0.75	4.40	2.60	1.25	3.65	31.40	30.67
1908	2.20	5.05	2.35	......	......	......	3.00	......	0.55	0.95	1.31	......	......	29.64
Mean	2.47	1.10	3.15	1.80	3.03	2.76	3.10	2.68	2.23	2.95	1.94	1.38	29.21	31.06
Monthly mean, 2.40														

PRECIPITATION AT ARBELA, MICH

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Amount.
1898	2.55	2.34	3.84	1.17	3.06	5.16	1.57	3.07	1.56	4.68	2.09	2.47	33.56
1899	1.80	1.90	3.91	0.88	5.40	2.46	5.12	0.45	5.18	4.95	1.45	2.23	35.73
1900	0.94	3.10	3.85	2.32	5.20	3.48	4.56	6.77	1.49	4.20	4.91	0.62	41.34
1901	1.28	1.50	2.06	3.30	3.71	1.58	4.00	......	2.00	2.10	0.78	2.86	25.17
1902	0.10	0.52	3.77	1.10	5.77	10.20	7.59	2.06	0.05	2.71	3.58	3.44	46.84
1903	2.95	3.97	1.65	4.32	6.13	6.25	4.45	7.77	4.52	2.95	1.95	1.27	48.18
1904	4.03	2.99	6.70	4.71	3.41	1.98	3.44	2.40	4.25	2.93	0.27	2.26	39.37
1905	2.22	1.70	2.71	2.80	5.19	4.40	3.56	2.34	2.29	2.64	3.00	1.53	34.30
1906	2.38	1.54	2.45	2.36	3.21	1.70	2.35	1.10	0.84	3.63	3.71	3.79	30.06
1907	5.11	0.33	3.54	3.97	2.46	1.79	2.03	0.94	3.28	2.72	2.45	4.58	35.20
1908	1.84	4.64	2.39	2.49	6.83	1.68	1.90	3.97	0.49	0.77	2.82	2.56	32.38
Mean	2.38	2.23	3.25	2.68	4.58	3.70	3.69	3.09	3.09	3.12	2.45	2.50	36.56
Monthly mean, 3.07.													

The average amount of precipitation in the state during the 11 years ending 1908 was 31.06 inches. At Bay City during the 1 years ending 1903 the average amount of rainfall was 33.56 inches and of snowfall 28.9 inches. At Harbor Beach during the 10 years ending 1899 the amount of precipitation averaged 27.98 inches and at Hayes 25.88 inches. During the 10 years ending 1907 the average yearly precipitation at Vassar was 29.21

inches and for Arbela 36.56 inches, or about the same as at Bay City. At Vassar the greatest amount of precipitation was 9.09 inches in July, 1901, and the least amount 0.27 of an inch during August, 1899. At Arbela the greatest amount of precipitation during the 11 years ending 1908 was 10.20 inches in June, 1902; the least amount during the same interval was 0.10 in January, 1902. At Vassar the average amount of rainfall during the 10 years ending 1907 varied from 28.99 inches in 1899 to 33.32 inches in 1905. February is the dryest month of the year there during the 11 years ending 1908, with an average of 1.10 inches, and July the wettest with a record of 3.10 inches. At Arbela during the 11 years ending 1908 the amount of precipitation varied from 25.17 inches in 1901, with the record of one month missing, to 46.84 in the following year, 1902. As at Vassar, February is the dryest month, the amount being 2.23 inches, but May and not July is the wettest month, with a monthly record during 1898-1908 of 4.58 inches. At Vassar the monthly average is 2.40 inches and at Arbela 3.07 inches during the 11 years ending 1908.

General surface configuration of the county.

The study of present conditions upon the earth, or any portion of its surface, shows us that change and not permanence, is the general law. No region is exempt from the operation of this law, although the rate of change in different regions is variable, from many causes.

In flat and gently sloping regions, the various effects of water erosion are reduced to a minimum, and the action of the wind in effecting changes on the configuration of the surface of the land, is practically nothing in a moist climate, yet other forces, acting either alone, or together, produce changes in such regions, which are quite as characteristic as the action of running water in mountainous countries, or that of wind in the deserts of the earth.

In general it may also be said, that while change is the rule, commonly no widespread change occurs, except slowly, and that we have to look carefully and often through long periods of time, to see that there has been a real change. If we go to the side of a newly-graded road, or rolled, or plowed field, and examine the surface, then visit the same place after a few days, we find that changes have occurred, even if no forces have been acting but sunshine and the wind. If we visit the place after a heavy rain, it will be found that still other and greater changes have taken place. A month's exposure will cause greater changes still, and at the end of a year, the field will show but little resemblance to its original smoothness, while the roadside will be gullied and roughened in a way that makes it very plain that change has been going on under the very eyes of the observer.

What is recorded as taking place in these selected spots, under favorable conditions for observation, has been going on also, with greater or less rapidity, over the entire land surface, and many of the changes leave records of their occurrence, so that we may read them, when once we understand the language in which they are written.

Moreover, from the fact that change has always been going on upon the earth, and because it seems probable that it has proceeded, on an average at about its present rate throughout geological time, it is evident that by studying the present surface of the earth, and the forces at work and modifying it now, we will find the key with which to unlock the history of the past, and with the thorough understanding of the present, the rock systems of the earth, or any part of it, become a more or less easily read record, in which the history of past ages is preserved. Therefore, it is well for us to take up the description of the present surface features, or physiographic form, of Tuscola county, and find out if it is possible to see how they have originated, and what changes they have undergone to reach their present stage of development.

If a traveller were to start at the shore of Saginaw Bay, near the mouth of Quanicassee creek, in the northwest corner of the county, and drive or walk across the country to Gagetown, he would find a surprisingly level and monotonous plain, unbroken by high ridges or deep valleys, and with no physical features of note, save here and there a poorly developed stream valley, and occasional low, irregular, sandy tracts, interspersed with more sharply defined sand ridges, with now and then a swampy tract. The uncultivated land, except near the shore of the bay, is heavily wooded, and the entire district gives evidence of having been poorly drained, because of its flatness. In the vicinity of Gagetown, the surface becomes more broken, the rolling land culminating in a low ridge, beyond which, it is nearly flat again to the limits of the county.

If the observer takes for his starting point the same place as before, and proceeds due east across the county, to Cass City, he will cross more than half the county, before he comes to a marked elevation, and will find much the same surface features as on the other route. Just before the middle of Elmwood township is reached, however, the plain becomes slightly undulating and then a well-marked ridge is approached, which appears lofty as it is seen from the flat land to the west. The slope is relatively steep, and when the top is gained, it is seen to be a rather sharp, double, or triple, crest running northeast and southwest. The crest is not more than a quarter of a mile wide, often less, and after passing it the ridge slopes with abrupt descent to the east, to the valley, in the bottom of which flows the Cass river, and whose farther border in this direction is east of the county line.

Again starting at Quanicassee, and crossing diagonally to the southeast corner of the county, the traveller would find once more the plain, the well-marked ridge, and the sharp descent into the valley of Cass river, which he would enter, if travelling on the line indicated, near Caro. In this valley, he would find the floor terraced by successive flood-plains of the river. In crossing to the east side of the stream, the terraces would be found at intervals on that side, and from the topmost of these a gentle ascent would next be traversed for several miles. Beyond this, a region with rolling, rather broken surface would be encountered, low clay ridges, with swamps between them, and then long lines of small, rounded knolls, which are succeeded, as the journey to the southeast is pursued, by a steep ascent to another ridge, higher and more massive than the one farther to the west. If Koylton township is crossed, the surface would be found very irregular, step, high ridges and poorly drained swampy lowlands, alternating without apparent order.

If again the route be changed, and the southeast corner of Watertown, instead of Koylton township, be the objective point of the traveller leaving the same starting point as before, the plain, the belt of rolling land at its eastern border, the ridge, with sharp descent into the valley of the Cass river, which broadens out across this course also, will all be encountered. Again, also, the long, gentle ascent from the river must be crossed, and at its border will be found a series of hillocks, beyond which, to the southeast, is a high ridge. When this is surmounted, and its crest crossed, it is found that a gentle southward slope begins, which extends beyond the limits of the township and county, ending in a valley to the east and southeast.

If one proceeds due south along the west line of the county, from our supposed starting point, a nearly flat plain, gently ascending however, and broken, near Reese, by a slight ridge, and farther south, by the valley of the Cass, reminds him of the conditions existing in the northern part of the county, along the route first selected.

It becomes apparent, from these journeys across the county, that its surface is easily divisible into a well-marked, broad, gently-sloping plain, bordered by a narrow, relatively high ridge, which runs from the extreme northeast corner of the county, southwesterly to a point nearly half way across, ending a short distance west of Vassar. East of this, and closely limited by it, on the western side, is the Cass river valley, which is bordered on the east by a well-marked tract of gradually ascending, undulating country, which in turn, gives place to a high, massive ridge, the most prominent relief feature of the county.

The plain bordering the bay is broken, here and there, by slight ridges, which extend, in general, in irregular lines, in a more or less northeast and southwest direction, roughly parallel with the margin of the bay. The elevation of these, above the general level, is so slight however, that they are rarely marked features of the landscape, even in a district where the general flatness makes any elevation conspicuous. These ridges are of gravel or sand, often mere strips of sand a few hundred feet wide, and, in the pioneer days, before the forests were removed and the land drained, they furnished the most convenient lines upon which easily to construct roads, and, even at the present time, some of these sand ridge roads are still maintained.

Elevations within the County. The general configuration of the land surface is represented in the contour or topographic map (*Plate IV*). The brown lines on the map represent vertical intervals of ten feet; i. e. they are supposed to be the edges of a series of planes, beginning with the surface of Saginaw Bay, which are successively ten, twenty, thirty, and so on, feet above this lowest plane, and exactly parallel with it; since, if these planes were cut out of paper or cardboard of uniform thickness, the cut edges of the planes following the contour lines, and the planes fastened together in their proper order, one on top of the other, a relief model of the surface represented would result, it follows that the contour map is a picture of the relief features, or irregularities, of the land on the flat sheet of paper on which the map is printed.

The topographic map, then, differs from the ordinary or flat map, in that it attempts to picture the real surface, the hills, valleys, plains and other forms of relief, of the area mapped, and convey to the mind a picture of the steepness of the slope of the land and height of the hills and other peculiarities, as well as the courses of the streams, the boundaries of the land and the location of places.

The topographic map (*Plate IV*), was constructed from elevations obtained from the profiles of the various railroads which cross the county, from surveys made for draining the flatter lands along Saginaw bay, and in other parts of the county, and from a very large number of barometric notes made during the progress of the present survey. Barometric readings were made at every change of level and noted, together with cyclometer and time readings, and, as often as possible, the barometric work was checked by crossing previously surveyed stations, or by readings along railroad lines.

In some cases the barometic work was repeated several times, to test its reliability, and conclusively demonstrated its value. No pretence of a high degree of accuracy is made for the method, but the map produced herewith is sufficiently accurate to permit one to lay out drain lines and to see where the rougher parts of the county lie, and could even be used to select possible lines for laying out a railway.

The base level, or datum plane, from which all elevations are measured in the region under discussion is, naturally, Saginaw Bay, or, what is practically the same, the mean low water of Saginaw river at Saginaw, and this was taken commonly, though not invariably, as the datum for the railroad surveys, which were the base lines used in making barometric observations.

In order to bring the map into harmony with others published by the Geological Survey, however, the barometric and other data used in its construction were ultimately all reduced, with sea level as datum, and Saginaw Bay and Lake Huron were considered to have had, at the time the field work was going on, an elevation of 581 feet above datum. For a full consideration of fluctuations in the level of Lake Huron, and the real value of the Saginaw City and other data, see the extended discussions of the subject by Lane[1] and Cooper[2] in other publications of the Geological Survey.

[1]Lane, Alfred C. Report on Huron county, Michigan Geological Survey, Vol. VII, Part II, p. 44.

[2]Cooper, W. F., Report on Bay county, Michigan Geological Survey, Annual report for 1905.

Elevations in Tuscola county. The highest points determined in Tuscola county lie just southwest of the village of Mayville, on the ridge, less than a mile from the Union School building, and rise slightly above 1,000 feet (barometric) above the sea, or about 450 feet above Saginaw bay. As will be seen from the map (Plate IV), much of the crest of the high ridge on which Mayville lies, is above 900 feet above the sea, and is from 100 to 200 feet above the top of the lower ridge on the north side of Cass river. Mayville is about 200 feet higher than Caro, as shown by railroad surveys, and enjoys the distinction of being the loftiest town in the county, its elevation being 940 feet above tide, or about 360 feet above Lake Huron.

The highest elevations on the ridge running southwest from Gagetown lie along the crest in Sec. 33, Elmwood, Secs. 7 and 18, Ellington, and Secs. 24 and 26 Aimer, which reach an elevation of more than 830 feet, or about 250 feet above the level of Saginaw Bay. Points on this ridge rise above 800 feet as far southwest as Watrousville, from which place the elevation becomes rapidly lower, until at Vassar, it barely reaches the height of 700 feet. The figures printed in brown near the town sites on the topographic map, give their altitudes above the sea, as determined by the railroad surveys; in most cases these figures have been corrected to correspond with the most recent surveys.

The lines of sandy dune ridges near the shores of Saginaw Bay rise scarcely 10 feet above the water level, and the marshes adjacent to these are so near water level, that in very wet times they are, even after draining, subjected to prolonged overflow, especially in the springtime.

As will be seen by farther study of the topographic map, somewhat more than one-third of the total area of the county is below the 680 foot contour line, that is, is less than 100 feet above the level of Saginaw Bay. This area lies chiefly on the western side of the county, but a portion of it extends up into the valley of Cass river, even beyond the city of Caro.

Surface Drainage Systems. From what has been said in the introductory paragraphs of the present chapter, it becomes evident that at least two well-marked barriers to the direct run-off of surface waters into Saginaw Bay exist in the county, viz.: the ridge running nearly across the county, from the northeast to the southwest, and the higher one in the southeast corner, which forms a divide in Watertown, Fremont, Dayton and Koylton townships, separating the waters of the south part of the latter three, and nearly all of those of the first-named, from those of the rest of the county and turning them to the south. There are thus formed, three well-marked and distinct systems of drainage, two of which drain nearly equal areas of the county and the third, one much smaller, but no less distinct.

Beginning on the west side of the county, we find that all the land west of the diagonal ridge is drained directly into Saginaw Bay, through four, small and relatively unimportant streams, two of which have so nearly disappeared that their original course is now doubtful. These streams are a branch of Quanicassee creek, Squaw and Craugan creeks and a branch of the Sebewaing river. Of these, the Craugan is practically the only one which has retained its individuality and persisted as a well-marked stream. The others have apparently become merged in a number of county and township drains and no longer exist as permanent and distinct natural water-ways. The area drained by these streams is, in the main, so flat that if it were not for a great development of artificial drainage by a well-maintained system of ditches, much of the land would be flooded by every heavy rainfall.

The facts seem to be, that much of this district has been so recently abandoned by the bay, that no well-developed natural systems of drainage have had time to form, especially as the land surface over a considerable part of the district is a fiat plain, upon which the maximum slope is but a few feet to the mile. The recently exposed bay bottom would, in any event, have a poor drainage, because of its newness, and this, combined with the-slight slope, would furnish two chief causes, which together with several minor ones, have undoubtedly operated to produce the shallow, weak valleys and the poorly developed systems of tributary streams which exist in connection with the streams mentioned. The same chief causes also explain the existence of extensive areas of swamp and marsh, which, before clearing and artificial drainage were resorted to, characterized the part of the county adjacent to the Bay. This district is what is termed by physiographers, a "young" region, and is in the early stages of its youth. The part of this district most recently left by the waters of the bay, is still so near the level of the water, that in the spring, and during very rainy times they are subject to flooding, and numerous drains of large size are necessary to reduce the length of these flood times to a minimum.

The Cass River Valley. Passing over the western ridge, so frequently mentioned, and immediately a very different state of things is encountered. From the top of the ridge a wide and well-drained valley may be seen, at the bottom of which is a swiftly-flowing river, of good size for the region. This is the well-known Cass river, down which in the days of the early settlements of Tuscola county, great quantities of logs were floated. The river itself does not rise in the county, but enters it from the north and east by two branches which unite just south of Cass City. The river flows diagonally southwestward across the county, following the ridge so closely on its west bank, that but very few small tributaries enter it upon that side, although most of the water falling upon the east slope of the ridge finds its way into the river. Upon the east side, however, the valley widens out into a comparatively extensive drainage basin, and ten tributaries, some of them of considerable size, find their way across the basin and enter the river from the east. The most important of these streams is White creek, which, like the Cass river, has two principal branches, a northern and southern one. The former rises in Sanilac county, and within our limits flows nearly due west the greater part of its course, while the southern branch has its source in Clark Lake and the adjacent swamps in Koylton township, and flows nearly northwest, draining a region which has many springs; hence it is a permanent stream. The next most important stream in this series is Sucker creek, which is the outlet stream for a number of small lakes and swampy areas in Dayton township, and, like White creek, it is a permanent and rather interesting brook.

These streams all give evidence of greater age than the streams of the western side of the county, for their valleys are broad and well-marked throughout the greater part of their course and they have also relatively numerous tributaries, which, though small, still materially aid in draining off the surplus water of this section of the county. The flow of the water of these streams is probably made more steady and much less subject to sudden fluctuations than that of the streams flowing directly into Saginaw Bay, because of the porous nature of the soil of the surface over most of the Cass valley, which absorbs and stores the water falling upon it in the form of rain and snow, thus permitting it to find its way to the streams slowly, through underground channels.

Lapeer River Tributaries. The streams which flow southward, and southeastward, into Lapeer river from this county are all very small and are now generally intermittent, flowing only during wet seasons, or the rainy part of the year, since the forests have been removed. Of the nine such water-courses, for they are little more at present, which are mapped on Plate IV, seven have less than two miles of their length, and the other two run but little more than four miles, in Tuscola county. In other words, they are the extreme headwaters of larger streams flowing into Lapeer river, which drain the southern slopes of the Mayville moraine. Of these streams, the outlet of Cedar lake, which flows through Fostoria is a brook several feet across, and is apparently permanent, flowing throughout the year.

It is apparent from the description of the drainage systems of this county that they are very simple and on a scale which sinks into in significance when compared with that of larger areas, but, on the other hand, it may be pointed out that there is quite a variety of conditions presented, and that most of the peculiarities of stream erosion and of the work done by streams may be well illustrated by the drainage systems of our area, which fact makes their study of value in courses in Geography and Physiography in the schools of the county.

Lakes, Ponds and Swamps. Lakes and ponds are depressions in the surface of the land, in which the permanent ground water level is above the surface; that is, they are natural wells, on a large scale. The distinction made in some parts of the country, of calling larger bodies of water, lakes, and smaller ones, ponds, is not maintained in the region included in this report, but all depressions, permanently filled with water, are known as lakes, regardless of size. When compared with the number found in some other parts of Michigan, there are very few lakes in Tuscola county, and these all lie in the southeastern part, chiefly along the northern border of the high ridges which characterize this part of the county.

Number and size. In all, 16 lakes and ponds may be found on the township maps, but two of these are partly in Lapeer county, and of those which lie wholly within our limits, but seven are now bodies of water of sufficient size to be given names. Of these, Murphy's lake, which occupies parts of Secs. 1, Millington, and 7, Watertown, is the largest and most beautifully situated, as it lies in an irregular basin surrounded by wooded hills. It is somewhat more than half a mile in length from north to south, and a mile from east to west. The region in which it lies is very gravelly and covered by low hills, and knolls of coarse gravel, except to the northwest where it becomes very sandy. A portion of the lake shores are now marshy and swampy where vegetation has partly filled the basin, but along the northern side they are firm and sandy or gravelly.

The lake next in size to Murphy's lake, is Cat lake, in Sec. 7, Dayton township. This is a nearly circular body of water, surrounded by a considerable marsh and is not easy to approach on this account. Beneath the marsh on the western side of the lake and probably in other parts as well is a deposit of fine white mud, bog lime or marl, which will be described elsewhere.

Of the remaining lakes, little need be said, as they present no peculiar features of importance. Each of them presents a phase of the process of filling to which all such bodies of water are subject, in most cases the result of the growth and decay of plants, either in the water or along the margin of the lake. In addition to this source of filling, some lakes, like Cat lake, have streams flowing through them and these bring sediments, which are always deposited in the lake basin, so that a stream which enters a lake turbid with mud or silt, leaves it clear, the suspended mineral matter being left to form a delta where the stream enters the lake, or on the bottom and sides of the basin in the form of a slowly rising deposit. Not all of the lakes represented on the map (Plate IV) have permanent streams flowing into them. Such are fed by springs and by the inflow of temporary rills during wet periods and are representative of a type of lakes known as tarns. Still another type is represented by the small pond marked "Spruce lake," Sec. 32, Watertown, and the basin just north of it, formerly known as Long lake. This type is of frequent occurrence in Michigan, in regions of sandy soils, and has no visible inlet or outlet, the water rising to a certain level, above which it seeps away, through the porous walls of the basin, possibly reappearing as springs at some distance away. At the time Long lake was visited, no water was visible in the basin, and the lake had apparently ceased to exist, as such, and had become a marsh, covered by reeds and sedges. Such an end may be expected, ultimately, for all small lakes of this area and will probably come rather quickly to those with shallow, muddy bottoms and marshy, quaking margins, such as Mud lake in Sec. 34, Arbela, Cedar lake, Sec. 28, Watertown, and the small pond in Sec. 6, Dayton, northeast of Cat lake, where bits of floating marsh, driven from side to side of the pond by the wind, foretell of the complete closing in of the surface by the turf-forming sedges.

Deepening the outlets of such ponds hastens their end, as this keeps the water level constantly lower which, in turn, encourages the growth of the aquatic plants, the water weeds, which are the chief agents in destroying lakes. If the water is drained away so that portions of the bottom of the pond are exposed to the light and air, the end is also hastened, since such exposure prepares the soil for the growth of land plants; these soon cover every available spot, forming islands from which the surrounding water surface is invaded and covered by the kinds of plants which can grow in such places, among which are the turf-forming sedges, the cat-tail, certain grasses, the button bush and other shrubs. The remains of these, partly decaying beneath the water, add to the deposit on the bottom, and build it rapidly higher, until the basin is filled above the water level.

Temporary Ponds. In the vicinity of the shore of the bay temporary, shallow ponds are sometimes formed by the action of storm waves, or currents which cut off parts of the bay by building bars across indentations of the shore line. Such ponds also occur behind the lines of sand dunes, back of the beaches on the edge of the marsh, as the result of accumulation of water which seeps in from the sand and from higher parts of the marsh.

These ponds are usually overgrown with bulrushes and sedges and are goon filled with peaty accumulations, resulting from such growth, hence are but evanescent affairs.

Swamps and Marshes. Swamps and marshes differ from lakes simply in degree, since they are places where the water level is either at or very near the surface of the soil, either just above, or just below it. A wet swamp or marsh may be in reality a very shallow lake, much of the time, but the shallow water tends to evaporate or drain away rapidly in dry times, and as the water level gets below the surface, the lake conditions cease.

Differences in the character of the dominant vegetation lead to the, commonly accepted distinctions between swamp and marsh, the former name being applied usually to tree-covered wet lands, and the latter to those having grass-like or reedy vegetation.

Originally, much of that part of Tuscola county lying west of the ridge extending from Cass City to Vassar, as well as large areas in other parts of the county, were either swamp or marsh. The swamps were riot only extensive, but were covered by a dense growth of timber, the removal of which was so great a task that it was only recently that some of the larger swamps have been cleared. The soil was wet, from two chief causes; first, its structure was such that it did not absorb water readily, that is, it was clayey, and second, it was so flat that the water which fell on it in the form of rain and snow was unable to run off with sufficient rapidity to permit the soil to dry out, and the heavy forest growth increased the wetness by preventing evaporation. After the timber was cleared away and the land ditched, these swampy areas made very fertile agricultural districts.

Near the shores of the bay are considerable areas of marsh, flat lands, which, in the primitive condition, were overflowed for a long period each spring, the water standing on the surface sufficiently long to prevent the growth of trees. These areas were covered by grasses or grass-like plants, except on low-lying ridges of sand, which crossed them here and there, and which supported groves of trees. In flood-time these marshes were very wet, but in the late summer and fall, became in many places, quite dry and firm, and after the region became settled, were known as prairies, a name which their treeless condition and wide extent, as well as their flatness merits.

The relation between the spring overflow and the growth of trees was clearly marked, since the timber extended sharply up to the edges of the district subject to flood and stopped in a sharp and well-marked border of old trees. Later, when the level of Lake Huron fell below the normal for a number of years, and the area of overflow was reduced somewhat, a border of young trees developed along the margin of the old forest, on what, until that time, had been only sedge-covered marsh land. Later still, after an extensive artificial drainage system had been developed and much of the marsh converted into farms, the uncultivated portions became quickly covered by shrubs and young trees, and it was evident that the land was adapted to tree growth, provided that the trees could get established.

Marshes of less extent occur around the small lakes and in other poorly drained places throughout the county, but, on the whole, these areas are of less importance than in most parts of Michigan of the same extent of surface as this county, if we except the marshy tracts which are adjacent to the Bay.

Both swamps and marshes, when fully drained, make exceptionally good farming land in this county, because, in addition to the decayed vegetable matter which they contain, the original mineral soil, as mentioned above, was usually a fine clay or clay loam. The famous areas of swamp land, which, formerly were well known and were supposed to be of little value, such as the great Columbia swamp, which extended up from southern Columbia township into Huron county, show now scarcely even vestiges of their former existence, but are cleared lands, the seat of fertile and prosperous farms, on which great crops of all kinds are annually produced.

Saginaw Bay and its beaches. Where it borders Tuscola county, Saginaw Bay is very shallow. For some distance from the shore bars and reefs of sand and gravel appear to rise nearly to the surface and cause the waves to break at a long distance from the shore, whenever the wind is strong. The shore line is nearly straight and unbroken by indentations, except where Quanicassee creek enters at the south end of the coast line, and where Fish Point protects the shallow bay into which Craugan creek empties near its northern limit. There are no harbors, even for small boats, except these, although in calm weather, rowboats of light draught may be drawn up almost anywhere along the beach. The shore of the bay is, in general, flat, with a low line of sandy ridges just above the high-water, storm-wave line, which is apparently from two to three feet higher than that of the present level of the water. These ridges nowhere exceed fifteen feet above the water level and are much less than this towards the south. They apparently reach their culmination near Bay Park, directly west from Unionville, where there are several rows of low dunes, some of them apparent marking a shore line of somewhat different configuration from that now existing. The dune lines extend northward to Fish Point and end there, being poorly marked on the east side of the inlet behind the point.

These ridges have the ordinary appearance of sand dunes, being irregular in form, with rounded, hummocky crests and with the leeward or shoreward sides usually steeper in slope than the bayward ones. The sand composing them is of fine and rather uniform grain, as is usual in such deposits. The beach lies between the duney area and the water, and is sometimes separated from the dunes by a slight depression. It slopes gently to below the water level and, in places, is sandy, or even pebbly, where the force of the waves is considerable, or above the reach of the ordinary summer waves. Below this line it is made up of finer material and is even muddy in places with small boulders scattered over it, and is usually covered, in less exposed spots, with a growth of low sedges and rushes, while the stems of the lake bulrush may be seen growing in the water for a considerable distance from shore.

The characteristics of the beach are, then a long, smooth, gentle, muddy, sandy, pebbly or bouldery ascent from below the water level, culminating in a slight ridge of coarser materials, above which may rise a higher, steeper, and broader irregular ridge, which when present, is composed of fine sand of uniform grain.

On examining the bottom of the bay beyond the foot of the beach, it will be found to be somewhat irregular, with well-marked, flattened ridges of sand and even gravel, together with other less definite areas of coarse material, which form shoals and bars. Upon these the waves break during storms and they are gradually built up by action of waves and currents, until they rise above the level of the water and may eventually even cut off portions of the bay and form a new shore line. The significance of considering the form of such deposits below the water level will be discussed in a later paragraph.

The effect of the lines of shoals on the present shore is important, since the higher waves from deep water break on the bars, where their force is expended, so that they strike the beach with but little force and modify it but slightly. In other words, the bars and shoals act as a breakwater to protect the beach from strong and high waves and hasten the deposition of fine materials brought to the beach by the lesser waves and currents, and the consequent building-up of the bottom, inside the barriers.

Aside from this, the shallow, protected areas are favorable for the growth of water plants, which help in filling up the basins in which they grow by the deposition of their remains at the end of the growing season, and by mechanically entangling sediments which come in contact with their stems and leaves during the period of their activities.

Ancient shore lines and beaches. Having examined the peculiarities of the deposits along the present shore of Saginaw Bay, it is but natural that the student of such matters, or even the causal observer, on turning away from the beach and crossing the wide stretch of open, prairie-like marsh behind it, should note that duney, sandy ridges, exactly similar in structure to those shoreward from the beach, form long lines, marked usually by trees, across the sea of sedges and grasses which cover the greater part of the prairie. Some of these ridges merge with those along the beach, while others run parallel with them, or diverge from them at various angles while slightly elevated, irregular, sandy, or gravelly tracts appear in the roads and fields, or are marked by the growth of trees on the marsh. A little reflection and study of the relations and structure of these formations, convinces one that the irregular sandy ridges are similar in origin to the dunes of the present shore and that they probably mark previous positions of the bay margin, while the lower, more even sand and gravel tracts represent the bars and shoals in the bottom of the bay, at present, as the marsh around is equivalent to the deeper parts of the bottom, when the level of the water was several feet higher than at present. These conclusions are strengthened by the presence, some miles inland, of a gently ascending slope, terminating in a long, narrow ridge of sand, or, in places, of coarse gravel, comparable in every way with the beach and dunes of the present shore.

The slope faces the bay, and the ridge has a level, clayey country behind it, which is some feet higher than the land to the west of the ridge. On following the ridge across the county, it is found to be continuous for miles, and that the slope to the west of it is equally persistent;

everywhere the form and structure of the two phenomena, if undisturbed, are readily identified with those observed at the shore of the Bay, except that the water is gone and the bars and shoals appear as real elevations, while the beach is seen to the very bottom of the bay on which it was formed. The slope, then, is a beach which has been left by the water; the gravel, or lower, sandy crest, marks the limits of the wave action, and the more irregular sand ridges shoreward are the sand dunes formed by the wind, from sand washed up on the shore by the waves.

Such beach ridges in early days were the road lines, first of the Indians and, later, of the pioneers, who used them when the clay soils were too poorly drained to permit roads to be cut across them.

The phenomena of these abandoned shore lines are especially prominent and easily recognized in the townships of Wisner and Akron, partly because of the generally very flat topography, which renders every elevation noticeable, as well as every change of soil, and partly because of the lack of trees which makes it possible to see long distances and follow the beaches with the eye, and thus become convinced of their continuity.

Some of the old ridge, or beach roads are still used in this part of the county, but drainage, clearing away the forest, and thorough settlement, as well as modern methods of roadmaking, have made the entire region passable without these sand ridge roads and soon the last of them is likely to be abandoned. The old road from Sebewaing to Unionville, in part, is built along one of the lower beaches of the series. This series at constantly higher levels, mark various lake stages for more than 200 feet in elevation, back quite to the east side of the valley of Cass river along the base of the Mayville moraine. Another well-known and much-used ridge road is the main road across Wisner township from Unionville to Bay City; this road, however, is seldom on the ridge, but simply follows along near its base. Another example of the shore formation, but possibly of a smaller lake, is the well known stone wall, just across the line in Sanilac county, in Greenleaf township. This is described and figured by Gordon,[1] and mentioned by Lane[2].

The numerous ancient shore lines are considered more fully in the glacio-lacustrine history of the region, (page—) to which the reader is referred.

[1]Gordon, C. H. Report on Sanilac county, Mich. Geol. Surv., VII, Part III, p. 18, 1900.

[2]Lane, A. C. Summary of the Surface Geology of Mich., Annual Report Mich. Geol. Surv., 1907, p. 105.

Diagonal Features of the County

In general, it may be said[3] as Winchell long ago remarked that the more important physical features of this county are characterized by a well-marked tendency to arrange themselves at a sharp angle with the political boundaries. As is well known, the system of political divisions, or units of government, the township and the county, in Michigan and adjacent states, is based upon the United States Land Office Survey, in which the unit of measurement was the section or square mile. For convenience in reckoning and for other reasons, these unit sections were grouped in larger squares of 36 each, called townships, which were measured off from south to north and from east to west. The survey was started from east to west on a carefully measured line taken as a base line in the southern part of the state and from a principal meridian, or north and south line, the spaces between the bounding meridians of the townships, north and south lines, 6 miles apart, were numbered consecutively from the principal meridian east and west, and called ranges, while the space between the lines parallel with the base line were numbered consecutively north and south from this line. Thus any township can readily be located by its range number, and 'its number north or south of the base line, for it is six times as many miles north or south of the base line and east or west of the principal meridian as its township and range numbers.

It is evident therefore, that there is a well defined basis for the rectangular arrangement upon the compass lines of the political boundaries, as well as the roads, which usually follow the section lines, throughout the region covered by this report, as throughout the entire area covered by the Land Office Survey. It is also evident, however, that these lines do not take into account irregularities of surface, or any of the physical features, hills and valleys, etc., hence the latter may cross them at any angle.

It has already been suggested in the opening paragraphs of this chapter, that the valleys and ridges run across portions of the County diagonally, but, since this characteristic is a well marked one in a number of ways, it merits more than passing mention, and some farther discussion of it may be of interest.

[3]Tackabury's Atlas, A. Winchell, 1883. Ninth Ann. Report Mich. Acad. Sci., p. 138.

(a) Strike and dip of the rock formations

As already stated, (page 130) there are but a very few limited exposures of bed rock in the entire area of the county, and these, of rock with nearly horizontal bedding. In studying the dip of the larger rock strata, by means of well records however, the general trend of the strike is found to be in well defined, diagonal lines from northeast to southwest, nearly straight across the county, the dip of most of the recognized beds being to the northwest.

(b) Surface slopes and drainage

The chief drainage system of the county, the Cass river, runs in a nearly straight line diagonally from northeast to southwest, until almost across the western boundary, where for a short distance, it turns west. Since the course of this stream determines that of its principal tributaries, they also, in a general way, run diagonally to the surveyed lines, but roughly, at right angles to the course of the main river, the only notable exception being White creek which has a westerly course; several of its tributaries, however, show a well-marked diagonal trend to the northwest.

The streams flowing directly towards Saginaw bay at first all take a definitely diagonal course, but, on reaching the wide plain, across which they have to find their way, they are turned chiefly to the north by low ridges, the significance of which will be shown later.

The two chief lines of elevations since they limit the valley of the Cass, also have well-marked trend from the northeast to the southwest, and, their slopes, being generally at right angles to their main axes, are also diagonal to the section lines, facing the northwest or the southeast.

The short coast line also runs almost a true diagonal across the sections which border it, and the same direction is very clearly followed by the abandoned beach lines, which as pointed out above, occur at a number of levels above those of the present day.

(c) The soils of the county, since they are very closely related to the surface features already mentioned, are, in general, found to follow diagonal lines, and the bounding lines of the different kinds, as of sands, clays and loams, are often found cutting diagonally across the sections, as if they had been carefully laid down with that in view. This arrangement of the soils gives variety to the natural vegetation and often makes diverse farming a necessity, as on a single farm many kinds of soil may occur and only certain kinds of crops can be grown on the poorer soils, while most kinds will give good returns on the better ones.

(d) A glance at the map (Plate VI), shows that there is a similar diagonal tendency in the arrangement of the areas of developed underground waters. This, of course, is to be expected, since the rock formations from which the waters come, have their edges exposed below the overlying drift, in the same way, and also since the surface relief forms are generally in diagonal relations, and these determine the height to which the water will flow above the surface from artesian basins. We would, therefore, expect to find the outlines of the well developed basins of artesian, or flowing, wells with diagonal borders and also that the lines bounding areas from which salt or brackish water may be obtained would show the same features.

(e) *The older highways*, having been laid out to follow lines of least resistance, and to avoid the more densely wooded and clayey swamplands, were generally more or less diagonal in direction. They frequently followed the sandy or gravelly beach ridges, because they were always dry, and such roads are still used in Akron township and other parts of the old lake bottom where these natural road lines exist. In similar fashion, diagonal roads were constructed along the sides of the higher ridges and sometimes on the terraces of the valley of Cass river, and only go out of use when the land is fully settled up and new roads are constructed on the section lines. But for these natural highways, it is probable that traffic in early days of the settlement of this region, and while the lumber was being cut off, would have been much more difficult than it was, and even at present these old, short-cut roads are very convenient and, where open, often much used.

CHAPTER III. THE GLACIAL PERIOD IN TUSCOLA COUNTY.

Introductory. The last interval of geologic time in which very different conditions prevailed from those of the present, was the Pleistocene, or Glacial Period. Belonging to the same great geological age, the Cenozoic, as the present, the lapse of time since its end is so small, comparatively speaking, and the records left by it so definite and easily read, as well as so fresh, that far more is known of its history than of any of the older and more remote periods of the life of the earth.

While a very full discussion of this age will be found in recent textbooks of geology, and, in the reports of this Survey[1] and of the U. S. Geology Survey[2], a brief review of the chief facts relating to it, may serve a useful purpose here.

The Glacial Period was a time, when, because of different climatic conditions from those preceding or following them, combined with other causes more or less obscure, a great glacial ice sheet of enormous extent and thickness pushed out from centers of accumulation in the north and covered a large part of Eastern North America, extending as far south as the Ohio river. In the region west of the Mississippi, the principal advances of the ice seem to have been earlier and less extensive than to the east, and, while at this time, glacial ice covered other parts of the earth in what are now temperate latitudes, nowhere are there evidences of greater glaciation than in the region of the Great Lakes, and especially in the Southern Peninsula of Michigan. This part of North America was covered by the ice sheet much longer than the region to the south of it, both because it was in the direct path of the ice movement to the southwest, from the great center of ice dispersal in the region of Labrador, and also, for the reason that the valleys now occupied by the Great Lakes were filled by thick masses of ice, which persisted long after the melting of the thinner sheets on the higher land and kept pushing out on to the highland under the influence of the pressure from the still active center of accumulation and dispersal to the northeast.

In considering the records of the Glacial Period, it must be remembered that the movements of glacial ice are due to a kind of flow, in which the ice moves like a very stiff liquid, and not as a mass of entirely solid matter. The ice, therefore follows the laws governing the flow of liquids and moves more rapidly where it is deepest, or thickest, and is retarded in its motion where it is thin. It also moves more swiftly down hill, and less so up a slope, and was apparently often halted for long periods, in its final stages at least, by lines of hills.

Moreover, the ice, in extending out from the centers of accumulation moved down the slope of the land in broad sheets, which, at the time of their greatest development, were probably continuous, but, moving more rapidly in the deeper portions, than where the ice was thinner, and hence extending farther beyond the general margin in such parts, giving the front a wavy, or scalloped appearance. In the later stages of the Period, it seems probable that there was very little movement in the thinner ice, while the thicker parts became slowly moving currents, through these stagnant portions of the sheet.

The fact that the glacial ice was so much deeper in the valleys now filled by the Great Lakes than on the surrounding high land, made these valleys lines of comparatively rapid movement, and records, in the form of deposits left by the ice, show that each great lake basin was the local center from which one or more lobes of ice pushed out for a greater or less distance over the adjacent high ground.

[1]Lane, A. C. Report on Huron county, Mich. Geol. Survey, VII, Part II; Annual Report for 1907.

[2]Leverett, F., Monographs U. S. Geol. Sur.; Mich. Acad. Sci. Reports.

The records left by these movements of glacial ice are of two sorts, those where the ice deposited material, and those where it removed it. Like water, ice is an agent of erosion, of transportation, and of deposition, but, unlike water, the ice is able to transport material of all sizes, from the finest rock-flour to huge boulders for long distances, and to deposit them together. Flowing water always sorts the materials which it transports, both in transit and while deposition is going on, but ice can carry rock masses of any size, side by side with equal ease, and in deposition, may leave them still together, so that ice-formed or glacial deposits are, at a glance, distinguishable by their lack of sorting, from those formed by water.

In its passage over the land surface, which, before its advance was undoubtedly covered by the products of rock-decay of long geologic periods, the glacial ice sheet, not only removed the soils and other forms of disintegrated rock from the surfaces over which it travelled, and included the material within its mass, often carrying it for hundreds of miles, but it also smoothed, rounded, scratched and even polished the surfaces of the underlying rocks, thus leaving records of its source and direction of movement. Most excellent examples of this kind of ice work have been found where limestone ledges have been recently exposed in the region of Saginaw Bay, and some exceptionally fine illustrations have been uncovered from time to time in the quarries at Bay Port, Huron county, a few miles north of the county line.

Glacial ice moves forward until it reaches a place where the rate of melting of the ice equals the rate of movement forward. At such places, the ice front remains stationary, and, as the melting of the ice releases the included mineral matter gathered up along its whole course, this accumulates in greater or less quantities in lines of low, irregular, rounded hillocks, known as terminal moraines. Where the ice melted faster than it moved forward, the ice front retreated from the terminal moraine, and the mineral matter contained by the ice was then spread more or less evenly over the surface covered by the retreat, and formed a ground moraine, or till plain. Ground moraines were also formed beneath the ice, because of melting in the lower layers due to various causes.

Successive halts of the ice margin, with retreats intervening, would leave as many moraines as there were halts, with broad valleys between them to mark the periods of rapid melting; advances would seldom be plainly recorded, since they would obscure or obliterate all previous records by burying them, or erasing them. The moraines thus formed would be composed of unsorted rock debris of all sizes, from fine clay to large boulders, while the floors of the valleys would be made up of similar materials, in most cases, unless modified by the action of water.

Accompanying the terminal moraines in most instances, were extensive accumulations of sorted material, sands and gravels. These are glacio-fluvial deposits, made by the water which flowed away from the front of the melting ice, either in the form of broad sheets of water, running down the slopes of the moraine, or, more often, as streams, either spouting from conduits in the ice, or running from its surface, down over the morainal deposits. The water of such streams, or sheets of water, was generally flowing swiftly and was heavily loaded with rock waste from the melting ice, and as soon as it reached the flatter lands at the foot of the slopes of the moraine, and the velocity of the current changed, the heavier and coarser gravels and sands were left behind, while the finer particles were carried farther away and the lighest and finest, the silts and clays only settled when some very flat area or basin was reached. The coarser materials often formed deposits which banked against the moraines, in the form of outwash, or over-wash, aprons, or were sometimes spread out to form the more extensive sand or gravel plains. When the material was carried down a well-marked valley, as was sometimes the case, it formed a long, narrow deposit, higher at the morainal end, known as a valley train.

Where streams spouted from tunnels in the ice, under pressure, the amount of material which was carried by them was often very great, and the coarser and heavier gravels were usually left in a heap which sometimes grew to large dimensions near the place where the water issued from the ice. Such deposits take the form of steep, rounded, often irregular gravel knolls and hills, and the gravels in them are usually more or less irregularly stratified, since the water which formed them was constantly varying in velocity and volume, as the ice melted faster or more slowly. Such gravel hills are known as kames, and are frequently found associated with moraines, as are also the other types of glacio-fluvial deposits mentioned.

Still another kind of deposit occurs more rarely, the esker, a long, winding, gravelly or sandy ridge, usually found on the iceward side of moraines, and running more or less at right angles to them. Such ridges, from their structure and position are supposed to have been formed by water which ran in tunnels or cracks in the glacier, somewhat back from the margin, and either at or above the bottom. The deposits of glacial ice are called collectively "till" or "drift" and are further often distinguished as stratified and unstratified, according as they have or have not been subjected to the sorting action of water, as they were laid down.

Before considering the local conditions found in Tuscola county in relation to the statements above, it must be pointed out that the basin now containing Lake Huron, was the seat of masses of glacial ice which moved out of it in two well-defined lines. The northern part of the basin held an ice mass which had its central line or axis of movement through Saginaw Bay, and moved southwestward across the southern half of the Southern Peninsula, and at the time of its greatest advance, reached to the Mississippi in the region of southern Illinois.

In its later stages, this was called the Saginaw lobe of the ice sheet and is the one which has left most of the definite records of ice invasion in the area covered by this report.

The southern half of the Lake Huron basin was filled with ice which moved westward over the low land of the southeastern part of the state into the basin of Lake Erie and formed the Huron-Erie lobe, which pushed out southward and westward on the east side of the Saginaw lobe, but did not over ride the highlands of the southern part of Michigan to any great extent, only covering a portion of the eastern and southern sides of the peninsula, south of Saginaw Bay. These two lobes were the only ones which affected the area discussed here, and at the time of the greatest extent of the ice sheet were not distinct, except, possibly, as lines of more active movement in their deeper parts, their margins probably being entirely fused together, and forming a continuous sheet.

After this period of greatest expansion, the ice sheet was melted back to the region from which it came, and finally disappeared entirely; this retreat, however, was only accomplished by slow stages during which there were periods of readvance and long halts of the ice front, the latest of which formed moraines, and other types of deposits, which constitute the principal surface features of the present.

In concluding this preliminary discussion of principles, it should also be stated that there were several periods or stages of extensive glaciation, with intervening times when the ice melted far back from the regions of greatest advance. As many as thirteen of these alternating stages of advance and retreat are recognized in various parts of the country, the last advance being known as the Wisconsin stage, because its deposits are well illustrated, and were first carefully studied in Wisconsin.

These stages of alternating glaciation and melting, left records in the form of drift sheets, which may vary in character and which show in the lower, and older ones, greater exposure to the agents producing rock decay and disintegration, while often between an upper and under sheet of glacially deposited material, there have been found beds of soil with the remains of trees and other plants, or even of peat.

Two sheets of drift of different ages may also be distinguished by differences in color and hardness or compactness, the older beds sometimes being cemented into what the well drillers call "hard pan."

Pre-Wisconsin drift. In considering the history of the Glacial Period, as expressed in the drift and other deposits of Tuscola county, at first inspection, all appear to be not only those of the Wisconsin stage, but to consist chiefly of such as were laid down during the latter part of that period, and of the time immediately following the final melting back of the ice into the basin of Lake Huron.

In the valley of some of the streams, notably Cass river, about a mile and a half south of Caro, on Secs. 15 and 16, Indianfields township, near the site of the power dam, and along Sucker creek, in Secs. 32 and 29, Wells township and northward, are exposures of a very dark, tough, gravelly, or stoney, clay hard-pan which is entirely different from the drift found on the higher land, in color, in texture and compactness, and in some degree, at least, in the character of the pebbles present in it, having apparently, a larger number of dark-colored, basic, volcanic rocks represented in these, than do the overlying or higher deposits of till in which granitic and other light-colored pebbles seem to be more numerous.

It seems to be this same material which is near the surface and occasionally crops out in the lower terraces of Cass river, opposite and above Caro, and in the valley of White creek. In these situations, the line of outcrops below the fluvial sands and gravels, is often marked by a line of strong springs.

This type of drift was not noted elsewhere in the county, but it is so distinct, both in color and compactness, being in places as compact as soft shale, that it has been considered to be of greater age than the more superficial deposits and for want of a more definite term, is here called Pre-Wisconsin drift. In addition to this outcropping material, as was pointed out to the writer by Mr. Frank Leverett of the U. S. Geological Survey, many of the records of wells and prospect holes, as well as mines, in the region around Saginaw Bay, show, at varying depths below the surface, "hardpan," a much tougher, darker clay than that above it, and when once this is entered, it continues to the rock surface. Well drillers have reported to the writer finding the same substance in Tuscola county, and, indeed, inspection of carefully kept well records shows the existence of such material in many places within its limits.

The most accurate and convincing records of the existence in Michigan of two stages of ice invasion, with a break of some length between them, have been found in the adjacent county of Bay, in the test holes and coal mine shafts. These have been carefully collected and placed on record by Cooper[1], who reports the occurrence of at least two distinct beds of plant remains in the drift of Wisconsin age.

To the writer's knowledge, no such beds have been found within the limits of Tuscola county, but it is probable they will be found if coal mines are opened.

The Pre-Wisconsin drift of Bay county seems to be chiefly sands and gravels and nothing corresponding to the tough and blackish clay reported above has been noted there.

[1]Cooper, W. F., Geological Report on Bay county, Ann. Rep. Mich. Survey, 1905, p. 339. Lansing, 1906.

The Wisconsin Drift. The surface drift-sheet and the chief relief forms of Tuscola county, are of the latest or Wisconsin stage and are records of very late phases of this, since not long after these deposits were formed, the ice retreated finally into the basin of Lake Huron and disappeared.

The drift consists of two well-differentiated types: (1) An unmodified bouldery, rather sandy till, or fine and coarse matter mixed, which occurs in the form of moraines, and constitute the higher parts of the two conspicuous ridges crossing the county; (2) Modified till in the form of glacio-fluvial and lacustrine deposits, which range from very coarse gravels through sand to the finest clays. These materials give evidence, in the mixed character of their constituent rock fragments, of glacial transportation, and in their sorted deposition, of the action of water.

Among other evidences of ice transportation for long distances, may be cited the presence in the till, and in the gravels, of large numbers of boulders and pebbles of crystalline rocks, such as are not found in the Southern Peninsula, nor in the region southward of it, but which are very wide-spread in the Northern Peninsula and the region north of Lake Superior, and in certain parts of the region northeast of Lake Huron. Besides this, many of these pebbles and boulders are not symmetrically rounded, as are those which *are water-worn, but are more or less angular, though smoothed and flattened on one or more sides, and also often bear deep scratches, the autograph of the glacier.

The relations of the glacial deposits and of the glacio-fluvial lacustrine features of the adjoining regions may be learned from previous publications of this Survey[1] and from the more extended work of the U. S. Geological Survey[2] soon to appear.

[1]Lane, A. C. Loc. cit. p. 60.
Gordon. Report on Sanilac county, Mich., Geol. Surv. VII, Part 3.
Cooper, W. F. Loc. cit.
Taylor, F. B. Surface Geology, Lapeer county, Ann. Rep., Mich. Geol. Surv., 1901, p. 111.

[2]Leverett, F., and Tailor, F. R. Prof. Paper U. S. Geol. Surv.

The Marlette Moraine. The oldest definite record of a halt in the ice front, within the limits of what is now Tuscola county, is a faint, rather poorly defined line of knolls, with sandy slopes, which enters the county just east of Silverwood and forms an irregular arc from this point west about three miles and then passes southwest into Lapeer county again. It also is represented by a ridge in the extreme southeastern part of Koylton township, and runs southeast from there through Marlette. This is Taylor's[3] Fifth Moraine and is but a beginning of the series of morainal ridges lying north of it.

[3]Taylor F. B. Loc. cit. p. 115.

The Mayville Moraine. Late in the Wisconsin stage, when both the Saginaw and the Huron-Erie ice lobes had melted back, and back, towards the Bay, from the higher lands south and southwest of the base of the Thumb, the ice margin finally made a long halt in what is now southern Tuscola county, and for a time the rate of forward movement equalled the melting. Marking this halt, is a high ridge which runs from southeastern Millington township, northeastward, across Watertown, Fremont, Dayton into Koylton and southern Kingston townships. In eastern Dayton and to the east, the ridge becomes somewhat lower and breaks up into massive, somewhat isolated hills, separated by flat, poorly-drained valleys. This structure is also well marked throughout Koylton, and in southern Kingston townships.

The moraine is some two miles wide just west of Mayville where it reaches its greatest elevation, something over a thousand feet above sea-level, a little over four hundred feet above the present level of Saginaw Bay. In this part it is characterized by a steep northern or iceward slope, a broad undulating top, covered by low, or, sometimes, high ridges, and a gentle southward slope. An excellent place to observe the northward slope and its peculiarities, is near the point where the road west from Mayville leaves the line between Secs. 27 and 34, Fremont township, and angles to the northwest. From this place, the north face of the moraine is visible for a considerable distance in either direction, and the valley of the Cass as well. The slope is at first steep and smooth, except for the gullies cut by rainwash, but about half way down, it becomes somewhat more gentle, and for some distance is covered by lines of steep, rounded hillocks, usually of coarse gravel, which., as they are seen from above, look like gigantic loads of earth, which have been dumped in lines along the slope. These are small kames, probably formed along, or under, the edge of the retreating ice, as it slowly melted, by the gravel-laden waters from numerous outlet streams from the ice, dropping a portion of their loads in these places, but not issuing near enough together, nor for long enough time, to build up a continuous moraine.

The conditions producing this form of deposit seem to have been temporary, as somewhat farther down, the slope becomes smooth and the descent is quite uniformly gentle, until the floor of the valley is reached.

The most remarkable deposits connected with this face of the moraine, however, are in the western part of Watertown township. Here the slopes are much steeper than in other places and face the west for a distance of some miles, running sharply down into the bottom of a narrow valley, less than a mile wide, in which is a great number of small kame-like knolls and short, steep-sided, sharp-crested, gravel ridges, with their main axes running about parallel with the moraine. This tract extends southward with some minor breaks, to beyond the county line, gradually passing into an area of gravel, which, from its surface structure, suggests a pitted outwash plain and the valley may have been for a time the outlet, towards the south, of the water from the front of the melting ice, but it is difficult to see under what conditions running water could have produced the large number of peculiar hillocks noted above.

The Millington Moraine. West of this valley just described, in Millington township, the moraine is lower by more than 100 feet, has a much smoother surface, and off to the south of Millington village, becomes a gently undulating plain. This occupies a considerable part of Millington township but becomes to the west a single, simple, morainal ridge, which runs southwestward from Sec. 18, Millington, diagonally across Arbela township, and, growing fainter and fainter, nearly disappears in the extreme southwest corner of the county.

This ridge, in its relation to the higher one, seems much the same as morainal tracts in sections 15, 16, and 17, and in 1, 2, and 3, Fremont township, and which, extends northward and northeastward into Indian-fields and Wells township; it is possible the series forms an interrupted moraine laid down under water during a brief halt of the ice margin, after it left the Mayville moraine. At this time, there may have been a considerable body of water lying between the moraine and the front of the ice, and the fact that the morainal deposits formed during this short halt did not rise much above the surface of this, would account for the smooth surfaces, gentle slopes, and somewhat sorted character of the drift in this peculiar line of elevations.

Glacial deposits formed under water in such a manner, tend to spread out in flat sheets, rather than to accumulate in moraines of the ordinary type and are called "water laid" deposits.

An objection to this theory that any considerable depth of water was present between the Mayville moraine and the ice front, while this material was being deposited, is the absence of any well-marked evidence of such an accumulation of water on the sides of the moraines. There are no traces of beaches so far as seen, on any of the slopes of the Mayville moraine, above 800 feet, and the ones observed at that level, are of somewhat doubtful character and need more study to learn their exact origin.

Whether two halts, or but one are assumed, the differences between the moraine east of Millington and that west of it, are very marked, and have some general cause.

In Dayton and Koylton townships, the Millington moraine loses its massive ridge form and takes on the character of an interlobate area, especially in Koylton, and southern Kingston, where the morainal areas are in the form of short ridges, broken by cross valleys, as if the ice forming them had been moving in from more than one direction, and had sometimes extended in from one way, covering up former deposits, and then from another, while the water from the melting of each mass found its way off to the south, over and between the deposits of both, modifying and cutting through them, until the lines of deposition can scarcely be traced.

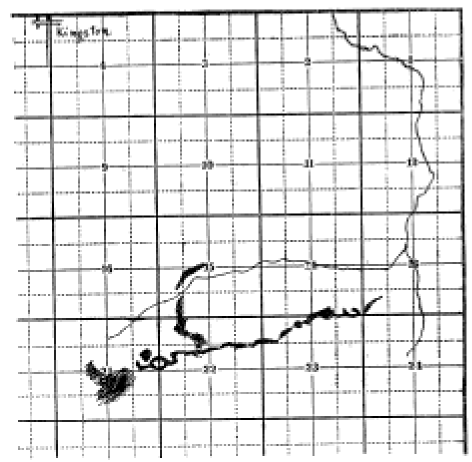

Figure 7. Esker in Koylton township.

Eskers. As described above, (page 151), Eskers are deposits of sand and gravel, which were formed within the margin of the glacier by streams of water running in tunnels in the ice, generally more or less at right angles to the moraines. When the ice melted away from around them, they were left as winding ridges, usually with steep slopes, the gravel taking the angle at which it would stand as the supporting walls of the tunnel disappeared.

Eskers are of rare occurrence in this part of Michigan, although found frequently in some other portions, but in Koylton township, a few small ones were seen, the most interesting of which extends across the broad marsh in the center of the township. (Fig. 7.)

It is nearly three miles in length, beginning in the southwest corner of Sec. 13, and running somewhat south of west as a faint, sinuous line of low, sandy knolls, with a trace of sand between them, for a mile or more, but on the northwest quarter of Sec. 22 it suddenly becomes prominent, and forms a well-marked gravel ridge which rises from 30 to 40 feet above the plain. Soon after it becomes prominent, it divides, the two branches curving around and uniting again to form a nearly perfect ellipse, the larger axis of which is about 500 feet, and the shorter about 300 feet long. This interesting formation is crossed by the north and south road between Secs. 21 and 22, just north of the quarter line. From the west end of the ellipse, which formerly enclosed a pond and is still marshy, the ridge rises quite rapidly, and near the center of Sec. 21, apparently ends in a well-marked group of high kames, which, doubtless, mark the outlet of the tunnel-confined stream.

The position of the kames at the western end of the esker, would indicate that the ice in which it was formed was melting back towards the east, that is, to the Lake Huron basin, which would tend to confirm other evidence that this part of the morainal tract was of an interlobate character, and that the deposits were made by ice of both the Saginaw and the Huron-Erie lobes, the latter being the latest to occupy this portion of the area under discussion.

The ice margin at the stage when it had melted back thus far, formed a rather open re-entrant angle into the sheet lying to the north, northwest and northeast, the eastern portion being rather thin, and at this time having but little movement, as is shown by the character of the deposits left by it. Other esker-like ridges, much shorter and smaller, occur in Sec. 19, of Koylton township.

Kames. Aside from the numerous small kames already mentioned, there is a notable one in Sec. 5, Dayton township, a mile northeast of Cat Lake, a high, gravel hill, rising abruptly more than 140 feet above the road at the northwest corner of the section. It is at the very northern border of the moraine in this vicinity and as seen from the north, has a bold and Striking appearance, which is characteristic of isolated kames, wherever they are found.

This kame on the surface and in places where cuts have been made, is composed of coarse sand and gravels, and probably marks the outlet of what must have been a large sub or en-glacial stream, which discharged here while the ice front was lying on the adjacent moraine and the ice sheet itself was spread over the country to the north.

A second kame, or group of kames of considerable size, lies on the town line between Indianfields and Fremont townships, about 3 miles west, and a half mile north, of the large one described above. This, however, is much lower and smaller and is much less a striking feature of the landscape than the first, as the area of the crest is much less, and its altitude nearly 100 feet lower.

Lake Basins. In the immediate vicinity of the Dayton Kame, are Cat Lake and a smaller pond whose basins had their origin at about the same time that the hill was being built up, as is shown by the relation of the gravel about them to the hill. In some way, through unequal melting, large masses of ice became detached from the main body, and around and over these, the water poured from the streams which flowed away from the glacier, and either wholly, or partly buried them in the rock waste which it carried.

This covering kept the buried masses from melting until after the ice front had time to retreat to the north far enough for the debris-laden water to find new channels and outlets at lower levels elsewhere. Deposition ceasing, in time the buried ice also melted, and the resulting depressions left in the clay or gravel filled with water, and became lakes.

All of the small lake basins of the county, except those of the very shallow ponds near the present shore of Saginaw Bay, have similar origin and may be attributed to the inclusion of ice masses in the drift, where they persisted until after deposition ended, and, on melting, left basins by the settling of the material which had covered them. It is a fact worthy of mention in this connection, that all of this type of basins in Tuscola county are found in the Mayville and Millington Moraines, or in the gravel plains directly associated with them.

The Bay City Moraine. After the ice front had formed the interrupted Moraine described above, there is excellent evidence, first collected and interpreted by F. B. Taylor[1] of the U. S. Geological Survey r that the next halt was not the obvious one, viz., the well-marked ridge forming the west side of the Cass Valley, but a much lower and more insignificant one, lying to the west of this, some miles down the slope towards Saginaw Bay. This moraine is a faintly-defined, broad, low,, somewhat interrupted ridge, scarcely more than a swell of land, which extends nearly parallel with the shore of the Bay, from northern Columbia township, where it is noticeable to the north of, and at, Columbia Postoffice, southwestward to Reese, beyond which, in Saginaw county, it is soon lost in the Lake plain, but reappears at Bay City, from which place it gets its name. It also extends into and across Huron county. This moraine has been manifestly subjected to, or formed under, conditions quite different from those already described, since it is generally clayey, is very broad in proportion to its height, and is so low that it can scarcely be called a ridge in any part of its course. Such structure and form indicate that the moraine was formed under water, in which the debris from the melting ice was spread out as it was freed from the ice, the currents and waves distributing it instead of allowing it to form a continuous, irregular ridge of the normal type. It is then, a good example of what is termed a water-laid moraine; it reaches its greatest height and breadth about a mile southwest of Fairgrove, where the altitude of the top is about 685 feet A. T., or slightly more than 100 feet above Saginaw Bay, at other points, both to the north and south of this highest point, it has an elevation somewhat more than 670 feet, (barometric).

As is noted above, this moraine was formed while the ice-margin, against which it was built up and whose position it marks, stood in the water of a temporary lake, whose other shore was the high land of the last-formed, or Millington Moraine. As the lake had a width of from 15, to more than 20 miles, and a much greater length, its waves were sufficiently strong to make a series of gravelly and sandy beaches along the foot of the moraine against which they dashed; we are thus able to determine the height to which the waters of this lake, Lake Arkona, as it has been named, rose, as the beach ridges give us a clearly-defined level to which we can measure.

From the evidence thus obtained, it has been determined that the water along the foot of the ice-margin while it was building the Bay City Moraine, was more than 100 feet deep in the deeper places, and was more than 60 feet deep over the top of the highest part of the Moraine, if this was not subsequently changed during the later history of this interesting formation.

[1]Taylor, F. B. VII Annual Rept. Mich. Acad. Sci., p. 30, Lansing, 1905.

The Saginaw-Port Huron Moraine. Following the time of rapid melting of the ice sheet, possibly caused by a dry time or a long-continued mild period, the ice again pushed up the slope over the moraine, which it had been forming, and finally rested along the ridge which runs from Vassar to Gagetown, and northeastward into Huron county. How much the overridden Bay City moraine was modified and changed in character by being buried by the ice and a certain amount of ground moraine as well, there is no way to judge. It may have been much or little, but the probability seems to be that, because of its already water-laid origin and its greatly flattened contours, there was little change in these, as the modern glaciers are known to cover their moraines in a similar way without obliterating them, or greatly changing them, and, while nothing can be proven, in this case, the assumption made above, is not improbable.

Before discussing in detail the moraine formed by this readvance of the ice into the territory once abandoned by it, Taylor's evidence and his reasons for considering the Bay City moraine of greater age than this one, which is farther away from the center of the ice movement and hence in a position where logically it should be considered the older of the two, should be briefly taken up.

The evidence cited, was gathered largely from studies of the beaches of the lake already mentioned, and is as follows: If the part of Lake Arkona which made the beaches on the east side of the Cass Valley, from Cass City southwestward, were only a narrow bay, a few miles wide, and comparatively shallow and sheltered by a towering ice mass on its western side, as it must have been, if it existed while the ice formed the Port Huron moraine it would not have formed a series of strong shore lines with well-marked gravel ridges on its eastern shore, because the west winds, broken by the ice mass, would not have caused waves sufficiently strong to build up such well-defined deposits as occur.

More convincing than this reasoning, however, is the direct evidence offered by the peculiar and interesting relationship of the beaches and the Moraine near Cass City. Here the beaches run up to the Moraine and abruptly disappear, plainly being covered up by it, making it clear that the ice margin actually did again invade the area which it had left long enough for the beaches to be built.

It must also be noted, that, if the Moraine were a long, narrow point, extending out into Lake Arkona, at the time the beaches were being formed, while the ice front was along the Bay City moraine, there would be corresponding beaches on the sides of this, at the level of the others, especially on the western side, as that would be fully exposed to the force of the waves caused by the west winds, but no such beaches exist; the sides of the Moraine at the proper levels are entirely free from any of the characteristic indications of lake action, and present slopes are indubitably of unmodified till.

Accepting Taylor's conclusions, as to the age of this Moraine in relation to other deposits in its vicinity, as supported by this accumulation of evidence, and still more fully confirmed by his investigations at other points along the same Moraine in the southeastern part of the state, is is only necessary to say that this Moraine marks the last stand made by the ice front before melting back finally into the basin of Lake Huron, beyond the present borders of the state. During the last stages of ice retreat, the only evidence left was the till of the ground moraine, a stoney clay, with little stratification; this is shown frequently in the walls of ditches, below the shallow lake deposits, and the soils which usually cover the surface.

The Moraine under discussion can be traced in a practically unbroken line from near Port Huron, northward through Sanilac county, through Huron county to near Bad Axe, where it turns southwestward into Tuscola county.

This Moraine has been called by Taylor and others in discussions relating to it, the Saginaw-Port Huron moraine, and this name is used here, but it is apparent, theoretically at least, that that part of the ridge from Bad Axe west, is quite distinct from that extending southward to Port Huron, since it was formed by the Saginaw lobe, while the other portion was formed by the Huron-Erie lobe of the ice sheet. The deposits of the two lobes also differ in definiteness and extent, those of the Saginaw lobe being of greater thickness and sharpness, indicating a thicker, more rapidly advancing sheet, or one much more heavily loaded with rock debris; the former seems the more probable, since in the region to the east and south of Tuscola county, the later moraines of the Huron-Erie lobe are generally not strong.

The differences between the deposits of the two may be due in part also to the fact that the region under consideration was not in the direct line of strongest and most rapid movement of the Huron-Erie ice, while it did lie near the axis of the path of the generally much stronger flow of the Saginaw lobe. Apparently the ice of the Huron-Erie lobe was thin, at this time, and its forward movement up the slope of the lake basin had almost ceased, or, to state it in another way, the ice in this portion of the ice sheet had become nearly stagnant.

The Saginaw lobe, on the other hand, apparently was still thick, and was perhaps moving forward with considerable energy, so that in melting, it left relatively large moraines, especially in the area here discussed.

The Saginaw-Port Huron Moraine enters Tuscola county from Huron, just north of Gagetown, where it is a narrow, but well-defined ridge, rising some 80 feet above the very flat plain which lies to the west and which slopes very gradually to Saginaw Bay.

The top of the moraine at Gagetown, has an altitude of 770 feet above sea level, or 190 feet above Saginaw Bay, nearly 20 miles west. It is here rather gently undulating, narrow, and slopes abruptly on the westward or ice side, and much less so on the east side, on which it fades out into a high slightly rolling plain, which is covered with indefinite knolls of till and gravel, and which comprises the greater part of Elk-land township; this area is doubtless covered by deposits of the earlier advance of the ice margin.

From Gagetown, the moraine runs south a short distance and then turns almost due southwest, as a definite, continuous ridge, to Watrousville, where it rather suddenly becomes lower, and swings more to the south, at the same time becoming superficially gravelly. From Vassar, it again changes its direction more to the west, and, in central Tuscola township, becomes water-laid, and is finally lost as a definite ridge, near the western border of the county, although it governs the course of the Cass river and the flow of the surface waters, as a faint divide, around the head of Saginaw Bay, again reappearing on the west side of the Bay as a definite ridge.

In Elmwood, Ellington and Aimer townships, where it is best developed, it is a single, symmetrical, definite ridge, from one and one-half to two and one-half miles wide at the base, with well-rounded, but not usually steep slopes. The crest is generally rounded, somewhat broad, and with a merely undulating surface, but frequently it becomes a single, continuous, sharp ridge, or, in the broader parts, a double or triple one. Barometric observations, made at many places along the crest, show that, in places, it rises considerably over 800 feet above sea level; to 820 A. T. in Sec. 18, Ellington, and from 810 to 820 A. T. at a number of points as far as Watrousville. From this point, it falls off to 720 feet two miles north of Vassar, while at Vassar, it is 20 feet lower still, and, where it leaves the county, in Sec. 19, Tuscola township, it is only 100 feet above the waters of the Bay, or 680 feet A. T., and cannot be distinguished by the eye alone from the surrounding plain, it is so completely flattened.

The isolated position of this moraine, its simple and typical form, its location in a very flat plain, where its height appears greater by contrast, all make it an especially good example for the elementary study of this kind of glacial deposit. Throughout its course across the county, it is not complicated by any other forms of deposit from the ice, even those usually found, such as kames, being almost entirely wanting. In a few places on the eastward slope, there are small deposits of gravel and sand, outwash or overwash gravels and sands, which were left by streams of water flowing from the melting ice, but these are surprisingly few and their absence indicates that the main outwash discharged into a lake or broad stream, which, at that time, occupied the depression between the moraines along the front of the ice.

The Saginaw-Port Huron moraine, as it exists in Tuscola county, represents a single line of marginal glacial deposits, due to a somewhat prolonged halt in the melting of the ice sheet, which was its last important stand before it left this portion of Michigan forever. As already stated the same moraine may be traced northeastward into Huron county, where it forms a well-marked re-entrant angle with the moraine of the Huron-Erie ice at Verona Mills, east of Bad Axe, as has been described by Lane in the Report on Huron county.[1]

As stated above, there is a notable absence of outwash deposits on the east side of the Saginaw-Port Huron moraine, that is, on the side away from the ice, and it is only on the lower slopes of the moraine that sand and gravel replaces the till of the higher parts, and then only in horizontally spread, superficial deposits, rather than as vertical tracts in the form of kames, delta-cones, or "aprons" as the thinner flat, limited gravel deposits, which are frequently found on the slopes of moraines, are called. Below these gravelly slopes, a broad, sandy plain, gravelly in places, stretches away to the east and southeast towards the Mayville moraine. This represents the accumulated outwash deposits from the ice when it was forming the Port Huron moraine, and also those from the ice as it was melting back from the Mayville moraine and from that which lay to the north and east while the Port Huron moraine was being deposited.

The plain was built up in the bed of the glacial lake already mentioned and its successors which were formed by the ponding of the water which flowed into the depression between the ice front and the recently abandoned moraines to the south and east. Such lakes frequently developed in front of a retreating glacial ice mass and were sometimes of great extent, and, as has been pointed out elsewhere lasted for long periods. In any case, they persisted until the level of their outlet was lowered, or the ice melted back far enough to permit the basin to be drained, either around the moraine or across some low place in its crest.

The area between two lobes of the glacial ice was always one in which, not only great quantities of water were discharged, since both lobes were tributary to it, but these waters were more than usually turbid, because of a concentration of rock debris near, and in, the opposed margin of the two lobes. The debris-laden waters, flowing into the shallow lakes, which bathed the lower levels of the Saginaw-Port Huron moraine, were deprived of their loads of sediments by the change in velocity as they entered the lake, and these were spread over the basin as deltas of sand and gravel, or as silts or clays in its deep parts.

Later, the waves and currents of the lake, or, after its subsidence, the wind, spread the lighter sands more uniformly over the surface or left records of their action in the form of beach and dune ridges, often of great extent, over the floor of the valley.

After the disappearance of the lake, the old lines of drainage were followed by the stream which drained the basin and the sides of the valley, and which cut for itself the well-defined channel in the western side of the plain which the present stream follows to the Bay. The waters of the lake subsided slowly, however, as is shown by the numerous beaches and other evidences of shore lines, and by the delta-plains and terraces of the streams which preceded the present river. The deltas may be recognized as broad areas of gravel or coarser sands, narrowing to the northeast, and breaking the continuity of the beach ridges, which are associated with them. The terraces, on the other hand, are the broad steps by which one descends to the bed of the present stream in crossing the valley from one side to the other. They are well developed at Caro, Vassar and at other points. The greater part of Caro is located on the highest terrace of the part of the valley where it is located; the coarse gravel deposits at Cass City on the other hand, are apparently part of a delta of a glacial stream, which followed the shallow valley down from the north and entered the lake along the ice front. The complete history of the lakes and streams of this interesting valley, however, is yet to be worked out, but the brief surveys of it which have been made, show that it is of exceptional interest to the student of local glacial and post-glacial geology.

Following the culmination of the readvance of the ice, which was marked by the Saginaw-Port Huron Moraine, melting back began again and, while the halts in this shrinking were probably numerous, they were too slight to leave any records in the form of morainal ridges. Accompanying the backward movement of the ice, the waters of the glacial lakes subsided as their basins were expanded, or as they found new outlets at lower levels; at each of these levels which was held for a sufficient length of time, shore lines of greater or less strength were established. The best marked one of these was built up at the foot of the Port Huron Moraine on the west side of the ridge, the Grassmere Beach, and from the size and continuity of this deposit, it is inferred by Taylor[2] that there was a long halt of the ice-front after it had shrunk back into the basin of the present lake, hence whatever record it left, is covered from sight. It appears certain that the beach in question could not have bean formed in any brief time, nor by a limited body of water, and the inference cited above is doubtless correct, for in no other way, can the prolonged elevation of the water at the required level to form such a beach be maintained.

Of the length of time which has elapsed between the end of the ice invasion and the present, little need be said, except that is probably measured by not much less than 10,000 years, possibly much more. The records of the intervening time, however, are very obscure, and there is but little on which to base conjecture. Such evidence as there is, is quite fully discussed by Leverett and Taylor in their forthcoming monograph already mentioned.

[1]Lane, Alfred C., Report on Huron county, Mich. Geol. Surv., VII, Part 2.

[2]Taylor, F. B., loc. cit.

CHAPTER IV. SOILS.

Nature and origin of soils. The most important natural resource of any area in that part of the earth where agriculture may be carried on, is its soil, for, while most other forms of such resources may, and sooner or later, must become exhausted, if they are utilized at all, no matter how carefully conserved, the soils, with reasonable and proper tillage and care, will go on producing crops indefinitely, and may even be improved with use.

Soil defined. The soil is the foot, more or less, of finely divided surface material which is ordinarily turned over by the farmer in the various processes of raising crops. More broadly, it is the uppermost layer of the crust of the earth, into which plants send their roots, and from which they derive water, mineral food and physical support.

This layer is made up of rock particles, usually mixed in the primitive condition, at least, with a greater or less amount of partly decayed organic matter, chiefly vegetable in its origin, which adds largely to the fertility by increasing its water-absorbing and water-holding powers, as well as by furnishing plant food.

Soil types. There are three chief types of soils, residual, transported and organic. The first is formed by the decay or breaking down of rock in place, under the combined action of percolating water, gases, effects of heat and cold, and various other agencies, which, taken together, are known as the weathering agents. Residual soils, however, do not occur in the region under discussion, unless on a very small scale by the decay of boulders, and on the very limited outcrops of bed rock, so need no discussion here.

Transported soils are those which have originated in some place at a distance and have been brought to the locality where found, by water, ice or winds.

Organic soils are such as have accumulated by the growth and partial decay of plants, and, to a less extent of animals.

Classes found in Tuscola County. The soils of Tuscola County belong to the latter two classes; of these the second greatly predominates in area covered and value for agricultural uses, and is that which will be chiefly considered in this discussion.

Origin of Tuscola soils. In the chapter on glacial and post-glacial history (page 148) the origin of the different types of surface formations has been given considerable attention. There it was pointed out that these were composed of rock fragments which were gathered up by glacial ice, some brought from long distances from the country to the north and east, while others, perhaps in places forming the greater part, were picked up but a short distance away in the same direction. When the ice melted, this material was either left where it fell, or was sorted by the subsequent action of water and later, modified by the growth and decay of plants, and by the weathering agents named above. Possibly, if estimates made by careful and competent observers are correct, from one-half to two-thirds, or even more, of the amount of ground-up rock, composing the glacial and derived deposits, originated within a few miles of the places where they were finally left, but a considerable proportion of it was brought from beyond the confines of the state. The chief fact to remember in this connection, however, is that little, if any, of this material was derived from the breaking down by chemical decomposition, or other means, of the rocks which lie immediately below the surface.

Ice-formed deposits. In the ice, the material carried by it was entirely unsorted, and consisted of pieces of rock of all degrees of fineness, from large boulders to the finest particles. As the transporting ice was converted into water by melting, sorting took place, both on the surfaces of the deposits left by the ice, and in those formed by the outflowing waters. In the deeper parts of the temporary lakes, which existed at different levels between the earlier moraines and the ice front, the finer rock particles finally settled to form silt and clay, while along the shores of these and in the beds and deltas of glacial streams, gravels and sands were accumulated by the action of currents and waves which carried away the finer particles from the deposits which they formed or with which they came in contact.

Differences between sand and clay. Clay and sand may differ, however, in other ways than in size and weight of the constituent grains, and usually have a different hardness and color, and different chemical composition. This is because softer rocks and minerals are usually more easily ground up, or crushed, and decomposed, than harder ones, so that clay is largely made up of the softer, less durable minerals of rocks, or of rocks possessing structural deficiencies. In the immediate region under consideration, the underlying, softer rocks were of two sorts, shales, made up of ancient clays, and limestones, which were largely formed by the growth and death of animals and plants.

The more remote rocks from which the clay-forming minerals were derived, were granites and other crystallines. Since the granitic types of rock were the most important of the crystallines in the region from which glacial movement into Michigan took place, it may be said that the minerals composing these are quartz, or silica, feldspar and mica, or hornblende, the latter two being, to a considerable extent, interchangeable. Feldspar is rather soft, readily decomposes under the action of the weathering agents, and, in the process of decay, breaks down into a fine powder; this, when segregated into definite deposits, is the clay of the eastern part of the country but not of Michigan. Mica, and hornblende also, are relatively soft minerals and may contribute to the clay deposits formed by the sorting of glacial debris.

Michigan clays usually differ from those of the east, which are wholly derived from the crystalline or schistose rocks, in the large amounts of calcium compounds, pulverized limestone and gypsum, which they contain; this is no disadvantage in agriculture, or may even be a distinct advantage, but it prevents such clays from being of the highest value for various plastic uses to which true clay is put. The fine-grained types of soil found in Tuscola County are so limey that they are nearly related to what are sometimes called marls by geologists, although not to be confused with the white deposits of bog-lime, or chara-marl, found in ponds, and commonly called marl.

The silica, or quartz, which is. the third component of granites, and related crystalline rocks, is harder than the minerals with which it is associated, and also so simple in composition that it is one of the most stable chemical compounds known, hence, when the rocks, of which it is a part, decay, or are ground up, the quartz, because of its stability, and hardness, retains much the form it had in the original rock. It therefore appears in the glacial drift in angular, somewhat crystalline, transparent grains; these are but little changed by subsequent sorting and form the major portion of the sandy types of soil, and, by long-continued action of the sorting agents, may form great masses of pure sand.

Boulders, cobble stones and the larger rock fragments of gravels, are mainly derived from the harder and more resistant rocks found in the region passed over by the transporting ice, the crystalline type being most common, because of its durability, and because of the immensity of the area covered by it, in the northeastern part of the continent, from which the glacial ice-sheet spread out, but a considerable per cent of the coarse material, in the form of chert, a variety of quartz, hard limestone, sandstone and even shale, has been derived from the nearer sedimentary rocks, and bituminous coal pebbles, are not uncommon.

Besides the essential and constant mineral constituents of soils, there is, in most cases, a greater or less amount of organic matter; this is least in sandy soils and greatest in the marshes and swamps, and constitutes the humus of the higher lands and the muck and peat of the low lands. The sources of this component are two: Plants, which furnish by far the more important part, and animals, which usually add but little, but may, under certain favorable conditions, contribute more largely.

Sandy soils lack humus, chiefly because they are so dry that they support but scant plant and animal population, and, when these die, the surface conditions are favorable for complete oxidation, or for dessication to such an extent that nearly all organic matter left is sooner or later blown away. The amount of humus which accumulates in a given soil type, is apparently governed more by the degree of dry-ness of the surface, induced by thorough drainage and by rapid evaporation during the summer, than by rainfall. Thus in Northern Michigan, where cool summers are the rule, considerable humus may accumulate on poorly drained, sandy areas, while in Tuscola county and the adjacent region, with a rainfall as large, or larger, but with much warmer summers, small, sandy islands in the marshes around Saginaw Bay, with less than a foot of elevation above the general level, have very thin humus, even when the surrounding marsh is covered by muck a foot or more in depth.

The humus content of soils adds certain kinds of plant food, and, at the same time, greatly increases their water-holding power and their capillarity, so that this component is extremely desirable from the agricultural point of view.

Classification of soils. Evidently so complicated a series of materials as soils, may be classified in a number of ways, according to the purpose which is sought in making the classification. If the ordinary, rough-and-ready method of the farmer, who seeks to group soils from the utilitarian standpoint, is taken, the texture, mechanical composition and ease of cultivation are made the bases of differentiation and the finer types are all called clay, the coarser ones, sands and gravels, and those which are mixed, coarse and fine, are known as loams. To separate them still further, a compounding of terms may be adopted, as clay-loam or sandy-loam, according as coarse or fine particles predominate in the soil, or, cultural terms, such as heavy-clay, light-sand, meaning that the soil is hard or easy to plow, may be introduced. Such a terminology is, of necessity, vague and indefinite, so that the sandy loam of one man may be equivalent to the sand of another.

Closely related to this, but more scientifically exact, since it is based absolutely on the measurement of the average size of the soil grains, is the classification of the soil physicist and especially of the Bureau of Soils of the U. S. Department of Agriculture, which is considered below (page 28.)

Another classification may be used upon the geological history and agents producing soils, and giving them their characteristic structure and distribution; such a scheme is given here.

Considered from this aspect, the soils of Tuscola County may be grouped under two general heads: (1) Those formed by glacial ice, the glacial deposits, and by its melting, the glacio-fluvial deposits. These intergrade so completely that they are not considered as distinct except in extremes of the series. (2) Those formed subsequently to the melting and final retreat of the glacial ice, by more or less complete assorting of the material left by the ice, and those built up by organic life in this group are river-formed or fluvial, lake-formed or lacustrine, wind-formed or Aeolian, and swamp-formed, or palustrine soils

The glacial soils are stoney, the stones varying in size from large boulders to small pebbles, and consist of an irregular mixture of un-sorted rock debris, with limited areas of partial stratification. They may be distinguished from all other types, by the characteristic and intimate association of large and small rock masses, great boulders and finest clay, side by side. This material is known to geologists by the name of till, and in Tuscola County, occurs in the unmodified form only m the higher ridges, especially the Mayville and Port Huron moraines. Three principal variations in the unmodified tills of this district were noted:

1) Clay till; that in which the finer rock particles predominate so as to give character to the whole. This may have resulted from the destruction of shales and limestones near at hand, or, from the more remote areas of Canadian Archaean, metamorphic and plutonic rocks, probably both sources contributed.

(2) Sandy till; that in which sand gives a distinctly coarser aspect than obtains tm clay till. These may have been the result of the destruction of sandstones, such as the Marshall sandstone, extensive areas of which lie just north, and to the east, of the region under consideration; or, the gathering up of pre-glacial sands by the ice in its progress; or, it may be due to the partial sorting and washing of materials previously laid down, incidental to the melting of ice advancing upon a moraine.

(3) Rock flour. This name is given to nearly white, fine-grained soils, resulting, apparently from the segregation of finely powdered silica, and other materials like limestone. This material makes up the larger part of some rather limited morainal tracts. The source of the silica may be silicious shales and fine-grained sandstones, which are known to occur in the outcropping beds of the sub-carboniferous formations a few miles to the north, and the limey material may have been derived from limestones lying in the same direction.

(4) Modified till. Glacial material, after it has once been left by the ice, immediately begins to be acted upon by agencies which produce changes and therefore, in the strictest sense of the word, there is no such thing as unmodified till, as distinct from modified, but, as already noted, the terms are here used to distinguish material which was originally deposited by ice, and that which, in the course of deposition, was more strongly modified by the streams of water, flowing out and away from the glacier, that is, glacial material partly, or wholly, sorted, while in the course of deposition. This type of till is to be found on slopes, at the bases of moraines, and sometimes forms on the tops of the lower ridges, distinct deposits over the ground moraine, as in the case of eskers and kames.

Of this type of till, it may be said that it differs from the fluvial and lacustrine soils only in the degree, of sorting, and the amount of wear which the constituent rock fragments show. The following forms may be recognized:

(a) Gravelly till is generally found on the sides of moraines forming "aprons" or sometimes cones, or even pockets, as the result of the sorting action of the overwash, or outwash, from the melting ice-front. Gravelly till is frequently very poorly sorted, having a large mixture of coarser materials such as cobble stones and boulders, and of finer sands and silt, due apparently to the frequent fluctuations of the force and quantity of water running away from the ice.

(b) Kame gravels. While gravelly till seems usually to have been deposited by water running in broad, shallow sheets, kame gravels were left by definite streams flowing out from valleys on the surface, or from under the ice, or from tunnels in it, and which had a relatively constant volume of water. Such streams, emerging from their confined courses, lost part of their velocity of movement near the outlet, and, in consequence, piled up in such places the coarser or heavier parts of their loads of rock debris in heaps, often of considerable height and extent, as in section 5, Dayton, noted above.

The size of the fragments and the completeness of the sorting depended, in part, on the volume and velocity of the stream as it issued from the ice, in part, on the length of its course, and in part, on the change of its velocity after leaving the ice. In this region, kame gravels are generally very coarse and often form hills which are of considerable extent, as is the case along the northern face of the Mayville moraine, through several townships. Esker deposits, though often sandy, are frequently sufficiently like kame gravels in texture, to be grouped with them.

(3) Sands and gravels due to glacial drainage. These are usually finer and more completely sorted than either of the other types mentioned, and, usually differ from them also, in forming long, narrow, continuous strips, either along the bases of moraines, or in the valleys adjacent to them, although sometimes spread out into broad, flat areas. They were formed by streams, resulting from the union of the many smaller ones issuing from the ice, and which found their way along the moraines and down the slope of the land towards the sea. These streams were of larger size, and more permanent, than those forming the types of soil described above, were, in fact, true glacial rivers, which sometimes persisted for long periods of time and whose erosive effects were not rarely more important than those of deposition.

Of this character are the great sandy areas in the Cass river valley, although some, and perhaps all of these, have been modified to an undetermined extent by the action of glacial lakes, if all of them were not laid down in lake waters as deltas, and, later, cut into terraces by the periodically lessening stream.

Lake beaches. Of practically the same type as that above and probably inseparable from it, are the sand and gravel beaches of the glacial lakes which occupied, north of Mayville, the lower levels of the county through all of the time after the retreat of the ice from the Mayville moraine.

The beach deposits differ from those of stream origin, generally in being well-marked ridges, instead of lying flat, or in terraces, and, in the more thorough sorting which the constituent soil grains have received. They may, for this reason, differ in agricultural value from stream deposits, having about the same structure and size of grains because of the differences in depth to which the ground water level may sink, and the quickness with which percolation may take place from the surface.

The lake beach type of gravel is well illustrated by the gravel ridge running from Vassar northeastward along the west side of the Port Huron moraine; the sandy type is frequently present on the plain between the moraine and Saginaw bay.

Closely related to beach sands and gravels are the flat areas of sand or sandy loam which are frequently found on the tops of low, broad elevations in the plain; these represent the shallows, or bars, in the waters of the glacial lake, where waves, and wind-formed currents, removed the finer clay and silt and left the sands and gravels as thin layers on the surface with the modified till below.

These areas are strikingly conspicuous on the open prairies near the Bay, in Akron and Wisner townships, where they form in part the well-known "oak islands" of that district. They are also to be found frequently in the cultivated lands, where, in the spring time, they may be seen as light-colored areas in the freshly-plowed fields.

Clay Areas. These are sometimes the result of the deposition of the finer rock particles, carried away by the glacial streams, in either very temporary or more permanent bodies of water, in which they settled in the deeper and more quiet parts.

Clay, or very clayey till, was also the result of the melting of the ice when the glacial ice-margin stood in the comparatively deep water of the lakes which formed as indicated above. In such cases, the morainal material was spread over the bottom of the lake and the finer particles being lighter than the coarse, were the last to settle and formed a clay stratum of greater or less thickness, according to the proportion of very fine matter to the coarse in the melting ice. Such areas are found in Tuscola township, and in connection with the water-laid moraine in Fairgrove and Gilford townships.

Post-glacial soils. Those formed after the disappearance of the ice-sheet. (1) Fluvial or alluvial soils. Stream-formed soils deposited by the modern streams of the region, are of infrequent occurrence within our limits, chiefly because of the steepness of the gradients of larger streams and the small loads which they carry, even in flood times. The latter factor is largely due to the porous, coarse-grained types of soil of the Cass river drainage basin, which prevents the accumulation of meteoric .water on the surface of the land, and, by absorbing it, give it tip to the streams gradually.

For these reasons, Cass river and the larger streams flowing into it, are cutting their beds, and seldom overflow, and have no extensive flood-plains, on which alluvial material and silt are periodically deposited. The bed of Cass river is swept clear of all fine material and the lower terraces, which are at times overflowed, have little fine sediment deposited on them, but consist of sands and gravels.

The streams flowing directly into Saginaw Bay, however, are much less steeply graded, and drain areas of till and other fine-grained soils, which are slow to absorb water and are easily eroded. As a result of these differences, this group of small streams formerly overflowed their banks and carried considerable fine silt during floods, and some of this was left each flood-time, as a thin layer of alluvial material, along the flood-plains of the old streams.

These deposits, however, have largely disappeared in the improvement of the streams in the course of carrying out ditching schemes, and the construction of the great number of artificial drains which have been dug in their drainage areas, have so changed the conditions, that the streams no longer overflow as they once did, even if they are still recognizable.

Small patches of alluvial soils, and stream-deposited sands, may still be found along Craugan and Squaw creeks, and in some places along the older ditches; in general, these deposits are bars, spits, and flood-plain types, the former of coarser material, in the bed of the stream, and the latter of fine grained sands, silts and muds, and, where of sufficient area, form fine, rich, agricultural soils of the river-bottom type.

Lake-formed or lacustrine soils of the post-glacial formation are in no way different in types, texture and origin from those formed during the glacial period. They are sandy and gravelly bars and beaches, or clays and clay loams. In fact, after the formation of Lake Maumee, the first of the recognized glacial lakes to invade our territory, the land surface of considerable of the county was contiuously covered by a body of water which, as the waters found new and nearly always lower outlets, left an almost continuous series of shore lines which come down so nearly to the level of the present bay, that it is difficult to say, in some cases, which is ancient and which is modern. The soils of this class, of recent origin, differ principally from the oldest, in being, probably, more thoroughly sorted, lighter in color, and generally less modified by weathering and organic agencies. They are also of less value for farming, because they have less humus.

Aeolian or wind-blown soils. These are invariably sands, so far as recognized and are usually closely connected with shore lines of some of the water levels, where conditions have favored the concentration of sand in considerable quantities. They form long, narrow, winding, often more or less discontinuous, irregular, sand ridges, or, in places, groups of ridges and hummocks, with steep slopes, and often rather sharp crests, which are composed wholly of rather fine, yellowish or gray sand, the grains of which are somewhat rounded and wholly without admixture of coarser material.

The most extensive areas of this type are found in Vassar township, and in parts of Fremont, but many smaller dune-lines and duney areas occur in other towns which lie in the valley of Cass River and on the plain to the west of the Port Huron moraine. Examples of small dunes in the process of formation are to be seen along the present shores of the bay, in Akron and Wisner townships. Here the process of dune building can be observed and the relation of the dunes to the water level of the bay may be seen.

The connection between shore lines and dune sands in this region, is a genetic one, that is, the sand of the dunes has been derived from material washed out from that laid down by the glacial ice, by streams, much of it left as delta deposits of the predecessors of the Cass river, and by the action of lake waves and currents and, after a final sorting, swept up on shore above the ordinary reach of the water, by storm waves. Here it has a chance to dry and is blown back, first to the line of debris which marks the extreme limit of storm waves, where it forms a slight ridge, and afterwards to a greater distance to a line which serves as the beginning for the greater accumulations, if the waves continue to bring in the necessary sand.

After sand dunes have been built thus, they gradually become covered by vegetation in a moist region and the sand becomes fixed, but, at any time, when the protecting plant cover is broken, the sand may begin to travel and blow about to form new dunes, as may be seen in many places, where roads have cut through dunes, as at Oak Park, on the present shore of the Bay, at Juniata Station, or where they have been plowed, in many places. It is worthy of note also, that near the southwest corner of Indianfields township the sand of dunes is advancing upon the woods quite extensively, partly burying the trees in the line of advance.

The facts that the most extensive dunes are formed on the east side of the valley formerly covered by the lake, and on the portions of the shore most exposed to the sweep of westerly and northerly winds, seem to point conclusively to storm conditions similar to those now existing.

No dunes were observed which seemed to have been formed by easterly winds, nor where there was a protecting highland on the west. Some of the most extensive dune areas on the eastern side of the Cass valley are not immediately connected with any recognized ancient shore line, but they occur at a nearly constant level, and are stretched out laterally, as if following a water line. It is possible that the most extensive of these dunes deposits, that about 750-765 feet A. T. may have been formed during a prolonged drought, but this seems hardly probable. The ease with which these wind-formed soils are blown about, after the sod, or forest, covering the sand is broken, their dryness, and their poverty in mineral plant food, make them poor soils for farming. On some of the lesser dune lines, where the sand was not more than 15 feet deep, apple and other fruit trees make good growth, and, occasionally light crops of rye and corn were grown on all but the highest dunes. As a type of soil, however, these wind-formed sands are the least adapted to agriculture of any soil observed in the county, and many acres were still uncultivated and probably should remain so.

Swamp-formed soils. The palustrine soil types constitute a class entirely distinct from those already discussed, in that they get their most important characters from organisms, chiefly plants; that is, these soils contain a large proportion of the more or less thoroughly decomposed remains of vegetation, and some are made up wholly of this material.

The principal conditions favoring the formation of such soils is the nearly continuous presence of water near, or at, the surface of the ground; that is, the ground water level must be so high that the soil is at all times nearly full of water, or actually covered by it, a state caused, or favored, by a flat, or slightly hollowed, surface, so that the water falling as rain or snow cannot run off quickly, and, by the presence of clay or other impenetrable subsoils, which prevent it from too quickly running into the ground.

Certain kinds of plants, especially those with long, narrow leaves, the rushes, sedges and grasses, grow with great luxuriance wherever wet, mineral soils are to be found. These soon form, a turf with their abundant roots and spreading underground stems, which, together with the dead leaves and stems accumulating on the wet surface, increase the wetness by checking the run-off and evaporation of the water.

The decay of dead vegetation is caused principally by certain low orders of plants, the bacteria and the fungi. The more important of these flourish best where there is moisture and a sufficient supply of air; they are killed by too much water, which seems effective chiefly, by shutting out the air necessary for their development and growth. The accumulation of soils of this type is favored, therefore, by the presence of a constant supply of water, but not by enough to prevent the growth of plants of the kinds which will furnish the material to make the soil.

Where the water level fluctuates much, either for parts of the year, or, from time to time, during drouth, or periods of great rainfall, the decay is hastened during the dry times and checked in the wet; the depth of accumulation, and the completeness of the physical and chemical breaking down of the plant remains in a given area of swamp-formed soil, other things being equal, may be taken as the indication of the part of the time which water covers the deposit. If it is shallow and has lost all trace of its origin, i. e., has slight vegetable structure, it has been uncovered a considerable part of the time; if it is of medium depth, and shows traces of decomposed plant tissues, it has been exposed to the air a less time; if it is of considerable depth, and full of easily recognized vegetable matter, it has been covered by water a large part, if not the entire time.

Palustrine soils are dark in color, brown, or often black, and vary in structure from soft, plastic, black mud, with much mineral matter, to fibrous, turfy or woody material, which, when dry, will burn as readily as wood; they are such soils as are known commonly as muck or peat. The purest vegetable soils and those of greatest depth are found in and around the margins of small lakes, and in the tamarack, cedar and spruce swamps.

On the prairies, marshes, and the swamps on flat, poorly-drained areas there is much less depth and usually also a considerable mixture of mineral matter. A large part of the western half, and portions of the eastern and northeastern parts of Tuscola County were superficially covered by soils of this type before clearing, drainage, and subsequent cultivation, so diminished the water-content and increased the amount of air in the ground, that much of the organic matter has disappeared, or, has been thoroughly incorporated with the mineral subsoil.

The direct loss of this kind of matter from the surface, may occur in several ways, some of which are avoidable. Much of it was destroyed by fire, in burning over the newly-cleared land while settlement was in progress; in some types of woodland, burning removed most of the organic soil; another very considerable loss is that due to drying out and blowing away as fine dust; a third principal one is that from rain wash and floods during the winter and such other times as the soil is unprotected by vegetation. Still other depletions are due to chemical, animal and plant agencies, so that unless they are very deep, or are very carefully conserved, eventually, under cultivation, the black swamp-formed soils become gray or lose their color entirely, through disappearance of the organic matter.

Soil fertility, porosity and permeability. The fertility of soils depends upon a variety of causes and conditions. Among these, are the presence or absence of certain mineral, chemical compounds from them, in such condition that they are sufficiently soluble to meet the requirements of crop-plants growing upon them, and the capacity to absorb and retain water in such quantities that the plants receive at all times, all of this vital substance they need, without ever being too wet. The essential mineral foods can only be taken into the plants through the roots, after having been dissolved, and, in order to get sufficient of some of the requisite compounds which are present in very minute quantities in the soil, large amounts of water have to be absorbed by the roots, and later evaporated from the excreting organs, the leaves.

Among other factors which control the water content of the soil, are the amount of space between the constituent soil particles, the size of the spaces and the size, shape and uniformity of the grains themselves. The proportion of the rainfall which is able to get into the soil varies greatly, most being absorbed by sandy surfaces, and least by bare rock. Of the water which runs into the soil, part evaporates from the surface, part sinks to the ground water level, and part is taken up, used, and evaporated by plants. That which is held in the soil is constantly being drawn away by evaporation and by plants, to be partly replaced from below by capillary action, but, eventually, unless new supplies come in from above, the ground water sinks so far below the surface that connection between it and the soil ceases, and a condition of dryness sets in.

Sandy soils, because of larger and more uniform size of grain, and larger spaces between the grains, permit water to enter and pass rapidly through them and, if deep, to so low a: level, that it cannot be reached by the roots of plants, hence, such soils become very dry during droughts.

The fine-grained types of soils on the other hand, take in water rather slowly, after a short time, and allow it to pass through them at such an exceedingly slow rate that the upper layers become saturated. Because of this slow percolation, the ground water level is usually high in clayey, or silty, soils, and, even where it is considerable below the surface, capillary action, which is poor in sand, is sufficiently strong to bring quantities of water to the surface to replace that lost by evaporation. The sandy soils are permeable, and clayey ones are impermeable types and, while cultivation and proper handling may decrease the rapidity with which the more permeable types lose their water, and may increase the absorbing capacity of the impermeable types, there are limits to the degree to which the improvement may be carried; hence, the most permeable sands and the most impermeable clays are of less value than those which are, by nature, of the right structure. The addition of humus to any soil type improves its capacity to absorb and to retain moisture.

Moreover, in a region, such as that under discussion, where the soils have been formed by a variety of agents, acting under changing conditions, the relative position of one type with regard to another may so modify its usual properties that its agricultural value may be quite different from that generally assigned to the type.

Some of these peculiarities of relationship are given below, and are found principally in the lacustrine or the Aeolian type, although not by any means wanting in the glacial and glacio-fluvial.

Shallow sands, or gravels, a foot or a little more deep, with clay, or clayey till, below. This is of common occurrence in areas which were formerly bars and shallows in the ancient lake, and along the beach lines marking their shores. Such sands and gravels are much better soils for farming purposes than deeper ones, because the water table is near the surface, and the deeper rooted plants can always secure a good supply of water.

The deeper sands and gravels with clay, or clayey till, below, as the beach and dune ridges, are probably also more moist than corresponding types with sand below. The clay keeps the water which is absorbed by the porous surface deposits from getting too far below the surface and makes the sand or gravel a reservoir, so that, as in the case of the extensive gravel beach ridge, the Grassmere Beach just west of the Port Huron moraine, an almost continuous series of springs occurs on the lower or waterward side of the beach, which formed a line of swamps along the ridge before the land was cleared and drained.

Where shallow deposits of sand are underlaid by bed rock, the permeability of the rock, and the shape of its surface, control the water content of the over-lying soil. Thus shales and limestones are nearly impervious to water, and sandstones quite pervious, and water running through the sand is either prevented from going below the surface of the rock, runs off on it, if the surface is slooping, or is absorbed by it. In any case, thin soil layers over bed rock are generally dryer than corresponding strata over clay or till.

Clay or till layers over sand, or other porous type, if thin, are much less moist than where they occur over clayey substrata, because the water which penetrates the soil is drained away by the coarser material below, and is not brought to the surface by capillary action; during dry seasons, therefore, the clay may be very barren.

Glacial soils, being less completely sorted than those subsequently formed from them, have less pore-space than the corresponding fluvial and lacustrine types, and also permit water to percolate through them less freely. It must be considered, however, that pure clays are usually wanting in glacial deposits and that the so-called clay tills, are strictly speaking, stoney silts, or even fine loams, hence, they absorb water more readily then sorted types, usually given the same name.

The post-glacial kinds of soils having more uniform structure than those mentioned above, since they have been subjected for a longer time to the action of water, permit the passage of water into or through them more readily where sand or gravel, or, retard it more completely, when finer than the corresponding glacial types. Most of the finer soils, those known as clays or clayey loams, need to be artificially and thoroughly drained to make them of the highest value for farming purposes.

As already stated (page 22), the finer clays of this region, and the finer parts of the tills, contain a large per cent of calcium salts, that is, they are limey, so much so, that a considerable proportion of most samples will dissolve with effervescence in dilute acids.

While the presence of an excess of lime is detrimental to the growth of some kinds of crop-plants, these are rather few, and the improvement which lime carbonate produces, both physically and chemically, in clay soils is well known and made use of by most farmers. In brief, the lime improves the drainage of the finer types of soils by flocculating the clay, that is, cementing the fine particles into larger ones and thus producing greater porosity.

Chemically, the lime carbonate helps, by keeping the soil free from injurious acids, by favoring the growth of soil organisms, and by hastening the conversion of crude, dead vegetable matter into humus. The limey clays of the region are, therefore, easier to care for, and give better crops of certain kinds than those of the same degree of fineness without the presence of this constituent.

Other systems of classification. The Bureau of Soils, U. S. Dept. of Agriculture, Washington, D. C., as noted above, makes the predominant size of the soil grains the basis of its classification, the measurements being made by running the sample to be classified through a series of sieves with standard size of mesh, the coarsest of which has a diameter of 2 millimeters, all material above this diameter being rejected as "skeleton."

This classification of grades is as follows:

Fine gravel	2 to 1 mm. (.079 to .039 in.)
Coarse sand	1 to 0.5 mm. (.039 to .02 in.)
Medium sand	0.5 to 025 mm. (.02 to .01 in.)
Fine sand	.025 to 0.1 mm. (.01 to .004 in.)
Very fine sand	0.1 to 0.05 mm. (.004 to .002 in.)
Silt	0.05 to 0.005 mm. (.002 to .0002 in.)
Clay	0.0005 to 0 mm. (.002 to 0 in.)

After separation, the weight of the various grades is determined and the particular mixture is given a name, usually that of a type locality, from which the sample came, such physical properties as color, feeling, and structure of the soil being taken into account as well as the size of the grains.

In the soil survey of the Saginaw area[1], made by the Bureau of Soils, and including a large part of Tuscola county, 17 types of soils were recognized, most of them having compound names, as "Clyde fine-sandy-loam," "Miami sand," "Saginaw sandy-loam," etc.

In this bulletin, so much is said regarding the agricultural value, methods of treatment and the special crops best adapted to each type there recognized that it is unnecessary to discuss these here, as the more complete publication can be had by application to the Secretary of Agriculture, Washington, or to the congressman of the district.

[1]Soil Survey of the Saginaw Area, Michigan, (with large colored map) Bureau of Soils, U. S. Dept. of Agric., Washington, 1905.

CHAPTER V. PALEOZOIC GEOLOGY.

BY W. F. COOPER.

Geological Column and Stratigraphy. By a geological column and stratigraphy is meant a section down into the outer portion of the earth's structure showing the various materials of which it is composed in that particular place.

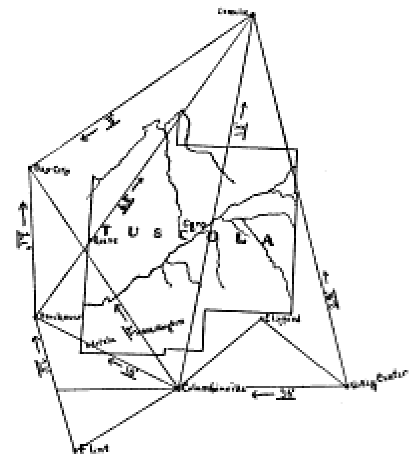

Figure 8. The underlined figures and arrows show the direction and amount of dip of the Berea grit in number of feet per mile.

To explain this we have the report on Huron county to the north;[1] the report on the deep wells at Bay City;[2] at Blackmar[3] located about 7 miles west and 5 miles north of the southwest corner of Tuscola county; at Clifford,[4] situated 4 miles west of the southeast corner of Tuscola county; Valley Center,[5] 16 miles southeast of Clifford in Sanilac county; Columbiaville an equal distance southwest of the same place and 5 miles south of the south central line of Tuscola; and Flint,[6] located 12 miles south of the southwest corner of this county. These places will now be considered going from east to west and from south to north excepting where the latter direction conflicts with the former. Taking the direction into account this arrangement generally conforms to the dip of the strata which form a part of the great basin or saucer-like formation, characteristic of the general geological structure of lower Michigan. Taking up the different localities in this order we have the arrangement as follows: Valley Center, Caseville, (Huron county), Clifford, Columbiaville, Flint, Blackmar and Bay City.

The figure which is here presented will give an idea of the location of the different places and the amount and direction of the dip of the Berea as described in the text. (Fig. 8.)

Before giving any account of the different formations which have been studied in the area adjacent it will be well to state that the rocks comprising that portion of the earth's outer structure open to observation have been divided into certain great groups designated as follows, beginning at the top: Cenozoic, Mesozoic, Paleozoic, Proterozoic, and Archeozoic. All the bed rock formations of lower Michigan are included in the Paleozoic, which has in turn been subdivided as follows, from the top downward: Carboniferous, Devonian, Silurian, Ordovician and Cambrian. In Tuscola and adjacent counties all of the bed rock formation which immediately underlie the drift belong to the Carboniferous period. It can therefore be seen that only a comparatively small portion of the geological column is represented for study here. In the deep wells at Bay City and in Huron county information has been obtained concerning a portion of the underlying Devonian rocks which come to the surface south of Detroit and at Alpena. The Carboniferous is subdivided into the early Carboniferous or Mississippian and the Pennsylvanian or Carboniferous proper. The rocks in Tuscola county as they are represented underlying the drift in available records, have been subdivided as follows, beginning at the top: Saginaw Coal Formation, Parma, Upper Grand Rapids (otherwise known as the Maxville or Bayport limestone), Lower Grand Rapids or Michigan series, and Marshall Formation. The Saginaw Coal Formation belongs to the Pennsylvania or Carboniferous proper; the remaining underlying formations to the early Carboniferous or Mississippian.

A brief survey will now be given of the different rock sections mentioned in the places given above, for the light that it will throw on the bed rock structure of the area under examination.

[1]Vol. VII, Part 2, Plate I and pp. 9-27, 59-78, 86-113.

[2]Vol. V, Part 2, Plate VI and pp. 50, 51. Annual report for 1905, pp. 151-159 and Plate II.

[3]Vol. V, Part 2, p. 52; and Vol. VIII, Part 2, p. 177.

[4]Vol. V, Part 2, p. 54 and Plate IX.

[5]Annual report for 1901, p. 279.

[6]Annual report for 1903, pp. 53, 292.

Valley Center Well. Location S. E. 1/4 of N. E. 1/4, Sec. 27, T. 9 N., R. 13 E. Elevation 805 A. T.

	Thickness.	Depth.	Elevation A. T.
Pleistocene, red sand and loam	5	5	800
Quicksand	90	95	710
Clay	22	117	688
Sand and gravel, plenty of water	32	149	656
Marshall sandstone	5	154	651
"Conglomerate"	20	174	631
Sandstone	30	204	601
Coldwater slate (blue shale)	10	214	591
Soapstone	175	389	416
Slate	150	539	266
Berea limestone	10	549	256
Sandstone	20	569+	236
Antrim shale, changing to soapstone below	272	841−	36
Traverse limestone	35	876	71

In the above section the abbreviation A. T. stands for above tide or above sea level. Mr. Lane remarks that "the descent of the Dundee limestone between Port Huron and Beard's is about 16½ feet per mile while between Port Huron and Valley Center the top of the Traverse shows a westward descent of 15 feet per mile, a reasonably close correspondence."[1]

[1]Annual report for 1901, p. 279.

Caseville, Huron county, section. The section which is here given was determined by Lane from the record of a well 2,270 feet deep at Caseville and one 1,920 feet deep at Harbor Beach.[2]

	Thickness.	Depth.	Elevation A. T.
Pleistocene. Lake sands, lake clays and till	100?	100	485
Saginaw Coal Measures. Black, white and blue shales, coal and sandstone	75	175	+410
Grand Rapids. Limestone, sandstone, dolomite, gray shale, gypsum	247	422	+163
Marshall. Napoleon, clean white sandstone	300	722	−137
Lower Marshall, flags and sandstone shales, nodules and conglomerate	260	982	−397
Coldwater. Blue shales with sandy streaks, often ripple-marked, frequently charged with carbonate of iron	896	1878	1293
Berea shale. Black shale	102	1980	1395
Berea Grit. White, gray or brown sandstone	70	2050	1465
Antrim shale. Bedford shale, light colored	50	2100	1515
Cleveland black shale	3	2103	1518
Chagrin (Erie) light colored shales	133	2236	1656
Huron dark brown or black shale	270	2506	1921
Traverse group. Calcareous shales, limestones	605	3111	2525
Dundee limestones	119	3230	2645

If a line be drawn from the well at Valley Center to Caseville it will extend in a diagonal direction northwest just west of the north, eastern corner of Tuscola county in Elkland T. 14 N., R. 11 E. Inasmuch as the top of the Marshall may be somewhat eroded at Valley Center the dip of that formation cannot be safely compared with the Marshall at Caseville. The top of the Coldwater, however, dips from 601 feet above sea level at Valley Center to 397 feet below at Caseville, a distance of 56 miles and in the same distance an increase in thickness of 561 feet. Thus the rate of dip of the top of the Coldwater is 18 feet to the mile and the average amount of increase in thickness, 10 feet to the mile. This would make the elevation of the top of the Coldwater 47 feet below sea level about 2 miles west from the northeast corner of Tuscola county, providing the average rate of dip and increase of thickness of strata is maintained, and about 695 feet thick. The reason that the Coldwater formation is first given in this connection is that it is the highest formation which is completely represented in the records at Valley Center and Caseville. While the thickness of the Coldwater shows a very considerable increase as we go north and west, this increase is not toward the lowest point of the geological basin of the Lower Peninsula of Michigan, inasmuch as the Coldwater decreases in thickness westward from Huron county and increases in thickness towards Grayling which is on the north side of the lower Michigan basin.

[2]Vol. VII, Part 2, Plate I, and pp. 9-27.

Below the Coldwater shales at Valley Center and Caseville is the Sunbury (Berea) formation. At Valley Center the Sunbury (Berea) shale is not represented, at Caseville the thickness is given as 102 feet thick as taken from the record of the Harbor Beach well. The top of the Berea grit in the records under consideration has a dip of 1,549 feet between the two places or about 28 feet to the mile. The increase in thickness amounts to 142 feet. Comparing the rate of dip of this formation with that of the Coldwater it will be observed how the rate of increase in the dip of the Berea is proportionate with the rate of increase of thickness of the overlying Coldwater. In the northeastern part of Tuscola county we might expect to find the top of the Berea at about 750 feet below sea level with a possible thickness of 140 feet.

Using the same principles for the underlying formations a dip of 30 feet to the mile is obtained for the underlying Antrim shale, which would give this formation a place some 890 feet below sea level with an approximate thickness of 390 feet for the same part of Tuscola county about 2 miles west of the northeast corner. For the underlying Traverse a dip of 34 feet to the mile is obtained with a depth of about 1,280 feet below sea level of the top of this formation. The thickness of this formation not being given at Valley Center it is impossible to form an approximate estimate of any value for this portion of the county.

It will have been noted that in this attempt to form an estimate of the thickness and depth of the underlying strata near the northeast corner of the county, no mention was made of the two highest bed rock formations which are found in the Caseville section but which are not given in the Valley Center well. The highest of these two, the Saginaw coal formation, is not represented in the northeastern part of Tuscola county. In Novesta township adjoining to the south are outcrops of the Marshall sandstone in the valley of the Cass River, and on the geological map of the State the Marshall is represented as underlying the drift, so that in all probability we have this formation capping the bed rock Paleozoic formations for the rest of the section which has been described for the northeastern part of Tuscola. Near the northeast corner of Sec. 3, T. 14 N., R. 11 E., where this approximate section has been located, the elevation of the surface is about 750 feet above sea level or above tide (A. T.). Six miles to the southward the beds of Marshall sandstone have a height of some 700 feet A. T. It is not known what the thickness of the drift and the Marshall is near the northeast corner of section 3, Elkland, but the estimated top of the Coldwater there was placed at 47 feet below sea level or approximately 800 feet below the surface, which would be divided between the drift and the Marshall sandstone. To the northward the Marshall is given a thickness of 560 feet which would leave 240 feet for the drift. In the well records given from that vicinity the amount of drift as given in one well is 72 feet, but other records show a very considerable variation in thickness for that township. It seems not improbable that the depth to the different beds as estimated for this location in the northeast part of Tuscola county has been overestimated but this is given as the only information at present available for that part of the county. The dips as given for the different beds would apply in general for the eastern line of Tuscola county.

Thence going west from Valley Center to Clifford this section is given:

Clifford 818 feet A. T.

Pliestocene:		
Surface	55	55
Grand Rapids formation:		
Blue sandstone	8	
Red sandstone	9	
Coal and rotten rock	1.5	
White quartz	3	
Loose rock of flint, copper, iron pyrites, streak of lead	6.5	
Red, flinty limestone	7	
Blue limestone	28	

Mr. Lane has the following remarks: "The report on the well at Clifford is quite meager, and the few facts since gathered by hearsay might perhaps be added. The well is about 10 feet below the railroad crossing; that is about 818 feet above tide. According to some accounts the bed rock surface was down to 80 feet instead of 55, as given in the record of Volume V. I am since informed that it was put down to respectively 600 feet, 630 to 640 feet. That at 300 feet it was cased, but water was obtained below that and at 400 feet where they drilled rock 2 feet there was a large flow of water and for 20 feet there were no drillings. That is to say there must have been a large flow of water which carried them away into some crevice in the rock. It seems, quite clear that this well which is just over the county line is in the Michigan series and it must certainly have gone beneath it and into the Marshall where a large flow of water may have been struck. I was informed by Mr. G. D. Richards that at the bottom 630 or 640 feet there were some signs of oil."

In order to get an idea, therefore, of the depth to any horizon below 300 or 400 we must refer to the records of some of the wells just cited. From these it will appear that the Berea Grit is probably from 1,500 to 2,000 feet down, the depth increasing toward the north and west. The dip, however, may not be very regular. The comparison of the elevation of the Berea at Valley Center with that at Bay City would give a dip of 24 feet to the mile, while a similar comparison of Columbiaville and Blackmar would indicate a dip of only 13.6 feet. It is probable that the latter dip is affected by the upper arching of the beds which seems to occur near Saginaw. It is quite likely, as I have elsewhere remarked[1] that there was some arching and folding of the earlier beds and there was certainly considerable uplifting and erosion of them during the time between the formation of the Marshall sandstone the last highest beds exposed on the extreme eastern margin of the county and the formation of the Saginaw coal measures. It is unfortunate that no record exists of the strata encountered by the deepest wells put down in the county at Vassar and Reese. The date which it has been possible to obtain have been given together in a later chapter.

[1]Annual Rept Mich. Geol. Sur. for 1903, p. 292, etc.

Valley Center, Caseville, Columbiaville, Section near Caro. Columbiaville is located 5 miles south of Tuscola county and 16 miles south of Clifford. The following reference is taken from the Annual Report of the Geological Survey for 1901, p. 108.

"Mr. J. J. Mason informs us that lie put down a well at Columbiaville 1,500 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 or 400 feet depth." The Michigan Central station is 763 feet above sea level there, which would possibly make the top of the Berea 647 feet below tide level. Columbiaville is 25 miles west of Valley Center, which would give a dip of 36 feet to the mile. If this is maintained to the westward it will serve to give an idea of the dip of the rocks along the west half of the southern line of Tuscola county, unless there are upward and downward flexures of the strata which would be indicated by any variation from this determination. It would appear that this rate of dip west from Columbiaville is too great, judging by the rate of dip between Blackmar and Columbiaville and from Flint to Blackmar.

Between Columbiaville and Caseville Berea has a dip of 13 feet to the mile. The line between these two places passes through the southeast corner of Aimer, T. 13 N., R. 9 E., 2½ males east of Caro. At that place the Berea is 960 feet below sea level if the same dip is maintained. The elevation of the surface there is about 700 feet A. T., which might make the Berea some 1,660 feet deep. In ascending order we would have here, above the Berea, the Coldwater shale with a thickness of from 770 to 896 feet, the Marshall from 470 to 560 feet thick, and the Grand Rapids from 247 to 290 feet. It is not impossible that the uppermost courses of the Grand Rapids formation have been removed here or exposed further to the eastward. The Saginaw coal formation is exposed farther westward. Below the Berea Grit is the Antrim shale from 300 to 386 feet in thickness, underlain by the Traverse group from 600 to 660 feet through. This section will probably hold fairly well for this location in the central part of Tuscola county.

Caseville, Blackmar, Section at Reese. Between Caseville and Blackmar the Napoleon or Upper Marshall shows a rise of 87 feet in 5 miles towards the southwest, this being 1.6 feet to the mile. The Berea in the same distance increases in elevation from 1,395 feet below sea level at Caseville to 1,045 feet below, at Blackmar, a dip of 6.5 feet to the mile. These rates of dip conform to other observations which make Blackmar either on the top or side of a more or less pronounced anticline of very considerable depth. If this rate of dip for the Napoleon is maintained between Caseville and Blackmar, we would expect to get the Napoleon at 227 feet A. T. at Reese, and some 400 feet below the surface at the depot there. An old well at Reese, said to be 500 feet deep, was in coarse white sandstone at bottom, probably Napoleon, water a brine, (C. A. Davis). The upper 80-90 feet is composed of drift and this in turn is underlain by the Saginaw coal formation from 200 to 350 feet in thickness. Below this we have the Parma, perhaps 50 feet thick, and this in turn is underlain by the Grand Rapids series from 60 to 280 feet through. The Napoleon underlying the Grand Rapids series varies from 90 to 260 feet in thickness between Blackmar and Caseville, respectively, and as has been mentioned above, might be struck at a depth of 400 feet, but this cannot be substantiated on account of the uncertainties of dip and possible faults in the western part of Tuscola county. From coal correlations in this part of the county it is highly improbable that there are any faults in the northwestern part of Tuscola county.

Using the rate of dip determined for the Berea it might be expected at Reese at some 1,135 feet below sea level, which would be 1,760 feet below the surface at Reese and about 1,300 feet below the top of the Napoleon or Upper Marshall sandstone formation. This elevation for the top of the Berea agrees very well with the determination made for the same horizon along the line between Columbiaville and Bay City, which makes the top of this formation 1,130 feet below sea level 2 miles south of Reese.

The section as given for Bay City, as might be expected from the geographical location, holds very well for this portion of the geological column. We would therefore expect the Marshall sandstone to be about 370 feet thick, the Coldwater shales 870 feet, Berea shale 40 feet, and Berea Grit 170. Below the Berea Grit are the Antrim shales 340 feet thick at Bay City, and 456 feet at Caseville; the Traverse limestone 660 feet at Bay City and 605 at Caseville. This would take the section down some 2,760 feet below the surface. While no great accuracy can be claimed for this section it will serve to give an idea of the rock structure underlying Reese. The dips which were given for the Napoleon and Berea would apply approximately for the northwestern part of the county.

Caseville-Bay City, Dip of Beds, Fish Point. Caseville is 40 miles northeast of Bay City. A line connecting the two places will run diagonally through the southeastern part of Saginaw Bay, crossing the shore line into Caseville township on the north shore of Wild Fowl Bay. It will serve to give a more or less correct idea of the dip of the beds adjacent to Saginaw Bay in Tuscola county and thus serve to round out what is known of the stratigraphy of that part of the county, which is underlain by the coal formation.

The following section is given from the record of the deep well at the North American Chemical Co. plant at South Bay City for purposes of comparison with the Caseville record already given:

	Thickness.	Depth.	Elevation A. T.
Pleistocene. Sand, clay, hardpan	100	100	485
Saginaw. Shale, sandstone, coal	390	490	95
Parma. Sandstone, conglomerate	50	540	45+
Upper Grand Rapids. Dolomite, limestone, sandstone	90	620	35–
Lower Grand Rapids. Dolomite, shale, limestone, gypsum	190	820	235
Napoleon sandstone. Sandstone	150	970	385
Lower Marshall. Sandstone, shale	220	1190	605
Coldwater. Shales	870	2060	1475
Sunbury. Black shales	40	2100	1515
Berea. Sandstones	170	2270	1685
Antrim. Blue, black, brown shales	340	2610	2025
Traverse. Limestone, shale, sandstone	660	3270	2685
Dundee. Limestone	238	3508	2923

From this section and the one previously given, the following dips are determined for the inclination of the different formations from Caseville to Bay City.

Grand Rapids formation	9	feet per mile.
Marshall formation	10	" " "
Coldwater formation	7½	" " "
Sunbury (Berea) shale	4½	" " "
Berea Grit	3	" " "
Antrim shale	5¼	" " "
Traverse group	3	" " "

This would make the average dip about 7 feet to the mile. At Fish Point, therefore, one might expect to enter the beds composing the different formations of the Bay

City section at about 115 feet higher than at Bay City, making due allowance for variations in dip and thickness. Otherwise the Bay City section will hold fairly well for this northern part of the county.

Columbiaville-Blackmar, Arbela. Between Columbiaville and Blackmar, a distance of 24 miles, the top of the Berea has a descent of from 647 to 1,045 feet below sea level, which would amount to 16 feet to the mile. Going west from Columbiaville the dip was apparently 36 feet to the mile as stated above, this rate being determined from the average rate of dip between Valley Center and Columbiaville. Data from other sources show this to be excessive. Arbela, located in the southwestern part of the county is on the direct line between these two places, and if the same rate of dip is maintained the top of the Berea would there have an elevation of 805 feet above sea level and 1,485 feet below the surface. The drift near Arbela is 210 feet deep, and below this is the coal formation, Grand Rapids, Marshall sandstones, and Coldwater shale down to a depth of 1,485 feet, which takes the section down to (nearly or into) the Berea Grit, more or less. Below the Berea is the Antrim shale series, underlain by the Traverse and Dundee limestones which is as deep as exploration has proceeded in this portion of Michigan.

Columbiaville, Bay City, Millington. Between Columbiaville and Bay City, a distance of 39 miles, the top of the Berea decreases in elevation from 647 below sea level at Columbiaville to 1,475 feet at Bay City, giving a dip of 21 feet to the mile along this line running in a northwesterly direction through the southwestern part of Tuscola county. Where this line crosses the western boundary of the county about 2 miles south of Reese the top of the Berea would be 1,130 feet below sea level. This elevation agrees very well with that obtained from this same horizon at Reese along the line between Caseville and Blackmar which gave the. Berea an elevation of 1,135 feet there. At Millington, in the southern part of the county, the Berea would be about 857 feet below tide and 1,617 feet below the surface. This place is located Just outside the limit of the Saginaw coal formation, so that we would first expect after passing through the drift to enter the Grand Rapids series, and then in descending order the Marshall sandstones and Coldwater shale formation down to a depth of 1,617 feet, more or less. Below the Berea would be the Antrim shale, Traverse and Dundee limestones of the deep Bay City well. The wells at Millington strike only sandstone like the Marshall with good, fresh water according to Dr. Davis.

Flint-Blackmar, Dip of Berea. The city of Flint is located 18 miles southwest of Columbiaville and 1 mile south of the southwest corner of the county. The Berea may possibly be represented there at a depth of 1,200 feet. The elevation of the depot at Flint is 711 feet A. T., which would make the Berea about 490 feet below sea level or some 157 feet higher than the Berea at Columbiaville. The line between Flint and Blackmar runs north northwest, passing 5 miles west of the southwest corner of the county. At Blackmar the Berea Grit is 1,045 feet below tide or 555 feet below the same horizon at Flint. This would give a dip of 26 feet to the mile and would make the Berea appromately 880 feet below the tide level 5 miles west of the southwest corner of Tuscola and about 1,535 feet below the surface there.

It was remarked that the dip between Valley Center and Columbiaville was 36 feet to the mile. If this rate of dip is projected to where it crosses the line from Flint to Blackmar, 6 miles south and 3 miles west of the southwest corner of Tuscola, there is a discrepancy of over 500 feet in the elevation of the Berea along an east and west, and north and south line, the westward dip being that much lower. It is therefore highly probable that the dip west from Columbiaville is not maintained and it may be that the Berea is on the anticline which possibly runs from Saginaw to Blackmar and thence southeast.

Blackmar-Bay City, Dip of Berea Grit. At Blackmar the Napoleon or Upper Marshall is from 360-450 feet in depth and from 160-250 feet A. T. As has been stated the Berea is found at a depth of 1,655 feet and 1,045 feet below sea level there. At Bay City the top and bottom of the Napoleon is 235 and 385 feet below sea level, respectively, and of the Berea 1,515 and 1,685 below sea level for the upper and lower limits of the formation. This would give a dip of 18 feet to the mile for the Napoleon and 21 feet for the Berea between Blackmar and Bay City. These two places are 7 miles west of the west line of Tuscola county and may serve to throw some light on the dip of the beds in the western part of Tuscola county.

The foregoing pages have had to deal with the rate of dip, stratigraphic position, and cross sections of the different beds embraced in the bed rock formations of Tuscola county and certain of the underlying formations forming part of the Devonian group. The remainder of this chapter is devoted to a consideration of the beds collectively, beginning with the lowest bed rock formation exposed in the county—the Marshall. The reader is referred to Volume V, Michigan Geological Survey, Part 2, for a general statement for the different beds of the Paleozoic in lower Michigan, and to Volume VII, Parts 2 and 3, for an account of the geology of Huron and Sanilac counties. In Volume VIII, Part 2, will be found references to the coal formation of this area. In the annual report for 1905 of the State Geological Survey is the report on Bay county. To the southward is the report by Taylor on the surface geology of Lapeer county, which appeared in the annual report of the Geological Survey for 1901. It will therefore be seen that the environs of Tuscola county have been quite fully examined and it only remains in this connection to sum up what is known concerning the bed rock formations of this area, leaving matters of a general nature to the reports referred to above.

MARSHALL SANDSTONE.

BY ALFRED C. LANE.

This is the oldest formation which is exposed at the surface (Section 12, Novesta) or beneath the covering of the drift as the first bed rock in the eastern part of the county. It is well exposed around Tyre in Sanilac county and along the shores of Huron county. It generally forms a ridge in the rock surface. If we look at the slope of the rock surface as indicated by the contours of Plate VI, it will be seen that the rock surface rises toward the east. This is as it comes up onto a ridge in the rock surface, which extends from Huron county clear way down to Hillsdale county, following the outcrop of the Marshall sandstone more or less closely. Before the last ice age this must have been the divide, between the two river systems and the surface of Tuscola county was drained by streams taking the rise from it and flowing westward. One of these streams, as may be seen by studying the rock contours of Plate VI, begins near the corner of Elkland and Elm wood and flows S. W. to Sec. 12, Aimer, then turns and flows nearly north to within 2 or 3 miles of Unionville, then turns sharply west and to about 1½ miles south of Unionville, then turns and flows north reaching the area where the bed rock surface is only 460 feet above sea level, or nearly 120 feet or more below the level of the lake. This area has either been scooped out by the ice, warped into its present shape in the course of the uplift of the land after the ice left, or possibly there is a channel leading out of it which the wells to bed rock have not been numerous enough to determine. It is possible that there may be a river opening west from Sec. 25, T. 15 N., R. 8 E., which off toward Saginaw Bay connects with the streams indicated in Cooper's map of Bay county. This deep trough in the bed rock runs north and south 9 or 10 miles and while it does not seem to continue southward, it is notable that there is an area equally deep about 8 miles west northwest of Vassar and the wells seem to show a deep hole in the bed rock where T. 13 N., R. 8 E. and 12 N., R. 7 E. meet. The Marshall sandstone near its outcrop and until it is covered with over 200 feet of other strata, is always a good source of water. It will undoubtedly be so throughout the whole east and southeast part of the county, and is the source of the supply of the Caro well (which see). But it is also a source of brine in the Saginaw Valley and possibly in the northwestern part of the county, where it is somewhat brackish, but generally less so than the overlying strata.

BY CHARLES A. DAVIS.

Section 1. Outcrops. As has been stated above, the red rock underlying Tuscola county only appears at the surface in a few limited areas, in quite widely separated localities, along the bed of the Cass river. In other places it is buried many feet below the surface by glacial drift, material made up of boulders, gravel, sand and clay, mixed in apparently hopeless confusion, and gathered from many sources. This material forms the residue from, and the record of, the great ice invasion which occurred in the rather recent geological past. It completely hides the rock surface in most parts of the Lower Peninsula of Michigan and with it the records of earlier geological ages, and Tuscola county is no exception in this respect.

In a few places in the county, however, the underlying rock is sufficiently near the surface to allow the Cass river to clear away the overlying drift, and expose the rock, and even to cut into it for a short distance. These outcrops are chiefly in the northern and northeastern parts of the county, and the most noteworthy of them is located not far from Cass City in Sec. 6, T. 13 N., R. 11 E., where the river cuts several feet into the rather soft, fine grained, dark colored micaceous sandstone.

Of this outcrop Rominger writes:[1] "Inland from the shore line, whose geological structure has been described in previous pages, we find the greatest part of the surface covered by deep drift deposits. The upper coarse grained sandrock comes to the surface in Bingham township, near the head waters of Cass river. Similar outcrops are found in the northwestern towns of Sanilac county, in Greenland and Argyle, and in Tuscola county, in the towns of Elkland and Novesta, where the bed of the Cass river is formed by the upper, coarse grained sand-rock inclosing vegetable remains, *Lepidodendron*. Further up the river, at Indian Rapids, in T. 13, R. 12, Sec. 7, some lower beds of finer grained sandrock interlaminated with shale, from vertical bluffs about 20 feet high on both sides of the river. One of the interlaminated seams is soft, almost entirely composed of mica scales and carbonaceous substance. The sand rock is mostly thin bedded, and without fossils, as far as observed." And in another place he writes: "Another locality where these lower beds of the carboniferous limestone series can be observed is on Cass river, 30 miles south of Caseville, in T. 13, R. 11, Sec. 16."

"At the farmhouse of Mr. W. H. Brown, situated close to the river bed, the water flows in rapids over the oblique edges of rock beds dipping at a moderate angle down stream. Here we find a coarse grained, whitish sandrock, with small punctiform ferruginous dots, and sometimes containing stems of *Lepidodendron* and other vegetable remains. Interstratified with them are greenish, micaceous, sandrock ledges and arenaceous, shaly seams. This sandrock is the equivalent of the Point of Barques sandstone, and forms, with few exceptions, the bed of the Cass river for 6 or 8 miles up its course to Indian Rapids, which were mentioned when I gave a description of the Waverly group. Only a few steps below Mr. Brown's house, the sand rock ledges are overlapped by a bluish, argillaceous limestone of a dull, earthly fracture, and moderately soft. It was from this rock that the Indians used to carve their smoking pipes. It contains numerous nodular concretions of zincblende, or Druse cavities filled with this mineral, or with Brownspar and Dolomitspar. The zincblende is mistaken by the inhabitants for Galena, and the same mistake occurs on the old maps of surveyors, lead ore being indicated as occurring in the vicinity of Cass river. Stories are afloat according to which Indians used to gather large quantities of lead on Cass river and transform it at once into bullets, but I have little belief in such accounts, especially since I have failed to find anything to substantiate them; the only mineral observed by me was zincblende. This lime rock contains a moderate number of fossils, Product us, *Spirifer marionensis*, *Spiriferina spinosa*, *Syringopora ramulosa*, and *Orthoceras* (*annulato costatum*?), the same as those found in the bed of Rifle river. Some vegetable remains can also be observed. The thickness of this limestone may reach 8 or 10 feet; above it is a seam of coarse-grained, drab colored, rusty dolomite rock, which is crowded with casts of *Spirifer marionensis*[4] and various kinds of *Lamellibranches*, *Terebratula Eudora*,[3] *Retzia*,[2] and others. Purer-calcareous beds, nearly all composed of shell fragments like those at Oak Point, are interstratified here, and higher we find blue argillaceous limestones of an absorbent, porous character, which contain somewhat of the *Productus* species mentioned several times before, but few of other fossils. A hard, calcareous bed, with flint concretions, overlies them, and then follow arenaceous shales and harder sandrock ledges of a bright red, or yellowish green and red varigated color; some of the layers are in brecciated condition. The total thickness of the red layers may be 15 or 20 feet, of the entire section exposed in the river bed, 50 feet. Further down stream the strata disappear under the drift, and no rock is exposed in the bed of Cass river until Tuscola village is reached, where small outcrops of the coal measures are ob served. Up stream between Brown's farm and Indian Rapids, by undulations of the rock beds the Waverly sandstone becomes sometimes bent downward into a synclinal trough, and the intermediate depression is filled out with the higher fossiliferous limestones, containing zincblende concretions."

A second outcrop of good size occurs on the county line on the east side of Section 12 of Novesta township where the road crosses the river. The rock here extends along the bottom of the stream for some distance, both east and west of the county line. It is a white, or very light colored, coarse grained sandstone, without fossils, so far as observed and forms a relatively smooth, horizontally bedded surface over which the stream runs.

This seems to be the upper part of the Marshall sandstone, the Napoleon sandstone as Winchell called it.

A third outcrop of some extent occurs in the bed of the Cass, well down in its course, near the village of Tuscola as noted by Rominger above. This is also a coarse grained, gray sandstone and from its position and the poorly preserved plant remains which have been reported from it, is undoubtedly a Coal Measure sandstone. None of these outcrops are extensive, or accessible enough to enable an observer to generalize from any studies made upon them, as to the wider relationships of the formations to which they belong. Since this is so the chief source of knowledge of the hard rock geology of Tuscola county and the formations represented in a geological column through it are the numerous records of deep wells furnished by the kindness of their owners, or by the drillers who put them down. Even these records are far from complete and were mostly obtained from the western side of the county, while in many of them the drilling was only carried a short distance into the rocks, so it is not possible to construct a section of any great depth from data collected within the limits of this survey. The absence of deep drilled wells such as are rather numerous in Bay and Saginaw counties, and not uncommon in Huron county, may be explained by the fact that the salt industry was never established in Tuscola county, and also because in that portion of its area where drilled wells are common, a good supply of excellent water is obtained either at the rock surface, or at a moderate distance below it, while some of the underlying formations are impregnated with salt and have to be avoided where water is sought for boilers or for domestic uses.

[1]Geology of the Lower Peninsula, Rominger, 1876, Mich. Geol. Survey, Vol. III.

[2]Now Eumetria.

[3]Probably Dillasma or Harttina.

[4]Probably Spirfer heidy or increbescens, Girty.

GRAND RAPIDS GROUP.

BY ALFRED C. LANE.

This group of beds coming between the Marshall sandstone and the Coal Measures marks a time in the history when mechanical waste of the land was slow and chemical waste relatively fast. Limestone, dolomite and gypsum are characteristic rocks, though various blue and red shales, and bluish grindstones and white ferruginous sandstones do also occur. It may be divided into two parts,—the Lower Grand Rapids, which is called the Michigan series, and in this gypsum and blue shale are dominant, though hydraulic and impure limestones also occur, especially at the bottom. The bottom line may be drawn just beneath a bluish dolomitic limestone. The upper part well exposed in Huron and Arenac counties and around Grand Rapids and at Bellevue, is a relatively pure limestone, with some fossils and occasional beds of white sandstone, but a good deal of it will run over 90% calcium carbonate. We see then that on the whole this formation with hard beds at the top and bottom, but easily eroded in the center, will tend to lie in troughs. It probably coats as a rather thin coating the rock slope which rises up towards the Marshall sandstone from Cass City down to Clifford, but its general course may be marked by the great trough from the channel just described in the southeast part of Elmwood township, past Caro to Millington, for though one valley turns off past Unionville as described above, the general trough continues, and another river valley seems to head near Watrousville and another near Millington. The water from this formation is often unsatisfactory, but does not appear so in Tuscola county, except possibly just north and northwest of Unionville.

COAL MEASURES. SAGINAW FORMATION.

BY W. F. COOPER.

The Coal Measures lie above the Grand Rapids series. Sections in many other parts of the State, especially around Jackson, show that the Grand Rapids and older groups were eroded before the Coal Measures were formed and that these are laid down in troughs in the land surface. It is therefore possible that small outliers of the coal measures may occur at various points beyond the main line, but in a general way the escarpment of the Saginaw Formation, lying above the Michigan series, is probably marked by the higher rock surface which run fairly continuously from 5 miles north of Vassar to Gagetown. It is probable that the Coal Measures have not been tilted quite so much as the later rocks, and that shows in the topography of the rock surface, which is much more irregular and cut into by winding stream valleys like the present topography in Kentucky.

Boundary. In Tuscola county, the eastern limit of the Saginaw Coal Formation passes through Millington, just east of Wahjamega, Caro and Colwood, in a northeasterly direction, thence describing a curve to the northwest to the southwestern corner of Huron county from where the boundary line is very irregular in the vicinity of Unionville and the southeast part of T. 15, N., R. 8 E., forming part of Akron township. This formation passes into Huron county just north of its southwest corner as delineated on the map prepared by Mr. Davis.

Thickness. On the Bay-Tuscola county line the Saginaw Formation has a thickness of 230 feet near the southwest corner of Wisner, increasing to 350400 at Bay City and 525 feet at Midland. In Columbia, 2. 14 N., R. 9 E., and adjacent townships to the west and south are 7 drill holes which penetrate through the coal measures and into the underlying Bayport limestones forming the upper part of the Grand Rapids series. The following table will give the main facts of the sections as represented among the drill records:

Location.	Depth of drift.	Thickness of coal formation.	Elevation of base of coal above sea level.
N. W. ¼ of 17, 14–9	71	107	454
N. E. ¼ of 17, 14–9	85	98	449
N. E. ¼ of 18, 14–9	132	55	445
N. W. ¼ of 20, 14–9	97	95	443
S. E. ¼ of 36, 14–6	133?	230	220
S. E. ¼ of 17, 13–8	104	201	353
S. E. ¼ of 16, 13–9	88?	99?	508?

This would make the average thickness of the Saginaw Coal Formation in Tuscola county 126 feet. The thickness of the drift and that of the coal formation in the first three records given above vary directly, depending in part on the elevation of the basement formation, the Bayport limestone below, and to a certain extent on the relative thickness of the drift and coal formation together. By this is meant that the sum total of the depth of drift, thickness of the coal formation and elevation of the base of this formation above sea level have a total which is the same for the first three holes located in Sec. 17, while the fourth hole located in this section shows a variation of 7 feet from the rest. It is therefore true to a certain extent, for local areas, that the amount of drift and thickness of the coal formation vary proportionately, the greater the thickness of the drift, the less that of the coal measures, and this relationship in turn depends upon the elevation of the underlying Bayport limestone, which is probably due to the eroded surface of that formation upon which the coal formation rests. This latter relationship would make the Saginaw series thicken and thin at the base according to the extent of erosion of the Bayport limestone. It would moreover, appear true that glacial action and the formation of drift from glacial debris acted along a level line within restricted areas, the result being that inequalities in the underlying bed rock were filled up leaving an even slope at the top with a very low grade lime. The above statements, however, do not relate to areas of any very great extent, as the facts mentioned above do not correspond with information obtained from Section 36 of T. 14 N., R. 6 E., and from the S. W. 1/4 of Section 17, T. 13 N., R. 8 E., located to the south and west.

Sandstone, Conglomerate. In six drill holes located in Akron and Columbia townships, T. 14 N., Rs. 8, 9 E. is a stratum indicated as "pebble rock" in drill records. Beds of this character have also been noted in Birch Run township, Saginaw county, on the west side of Saginaw at the plate glass works, and also in a deep well put down by W. L. Ralston in Section 4, T. 14 N., R. 4 E. Bay county. They are known as conglomerate to geologists and are considered shore line deposits. In Tuscola county this layer in most of the records may possibly represent the Parma. In two of the records it is described as sandstone. The general trend of this bed of sandstone conglomerate is northeast as far as it has been described in the drill records, and conforms in a measure to the shore line of the ancient sea or bay in which the coal beds were laid down. In a northeasterly direction the beds extends for a distance of three miles, while the greatest width as far as determined is one mile. The average elevation of the bottom of this bed is 448 feet above sea level and above tide (A. T.), the elevations varying from 443 to 454 feet. The average height of the top of this layer is 453 feet A. T., the limits being from 447 to 465 feet A. T. but with the exception of one record from 447 to 453 feet A. T. This would make the average thickness of the bed 5 feet and the average elevation 450 feet above sea level, taking the seam as a whole. In two out of the six records this layer is said to be sandstone; in the rest "pebble rock."

The following details are culled from the records obtained by Mr. Davis:

N. W. ¼ of the S. E. ¼ of Sec. 8, T. 14 N. R. 9 E. Top of hole 627 feet A. T.

"Pebble rock"	174–178	453–449 A. T.

S. E. ¼ of the N. E. ¼ of Sec. 17, T. 14 N. R. 9 E. Top of hole 637 feet A. T.

Fire clay	172–172 ft. 2 in.	
Sandstone	172 ft, 2 in,–183	
Bastard limerock	183–193	465–454 A. T.

S. W. ¼ of the S. E. ¼ of Sec. 18, T. 14 N., R. 9 E. Top of hole 630 feet A. T.

Bed rock	75
Coal	174 ft. 4 in.–177 ft. 5 in.
Sandrock	183 ft. 5 in.–187 ft. 5 in.
Limerock	187 ft. 5 in.–191 ft. 5 in.

N. E. ¼ of the N. E. ¼, Section 18, T. 14 N. R. 9 E. Top of hole 632 feet A. T.

Bed rock	132	
Coal	182 ft. 9 in.–182 ft. 10 in.	
Pebble rock	182 ft. 10 in.–187 ft. 6 in.	450–445 A. T.
Limerock	187 ft. 6 in.–188	

N. E. ¼ of the N. E. ¼, Section 18, T. 14 N. R. 9 E. Top of hole 635 feet A. T.

Bed rock	97	
Pebble rock	186 ft.–186 ft. 6 in.	449 ft.–448 ft. 6 in. A. T.
White sandrock	186 ft. 6 in.–192 ft.	
Limestone	192–204	

S. E. ¼ of Sec. 24, T. 14 N. R. 8 E. Top of hole 635 feet A. T.

Bed rock	109	
Coal	183 ft. 4 in.–183 ft. 10 in.	
Pebble rock	183 ft. 10 in.–184 ft. 7 in.	452–451 A. T.
Coal	186 ft. 11 in.–191 ft. 2 in.	

Limestone not penetrated.

These records are of interest as showing the persistence of the bed within a rather small area at the same elevation, but the last record is of especial value as showing this bed of conglomerate, "pebble rock," at about the same average elevation as to the northeastward and with a bed of coal below. The remainder of the record through the coal formation would be of very considerable value. With the exception of the last record it will be noted that this bed of conglomerate rests on the Bayport limestone in much the same position as the Millstone grit (Sharon) of Ohio and the Parma of Michigan, but it is hardly safe to conclude that this bed of "pebble rock" is the same formation. The last record, moreover, is of interest as indicating how the coal basin became filled in and gradually levelled up from the bottom, leaving the uppermost beds of greatest extent and with the least oscillation of the level as in a saucer-like area. This conclusion is only supplementary to information printed in the general report of the Saginaw Series by Lane and also by the writer from numerous records obtained in Bay county.[1] It only remains to be added that there are rather numerous records from this part of Tuscola county which do not show this bed of conglomerate either at 450 feet above sea level or above or below, but this may be due in part to deficiencies in the drill records. Beds of conglomerate have recently been found in drilling the coal formation at the Central Station of the Lansing Water Works by Elmer E. Strope of Mason, associated with thin seams of coal, and also at East Lansing by Mr. Jas. Packard of Lansing.

[1]Volume VIII, Part 2, Mich. Geol. Survey, 1902, and Annual report for 1905, pp. 135-426, Bay County.

Washouts, Drift Filled Channels. By this is meant the former drainage channels on the top of the coal formation, before the present drift or overburden was brought down by the ice sheet and deposited, smoothing over all inequalities in the underlying bed rock. In Bay county this early drainage system trends to the west and southwest into a main channel meandering below St. Louis and Alma arid thence towards Manistee and Ludington on the Lake Michigan shore where the drainage was at the present elevation of sea level. This main drainage channel has been designated the Alma washout or Alma channel from the location at that place in Gratiot county where the depth has been obtained.[1] In Bay county this Alma channel is probably represented, at least in part, by the Amelith washout and channel. The depth of this channel where it leaves Bay county in Saginaw Bay and not far west of the Saginaw river is 400 feet above sea level. The continuation of this Amelith washout would seem to be represented by the buried channel running north from Unionville, but inasmuch as this can not be verified it may be well to designate this ancient water course the Unionville washout and channel. Inasmuch as the depth of the deepest wash does not appear to reach below 480 feet A. T. it would not affect in any way the mining of the Saginaw seam found at about 400 feet above sea level. The same may also be said of the Middle Rider, if workable, which is found at about 424 feet A. T., the Lower Verne at about 441 A. T., the Upper Verne at 459 feet A. T., and scarcely the Upper Rider at 480 feet if this bed is ever developed commercially. However, when it comes to the Salzburg coal found at an average elevation of 497 feet A. T. it may be determined that the drift cuts into this bed in the old drainage channel north and south of Unionville. The same remark holds true to an increasing extent of the overlying seams of coal, for the most part in the eastern tier of sections of Akron, T. 14 N. R. 8 E. Not only is coal lacking in these washouts when deposited at a sufficiently high elevation but they may be the source of strong underground water currents which would interfere in coal mining operations.

[1]Michigan Academy of Science, 9th Annual Report, p. 141, 1907.

Coal Seams. In the report on the coal formation of Bay county[2] the following names were given to the different coal seams from the top downward Salzburg Rider, Salzburg coal, Upper Rider, Upper Verne, Lower Verne Rider, Lower Verne, Middle Rider, Saginaw Coal, Lower Rider, Lower coal, Bangor Rider, Bangor coal.

Near the southwest corner of Wisner township is the record of a hole 495 feet deep put down by the Bullock Co. of Chicago for N. B. Bradley of Bay City. The upper seams as laid down in Bay county are not represented there, but the following determinations were made of those lower down, as nearly as possible:

Lower Rider 1 ft. thick, 257 ft. deep and 326 A. T.
Lower coal 1 ft. thick, 293 ft. deep and 290 A. T.
Coal 6 in. thick, 308 ft. 3 in. deep and 275 A. T.
Bangor Rider 6 in. thick, 327 ft. 3 in. deep and 256 A. T.
Bangor coal 1 ft. thick, 360 ft. 9 in. deep and 222 A. T.

In examining the records which are printed with the well data in a subsequent chapter it is at once apparent that the different seams of coal as described in the report on Bay county are also found at the same elevations above sea level with the exception of the four seams underlying the Saginaw coal. This is due to the increase of elevation of the basement formation, the Bayport limestone, Upper Grand Rapids, underlying the Saginaw formation. On the other hand there are at least two beds of coal found above the Salzburg Rider, which is the highest layer of coal thus far identified in the Bay county area. While the different coal seams oscillate considerably in elevation in Tuscola county it has been ascertained that in no case do these variations extend into overlying or underlying coal beds. This may be due to the limited extent in which coal exploration has thus far been carried on as far as ascertained. It is, however, to be remembered that the correlations which follow are more or less doubtful in view of the fact that no opportunity has been had of checking up from shaft records. The height of the different beds of coal are given above sea level or above tide (A. T.). The depth to the different beds can be found from the records given on a subsequent page, but in exploration work the depth to the different seams can also be approximately ascertained by either referring to the tables given and subtracting that elevation from the county surface contour map, or by determining the difference in elevation from the general average of a given seam at any place where the drill may be located. This method could also be used in tracing the same seam of coal across any adjacent territory. By way of illustration may be taken the Saginaw seams. In Bay county this is found at an average elevation of 400 feet A. T.; in Tuscola there are two drill holes in the N. E. 1/4 of Sec. 34, T. 13 N., R. 8 E., where it may be found at 407 feet A. T. The elevation of the surface here is about 600 feet A. T., which would make the depth to the bottom of the coal 193 feet. In the N. E. 1/4 of Sec. 36, T. 12 N., R. 7 E., the surface elevation is 700 feet A. T. in one place which would make the depth about 293 feet. A contour map of the county was printed as Plate IV in the annual report of the Geological Survey for 1903.

The following tables have been prepared from coal drillings obtained by Mr. Davis and are designed to show the elevation of the different beds, thickness, depth and character of the foot and roof. The names of the different drillers will be found given with the records. The different seams will be described from the top downward in order to meet conditions found in drilling operations. There are indications of two seams of coal above the Salzburg Rider, the highest bed thus far described in Bay county, which will here be given special notice.

[2]Annual Report of the Mich. Geol. Survey for 1905, p. 175.

Reese Coal. The coal bed highest up has been penetrated in five drill records. It has an average elevation of 561 feet above sea level, but varies in height from 552 to 568 feet A. T. or 20 feet below the level of Saginaw bay. In case this bed of coal is found well developed it might be designated the Reese coal from its occurrence in Denmark township, T. 12 N., R. 7 E. The reason that this bed was not noted in Bay county may be due to the much geater erosion of the bed rock surface there, especially where coal exploration had taken place previous to the publication of the Bay county report. The following table will give all the information known about this coal bed:

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. E. 1/4 of Sec. 9, 12-7	6 in.	82 ft. 6 in.	568	Fire clay	Slate
N. W. 1/4 Sec. 17, 12-7	4.5 ft.?	85 ft.	555		Drift
N. W. 1/4 Sec. 18, 13-8		78 ft.	552		Drift
N. W. 1/4 Sec. 30, 13-8		74 ft.?	564		Drift
S. E. 1/4 Sec. 12, 14-8	10 in.	158 ft. 10 in.	567		Gray shale

Inasmuch as this seam is found at an average elevation of 561 feet A. T. it would be necessary to drill above the elevation of that rock contour line as given for Tuscola county and within the limits of this formation as indicated on the geological map of the county. This would include the south and west halves of Arbela and Millington townships, respectively, and a comparatively narrow but very irregular area north of there. In Bay county exploration could be carried on in the area above the 560 foot contour line in the northern part of the county.

Unionville Coal. Next below this horizon is found another coal bed at an average height of 531 feet A. T. The elevation varies from 527 to 537 feet A. T. This seam is also above the highest bed of coal described in the Bay county report and might be designated the Unionville coal from its location in Columbia, T. 14 N., R. 9 E. The following table will give information concerning its occurrence:

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. W. 1/4 9, 12-7	4 in.	119 ft. 4 in.	536	Sandy shale	Sandrock
S. W. 1/4 6, 13-8		77 ft.	535	Sandstone	Drift
S. W. 1/4 1, 13-8		140 ft.	528	?	?
Sec. 34, 15-8	2 in.	68 ft.	527	Fire clay	Gray shale
S. W. 1/4 18, 14-9	4 in.	101 ft.	528	Slate	Light shale
S. E. 1/4 21, 14-9	2 ft.	118 ft.	527	Soapstone	Drift.

Salzburg Rider. This, the highest bed of coal described in the Bay county report is found at an elevation of 515 feet A. T. in that county and at 518 feet on the average in the area under consideration. Associated with this is a coal bed which may prove to be distinct in this area which is found at an average elevation of 508 feet A. T., the seam varying from 507 to 509 feet A. T. The Salzburg Rider varies in elevation from 517 to 519 feet above sea level here in Tuscola county. There is no single drill hole showing both beds at the elevation given above, but in two places the above differences are noted in near by adjacent localities with the lower bed persistent at the same elevation A. T. in two places where the three seams are located, in the latter part of the two localities. It seems not improbable that the two horizons are distinct, but for the time being they will be designated as the same layer.

The subjoined table will show where this coal seam has been found, and the main factors of its occurrence.

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. W. 1/4 8, 13-9	?	150 ft.	508	?	?
Sec. 34, 15-8	5 in.	88 ft. 5 in.	507	Fire clay	Gray shale
N. W. 1/4 9, 12-7	5 in.	145 ft. 9 in.	509	Sandstone	Slate
N. W. 1/4 18, 12-7	4 in.	128 ft.	507	Sandstone	Sandstone
Sec. 34, 15-8	8 in.	88 ft.	507	Fire clay	Gray rock
N. W. 1/4 34, 12-7	?	117 ft.	518	?	?
N. E. 1/4 2, 14-8	1 ft, 1 in	88 ft.	517	Sandstone	Limestone?
N. E. 1/4 12, 14-8	4 in.	106 ft.	519	Shale	Slate
N. W. 1/4 4, 13-9	1 ft. 8 in.	147 ft.	518	Dark slate.	Sandrock

The 508-foot seam might be designated the Salzburg Lower Rider if further investigation gives additional information concerning the distribution of the bed in Tuscola and Bay counties. This would leave the upper seam at 517-519 feet A. T. the equivalent of the Salzburg Rider of Bay county.

Salzburg Coal. This bed has been described in the Bay county report to which the reader is referred for further particulars.* The average elevation there is 494 feet A. T. Here in Tuscola county the height varies from 492 to 501 feet above sea level with an average height of 497 feet A. T. as given in 7 holes. This is 3 feet higher than the average elevation in Bay county. The following points were determined from the drill records.

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. W. ¼ 9, 12-7	6 in.	156 ft. 3 in.	499	Fire clay	Shale
S. E. ¼ 13, 14-8	2 in.	127 ft. 2 in	501	Fire clay	Gray shale
Sec. 34, 15-8	4 in.	103 ft. 4 in.	493	Sand rock	Fire clay
S. W. ¼ 36, 15-8	4 in.	132 ft. 4 in.	492	Fire clay	Slate
N. W. ¼ 13, 15-8	3 in.	88 ft. 3 in.	497	Sand rock	Lime rock
N. E. ¼ 5, 14-9	1 ft. 10 in.	119 ft. 10 in.	496	Black slate	Slate
S. W. ¼ 18, 14-9	4 in.	129 ft.	501	Fire clay	Slate
	2 ft. 8 in.	131 ft. 10 in.	499	Fire clay	Fire clay

*Annual Report for 1905, Bay county, pp. 192-194.

Upper Rider. In Bay county this bed of coal has an average elevation of 482 feet A. T., and in the eastern part of the county is found at 480 feet above sea level. In the area under consideration the average elevation is 480 feet A. T., the variation in height being from 474 to 488 feet. The table below will give all the information that has been obtained concerning this coal bed.

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
S. W. ¼ 31, 12-7	?	175 ft.	480	?	?
S. E. ¼ 8, 14-8	4 ft.	107 ft.	488	Flinty rock	Slate
N. E. ¼ 12, 14-8	3 ft. 1 in.	151 ft.	474	Fire clay	Black shale
S. E. ¼ 27, 15-8	1 ft. 8 in.	111 ft.	476	Soapstone	Slate
N. W. ¼ 13, 15-8	6 in.	88 ft.	479	Slate	Sand rock
N. W. ¼ 6, 14-9	4 ft.	144 ft.	481	Slate	Slate

Upper Verne. This is the most important seam of coal which has been thus far commercially developed in Bay county. In that area it has an average thickness of 29 inches where represented and an average elevation of 463 feet A. T. In the eastern part of Bay county it may be found at 454 and 462 feet A. T. In Tuscola county the average height is 459 feet above sea level, the elevation varying from 451 to 468 feet A. T. It is, as far as the drilling shows, more extensively developed than any other bed of coal in this area, thus conforming to the importance of this seam in the adjacent area to the west and north, in Bay county. In the table given below will be found the essential facts concerning this coal horizon:

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. E. ¼ 12, 14-8	3 ft. 2 in.	162 ft.	463	Slate	Gray shale
S. E. ¼ 12, 14-8	3 in.	163 ft.	462	Fire clay	Slate
S. E. ¼ 13, 14-8	6 in.	173 ft.	455	Sandrock	Sandrock
S. E. ¼ 24, 14-8	6 in.	184 ft.	451	Pebble rock	Dark shale
S. W. ¼ 26, 15-8	4 in.	132 ft.	461	Fire clay	Slate
N. E. ¼ 18, 14-9	3 in.	170 ft.	465	Rock, sulphur	Gray rock
	4 ft. 3 in.	174 ft.	461	Black slate	Rock and sulphur
S. E. ¼ 18, 14-9	3 ft. 1 in.	177 ft.	453	Sandrock	Slate
N. W. ¼ 19, 14-9	1 ft. 8 in.	178 ft.	456	Black shale	Black shale
N. W. ¼ 20, 14-9	1 ft. 8 in.	176 ft.	459	Sand rock, sulphur	Gray rock
N. W. ¼ 30, 14-9	1 ft. 5 in.	167 ft.	468	Fire clay	Dark shale

There are indications that this coal may be, in whole or in part, the Lower Verne seam of Bay county, as sulphur has been noted in the drill records, as indicated in the table above. It would be well to have samples from this bed examined by a competent chemist in order to determine its value for fuel purposes before attempting any mining operations.

Lower Verne. In the county coal field this seam is found at an average elevation of 440 feet A. T. being found at a height of 444 and 450 feet above sea level in the eastern part of the county. In Tuscola the seam has an average height of 441 feet A. T. comparing very well in elevation with its extension westward into Bay county. As will be seen from the table given below the elevation varies from 435 to 447 feet above sea level.

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. W. ¼ 7, 12-7	?	200 ft.	435	?	?
S. ¼ 28, 11-7	3 in.	202 ft.	438	Soft clay	Sandrock
S. E. ¼ 12, 14-8	7 in.	184 ft.	441	Shale	Black shale
S. E. ¼ 24, 14-8	4 ft. 3 in	191 ft.	444	Slate	Black slate
N. W. ¼ 13, 15-8	5 ft. 9 in.	146 ft.	444	Slate	Slate
N. W. ¼ 30, 14-9	4 ft. 4 in.	189 ft.	447	Fire clay	Black chip slate

In general this bed of coal increases in elevation toward the northeast. If of the proper quality it would probably be valuable for mining purposes, but should be carefully analyzed before any money is spent in sinking a shaft.

Middle Rider. This name has been given to the rider of the Saginaw coal. In Bay county it has an average elevation of 421 feet above sea level. In the southeastern part of the same area it is found at 430 feet A. T. in one drill hole. In the area under consideration it is found in three drill holes at from 422 to 426 feet A. T., having an average height of 424 feet above sea level.

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
N. E. ¼ 5, 13-8	2 ft.	200 ft.	423	?	?
Sec. 34, 15-8	1 ft.	171 ft.	425	Fire clay	Black slate
Sec. 34, 15-8	5 in.	174 ft.	422	Fire clay	Fire clay
Sec. 34, 15-8	9 in.	169 ft.	426	Fire clay	Slate

Saginaw Coal. In Bay county this bed of coal is 400 feet above sea level on the average. It is mined in the southwestern part of Merritt township about 6 miles west of Tuscola county. Commercially it is the most important bed of coal in Saginaw county and sustains to that region the same relation that the Upper Verne coal does to Bay county at the present time. It has thus far been noted in only one drill hole in Tuscola county, as indicated below:

Location.	Thickness.	Depth.	A. T.	Foot.	Roof.
Sec. 34, 15-8	6 in.	187 ft.	408	Slate	Shale
Sec. 34, 15-8	5 in.	188 ft.	407	Fire clay	Slate

Nomenclature. Summing up the names given to designate the different beds of coal as given in the preceding pages we have the following order, beginning at the top, for the Saginaw drainage basin. Reese coal?, Unionville coal?, Salzburg Rider, Salzburg Lower Rider?, Salzburg coal, Upper Rider, Upper Verne, Lower Verne Rider, Lower Verne, Middle Rider, Saginaw coal, Lower Rider, Lower coal, Bangor Rider, Bangor coal.

Additional records which will serve to give more information concerning these different beds are greatly to be desired, and any information which coal operators and drillers may be at liberty to give will be appreciated.

CHAPTER VI. ECONOMIC PRODUCTS.

In general, since the bed rock is so far below the surface, and the rocks which underly the region, so far as is known from drillers' records and samples, are wholly of sedimentary and organic origin, i. e., sandstones, shales, limestones and carbonaceous rocks, or coal, in an undisturbed condition, it may be postulated that no very rich accumulations of metallic ores, or, mineral deposits, in the commonly accepted usage, are likely to be found, because the conditions known to be favorable to their occurrence have not existed at any time since these rocks were laid down as sediments in quite early geologic times.

It is therefore, useless to expend time, energy and money in drilling into the bed rocks in Tuscola county in the hope of finding bodies of the metalliferous ores, or to expect that they occur in economic quantities in the region. It is possible, however, that here and there, boulders will occasionally be found which contain small quantities of some of the ores of the rarer or more important metals, as such are somewhat widely scattered through the drift, having been transported from the great areas of the crystalline and metamorphic rocks which lie to the northward and northeastward in Canada. Such boulders have no more significance, however, than those of granite, or other foreign material, and are of interest chiefly because they point out very clearly the direction of the ice movement during the glacial times, and give us definite information as to the sources of the great ice sheet, (pp. 13-15.)

The only exception to the statements just made, are the cases of iron and zinc, both of which are found in small quantities in the form of sulphides in the bed rock, as noted below. Iron may also occur occasionally in the bed rock in the form of the carbonate, in nodules; it is also almost universally disseminated in the rock and soils as oxides, but so unconcentrated as to be of no economic importance except as plant food. It is this substance that gives the yellow and reddish color to soils.

Coal. Of the possible mineral natural resources of this county coal is the one which has been most looked for and which has the widest and most generally important economic use.

The history of the occurrence and development of coal in the Michigan coal field has already been fully discussed in other reports[1] of this survey, and those interested are referred to these papers and to Chapter V above, for information relating to these phases of the subject.

Since the time when tubular drilled wells were first put down into the rock, there have been reports of the occurrence of seams of coal within our limits, and after the mines were opened at Sebewaing, and, later, those in Saginaw and Bay counties, where successful mining operations are carried on, and much exploration work was done to determine if workable coal beds existed here. Coal was found quite widely distributed, having been reported to the writer in nearly every township where the wells reached the rock, but usually only in thin seams. Where thicker ones were found, they were generally of small extent, either from the fact that the basins in which they were formed were small, or because the rock surface was uneven from glacial or pre-glacial erosion, or from faulting, or breaking and slipping of the rocks, or other causes. In many cases, the coal was without stable roof, the coal itself forming the rock surface. These facts can easily be demonstrated by plotting the records of the wells in the chapter on water supply (page 63), on a map and noting, that while one record in a section may have a good coal seam, others, made with equal care by reliable drillers, will show no coal, or but a thin bed of no economic value, at about the same depth.

Because of these peculiar features of the coal of the county, in spite of the activity in putting down test wells, the general talk of excellent coal prospects and probable mining developments, no coal mining was actually done within its borders during the progress of the field work on which this report is based, nor for some time afterwards.

More recently, however, mining operations have been undertaken in at least two places in Tuscola county. The first of these, located near the county line, was for the purpose of mining both coal and pyrites, and after a time, was abandoned. In 1907, however, the Handy Brothers Coal Mining Co., of Bay City, sunk a shaft some three miles northwest from the village of Akron in Akron township, and now have a mine in operation. The shaft is reported to be the deepest coal mining shaft in the State, the coal being 225 feet below the surface, and of the unusual thickness of from 5 to 6½ feet; it is also said to be of superior quality. No opportunity has presented itself to visit this mine, hence no more than brief mention is made of it.

The coal seams as indicated by the records of test wells, are formed at various depths, rising, however, to near the rock surface towards the east, as would be expected, since the margin of the coal basin lies in that direction. It is difficult, however, to locate and trace the exact border of the eastward extent of coal, because of the very few drilled wells and test holes put down in the region east of the Saginaw-Port Huron moraine. The map (Plate VI), shows the approximate location of all the wells from which coal of whatever thickness was reported. These reports vary in credibility to a considerable extent, and the records were obtained from every possible source, varying from the statement of some member of the owner's family, that 8 or 9 feet of coal had been found in the drilling of the well, to the carefully kept log of the professional prospector, the details of which are given in the list of records of wells and test borings.

Despite this, it is evident that the reports confirm one another and it is hardly probable that the reports of coal in the eastern part of the county are to be considered as unreliable, for they are too widely scattered to be all false; nor does the fact that no coal was reported in the few rock wells in the southeastern part of the county, necessarily indicate the entire absence of coal there, because, even where it is well known to occur, in other parts of the county, of two holes on the same farm, put down to equal depths, one will have a seam of coal and the other will not show even a trace of it. It is, as has been said above, this irregularity in the occurrence of the coal, which, in large part, has kept the workable seams from being mined.

A close inspection of the more carefully kept records of the test wells, makes it evident that there are here, as elsewhere in the Michigan coal field, at least three depths from which coal may be found, a very deep deposit probably at its best in the mine near Akron, an intermediate deposit, which is probably the deeper of the two found in the wells about Reese and a still higher seam which is found in the wells in Wisner, and other parts of the western side of the county.

It is evident, that, since the strata dip towards the west, and because the margin of the basin is to the east, that the beds of coal found near the surface of the rock at the east, would get deeper and deeper to the west, and would be older as well as deeper than the beds found near the surface towards the west. It is important to remember this in searching for a given stratum in going from east to west, as, if the bed is extensive, it will dip with the rock, and, while it may start at the surface of the rock, to the east, if it persists, which is not usual, it will get deeper and deeper to the west and have good roofing rock.

Because the coal was probably formed in swamps which bordered a shallow sea, and these were limited to narrow areas of the undrained shore, much as the present marginal marshes and swamps are now, there is an excellent reason why the earlier and lower beds should be thicker near the borders of the basin, while they thin out to the west, because, at the time when they were formed, the water covered the part of the basin, which, later, by the building up of new sediments, became swampy as the water shrunk away into the still deeper parts of the basin.

[1]Lane, A. C., Coal of Michigan, Geol. Sur. Mich., VIII, Part 2.

[1]Lane, A. C., Geol. Rept, on Huron county, Geol. Sur. Mich., VII, Part 2.

[1]Cooper, W. F., Geological Report on Bay county; Annual Rept. Mich. Bd. Geol. Sur, 1905, pp. 160-332.

Sandstone. The very limited outcrops of sandstone in the northeast era part of the county, already referred to (pages 33-4), might be used in the case of the thicker beds at least, for foundation and other building purposes, while some of the finer-grained beds would doubtless serve for the manufacture of grindstones, if they are not already so used, as they belong to the same formation as the famous sandstones used for grindstones so extensively quarried in Huron county; it is probable, however, that they belong higher up in the Marshall sandstone than the beds at Grindstone City, and will generally run too coarse for making the finer grades of stones.

In places, where the sandstone is compact, and thick-bedded enough to permit it to be taken out in pieces sufficiently large to saw into slabs, for flagstones, it might be so utilized, but the depth to the rock, entailing a considerable amount of expensive stripping before it could easily be quarried, will doubtless render such use impracticable for a long time to come.

Boulders. Scattered over the surface of the moraines, the beaches of both modern and ancient lakes, and especially, along the sides and bottoms of the channels through which the water escaped from the melting border of the glacial ice sheet, and in the bed of the Cass river, are numerous boulders of many kinds of rock, crystalline, metamorphic and sedimentary. In some places, as in certain parts of Wells township these are so numerous, that in cultivating the land they are gathered together in great heaps, or built into rough fences. In others, especially in the lake plain districts, they are of infrequent occurrence and are seldom seen. The greater number of these boulders are of very hard durable rock; the very fact that they occur at all, is an indication that they were capable of enduring much hard usage, since, as is shown above (page 16) they may be traced back hundreds of miles to the northeast, from whence they were brought by the glacial ice whose sign manual may often be found upon them, in the form of polished, striated or irregularly smoothed surfaces.

Not all of these boulders have been brought from a distance, however, for some are easily recognized as of local, or near-by origin, by their close resemblance to the rocks outcropping in the adjacent region to the north. These are chiefly sandstone blocks, less often, limestone, which show by their lack of rounding and erosion that they have not been transported far.

The fact that these boulders, "field-stone" as they are often called, are so frequently of hard, tough rock, makes them good building stone, and their usually moderate size, makes them convenient to handle and work up into building blocks, and they are favorite material for foundations and for entire structures where they occur abundantly enough to furnish a supply. Buildings in which they are used present a pleasing appearance, especially if a little care is taken in arranging the stone to harmonize the variety of colors, chiefly pinks and greenish grays, which usually is found in a mass of such boulders.

In a locality where boulders abound, they sometimes are piled up in great heaps in the fields in the course of years of cultivation. Such boulder heaps as those in parts of Wells, Dayton and Fremont townships could be utilized as the source of crushed stone for macadamizing the main roads of the region, and, by using modern, portable, stone-crushers, much of such material could be prepared, which would be of vastly better quality and more durable than that made from any rock native in the region.

The most remarkable mass of transported rock of which any record was obtained, was that on the farm of Mr. H. Post, near the center of Sec. 8, Aimer township. The well here was 180 feet deep, with bedrock first struck at 130 feet. On the back of the farm, near the center of the section, considerable slabby, yellowish limestone had been plowed up, and, later, according to the owner, rock was struck in digging post-holes, for several rods. A hole was dug and several wagon loads of stone taken out, without getting to the bottom of the mass. Slabs three or more feet square and three or four inches thick were separated from the mass and used for door stones, about the wells, and yard for flagstones. At the time it was visited the hole was filled up, but the slabs were seen in use about the premises.

Another large mass of limestone, of quite different character was found in the bed of Cass river, a short distance above Vassar, but this boulder would not weigh more than a few tons.

Large boulders of the crystalline rocks, such as granite, syenite, or some of the darker types, when of good quality and color, and located within easy hauling distance from a railroad, are salable for monument construction to city stone cutters, who get some of their choicest stone by the purchase of this sort of material. Boulders properly piled, make a nearly permanent fence, but the art of building fences from round boulders is not easily acquired, and the first cost of construction is heavy, at the present price of labor.

Sand. The extensive sand beaches, and, more especially, the sand dune lines, which cross the county at various elevations, furnish immense quantities of well-sorted sand for various purposes, such as masonry. That of some of the dune areas, such as those of the region between Vassar and Millington or at Juniata station, as well as in numerous places near other towns, should be excellent for making concrete building blocks, and especially for making cement and sand brick, as it is pure, of even grain, and of good color. The availability of these deposits and their nearness to the railroads at various points, as well as the quality and abundance of the raw material, commends them from the commercial point of view.

Gravels. The gravel deposits of Tuscola county are almost as extensive and well distributed as are those of sand, nearly every township having some excellent gravel pits, while in many of them, across which gravelly beaches run, or in which kames, or other glacio-fluvial deposits occur, the number of pits is only limited by the requirements of the inhabitants.

These gravels, as has been pointed out in another chapter (page 23), are of three degrees of sorting, according to origin: (1) The gravels of the glacio-fluvial type, often poorly-sorted, and with much fine and very coarse material in them, and found in the immediate vicinity of, or as deposits on moraines. (2) Fluvial, or river gravels, those formed along the terraces, bars or deltas of the ancient or modern streams, in which the sorting has gone farther and much of the coarser material has been eliminated by the stream action. (3) Lake or beach gravels, which show still greater sorting and have but little very coarse or very fine matter, but contain small and medium-sized pebbles of uniform weight, and more or less coarse sand, according to the force and constancy of the wave action to which the beach was subjected and the coarseness of the original material upon the shore.

Of these three types of gravel, the coarser, more poorly-sorted is found along the north face of the Mayville moraine in the kames which are adjacent to it, and sometimes in limited quantities on the higher parts of the moraine itself, where the till becomes gravelly. This kind of gravel is used extensively in road building and for grading and ballasting railroads, wherever it is needed for such purposes. Where used for building or repairing wagon roads, the boulders and large-sized cobble stones are picked or screened out, and, in gravel pits of this type, it is usual to find piles of these rejected stones. In general, the slight sorting which this material shows, makes it rather poor road metal, but certain grades of it are very valuable for the purpose.

In some parts of the state, large deposits of such gravel are systematically worked, the gravel being dug with a steam shovel, sorted by a rotary, cylindrical, power screen and the various sizes of pebbles shipped by the carload to distant points.

If a county system of road improvement is adopted in Tuscola county, as doubtless it will be, some of the bouldery kame gravel deposits in Fremont or Dayton townships, to be located after a careful examination of the west slope of the Mayville moraine, could be made the center of distribution, not only of screened gravel, but of a considerable quantity of crushed stone as well. If less bouldery material is required, nearer the center of the county, nearly the whole length of the Forest and associated beaches along the western side of the Saginaw-Port Huron moraine, from south west of Vassar, near which place is an extensive railroad gravel pit, to Gagetown, furnishes good opportunity for the establishment of such a plant; already there is scarcely a road which crosses this beach upon which there is not a gravel pit.

Still farther west, on the Bay City moraine, and the beach lines occurring on its western side, are other deposits of gravel, notably the one at Woodman Station, on the Pere Marquette R. R., which has been drawn upon extensively for ballast for the railroad; there are several minor gravel pits in this neighborhood, and to the southwest in Gilford township, which have already been used to the great betterment of the roads in their vicinity. In some of these, the gravel is well sorted; in others, it is rather sandy, but, on the whole, is well adapted for use on the more clayey types of roads which are common in this district, and which are rendered more clayey by the construction of wide ditches on either side of them, from which the material removed, is scraped into the roads.

These gravel deposits are so widely distributed in the various sections of the county, and so conveniently located to the areas where good roads are needed, that they will, without doubt, be much more extensively worked than at present, as soon as a more rational system of road construction than that in use, is adopted.

The gravel deposits which are located near the towns are already drawn upon in annually increasing amounts for use in concrete construction, and doubtless this use will become greater as the concrete proves its value as a building material, as with proper mixing and good cement, it is certain to do.

Molding sand. This material, used by founders for making molds for castings, is a fine-grained river deposit, in which there is sufficient clayey matter to enable it to retain a given shape without crumbling or cracking when packed in a nearly dry state. It occurs in small pockets in the present flood plain of the Cass river and its tributaries, and probably also in parts of the older flood plains as well. The foundry at Cass City obtains all of the molding sand used in its operations from deposits in the vicinity of that town, and the quality was reported by the owner to be excellent. He stated there were no large deposits, but that he obtained a wagon-load, or part of a load in a place. It is possible, however, that a careful search along the valley, would lead to the location of considerable amounts of this rather important material, although these might be located so far from railroad stations as to be valueless. The very limited demand in the county is already supplied, and it would be necessary to seek an outside market, even if a commercially valuable supply of the proper consistency were found.

Clay and Clay Industries. The formation of clays has already been discussed to a considerable extent in the chapter on soils, and the occurrence, properties, and qualities of Michigan clays, and clay rocks have been fully described by Ries[1] in a previous report of this survey. The types of clay occurring in Tuscola county are (1) Glacial, (2) Glacio-fluvial, (3) Lacustrine. The first occur both in the terminal and in the ground moraines, and are often stoney and contain much lime, either in the form of fine grains, or as pebbles. In the latter form, it is very injurious as it causes a scaling and bursting in bricks made from the clay during the burning of the bricks; the carbonate of lime is converted into quick lime, which, later, is slaked, and, by expansion, causes a bursting, or less defect, in the brick. The presence of the finely-divided lime in the clay gives bricks and other materials a light color and causes it to fuse at a lower temperature than if it were absent; this is of no disadvantage in brick, tile and earthenware manufacture, because of the low temperature at which burning is done.

The lake clays are less likely to have pebbles of any kind in them than the other types, being more thoroughly sorted, but deposits of this sort are probably rare in Tuscola county, except as superficial layers over the ground moraine of the last retreat of the ice sheet.

The principal industry based on the clay deposits is that of brick and tile making, and the chief establishment of this sort is located at Caro and is utilizing a deposit of glacial clay.

[1]Ries, H. Clays and Shales of Michigan. Geol. Surv. Mich., Vol. VIII, Part I, Lansing, 1900.

Shales. The shales outcropping in the bed of the Cass river, and those which lie over the county line east of Cass City, are of such character that they might be used in the manufacture of some of the more refractory grades of bricks, since they contain less lime than the superficial clays. It is also probable that some of the shales associated with the coal seams now being worked near Akron, could be used in the manufacture of paving and fire brick.

Fire clays are reported in the records of numerous wells throughout the county, wherever they penetrate the rock, but the name seems simply to mean a light-colored shale, although sometimes the samples taken from the drill holes have been tested by the driller in his forge-fire, and found to be sufficiently refractory to resist such heat as could be thus obtained without melting.

It would seem as if there were sufficient workable clay deposits so that all of the brick and drain tile needed in the county could be manufactured at home, if fuel is abundant enough, and cheap enough to warrant the outlay necessary to build the plants.

Iron Pyrites. This material is almost entirely found in the bed rock in the coal measures, and it is frequently reported by well drillers as being a constitutent of the rocks through which they drill. This mineral, known as sulphur by the coal miners, was very abundant in the mines at Sebewaing, both in the coal and in the associated shales, and great quantities were taken from the mines with the other refuse when they were in operation, but no use was made of it. Pyrites is used as a source of sulphur in the manufacture of sulphuric acid, and, while it is imported in considerable quantities into this country, the high cost of production and freight to the manufacturing centers, makes it unlikely that it would pay to mine it under existing conditions. In fact, the attempt to do so in the county made a few years ago, did not prove a success, and had to be abandoned.

Lead and Zinc Ores. For many years, dating back to the earliest settlement of the region, there have been persistently repeated legends of an Indian lead mine, located in various parts of the Thumb, among others, in the Columbia swamp. In the course of the Geological Survey of Huron county, Lane[1] made careful examination of the evidence and reached the conclusion that whatever lead, if any, had been found, was obtained from the drift. Rominger[2] as already cited (p—) 25 years before, also came to the conclusion that little belief could be placed in the then current accounts of Indian mines.

The writer was also informed by a well-known citizen of Cass City, who was interested in minerals, and familiar with many of them, that he had spent many hours along Cass river, and it tributaries, both up and down the stream, panning the sands and gravels, but, while he had found particles of zinc sulphide in some abundance, he had never found any traces of galena, the lead sulphide, or of any other lead compound.

Small particles of Sphalerite, or zinc blende, the sulphide of zinc, as pointed out by Rominger on the passage cited, are present as small shining nodules and particles in the limestone at the outcrop on the Cass river, but not in any commercial quantity.

[1]Lane, Alfred C. Geol. Surv. Mich., VII, Part II, p. 221.

[2]Rominger, C. Loc. cit., p. 104.

Mineral Waters. By mineral waters are meant such as are ordinarily bottled and sold, because of some real, or fancied, medicinal or remidial properties possessed by them, due to the presence of certain soluble mineral salts. The only well in the county known to the writer, from which water has been shipped commercially, is a deep well near the railroad crossing at Vassar, put down by L. H. Gage, it was reported, to a depth of over 600 feet.

This well was flowing a 2-inch stream of brackish water, when visited, the water escaping into an artificial pond.

The statement was made to the writer that small shipments to several cities had been made for a short time, soon after the well was completed, but no details could be obtained. At the present time, when so much water from various sources is bottled and shipped long distances, for table use in cities, it would seem as if that from some of the flowing wells in the vicinity of Unionville could be used for this purpose, as there is no water in Michigan more free from all objectionable features than that from the wells from the sandstone in Columbia township; it is very low in all mineral matters, is free from contamination, and is without odor or taste. There is enough of this kind of water runs to waste daily in the township mentioned, to supply a good sized city with all the water which would be used for domestic purposes, and it would seem as if some of it could be shipped to the nearby cities, either bottled or in tank cars, and sold for enough to make the transaction profitable.

Salt. As has been pointed out in the section of this report dealing with water supplies, a considerable area of the western part of the county is underlaid by rocks which yield only salt waters. From a few wells which have been put down to greater depths than the usual farm wells, or prospect holes, it has been learned that the deeper strata have stronger brines than the upper coal measures. At Reese, for example, a very strong brine was obtained from a coarse, white sandstone, possibly the Upper Marshall or Napoleon sandstone, at about 500 feet. At Caro, also, salt water was found in the deeper wells, so it is apparent that salt-bearing strata are present at moderate depths, but, because of the absence of cheap fuel, the salt industry seems never to have been established at any place in Tuscola county, and is not likely to be undertaken under existing conditions.

Marl. Marl is a white, or grayish clay-like substance, often faintly yellow, when wet, which occurs in parts of Michigan in extensive deposits in lakes and swamps, and which has been somewhat generally used as a source of lime in the manufacture of Portland cement. When pure and dry it consists of about 90% of Calcium carbonate, a small amount of other mineral salts, and a variable quantity of organic matter, due generally to the presence of partly decayed vegetation.

Marl is always found in wet places, usually in lakes or ponds, or in basins formerly filled with water, and now filled by the marl itself. Generally, but not invariably, these basins are of considerable depth, so that marl deposits may be 30, or more, feet deep, but it is not uncommon to find marl in shallow depressions in which it is but a foot, or even less in thickness. While this material is frequently called "shell marl," in the greater number of instances, shells have very little to do with its formation. Its accumulation is very largely due to the growth of Chara, plants closely related to the Algae, which secrete the lime from the water in which it is dissolved, and, concentrating it in their cells, the solution in the cell sap soon becomes so strong that there is a slow passage of the salt through the cell walls to the outside, where it crystallizes in the form of the carbonate, which is insoluble in the water, hence the plants become incrusted with a coating of mineral matter, and, when they die, the mineral matter accumulates at the bottom of the water. Succeeding generations of plants continue the process, and, in time, the quantity of the marl becomes sufficient to fill the basin. A somewhat detailed account of the development of marl beds may be found in Vol. VIII of the Reports of this Survey[1], to which the reader is referred.

Besides its use for cement manufacture, marl has been used for making quick lime, and, with considerable success, as a fertilizer for soils deficient in lime, such as sandy or sandy loams, or those with an excess of organic matter, especially peaty areas, which are greatly benefited by the addition of the marl. The marl has practically the composition of air-slaked lime, and has the added advantage of generally containing a small amount of phosphorus, probably as calcium phosphate. Added to sour or acid soils, such as peat often is, it neutralizes the acid and by its action on the combined nitrogen which is present, renders it available for crop plants. The marl is especially valuable, since it occurs very often in intimate association with the very soils on which it may be used most profitably; that is, the peat or muck beds quite generally are built up above marl deposits.

In Tuscola county no marl beds of sufficient size to be utilized for the manufacture of Portland cement were located. The area of beds of marl which can safely be used as the basis of a Portland cement plant, is somewhat dependent upon the depth of the deposit, but it is generally agreed among those familiar with the promotion of such enterprises, that the least area that can be considered is one which will give an estimated life to the plant, operated at full capacity, of at least 50 years, and presumably of 100 years. To insure this, the extent of good marl-yielding land should not be less than 250 acres, and, if the deposit is shallow, it must be much larger. To warrant the large investment of capital necessary for the equipment of a cement plant, a good and easily accessible market must be provided, which, in turn, means first rate transportation facilities and other economic considerations which needs no discussion here.

The marl deposits of Tuscola county, so far as known, all lie on the east and southeast side of the county. In the vicinity of Cass City, in Novesta township, near the county line, are shallow beds of marl, some of which have an area of 60 to 80 acres. These were not visited by the writer, although similar beds just east, in Sanilac county were examined. The conditions are such that similar shallow beds of marl may occur in the swampy areas throughout eastern Novesta and Kingston townships, underlying the muck or peat which covers some good-sized areas in these townships.

At least two of the small lakes of the county have marl deposits in and around them, Shay's lake and Cat lake, but beyond the fact that in both of these the marl is present and over 6 feet deep, where tested, little is known, as at neither of the lakes was it possible to make any extended examination, even if the small size of the deposits and their inaccessibility had not rendered this unnecessary. These deposits might be utilized by their owners as a source of lime for fertilizing their land, but it is doubtful if even for this use it would pay to dig the wet marl under existing circumstances and draw it on to the land.

It is evident, therefore, that the known marl beds of Tuscola county have little economic value at the present time, being too small, and too inaccessible for possible utilization, under existing conditions.

[1]Marl, (Bog lime) Geol. Surv. Mich., VIII, Part III, Chap. V.

Peat. Another type of swamp-formed deposits, which, under certain conditions if of economic importance, is peat. As has been pointed out in the chapter on soils, (page 111), this substance is partly decomposed and disintegrated vegetable matter, which has been preserved by thorough and continued saturation with water, therefore it is found always in wet places, and is most abundant where water either stands permanently above, or at the surface.

Peat differs from muck chiefly in the greater amount of mineral matter which the latter contains, but in ordinary usage no distinction whatever is made, and by the entire farming population, peat is quite generally called "muck."

Peat deposits may be divided, for convenience, into two classes, according to the form of the land surface upon which they are found, built-up deposits and filled depressions. The former usually are found on fiat lands or very slight hollows, with clayey, poorly-drained soil, while the latter occur around lakes, or in regions where the land surface has numerous depressions without definite outlets, in which lakes and ponds form. In these, the remains of water plants accumulate below the surface of the water and gradually raise the level of the bottom, while at the same time plants extend out from the shore, forming a turf, or floating mat with their roots and underground stems, and hasten the filling begun by the water plants. The history of the development of peat deposits in Michigan, the kinds of plants which form peat and the relations of the important peat-forming plants to depth of water and other factors of environment, will be found in a recent report[1] of this Survey.

In brief, it may be said that peat formation in ponds and lakes starts whenever vegetation of any sort becomes sufficient in quantity to form a definite deposit. The deepest water in which the seed-plants having roots and attaching themselves to the bottom will grow, is rarely over 15 to 25 feet, depending apparently, however, on the clearness of the water. But very few plants of any sort grow at the maximum depth, and, these, except their flowers, are submerged. The plants which grow in shallow water from 10 feet up to about five feet in depth, in some cases have floating leaves, but none grow with leaves or stems out of the water. The plants growing between these depths are chiefly pond-weeds (*Potamogeton spp*.) the water lilies, and a few other types, some of which, like the bladderworts, have no roots, and float about near the surface of the water.

Where the water is about five feet deep, and from this depth shoreward a larger number of plants, both in kinds and in numbers of individuals, is found, where the conditions are favorable, and among them are several types which have their stems, or leaves, or both, growing above the surface of the water; while in the moist soil of the shore and the very shallow water of the margin, a relatively large flora is found, some members of which push out long, underground stems and form a dense mat, as already noted above.

Because the depth of water decreases wherever any of these plants establish themselves since their remains constantly accumulate where they grow, the shoreward types move out to them and crowd the former occupants into the deeper water again, and, after a time, the duration of which depends on many factors, the filling is completed. Nearly all of the seed-plants, growing in the water and in damp soil, multiply by sending out long, underground stems and branches, from which buds and leaf-bearing branches arise. As a result, the few kinds of plants present in a body of water are represented by great numbers of individuals, these, because they are largely limited in the area they will occupy, by the depth of water in which they can grow, arrange themselves in bands or zones around the deeper part of the lake, each zone being marked by some characteristic group of plants. Because of this, in cutting vertically through peat formed in such a basin, the remains of a variety of these zones will be passed through, as each one has in its turn helped to build up the deposit. In ordinary lakes in Michigan, the zones found in passing from water of the greatest depth at which plants will grow, to the shore, have as the dominant plants, (1) Pondweeds, (2) Water-lilies, both yellow and white, (3) Bulrushes, (4) Sedges, chiefly *Carex filiformis*, although any, or all, of a number of species may be found, most of which form a turf and may grow on the land, or after building out from the shore, float partly submerged. Above water, the zonal arrangement is maintained and upon the turf formed by the sedges, at a short distance above water level, certain shrubs of the willow and heath families, together with *Sphagnum*, a moss, and, lastly, indicating that the peat has nearly reached its limits of growth upward, trees appear. It is apparent, on giving the matter consideration, that the zonal arrangement described, is primarily controlled by the depth of water in which the characterizing plants will grow most free from the competition of other types. It follows that in shallow water, or on wet, swampy soil, the whole area may be occupied by plants of a single zone, and all of the peat may be built up by such a group, if, as the surface of the peat is built upward, the water rises with it. On flat areas this not infrequently occurs, and the whole deposit may have been formed by plants of a single type, such as sedges, or shrubs, together with Sphagum and sedges.

Because there are so many possibilities as to its origin, peat may vary in structure, color, density, degree of decomposition, compactness and in other properties, not only in different deposits, but different parts of the same bog. Not only is this true, but it is invariably the case in filled, deep depressions, in which the lower parts of the deposit are made up of the disintegrated remains of water plants, while the top strata may be wholly composed of the fibrous residue of sedges and other grass-like plants, or, of these mixed with the remains of mosses and of the more woody remains of shrub and trees.

In Tuscola county, the areas where peat in considerable quantities may be looked for, lie chiefly in the eastern and southeastern parts in the townships of Novesta, Kingston, Wells, Fremont, Dayton and Koylton.

In most of the swamps in these townships, there was peat at the surface but no soundings were made to determine its depths.

It is probable that smaller and shallower deposits also exist in many of the other towns, and such were noted in Columbia township on sections 1, 2, 11, 13, 14 and 34; in Wisner, on sections 25, 35, and 36; in Gilford, over a considerable area in the great swamp in the northern and central part of the township; in Akron, in the southwestern part; in Elmwood, in the northwestern part; in Elkland, in various small areas. Very small areas were seen in other townships, but need no mention here.

[1]Davis, C. A., Peat: Its Origin, Uses and Distribution in Michigan. Rept. Mich. Bd. Geol. Surv., 1906, pp. 92-395, Lansing, Mich.

Uses of peat. Without doubt, the most important and successful use of peat in an agricultural community is a fertilizer. This use is well known in most farming regions, but in many cases, the peat is wrongly handled and not nearly as much use is made of it as its value warrants. The peat as it is dug from the bog, should never be used, as it is full of water, and on drying, it forms water-proof, tough, hard lumps, which have no more fertilizing value than stones.

Besides this, it must be remembered that the peat, when freshly dug, is generally at least nine-tenths water, so that a ton of it only yields 200 pounds of dry, organic matter, which makes the cost of hauling it far in excess of its value for any purpose. The proper procedure is to dig the peat and throw it into heaps on the surface of the bog, and let it stand for a long time, until it is thoroughly drained and disintegrated. If it is dug but in the late fall, and is allowed to lie over winter, and the next summer, it will generally be in proper condition for use in the fall, when it may be drawn out and spread over the land.

A much better use for peat obtained in this way is to spread it in the barnyard and in the stables, where it acts as an absorbent and deodorizer and saves the liquid and easily decomposed parts of the manure. It is a well-known fact that ordinary barnyard manure, which is allowed to lie exposed to the weather for a relatively short time, loses through leaching, fermentation and the formation of ammonia which passes into the air, from 50 to 75% of its nitrogen and other most valuable constituents. Dry peat, properly disintegrated, or powdered, is a greedy absorbent of both liquids and gases, and, also, to a considerable extent, an antiseptic as well. It may, therefore, be used most advantageously to compost with stable manure, and by this treatment a load of peat becomes quite as valuable as a load of manure, while the manure with which it is composted loses nothing in value compared with that treated in the ordinary way. By composting, a considerable part of the two to three per cent of combined nitrogen of the peat is also made available for immediate use by the plants.

The coarser forms of peat, those with much moss and grass-like leaves and stems, makes excellent bedding for stock and horses, and is much superior to straw, or other material in common use, in springiness and absorbing power and taking up several times as much water; it also has a deodorizing and disinfecting power entirely unknown in ordinary bedding material, so that after it has been several times saturated with urine, and dried, no odor can be detected. This should commend this material for use in dairy barns where odors and disease germs are exceedingly detrimental to the quality of the milk produced; its use in stables in cities and towns should tend to reduce their many disagreeable features.

This material may be gathered by raking the top layers of the peat into windrows, and "making" it as of it were hay, or, after the bog is drained, and the surface cleared of stumps and bushes, it may be plowed up and harrowed before gathering. It may best be transported in bales, compressed in an ordinary hay press and covered with sacking. If put on the market, the coarse and fine material may be separated by some form of screening machine, of which several patterns of foreign make, and at least one of American design, are on the market. It may be said in passing, that thousands of tons of the unsorted, coarse peat, under the name of "sanitary moss liteer" have been imported into this country from Europe, and used in the large cities. The Sphagnum moss itself has considerable use for packing plants and nursery stock and is on€ of the most valuable materials for this purpose, because of its ability to hold moisture. Large quantities of the baled material are sold annually by the wholesale dealers in nurserymen's and florist's supplies, but none is produced for the market in Michigan. There are but few places in Tuscola county where the proper kind of peat moss for this use is known to occur.

Cultivation of peaty soils. In reclaiming swamps it is not infrequently found that, after a crop or two has been raised upon cleared peat land the soil ceases to be productive, except for grass, or, more often, for no cultivated crop, and is allowed to return to the wild condition. Such difficulties may be due to several causes, but among the important ones are the undecomposed condition of the surface material, over draining, excessive drying out in the summer, acidity, and lack of certain essential mineral matters in available form.

The first of these can only be remedied by allowing the area to lie fallow, or by seeding it to grass and waiting. It has been reported that the use of barnyard manure hastens the process of rendering the coarse, fibrous material compact and tillable. The practice of burning, so often resorted to in clearing such land, is exceedingly wasteful of valuable material, and should not be resorted to, except at times when only the very top is dry enough to burn, if ever.

In spite of the generally wet character of peat, it is the most difficult type of soil known for plants to get water from, because it is held in the remains of plant structures of which the peat is composed, and the peat may contain enough water to make it feel moist to the touch and yet have none whatever for the roots of plants. This dry condition may be brought about by lowering the water level too much, or by general drought. It is probably safe in planning the drainage of this type of soil to make the ditches no deeper than is absolutely necessary for cultivating and then deepen them as the surface material compacts and lowers; but, at the same time, the drainage always should be efficient and thorough.

In many cases, the poor results obtained by cultivation of peaty soils, seems to be due to acidity, and this may be corrected in part at least, by the use of air-slaked lime, or, if it is easily obtained, of marl, which should be allowed to dry out before spreading it on the land, the best method of handling it being to allow it to dry as nearly as possible where dug, to save the cost of moving the water which makes up a large part of the freshly-dug marl. The application of the lime, or marl, adds mineral matter to the soil as well as renders the injurious organic acids inert. The marl may sometimes be mixed with the peat by subsoil plowing where the peat is shallow.

Such soils are often greatly improved by the addition of potash in some form, probably the muriate (chlorid) or sulphate, in the proportion of 25 to 50 pounds to the acre. Such application is also excellent for unproductive, black sandy soils.

In dealing with questions of this sort, however, each has to be dealt with individually, after thoroughly studying the actual conditions presented by the particular area to be worked, and only in a general way, may the suggestions made above be relied upon to modify the state of unproductive areas.

Peat Fuel. An important use of peat in European countries is for fuel; there, from time immemorial, air-dried, cut peat has been used for all ordinary domestic fuel. Of late years many improvements have been made abroad in the preparation of fuel from peat and it is now used successfully in various manufacturing establishments in Germany, Sweden and Russia, as a substitute for coal, for generating power. In this country, within the past few years, the interest in the possibilities of the great deposits of peat known to exist, has increased, and a considerable number of plants have been established for the manufacture of peat fuel but, with few exceptions, these have not continued in operation long enough to enable consumers to get used to their product. The exceptions mentioned easily dispose of their entire output at satisfactory prices.

There are several ways in which peat is prepared for fuel, to render it transportable, compact and efficient:

(1) *Cut peat* is the material as it is cut out from the bog, with a peculiar long, narrow spade, with a sharp projection on one side of it, and at right angles to, the point; this tool is called a "slayne" or "slane," and cuts the peat into long blocks, or sods, which after being partly dried, on the surface of the bog, are stacked up in a convenient place for complete drying. In this form, peat is very bulky compared with coal, and has but little higher fuel value than wood.

(2) *Machine, or compacted peat*, is dug from the bog, ground wet in a machine, something like a pug-mill of a brick or tile machine, which breaks up the fibers and thoroughly mixes the coarse and the fine parts together, and then forced out from the machine in a long cylinder, or prism, when it may be cut into bricks of any desired length. These are dried by exposure to the air, as are ordinary bricks, and are much tougher and more compact than the cut peat, as well as better fuel, approaching soft coal in fuel value, and costing about $1.00 per ton to produce.

(3) *Briquetted, or compressed peat*, is made by drying the raw peat thoroughly, after it has been disintegrated, and then compressing it in a briquetting

machine under enormous pressure, developed by steam. This product requires a very expensive plant, costs more to produce, and the briquettes do not stand handling well, unless some binding material is used to keep the particles together. On the other hand, the peat briquettes are of desirably uniform size and shape, and are clean and very efficient fuel, equalling anthracite coal in fuel value; peat briquettes have never been put on the market in this country, up to the present writing, except as the result of experimental runs, in small lots, which have been eagerly bought as offered.

(4) Dust Peat. As the result of the development of a special form of peat gathering machine, invented in Canada, by which air-dry peat, in the form of powder, is picked up by an exhaust fan, from the surface of a bog, after it has been lightly, harrowed, an abundance of material is obtained, which after grinding still finer, may be burned under a boiler in a jet burner, much as gas is burned. In this form peat has proven a very cheap and highly efficient fuel.

(5) Peat Coke. Peat, like wood and coal, when heated away from the air, yields gas in quantities, tar-water, and tar, and the greater part of the carbon is left behind as charcoal, or coke. The coke obtained from peat, is firm, as hard as good hardwood charcoal, of a lustrous, grayish black color, and possesses all the desirable properties of wood charcoal. In the most practical and commercially successful process for making peat coke, the peat is first formed into bricks and thoroughly air-dried; it is then heated in closed iron retorts, the incondensible, inflammable gases being conducted by pipes to the heating furnaces and there burned to keep up the process, while the others are condensed and separated into various important commercial products, like wood alcohol, acetate of lime, Ammonium sulphate, certain illuminating and lubricating oils and tar. The peat coke is successfully made in Germany and Russia, where it commands a high price for use in smelting iron and copper ores, being used instead of charcoal. It has not been made in America.

(6) Peat Gas. As already noted above, when peat is heated away from the air, it gives off inflammable gases in abundance, yielding a much larger proportion than coal. These gases may be used for fuel or for illuminating purposes, and, among other suggestions which come to us from abroad, regarding the utilization of peat deposits, is one that gas plants be established upon them, and the gas piped to the nearest towns to be used there for lighting, heating and the generating of power.

Peat gas is very efficient in the producer gas engine; in this type, the gas is used as made, is converted into power by explosion in the cylinders of the engine, the entire body of the fuel being converted into gas, instead of but part of it, as in the case of production of illuminating gas from coal. This sort of engine is quite rapidly displacing the steam engine in large plants, and needs but comparatively slight improvements to be more generally used in smaller sizes, and may at any time displace the older, less efficient kinds, just as the gasolene engine is even now displacing the steam engine and the windmill. When easily handled, producer gas engines of small horsepower, capable of using peat and other easily obtained fuels, are placed on the market at a moderate price, one of the problems of farm labor will be fully solved.

Peat has numerous other more or less important uses, already established or projected, among which may be mentioned its manufacture into various fabrics, such as rugs, blankets, various kinds of cloth, mattresses, antiseptic dressing for wounds, felt, a kind of flooring material, artificial wood and paving blocks.

It is also manufactured into paper, and a large factory, the only one in the world, has been in successful operation in St. Clair county for the past two years. The kind of peat required for these uses is that which is very fibrous, found in quantity in but few places.

It is apparent from this brief resume, that peat has many and important uses, and, at no very distant day, as other natural resources are exhausted, or diminished in quantity, that important industries will be based upon peat.

Water Power. With but a single stream, having a limited drainage area, the possibilities for the development of water power are not great. Cass river, however, has quite a good fall between Cass City and Vassar, and, at Caro and Vassar, small dams have for years furnished a limited amount of power for grist and other mills. A larger dam, built below Caro, capable of ponding a considerable amount of water, to be used to furnish electric power for various uses at Caro, failed, because of faulty construction, but there is no reason why a series of dams from above Caro to the county line should not be constructed with a good expectation of success, since the rainfall over a large part of the drainage basin finds its way into the ground, and a considerable proportion of this later appears in the river from the tributary streams and the springs along its banks. The damage from flowage would not be large, since the present course of the Cass is through a sandy, largely uncultivated region, which is of small agricultural value, present or potential. At present, it hardly seems likely that such a development of power along this river will be undertaken, because of the initial cost of constructing the dams.

CHAPTER VII. UNDERGROUND AND ARTESIAN WATER SUPPLY.

Importance of this matter. Water is the paramount necessity of man's physical organism, constituting a large proportion of the weight and bulk of the human body, as well as that of the plants and animals, forming as it does, not only a large part of all circulating fluids, but also, of most of the organs. The need of water is, therefore, ever present, and affects profoundly all forms of life upon the earth.

Civilized man in particular, having created artificial conditions of environment, has to make special provision for supplying this essential fluid at all times and in all places wherever he carries on his activities, and has had to do so from prehistoric times, whenever he has emerged from the hunting stage of savagery.

Primitive man, that is, man in that state in which he had no fixed home and was living in an environment upon which he himself had made no changes, made his temporary camp by the side of some clear spring, or stream, wherever he found water convenient to his sources of food supply, and, if this failed, a new temporary home and water supply were soon located in a more favorable place. Such people had no interest in the ultimate sources or the possibilities of contamination of the water which they used, or even knew that it could be made injurious.

In arid regions of the earth, however, wells came into use very early, especially among people who tended herds of animals, where both springs and streams were infrequent and often ran dry. It was a most natural thing for the herdsman, when he had found a pool dry, where he had expected to water his flock, to dig in the bottom of it, in hopes that some of the coveted fluid might have soaked into the ground, and, it was soon discovered that water often could be found in the ground, even if there was none at the surface.

From such a discovery, to the establishment of permanent wells seems but a step, but it is probable that the time interval between the two was long; of this nothing is known, since the people of the dry regions of the old world, and also of the moister parts, have made wells from prehistoric times, and some of those of Palestine have been continuously used since early biblical times, if not from still more remote antiquity.

Origin of ground water. The ultimate source of the water stored up in the ground, is the ocean. From this great revervoir, the water, in the form of vapor, is lifted into the air by the sun's heat, transported by the winds, it may be for long distances, and finally falls to the earth as visible water in the form of fog, rain, snow or hail. The air also, gets considerable moisture from lakes and streams, as well as from the land surfaces over which it passes, especially when it is lightly charged with watery vapor; drying winds are well-known summer phenomena, and may occur at any season.

The annual precipitation, rain and snow fall, in the part of Michigan here considered, averages slightly more than 30 inches. Of this amount, a part is evaporated from soil and plants, a part runs off on the surface, and the rest soaks into the ground, where it finally may become part of the ground water. Even here, however, it seldom is at rest, but moves about under the influence of gravity and capillarity, sometimes finding its way through cracks and other well-defined subterranean channels; more often, through the pore-spaces of the rock, so that there is a constant tendency for the ground-water level, that is, the surface of the zone in which liquid water will flow into any depression made in it, to become lower.

As is stated in the discussion of soils (p. 172), water moves with comparative rapidity through gravel, sand and sandstone, and very slowly in clays and fine-grained rocks, like shales. Of the approximately 30 inches of rain which falls on the surface each year, probably the average amount which finds its way to the ground water, under ordinary agricultural conditions is less than one-third, or 10 inches. This amount is considerably increased where the land is not cleared or plowed and, in such places the ground water level is generally nearer the surface than in a cultivated region of similar character, because the proportion of run-off to absorbed water is less in the former than the latter. In the cultivated districts, practically the entire precipitation of the winter is lost to the soil, since it cannot penetrate the frozen upper zone, and also, because it finds ready channels through which to run away, while under forest conditions, the melting of the snow takes place gradually, and the surface of the ground, covered by leaves, being very absorbent and only lightly frozen, takes in the water before it can get .away over the surface.

In like manner, during the rest of the year, cultivated lands take in less of the rainfall than those covered by forest, which results in permanently lowering the level of water below the surface, as that accumulated in the ground finds outlet, or is used up.

Chemically pure water is one of the rarest compounds in nature, if it ever occurs, under natural conditions, because water is perhaps our nearest approach to a universal solvent. Rain water as it falls to the ground, absorbs certain gases and washes various forms of dust from the air; as it enters the ground, it contains some of the gases dissolved in its passage through the air, among which are carbon dioxid, minute quantities of ammonia, and oxygen.

In passing through the upper layers of the soil, it gathers certain acid organic compounds and more gases, and, with these to assist, it attacks some of the mineral constituents of the soil particles and dissolves them. This process of solution continues as the water slowly finds its way downward, until, in regions where the rocks and soils contain much easily dissolved mineral matter, the waters of the lower strata may become so strongly mineralized as to be unfit for domestic and manufacturing uses.

Compounds of sodium, calcium, magnesium, iron, aluminum and silicon are among those which are of most frequent occurrence and most easy solubility in the rocks and soils of eastern Michigan, sodium chloride or common salt, and sodium sulphate are sodium compounds which occur in the rock waters of the region, the former so abundantly as to cause serious difficulty in getting fresh water in a large area of the western part of the county, where the people are dependent on the underlying sandstones for water for farm use.

Calcium carbonate, or carbonate of lime, and calcium sulphate, or gypsum, are the calcium salts which are abundant in the superficial deposits and compose extensive beds in the underlying rocks. It is these minerals in solution which make the water from the glacial clays, from certain shales and from limestones "hard" and which also form the greater part of the boiler and tea-kettle "scales" which are universally present where hard water is used.

Magnesium compounds are not as well known, and are less easily detected than the others mentioned, but occur in some districts, especially where the water is obtained from shales, giving a slightly bitter taste to the water, which can be detected by those unaccustomed to its use. These compounds are rated as distinctly beneficial by writers on the medicinal value of mineral waters.

Iron, in the form of the acid carbonate, and, more rarely, as the sulphate, is quite generally dissolved in the rock and soil waters and may be detected by the reddish, or rusty, color which it gives to tea-kettle scale and by the blackish tint, which, when freshly drawn, it imparts to strong tea. Iron sulphate gives a puckery taste to the water in which it occurs; it is quite often found in Tuscola county in the water which comes from the coal measures, or from coal seams, from which it is probably derived by the oxidation of iron pyrites, the "sulphur" of the miners.

Aluminum and silicon compounds are inert substances and where present give neither taste nor odor to the water. They may appear as white, tasteless, insoluble powder in the residue left by the evaporation of water in which other salts are absent. Compounds of both of these elements are exceedingly abundant in the rocks and soils of all types and hence are found in the ground waters coming from them.

Of the gaseous compounds which are dissolved in the ground water, that already mentioned, carbon dioxid, or carbonic acid gas, is present in considerable quantities in water from many different levels from the surface downward; this gas, however, is odorless and tasteless, being the familiar gas which gives the sparkle to "soda" water and similar beverages, and, in the natural waters of this region is seldom present in sufficient amount to give any visible bubbles in the water. Its presence is indicated when water becomes clouded after standing; the cloudiness is produced by the escape of the gas from calcium and iron acid carbonates, which thus become visible in the water, being changed to the less soluble normal salts.

A much more troublesome and disagreeable gas is hydrogen sulphide, which is sometimes present in the water of deep wells, to which it gives the characteristic odor of spoiled eggs, the "sulphur" odor. Water containing small quantities of this gas can be used for ordinary domestic purposes, but, if it is at all abundant, it is usually available only for sulphur baths and medicinal uses. Generally, in Tuscola county, only very deep wells from certain shales yield strong sulphur water, but occasionally shallower ones, which reach, or penetrate, coal seams, have water with an odor and taste of the gas, which makes it distasteful to those unaccustomed to its use.

Marsh gas, derived from partly decomposed plant remains, sometimes is present in the water of wells in the drift, and may be readily identified by its lack of odor, and its inflammability. In other localities of the State, this gas is occasionally found in pockets of sufficient size to furnish a considerable quantity of fuel, but no record was obtained of the finding in the county of sufficient of this or any other inflammable gas to burn at the mouth of a well.

It is evident, then, that but few mineral substances are found in the waters of the region under consideration, in amounts large enough to affect the value of the water for ordinary uses. Of these few, salt is by far the most generally distributed and the most detrimental since it takes such a relatively small amount to render the water unfit for use, as even a slightly brackish taste in water used for drinking, makes it unpalatable to many people.

Calcium compounds, while they make the water containing them disagreeable to use for washing and some other domestic purposes, do not seriously affect its taste nor make it particulary unwholesome; the same may be said of the other mineral compounds mentioned.

The presence of organic life in well waters practically invariably implies direct connection by fissures or openings of some sort between the surface of the ground and the water of the well, unless the well itself is very shallow, and in poor repair. This topic will be more fully discussed under another heading, (p. 52.)

As already indicated above, some of the rock-forming minerals are more susceptible to the solvent action of water than others, and therefore, the rocks of which they are parts are similarly variable. It follows that the water from different types of rocks will vary in the quantity of mineral matter which it contains, according as they have much or little soluble matter. This fact is not only of interest, but may be of practical and scientific importance in making possible accurate predictions as to the quality of water which can be obtained from the bed rock in a given region, or, on the other hand, to determine the character of the underlying rock from the kind and amount of mineral matter in the water which comes from them.

In the case of sedimentary rocks, shales, limestones, sandstones and conglomerates, the water may not only dissolve mineral matter from the constituent grains, but, also, may find soluble matter between them, either acting as a cement, or crystallizing in the pore-spaces, or, even, in the case of very soluble compounds, like common salt, in the form of concentrated solutions in the interstices.

It is apparent, therefore, that the water from limestones, or from gypsum, will be hard, that from silicious shales and sandstones will have little mineral matter, unless some soluble cementing materials, like iron or calcium compounds, are present, or, as happens in the region of Saginaw bay, brine is stored up in the rock.

These types of rocks, differing in the size of their constituent grains, act much as soils do in regard to the transmission of water; those with coarse grains transmit water freely and, below the ground water level, generally yield quantities of water; the fine-grained ones, like clays and shales are impermeable and what water they contain is transmitted very slowly, hence even below the ground water level, but little water can be expected from them and they are often entirely dry.

From sandstones, then, good supplies of water may be expected; the quantity of this water will be dependent upon the conditions under which the rock was formed, and the materials which are associated with the sand grains. From limestones, a fair supply of hard water is often obtained, or not infrequently, large supplies come from well-defined channels which have been dissolved through the rock by percolating waters. Channels of this sort are indicated when, in drilling, the drill drops suddenly.

Effects of drainage on the ground waters. Since the rainfall either soaks into the ground or runs off into the streams, and conditions favoring its rapid absorption into the ground are unfavorable to agriculture, it has become the custom to hasten the escape of water from agricultural lands as much as possible by ditches and underground drains.

This treatment, without doubt, increases the present fertility of the land, but it also decreases the amount of water which is stored up under ground to a very marked degree. A direct result of clearing the land and reducing it to a state of cultivation, is a decrease of the quantity of the ground water, both at the surface and below it, to considerable depths. Those responsible for this condition are among the first to suffer from it, somewhat as follows: The first settlers in any region of moderate fertility, easily obtain water either from natural springs or shallow wells dug near their houses. At this time, streams are numerous and usually run full all of the year.

After the forest is removed, and the soil cultivated, the abundance of water at all seasons is gradually diminished until the stream beds are dry for a larger part of the year and for the rest of the time are filled with a flood of turbid water, which rises suddenly in the spring, and after storms, and as suddenly falls on the approach of summer or fair weather. Gradually, also, the springs cease to flow, and the wells, so satisfactory at the outset, go dry, or give but a scant yield of water.

Under such conditions it is necessary to increase the depth of the wells, and draw water from a lower level than formerly, out of the supply accumulated in the ground. This naturally entails expense, and, since more and more of the rainfall is diverted from the ground by the development of elaborate superficial and subsurface drainage systems, as the country becomes more densely populated, while, at the same time the ground water is constantly being reached by new wells, it is evident that a well-settled region, which is thoroughly drained, may find that it has overdrawn its most precious asset in some dry time, when it is most needed.

Especially is this true in the flat lands of the western part of Tuscola county, where the surficial deposits are compact, clayey tills, and the bed rock, which yields potable water, is of very limited thickness and storage capacity, or is entirely filled with brine too salt to be used. The precautions to be taken to prevent the water famine which these causes threaten, are so obvious, that they scarcely need stating. Among the most important are holding back the rainfall during the fall and winter to give it time to penetrate the ground; this could be done by closing the outlets of the main ditches on each farm from the time the crops are off the land, in the fall, until spring. The construction of ditches along the contours of the land, instead of down the slopes, especially where these are marked, would enable a greater per cent of the meteoric water to find its way into the ground than at present, besides preventing the gullying which frequently damages ditches and the land adjacent to them.

Probably more important than either of these causes mentioned above, in preserving the ground water supply, is stopping in some way the foolish waste which comes from allowing flowing wells to run at all times, a stream which represents the greatest possible flow of each well, regardless of the needs of the owner.

No natural resource is truly inexhaustible, and none can be willfully or carelessly wasted to such an extent as is the stored-up water, without the consequences, sooner or later, becoming serious, and the longer the present wasteful methods continue, the more severe the penalties will be.

The sources of water supply are, then, rainfall, snowfall, the water running off on the surface in the form of streams, and that stored in the ground, either in the unconsolidated glacial deposits, or in the underlying hard rocks, of which the sandstones are the most capable of storing and transmitting large quantities of water. If the unconsolidated deposits are clayey, the amount of water which they will hold is large, but they transmit it very slowly and yield small quantities of water to wells penetrating them.

Relation of Saginaw Bay to the ground water. It is a commonly expressed belief among the residents of the region adjacent to Saginaw bay, that there is some direct connection between the water of the bay and the ground water. It may be said regarding this notion, that no such connection is known to exist between Saginaw bay or Lake Huron, with the underlying formations, and none is possible, except such as exists from the precolation of water into the strata forming the bottom of the bay, where these are porous enough to take it in. It is unnecessary to call attention to the facts, that the surface of the land everywhere is entirely above the level of the bay, and a few miles back from the shore, rises to such a height that this level would be practically out of the reach of ordinary pumps. The beds of the rock formations which lie deep below the clayey bottom of the water, not only do not extend eastward within the shore line but they dip at a considerable angle towards the bay, thus presenting unfavorable conditions for furnishing the supposed supply. Still more convincing than other evidence is the saltness of the rock water in the districts near the Bay, for, even if the salt in these brines were dissolved, from the rock, as the water is passing through it, as it moved from the Bay, it is manifest that it could not be salt here and fresh at a greater distance from the supposed fountain head.

It is apparent then, that the water supply on which the people of this region must depend, is that which comes from a rather limited depth of compact glacial till; from a less depth of sandy deposits; and from the bed rock, some of which contains large quantities of pure water, while other portions of it, and all below a varying depth, have only salt waters.

Part of the county especially affected by a limited water supply. A considerable part of that portion of the county, embracing the western tier of townships and, in some places, more, is underlain by brine-bearing rock, above which is a thick stratum of compact till. Here the question of water supply is a serious one, and, as this district becomes more thickly settled, will eventually call for the development of some artificial system of distributing water, probably from Saginaw bay. The saving of some of the abundant rain water in large cisterns, or the use of stills to give sufficient pure water for cooking and other domestic uses will doubtless make it possible to continue the development of the district for a long time to come; and, in many cases, the brackish or salty water is used even for drinking after the people become accustomed to it.

Springs. Before the first forest was cleared away, springs must have been numerous in sandier parts of the county, and, even at the present time, they are common, especially in the valley of the Cass, and along the Grassmere beach and some of the lesser beach ridges of Lake Algonquin.

In the Cass river valley, and those of its tributaries, springs appear wherever the streams cut through the sandy or gravelly surface deposits into the clayey till beneath. The water penetrates the porous material to the clay, and runs along on its surface until an outlet is found, generally in some stream valley, as indicated above.

Along the western side of the Forest beach, is a line of strong springs, in which the water has some "head," rising a foot or more above the ground surface at the foot of the ridge when confined in a box or barrel. Here, a somewhat unusual condition exists which merits description. The beach is a broad and rather high ridge of coarse, sandy gravel, renting on a substratum of compact, clayey till, or in places, nearly pure clay, with its surface sloping gently to the west. Near the foot of this slope originally was another low ridge of fine silt or clay; this may have been formed along the line where the fine material dragged back from the upper part of the beach by the undertow from breaking waves, was deposited in the slack water where the undertow met the incoming waves. The secondary ridge may also be a faint beach formed as the lake water made a temporary shore line, during its subsidence to the next lower, more permanent level. At present, it is buried by the accumulated peaty deposits formed by the vegetation whose growth was favored by numerous springs, whose outflowing waters it slightly ponded. The main ridge acts as the catchment or absorbing area, and the water penetrating to the clay below, spreads out upon it, and runs out along the line of union of the gravel and clay, or a little above it. The swamp deposit, spreading up the slope, forms a capping stratum, which, if cut through, will sometimes give a supply of water which will rise in its casing. Springs along this beach are sometimes powerful and yield a large supply of excellent water. In some cases, the waste from them has been used to fill small fish ponds, and others might well be so utilized. The head of several of these springs was sufficient also to run a hydraulic ram for pumping water to farm buildings, but none were so utilized when visited.

In the lower sandy beach ridges, the slope on the water side is not usually noticeable and the water which is absorbed by the sand simply runs off below the turf along both sides of the ridge, but usually where-ever a box or barrel is sunk in the ground, at or near the foot of the ridge, water bubbles up into it, and wells dug through the sand into the clay, are found to be very permanently supplied with water.

In the southeastern parts of the county, along the northern face of the Mayville moraine, where gravelly glacial deposits overlie clayey ones, numerous springs are also found, the gravel absorbing the rainfall and the water reappears in favorable places as springs, at the line of union of the two.

Types of Wells. In most rural communities, in a recently settled region there is a considerable variety in the kinds of wells in use, the type prevailing in a given locality, depending upon the availability and accessibility of the underground water, the wealth and progressiveness of the owners and other factors which need not be discussed here. In general, it may be said, that there are two distinct classes, the dug, or surface, and the tubular, or deep wells.

The first type consists of an open, usually circular hole in the ground, dug to, or slightly below the usual ground water level, or to some water-bearing stratum or "vein," from which the water flows more freely than from the more compact layers. Gravel, or coarse, sandy strata, if not too deep, are most satisfactory, as they fill up from the surrounding finer soils, and freely transmit the water to the well as this is drawn upon. The areas of Tuscola county where dug wells are most prevalent are described in another place, (p. 58.)

Relation of dug wells to the health of their owners. At the present time dug wells, even for farm use, are not looked upon with much favor by students of water supply problems, because of danger of contamination from the surface, either through injurious matter washing or blowing into the mouth of the well, or through its finding its way through cracks in the ground into the basin. It is now generally known that the chief sources of danger, if not the only ones, which seriously affect the healthfulness of water supplies are microscopic organisms, both plant and animal, the former most frequently, and which are known as "disease-producing germs."

These organisms do not usually affect the transparency, color, odor or taste of the water, and their presence in a given well, is usually first known by the appearance of the disease which they cause among the users of the water. Typhoid fever and a number of other diseases are frequently caused by the contamination of surface wells by seepage through the soil from sink drains, cess pools or vaults, by refuse and slops which have been thrown on to the surface, or by the same matter in the form of dust, being blown or washed into them.

Wells dug through clayey soils are more liable to infection than those in sand, because the clay is more liable to cracking in drought, and flooding during heavy rainfall, while the sand acts as a filter, and, if deep enough, and unless very coarse, is a satisfactory one. Dug wells of less than 20 feet in depth are probably never quite safe, although they may never become infected, even in a populous community.

Types of wall for dug wells. It is certain that the kind of wall used to prevent the sides of the basin from caving in, may materially aid in preventing contamination, and users of this type of well should see to it that the upper part of the wall, at least, is water tight. The poorest and least safe material for the purpose is planking or timber of any sort, for this is a comparatively brief time, rots, and not only allows the water from the surface to flow directly into the well, but furnishes a medium in which bacteria, or disease producing germs, may persist for a long time, ready to infect the well-water whenever a piece of the wood shall drop into the well.

Stone walls, built up of uncemented, irregular stones, with considerable crevices between them, are little better, since surface water can always find its way through the crevices to the basin. Brick walls, laid in mortar, or better, cement, are much better than the other two mentioned, if no cracks develop on account of settling.

Cement wells, made by sinking a large, thick tube of Portland cement, as the hole is dug, are most satisfactory from the sanitary point of view, and can be constructed cheaply and quickly by a skilled man; such wells are free from cracks and are strong and durable, when properly built, and are easily kept clean.

Wells walled up with glazed sewer tile of large diameter are of similar value, if the joints between the tiles are carefully cemented, and the tiles do not crack. In constructing any of these types, the masonry should be carried enough above the surface so that the soil can be graded up around the mouth sufficiently to give a good slope away on all sides of the well; a tight, double cover and platform should be built over the mouth, and provision made to carry off all waste water to some distance from the mouth of the well before allowing it to enter the ground.

Koch's Well. This name has been given to a type of shallow well reported to have been suggested by the German physician and bacteriologist, Koch, famous for his discoveries in regard to tuberculosis and other communicable diseases. The well is dug to the water bearing stratum and may, or may not, be stoned or walled up, as in ordinary construction. A good-sized basin is dug at the bottom and a 2 inch or larger, galvanized iron pipe, sufficiently long to reach above the surface and having a strainer at the lower end, is placed in the center, in an upright position; after this several loads of clean, coarse gravel, from which the sand has been screened are placed around it, forming the collecting basin of the well. Above this finer gravel to the depth of several feet, should be packed, and, on top of this, fine, clean sand to near the top, which should have a capping of compact gravel, or even clay. Such a well is not liable to any sort of contamination from the surface, and the coarse gravel at the bottom insures the collection of a good supply of water from the water-bearing area around it. An ordinary, open dug well, after thorough cleaning, could be converted into this type at small expense, although if it is known that there is a good water-bearing stratum at the bottom of the dug well, it would undoubtedly be cheaper and more effective to drive the pipe to the water gravel in the vicinity of the old well. The Koch well would be the kind to use where the water-bearing strata are small, and the earth below the ground-water level clayey, since a considerable depth of gravel could be put in and the water allowed to collect in it from the surrounding fine-grained strata, which would not yield water rapidly enough with an ordinary tubular well, to supply a pump.

Tubular Wells. These differ from the open, dug basin type in having small diameter, practically always less than one foot, and in being completely closed from the top to the water-bearing stratum, by a continuous water-tight tube. The pump is usually tightly screwed to the top of the tube in the smaller sizes, and, if the water comes from sand or gravel, a strainer of fine brass wire gauze is fastened to the lower end.

Bored Wells. Tubular wells may be bored, using a common auger, or better an earth auger of special construction, in which an open spiral encloses the plug of earth which it loosens and thus makes it easy to bring it to the surface. In most cases the auger is of small diameter, less than three inches, but in some clayey districts, in the state, 6 inch, 8 inch, or even larger tools are used, and the boring is done by horse, or other power. Generally, the hole is kept open by a pipe, which is pushed, or driven into the ground, as the boring progresses, but in very compact soils, wells are frequently bored to a depth of 30 feet or more, with no casing beyond a few feet. In the larger sized, bored wells, glazed tiles are used for casing, and sometimes sunk without difficulty to a depth of more than 100 feet.

The cost of bored wells is generally the least of any, since the outfit for putting them down is very inexpensive, and no particular skill or experience, and but a comparatively small amount of labor are required.

Where the soil is free from stones, and compact, bored wells are easily constructed and are satisfactory, provided that the water is not too far from the surface and in good quantity.

Driven or drive wells. In constructing this type of tubular wells, the pipe is usually provided with a sharp, perforated point, and the whole is pounded into the ground, a maul being used if the water bed is near the surface, or, if deep, a heavier power-driven tool, operated with a derrick is used. In deeper construction, and in compact soils, a sand pump is employed to remove the material from the ground, ahead of the pipe, water being turned down from time to time, to soften up and aid in taking out the earth.

In sandy or gravelly soils, where the water is not too deep, drive wells can be made at a less cost than any other type of tubular wells. In compact and stoney ground, considerable skill and experience are required to prevent bending or breaking the casing in driving. Commonly the casing is driven a short distance into the water-bearing stratum, after which a considerable amount of sand pumping is done to give a basin for the accumulation of water to compensate for the small diameter of the well.

Drilled Wells. These differ in no way from the others discussed except that a drill, generally of the gravity, or "churn" type is used to loosen up the earth ahead of the casing, through which it is lowered and operated at the end of a rope. The loosened material is removed by a sand-pump and the casing is driven, as in the other types. The drills vary in size according to the size and depth of the well to be made, from small, light affairs, operated by a spring-pole and manpower, to huge masses of steel, weighing hundreds of pounds and requiring for their operation an outfit of a steam engine, derrick and cables, which may represent a very considerable investment. The small, compact outfits in use by well drillers, and coal prospectors, in which the light derrick and steam engine for operating the drill, and handling and driving the pipe for casing, are all mounted on a strong wagon, and are becoming familiar to all who live in the region of Saginaw bay, as they are rapidly displacing the older, more cumbersome and less efficient types.

In all of the churn drills, the drill itself is lifted a few inches, or feet, and allowed to drop, being turned slightly with each stroke, and, in this way, the hole is kept round and straight. With this tool, wells may be drilled for long distances through solid rock. Various other kinds of drills for making wells in the rock are used, but to much less extent than that mentioned, which is much more common than all the others combined.

Artesian or Flowing Wells. Artesian wells are those from whose top the water flows over, or above, the ground surface. Wells of any type of construction, therefore, may be artesian, if the water flows from their mouths; because tubular wells are more common where artesian conditions exist, it is often thought that only tubular flowing wells may be called artesian.

Conditions necessary to produce flowing wells. Areas where flowing wells occur, are usually known as artesian basins. In its simplest form, a flowing well basin consists of a bowl or trough-shaped, porous water-bearing stratum, such as sand or sandstone, through which water moves freely, lying between two impermeable strata, like clay or shale. If the water level in the porous stratum rises higher than any other part of the ground surface, within the basin, the wells reaching the water layer from the depressed surface will flow, because the hydrostatic pressure forces the water up through the well, to about the same height that it stands in the underground stratum. In valleys, these simple conditions sometimes occur, and the wells in the floor of the valley will flow, while those on its sides will show only a slight rise of water from the same stratum, the amount of which depends on the nearness of the level of the bottom of the well to the "head" in this layer.

Inclined porous strata, capped by less porous ones, often yield flows of importance, especially when they are extensive, as are some sandstone formations.

Flowing wells from the drift, frequently occur in the neighborhood of moraines in small basins, especially on the ice-ward side. These are doubtless due to the fact that beds of gravel and sand which were deposited by the melting ice on the slopes of the moraines, were covered by later deposits of more compact material, which forms caps to the porous ones, and holds the water in them until it accumulates up the slope and gives head; when the sand is reached by a well near the foot of the slope, the water flows from it. The Millington moraine, across Arbela township, and the Mayville moraine in Fremont and Dayton and Wells townships, have various areas of flowing wells along the northern side, and it is probable that careful examination would much extend the area as noted below, (pages 58-9.)

Flows may also occur from a part of a saturated stratum, and not from the rest; for example, an extensive stratum of fine sand or till may have coarser beds scattered through it, and the whole be capped by till stratum. The fine sand is full of water, but does not yield it fast enough to a tubular well to cause it to flow, while the coarse beds will do so, because the water flows into them from the surrounding sand and rapidly enough to give a supply for the flow, provided the head is sufficient.

Occasionally such conditions wall occur on a gentle slope, where the "head" seems to be derived from the pressure of the column of the local ground water on the water in the water-bearing gravels. In such cases, the "head" is very slight and the flows are intermittent, depending on the rainfall, and failing almost at once on the approach of a drought.

Similar to the last, is the interesting occurrence of artesian water in buried valleys, in the rock below the glacial till. In these, the "head" comes from the rock, apparently, the water probably also gathering in the gravel filling of the valley from lateral seepage from the same source, and, because of its greater coarseness, transmits the water to the wells more rapidly than does the finer-grained rock.

Such buried valleys, as mentioned below, are well-known sources of flowing water in certain parts of the county.

For the reason that coarse strata give much larger flows than fine, because they transmit the water rapidly, a thin gravel or stoney stratum on top of the bed rock will often be the source of flowing wells, when it is perfectly evident that the "head" and water are derived from the underlying rock, and many flowing wells in the western half of the county are of this sort, reaching nearly to, but not entering the rock.

Application to Tuscola county. The general principles stated, show that the question of an adequate and wholesome supply of water, even for farm use, is not only a complicated one, but one of the greatest importance since any region is incapable of development as a farming community, where sufficient quantities of pure water cannot be obtained.

Tuscola county, as was pointed out in the opening chapters, consists of a number of quite different areas, of which the lake plain, the morainal districts, the Cass river valley and the Flint river watershed are the most important.

Sources of Water Supply in the Lake Plain. Of these, the lake plain is the one presenting the greatest variety of conditions of soil and water supply and, because of its fertility, geological structure and drainage features, is more restricted as to the sources of water supply than the other districts. The fertility of the soil is such that all or nearly all of its area has been brought under careful cultivation and its lack of well-marked slopes has caused a most extensive artificial drainage system to be developed in order that the water pouring down onto this area from the higher lands to the eastward, may be carried quickly and thoroughly away, in order that the generally heavy soils may be cultivated. While this treatment is necessary if agriculture is to be carried on, it is evident, from the discussion below and what has been said in a former paragraph, that it complicates the problems of obtaining an adequate water supply, even for farm use, in many districts, and restricts the possible sources of supply.

1. **Surface Waters**. In the early days of the settlement of the region this part of the county was covered by a heavy swamp forest, and the ground water level was near the surface; in fact, in many places, the ground was flooded during the rainy part of the year, and especially when the snow was going off in the spring. At this time water was easily obtained from dug wells. As settlement, accompanied by clearing and draining progressed, more and more of the rainfall was carried rapidly away, and as a natural result the ground-water level sank until the dug wells gave out or were deepened. In a few cases they were carried down nearly a hundred feet. Usually, however, they were deepened not by digging, but by boring, with large-sized well augers, 4 to 8 inches in diameter. This method was in use some time, but it was soon found that in many areas no permanent supply of water could be had in the clays above the bed-rock, and the next development was the driven well, reaching down nearly to the rock surface, where, a fairly satisfactory supply of water is frequently to be found. In many eases, however, conditions seem to have been unfavorable for storing such a supply, and the drilled well in the rock was the last resort. At the present time, since the region has become more thickly settled, and the system of drains has been largely developed, drilled wells reaching down considerable distances into the bed-rock are the usual type over a large part of the trict.

The surface waters, as they are termed,—i. e. those which are obtained from shallow dug wells—vary in quality according to the type of surface material, whether of clay or sand. The clay soils were originally so swampy that the water in the wells of the old dug-basin type was never looked upon with favor, and was probably justly condemned, as the conditions were all in favor of contamination from the surface, and the waters probably were frequently the cause of disease, especially when the supply was diminished by drought.

It is evident that the original swamp soil could be easily infected by disease germs, as it was damp, contained large amounts of organic matter, and was easily warmed by the sun in the summer time; that in flood times, which were frequent, the waters from cess-pools, drains and other sources of infection would be spread over the ground, and might, and often did, find their way to the wells; and that in dry times, cracks would open up in the clay, on account of shrinkage, and, through these, water from the contaminated surface, from sinks and other drains, and often from privy vaults, could find a way to the wells. Under such conditions it is not difficult to understand that the dug wells were not in favor in the clay regions. In addition to these considerations, it must be taken into account that the soil contains much finely pulverized limestone, which renders the water hard. And, as was usually the case, when the water contained considerable amounts of organic matter, iron, as well as lime, was dissolved and gave it a strong, astringent taste.

In places where there were several feet of sand, however, the water of shallow wells was more wholesome, better in quality, and more abundant, this being due to the filtering power of the sand, which removes and holds near the surface organic matter and disease germs, to its greater permeability, and to the scarcity of lime and iron salts. Cracks and fissures do not easily develop in sandy soils, and hence direct channels between the well waters and the sources of contamination are less frequent or entirely wanting. For these reasons, and because the supply of water is so much greater in the sand, dug wells are general in the sandy areas, where the sand is deep enough to afford any permanent supply. Upon sand ridges, especially, the wells are generally shallow, open basins dug through the sand to the underlying clay.

2. **Deep Drift Waters**. In general as pointed out above there is very little water in the clay between the surface and bed-rock. The clay is to fine and too compact to be porous, and on this account absorbs little water, and is too slowly permeable to yield it up readily, even when nearly saturated. The clay seems to have been laid down under water, and has very little interbedded gravel or sand, into which water can penetrate and accumulate. Where water-bearing strata are found, however, the water is healthful, but it is hard and contains much iron. Water-bearing strata in the clay are thin, limited in area, and occur at all depths, but are not generally depended on as sources of supply, in the flat lands.

A more constant source of supply, utilized over a wide area, and not infrequently yielding flows, is a porous stratum just above the bedrock. This seems often to be bowldery gravel lying on the rock surface, and is from one to several feet thick. This generally yields a good supply of water, which is frequently so like that from the rock itself that the natural inference is that the water comes from the rock and is forced from it, into the overlying gravel, by pressure. On the other hand, it not infrequently happens that the water in the rock will be brackish while that above will not taste of salt at all, in which case it seems probable that the water in the gravel is derived from above, rather than forced up from the rock. All of these water-bearing beds may be reached by dug, bored or driven wells.

3. **Rock Waters**. These are of varying character, according to the geologic formation and the type of rock from which they come. The water comes from sandstone, or rarely from shales, of the Michigan formation in the eastern and central parts of the county and from those of the Carboniferous in the western part. It should also be stated that a large part of the present supply of water for farm and house use in this district comes from bed rock.

The rock water is, in a marked degree, less hard than that from the drift, and in many cases it is so free from dissolved lime or calcium compounds as to give no trace of these by ordinary tests; in a few cases it was reported as "softer than rain water." This softness may be attributed to the absence of calcium minerals from the sandstones in which the water is moving, and also to the probable fixation of the calcium by the action of sodium or magnesium sulphates upon the more soluble calcium compounds. In many cases the purity of the water is such that the first explanation seems reasonable and probable, but in the case of salt and bitter waters, the second is quite as likely to be correct. Three well-marked districts may be distinguished by the character of the water from the rock as follows:

1. The district of fresh, soft, or relatively soft water, extending from the foot of the low, central moraine, westward to the northwest corner of Columbia township (T. 14 N., R. 8 E.), and thence diagonally south-westward nearly to Reese, whence it runs more nearly due south, finally leaving the county near the northwest corner of Arbela township (T. 10 N., R. 7 E.). This district may extend still farther eastward than the moraine, but there are few rock wells to show its limits, in this direction.

2. A belt a mile or two, rarely more, in width lying just west of the first district in which the rock water is all more or less bitter to the taste of a person not accustomed to it, and is frequently slightly brackish as well. This belt is not well-marked at the northern end, but is easily traced across the county. This bitter water is so free from lime and its compounds that it seems probable that a chemical precipitation of the calcium salts as the sulphate has occurred, and that soluble magnesium chloride has been formed, to which substance the water owes its bitter taste. In general these bitter waters show only a small amount of sulphate present, but considerable amounts of chlorine, leading to the conclusion that the bitter taste came from magnesium chloride rather than the sulphate; however, no very careful examination of the water was made to determine this point.

3. An area immediately west of the last, lying between it and the Bay, under which the rock, as pointed out above, contains brackish water or, frequently, that which is so salt that it is unfit for cooking and can be used only for watering cattle, or for drinking, after one has acquired a taste for it. The saltness of the water increases as the district is crossed from east to west. In the western part, also, the waters near the rock surface are more likely to be usable, the deeper ones much less so. In one small area in Wisner township, near Saginaw bay, the drift wells, even where shallow, were said to be salty, and it was reported that in early days "deer licks" were found in this vicinity, and indication either of a percolation upward from the rock surface, by the salt water, or of the presence of direct fissures, not improbable in a region

where the bed rock is known to be more or less faulted and the overlying deposits are compact clays. These salt waters were often very nearly without hardness, showing only small traces of calcium salts. The salt comes from the shales and sandstones of the coal measures which are strongly saline in this region.

The deeper beds of the Marshall sandstone are also salt-bearing, while the upper ones yield little or no trace of salt, this substance having been leached out, possibly, as suggested by Lane, by the great draft on the lower brines by the salt-manufacturing industry in the Saginaw valley. Whatever the cause, the salt is gone from these beds, but at lower depths, the water, even from the Marshall sandstone, is salt, so that wells in the lake plain more than 300 feet in depth are usually salt or brackish.

Depth to rock. (See Plate VI.) The drilled wells in the district under consideration are so distributed as to make it apparent that the rock surface is a gently sloping plain, with at least one well-marked valley in it, and possibly more than one. The slope of the surface of the rock is towards the west and about the same as that of the present land surface (on an average about 10 feet to the mile). Local elevations of the land surface do not usually coincide with those of the rock surface, so that there are minor areas in which considerable variations in depth of rock are shown, which would entirely disappear if the land surface were a plain. On the other hand, there are equally great differences where the land surface is flat.

In the following table it will be seen that the average depth to rock in the various townships is relatively uniform, varying only about 20 feet from the lowest, found in the northern and western part of the area, to the highest, found in the extreme southern part. Wisner township has the lowest average and the least variation, but three others, Akron, Columbia and Fairgrove, show an average depth but 6 or 7 feet greater, although the surface of the county is more uneven and rises many feet higher.

Rock wells in Tuscola county

ROCK WELLS OF TUSCOLA COUNTY.

Township.	Tp. N.	R. E.	Number of wells reported.	Number of wells in which rock is over 100 ft. deep.	Depth of rock. Greatest Feet.	Least Feet.	Average Feet.
Wisner	14	7	7	0	85	70	77
Gilford	13	7	76	11	170	70	86
Denmark	12	7	45	8	140	60	89
Tuscola	11	7	9	3	200	49	79.8
Arbela	10	7	2	1	120	70	95
Akron	15	8	51	9	229	60	83
Fairgrove	13	8	60	6	230	55	84
Juniata	12	8	6	4	112	84	98
Columbia	14	9	70	11	+160	50	83.6
			326	53	+230	49	81

The greatest depths occur in certain restricted areas which seem to be definitely related to each other and indicate that there is a buried valley extending from Huron county southwestward beneath the village of Unionville, across Akron and Fairgrove townships, into Gilford and Denmark where it is lost track of. This valley is of interest, since in places it furnishes abundant supplies of water, sometimes with a strong head, so that fine flows are obtained from it, but, in other places it seems to contain little water, and when struck increases the cost of well-driving by adding to the number of feet of casing required to reach bed rock.

FLOWING WELLS.

Distribution. (Plate VI.) Over a considerable part of the lake-plain area the water from the rock is under sufficient pressure to rise nearly to, if not above, the surface of the ground, and there are in consequence many flowing well districts. It might almost be said that the whole area constitutes a single district, for the water will overflow the surface when this is low, or when very permeable strata are struck; but in places where the surface elevation is high, or the water-bearing strata are very fine-grained, a flow will not be obtained. The low-lying districts, depressions, and valleys then, are the places where flows are found in the greatest numbers and even slight ridges are sufficient to shut off the flows. The largest areas of flows were found in Columbia township, where depressions of the surface of several square miles in extent exist, over the whole of which it may be possible to secure good flows of excellent water from the rock, and in occasional wells almost equally good supplies from the drift near the rock surface.

Extending west and southwest from this township are numerous other areas, usually of small extent, in which both rock and drift flows are found, the water usually flowing in good quantity, but being, as pointed out, often brackish or salty, in the western part. (See Plate VI for limits of salt water.) The water from the drift, where flows of this type occur, was reported to come from near the surface of the rock, and may get its pressure from the rock itself.

Loss of head. In northern Akron township, north and west of Unionville, are several small flowing well areas, in which the flows have greatly diminished or in many cases entirely ceased. The date at which the failure began, was so closely connected with the opening and working of the coal mine at Sebewaing, that the owners attribute the loss of the head to the immense drain on the underground waters which the operations in these mines entailed. The connection between the two phenomena is the more close, when it is considered that the wells to the eastward of what is assumed to be the border of the lowest beds of the coal measures were not affected, as they draw their supplies of water from the beds which are below the ones worked for coal at Sebewaing.

Loss of head was noted at many other points where single wells, usually on high ground, as compared with the others in the same area, were reported to have flowed formerly. (See lists of wells, p. 63.) Not infrequently the time when the flow ceased could be fixed by the date when some neighboring well on lower ground was completed. In a few cases, deepening a well was reported to have restored the flow after it had ceased.

During the excitement upon the development of the coal deposits about Saginaw, many holes were drilled by coal prospectors, which, after the drilling was completed, were plugged, more or less perfectly, and the casing pulled out. In some cases, because of imperfect plugging, the water from the rock worked it way out to the surface, and, flowing freely, was the cause of diminution or loss of head of several wells iii the neighborhood.

It has already been pointed out that the rock surface rises from the bay eastward. At the shore of the bay the altitude of the rock surface is about 520 feet above sea level, or about 60 feet below the bay; near Cass City it crops out in the bed of the river at an elevation of about 700 feet above sea level, while to the northeast, at Tyre, it rises in places to about 800 feet. These elevations are important, as they show a steady increase in the height of the rock surface, sufficient to give pressure to the water at the lower elevations, especially since the dip is from the higher to the lower elevations. That these differences are really sufficient, is evident when it is remembered that the majority of areas of flows occurring in the lake-plain district are below the 660-foot-surface-contour-line, and none are above the 680-foot contour, i. e., the surface in the flowing well areas in Columbia, Akron and Fairgrove townships is from 30 to 50 feet or more below the surface of the rock in the valley of the river a few miles to the east, and much more below what it is a little farther northeast. In the same regions, where the rock surface is higher, the surface deposits are very absorbent, and a much larger percentage of the rainfall penetrates the ground and finds its way into the permeable sandstone than in the clay-covered districts. These areas may then supply much of the water, as well as the pressure of the flowing wells, the objection to the theory being probable lack of continuity to the porous beds, and their dip to the west at a considerable angle.

In this connection it may be well to note that the rather pervious moraine, or high ridge, between Cass river and the flowing well areas under consideration, is also a catchment area of considerable importance and if the clay underlying it is as penetrable to water as its own surface a large part of the rock water, and the head as well, could be derived from it. One objection to such an hypothesis is the small amount of lime in the rock water, compared with the amount of lime and other mineral matters in water from the drift, which would hardly be eliminated in the passage of the water through the rock. The sandy areas to the northeast and east would not yield the soluble minerals, hence are the more probable sources of supply.

LAKE-PLAIN REGION.

Flows from drift. In the lake-plain district, flows from the drift are rare, compared with those from the rock. The largest area is situated a mile southeast of Unionville, and is about a square mile in extent, the group consisting of eight or ten wells which have good flows, with a head of from 3 to 5 feet. The depth of these wells is from 50 to 75 feet, and most of them get their water from a stratum of quicksand which lies upon the surface of the bed rock, from which neighboring wells draw their supply at slightly greater depth. The water of these wells is generally of about the same character as that from the rock, and it is probable that it finds its way into the sand from the rock, rather than from the clay above.

A small group of flowing wells from the drift also occurs a mile west of the town of Akron. As in the Columbia area, these go down nearly to the rock surface and get their water from quicksand or fine gravel just above the rock.

Aside from these areas there are about thirty small areas with one or two wells each, located near, or in, areas of flows from the rock, which present about the same characteristics as the two areas mentioned above. In all these wells, with possibly one or two exceptions, the water comes from the surface of the rock, and it is difficult to say whether the wells should be classed as drift or rock wells, since it seems probable that the water comes from the rock, while the wells extend only into the quicksand, which is part of the drift.

It is reported by one of the early settlers that the first well to flow in the northern part of Tuscola county was a dug well about half a mile south of Unionville, put down, or deepened, in a very dry time, until it had penetrated the clay about 90 feet. The diggers left the hole at noon to go to dinner and when they returned the well had a large amount of water in it, and soon was flowing over the top. This well was the means of showing the farmers of the region that abundant water was to be obtained near the rock, or from it, and deep wells, bored, or driven, soon became common.

As has already been pointed out, the districts where the soil is sandy, or gravelly, get sufficient water for ordinary use from shallow, dug wells from 10 to 40 feet deep. The eastern border of the plain, where it approaches the foot of the ridge which marks the limits of the flat lands, becomes sandy or loamy, and is much more permeable than the clays, and furnishes much more water in the upper layers of the drift. Here also, are ridges of gravel or sand marking former shore lines and extending for many miles parallel to the high ridge to the east, and these furnish extensive reservoirs of water, which appears in dug wells, or in the form of springs at the edges of the ridges, or in marshy areas bordering them. The whole length of one of the best marked of these waved-formed ridges is bordered by large springs, some of which are impounded for domestic uses, in one or two cases, forming good-sized fish ponds. The water from these springs is medium hard, fresh, and of excellent quality, and often the quantity is large, especially after the outlets have been enlarged. The wells in such localities are usually only a few feet deep and yield an abundance of water.

MORAINAL REGION.

General Conditions. The height of these districts above the level of the bay, amounting to about 200 feet in the western and from 300 to 400 feet in the southeastern portion, makes the rock surface hard to reach, and precludes getting flowing waters from the rock, and, on the highest land, from the drift. The greater permeability of the surface soils of the ridges compared with the clays of the lake-plain district permits a much larger percentage of the rain-fall to be absorbed, while the unsorted and loosely compacted subsurface materials serve to give storage to the water thus absorbed, at no great distance down. In these districts the wells are of the open dug type, of depths varying from 12 to 60 feet, beyond which, they are usually deepened by boring or drilling. In a few cases it was found that wells had been drilled through the drift to the rock, sometimes nearly 300 feet down; but this is rarely done.

The location of wells in the morainal districts is often most disadvantageous, since they are placed on, or near, the tops of the ridges, where the water table, or zone of permanent ground water, is the farthest possible from the surface, and is much more subject to fluctuations than it is in the depressions or near the bottoms of the slopes. Even when a well gets its water from a gravel vein, it is evident that the water is much more quickly exhausted, at least so far as a given well is concerned, if it is tapped near the top of a slope than at or near the bottom, because of the effect of gravity, which is constantly drawing the water down the slope and away from the higher levels. The deepest well of which record was obtained in these districts was one in the northwestern corner of Watertown township, which was reported to be 352 feet deep, with bed-rock at 272 feet from the surface, the altitude of the surface being 900 feet above sea level.

The water from the wells of the morainal districts is variable in the amount of the dissolved mineral matter which it contains, consisting chiefly of lime, or calcium, and iron compounds. It is harder in clay strata than where it passes through sand or gravel. No saline or brackish water known to come from the drift was found in these areas.

Flowing Wells. Near the foot of the steeper slope from the high morainal district toward Cass river are five small areas of flowing wells from the surface deposits or drift, and one from the rock. On the southward slope from the same ridge, extending also into Lapeer county, is still another group.

Two of these districts are situated in Arbela township, one in Watertown, one in Fremont, and one in Wells, on the north side of the ridge, and one in Dayton township on the south side. The others are small in the extent of area covered, embracing from one to three wells.

Arbela Township. The first area in Arbela township is on the line between secs. 14 and 15, where the wells are about 30 ft. deep, with a slight head of hard water. The well on the farm of D. H. Van Wormer, for instance, is 27 feet deep, having surface clay and gravel to 10 or 11 feet and hardpan thence to the bottom.

The second area is on the east side of sec. 13, and consists of two wells 60 feet deep. These are at the foot of a sharp slope of a ridge, and the water was reported to come from gravel, was hard, and contained iron. It flows with a head of about 2 feet, and discharges less than one gallon a minute.

The sources of head and the catchment area are apparently in the ridge lying to the south, which is a western extension of a higher moraine to the east.

If this ridge is the catchment area, there seems to be no good reason why the present areas should not be extended both east and west of the present development over an area extending a mile, more or less, from the foot of the steeper slopes and flows obtained from various depths. This seems the more probable because in Saginaw county the same ridge and conditions exist, and the area of flows is much larger than here.

In the center of Arbela township, at the town hall, is a flowing well 270 feet deep. The record as follows:

	Thickness, feet.	Total feet.
Surface clays and hardpan	70	70
Shales	194	264
White sand rock yielding a flow	6	270

Fremont and Watertown Townships. Both of these townships, which have each a single well in the present stage of their development, lie near the foot of the high moraine in the southeastern corner of the county 4½ miles west of Mayville. The Fremont well was not visited, but was reported to be about 70 feet deep and to flow a good stream. From the situation and topography it seems likely that flows might be had northeast and southwest of the present location. The well of Mr. Arthur Wills, in Watertown township area, is situated one mile south and 5½ miles west of Mayville, on the north side of sec. 6. It is 65 feet deep, has a two-inch casing which is reduced at the outlet to one-half inch by a valve used to shut the water off so that it will flow to the barn. The flow is about 5 gallons a minute, with a head of more than 6 feet, and but for the reduction of the size of the outlet, the water would apparently flow the full size of the pipe to this height. The water has a temperature of 40 degrees F., is hard, and contains considerable iron, and is of good quality. It seems probable that this area, would be connected with the Freemont area and extend to the west and south along the gentle slopes at the foot of the high ridge, but the district is at present sparsely settled and the rather sandy till yields sufficient water for general uses in open dug wells of slight depth.

Wells Township. This area is situated in a recently cleared district on sees. 27 and 34, 1 mile and 4½ miles west of the village of Kingston and about 11 miles southeast of Caro. The district is at present less than a mile long and contains two wells 43 and 48 feet deep, respectively, which derive their water from gravel. The head is about 18 inches and the flow about 1 pint to 1 quart a minute. As these wells are near the foot of the slope from a high ridge to the south, they probably derive their head and supply from this source, and the area may be capable of extension both east and west along the same level and possibly also north of the present area.

Along the foot of the moraine, where it crosses sections 25 and 26 of Wells township, is the outcropping of a more compact, less permeable clay, under a gravel deposit of considerable extent. The clay exposed forms the lower part of an extensive slope, down which the water that runs out upon it from under the gravel, finds its way, often forming springs of considerable size. One of these springs appears by the road on the northeast quarter of sec. 36 and flows into the roadside ditch. The water comes from sand, is hard, contains iron, and is of excellent quality. The amount of water furnished by this spring was about 15 gallons a minute after a long period of drought. The whole district along the base of the ridge is more or less favorable to the development of springs.

VALLEY REGION.

Cass river valley, in Tuscola county, is a well defined district in which the water-supply conditions differ from those in either of the other districts. The Glacial or lake history of the valley explains the generally sandy nature of the surface deposits throughout the upper and central parts of the districts, but can not be entered into in this place except to state that the valley was first occupied by ice, then by an arm of the Glacial lakes, Maumee, Saginaw and others, into which flowed a large stream from the melting ice to the north. This lake subsided by slow stages, leaving shore and shallow-water deposits in the form of sand, which was either heaped up into ridges or spread out into thin layers over the surface by falling waters. The stream constantly brought-down more sand, which was built into bars and deltas. All these deposits are readily permeable by water, and nearly all the rainfall upon the surface is readily taken up by the coarse soils. This either runs off below the surface, or remains in hollows upon the top of the clay subsoil, or upon the top of the rock, where this was the underlying stratum, as it is in the north-eastern part of the county.

As the result of this structure and history, in most parts of the area shallow wells, dug down to the surface of the clay or into it a short distance furnish a good supply of water.

Aside from this ease in getting water from shallow wells, the district is much more fully watered than either of the other districts by small streams tributary to the river. These and the river furnish water for stock in large quantity. The valleys of the streams, and of the river as well, in many places cut through into the clay underlying the sand. This clay is dark-colored, very hard and compact, is probably of greater age than the surface clays of the other districts and is nearly inpenetrable to water. Along the junction of the sand and clay, the water flows out into the valleys, forming springs, which vary in size from seepage lines, scarcely recognizable, to large outflows of many gallons to the minute, such as the springs from which the town of Caro draws its water supply in part.

This area, however, is the least thickly settled in the county and is likely to remain so, because of the small agricultural value of much of the land; hence the water resources are poorly developed and little utilized.

At Tuscola, Vassar, and Caro, and in the immediate vicinity of these towns, are a few rock wells, which will be considered in connection with the water supplies of these towns.

MISCELLANEOUS TOWN SUPPLIES.

Each of the districts described above has some of the towns of the county located in it, and in general it may be said that the village supplies in each district are characteristic of that area in which they are obtained.

Lake-Plain Region. *Unionville*. This village, with a population of 457, has no public supply and gets the water for domestic use and for manufacturing from wells, which in many cases penetrate the rock, here from 90 to 150 feet below the surface. The greater depth varies abruptly from the least to the greatest, indicating a valley in the rock, as the land surface is nearly level. A few of these wells flow, but usually the water is pumped, and is soft, and fresh and in good quantity for all present needs.

In case a public supply is required the rock should, from present indications, furnish a good and very pure supply, and if the wells were put down in the lowest possible places they would in all probability flow.

Akron. This village is situated on a low, broad sand ridge. It has two sources of supply, the clay under the sand and the rock deep down below the clay. There is no public supply, and a large number of people get water for domestic use from shallow dug wells 10 to 15 feet deep.

As this supply chiefly comes from water which leaches through the shallow sand, it is more or less likely to be contaminated by percolation from cesspools, drains, and vaults. Such wells, especially in dry times, are unsafe unless every precaution is taken to guard against pollution. As the population increases, these shallow wells will have to be abandoned, as the supply is limited because of the small catchment area, and even at present is noticeably affected by dry weather.

Bored, driven and drilled wells in the neighborhood of Akron reach rock at about 70 feet and some penetrate it to a depth of 100 or 150 feet. Some of these rock wells flow 3 or more feet above the surface. The water is fresh and nearly soft, but has a slightly bitter taste, not noticeable except to those unaccustomed to its use. If the town ever develops a public water supply, the rock will be the best available source, though wells to it will not flow unless located on the low ground, or off from the ridge. The upper strata of rock seem to be shales, so, for a large supply, the wells must be sunk to underlying sandstone at considerable depth.

Fairgrove. This village is situated on a low, broad, morainal clay ridge, somewhat above the surrounding plain, and is too high to have flowing wells even from the rock. The town has public water supply for fire protection and sprinkling purposes, the water being obtained from surface supplies distributed from cisterns. Supplies for domestic and farm use are obtained from dug wells ranging from 12 to 35 feet in depth, and from driven or drilled wells which reach, or enter, the rock. The water of the dug wells comes from sand or gravel beds in the drift, and is hard, but otherwise of good quality, except in the shallowest wells, in which it is liable to contamination from the surface.

The depth to the rock surface is from 90 to a 100 feet and more. The deepest well in the village is probably that at the railroad station, drilled by Mr. McMillen in February, 1895, of which the following record has been preserved.

RECORD OF WELL AT FAIRGROVE STATION.

	Thickness, feet.	Total feet.
Glacial till (earth, clay, etc.)	98	98
Lime, solid and hard	2	100
Sand and gravel, cemented	4	104
Gray shale	11	115
Light shale	13	128
Dark colored shale	7	135
Black shale	26	161
Gray shale	54	215
Hard, flinty sandstone	10	225
Gray shale	18	243
Black shale	34	277
Soapstone	6	283
Dark shale	16	299
Fire clay	6	305
Hard gray lime-rock	7	312
Gypsum	3	315
Very hard, gray lime-rock	10	325
Brown sandy shale	8	333
Gray lime-rock	12	345
Fire clay	2	347
Gray lime-rock	10	357
Gray sandstone	31	388
Brown lime-rock	½	388½

This well furnished a large supply of good water. If the record is typical of the locality, it is evident that the most easily obtained supply is from the layer of cemented gravel near the surface of the rock. Below this level shales are likely to predominate, and do not furnish good supplies of water.

Reese. This village, with a population of 427, is located on the slopes of a somewhat gravelly morainal ridge, and spreads out upon a plain at its base. As in all cases where there is a porous surface stratum with less pervious strata below, shallow dug wells are the chief source of water supply for domestic use. Here this type of well is reported to vary from 12 to 20 feet, rarely more, in depth, and to furnish a sufficient supply of hard water. The public supply comes from wells of this type, and is pumped for fire protection, sprinkling, etc., but is not used much, as yet, for other purposes. Aside from these shallow wells, others are drilled and driven down to, and into, the rock, which here ranges from 80 to possibly 100 feet from the surface. The following record of wells in Reese shows the character of the strata passed through:

RECORD OF WELL NO. 1 AT REESE.

	Thickness, feet.	Total feet.
Stiff blue clay	45	45
Soft blue clay	27	72
Sand and small gravel	7	79
Soft soap rock (shale)	7	86
Harder soap rock	3	89
Soft soap rock	14	103
Soap or white chalk rock	2	105
Sand rock	1	106
White, hard, slate rock	1	107
Black soap rock	4	111
Soft soap rock	3½	114½
Hard slate rock	1½	116
White soap rock	1	117
Black soap rock	4	121
White soap rock	3	124
Sandy soap rock	4	128
Sand rock with 4-in. coal bed	5¼	133¼
Brown soap rock	9¾	143
Gray sand rock	4	147
Brown soap rock	3¼	150¼

RECORD OF WELL NO. 2 AT REESE.

	Thickness, feet.	Total feet.
Red clay	12	12
Blue clay	66	78
Gravel and sand	2	80
Hard lime rock	6	86
Soft brown soap rock	3	89
Hard white chalk rock	9	98
Soft soap rock	13	111
Hard white sand rock	4	115
Quite hard soap rock	2½	117½
Gray flint rock	½	118
Blackish soap rock	9	127
Black slate rock	2½	129½
White chalk or soap rock	1	130½
Hard sand rock	3	133½
White chalk rock	½	134
Hard sand rock	3¾	137¾
Dark slate	¾	138½
Sand rock	4½	143
Dark slate	2½	145½
Brown slate	5	150½

The water from the rock wells here is brackish or salty; the deepest, which formerly flowed, found strong brine from white sand stone at about 430 feet.

Ridge Region. Of the ridge region nothing need be said aside from what has already been noted in connection with the general discussion of these districts.

Gagetown. This town with a population of 400, is near the northern county line, upon the crest of the western moraine. Dug wells with a depth of 10 to 40 feet, or occasionally more, are the most common source of supply for domestic use. The water comes from sand or gravel beds in the clay, is hard, of sufficient quantity for ordinary demands, and is said not to be affected by the seasons. It rises in some of these wells to within 10 feet of the surface.

Wells are occasionally drilled to rock, but no records of the depth were available. The deepest well in Gagetown is reported to be 140 feet.

Kingston. This village, with a population of 350, is located on a morainal ridge, 30 to 40 feet above the bottom of the valley in which the railroad runs. The wells are generally dug, and range from 20 to 50 feet in depth, with an average of 35 feet; the water is hard but of good quality, and of sufficient quantity for domestic use, and is said not to vary with the season. The supply comes from sand or gravel beds in some of the wells.

A waterworks system owned by the village was installed in 1902, the water being pumped from a 4-inch drilled well 217 feet deep, which reaches rock at about 150 feet. The water comes from sandstone and rises to within 10 to 12 feet of the surface, giving ample supplies. It is distributed from a standpipe, and is used for fire protection, sprinkling and boilers. There is also a well 215 feet deep, in rock, at the schoolhouse, having the same characteristics as the waterworks well.

Along the railroad, and at the bottom of the valley west of it, both of which lie 15 to 20 feet below the water level in the waterworks well, it is probable that water from the same source would be reached at about 185 feet or a little more, and would flow with strong head. In the valley is a small stream, and along the margin of it are seepage springs, the water from which is sometimes used.

Mayville. This town with a population of 750, is the most elevated in Tuscola county, the moraine rising to nearly 1,000 feet above the sea level within its limits. As a result of this situation, the wells for domestic supply are often deep, but do not reach the rock surface. There is no waterworks system; one was projected some years ago, but was abandoned on account of the difficulty of getting water in sufficient quantities.

A test well was drilled 400 feet and bed rock was reached at 285 feet. In this well, water rose from sandstone about 300 feet, or to within 100 ft. of the surface.

The dug wells are often shallow, from 15 to 20 ft. deep, the shallowest being only 10 ft., but driven wells in the higher parts of the town often go down nearly or quite 100 feet to reach water in sufficient quantity. The water in the shallow wells is said to come from sand or gravel beds in the till, is hard, and never large in amount; yet the supply is fairly constant, so that moderate demands on it are met, except in very dry weather, when it may fail.

Bed rock is the most available source for a large supply for the town, but the great depth to which it is necessary to go to reach rock, and the depth from which the water must be pumped makes it an expensive source. If, however, wells were put down in the lowest part of a town, or, better still, in the valley north, and pumped from these to a reservoir in the highest part of the town, from which it could be distributed, it seems probable that a satisfactory supply may be had. Nearly 100 feet in the depth of the wells could be saved by locating them in the lowest part of the valley, which runs through the eastern part of the town.

Millington. Millington with a population of 632, is situated on a broad gently-sloping, sandy, and gravelly plain, which is on the edge of the rolling country, and is morainal in origin. The surface soil is permeable enough to take in a considerable amount of rainfall, and this accumulates in the underlying gravels, which lie from 15 to 20 feet below the surface. This supply is easily reached by open dug wells, and is largely drawn upon, the majority of the houses of the town depending on wells about 20 feet deep for their supply for domestic uses. This supply is uncertain and effected by drought. Persons requiring larger supplies drill down to bed rock for water, reaching it at from 90 to 112 feet. In this rock which is sandstone, water may be found at varying depths in good quantity and of excellent quality.

In 1904, the village completed its public waterworks, the water being obtained from two 4-inch drilled wells 187 feet and 200 feet deep, respectively, located near the center of the town. The rock surface is about 110 feet down, and the rock was reported as sandstone the whole distance until water was struck. The water rises to within 17 feet of the surface and is said to be of excellent quality and abundant. It is distributed from an elevated tank or standpipe, into which it is pumped from the wells.

Fostoria. This village lies on a slope from the high moraine to the north and, so far as learned, gets its supply for domestic use from dug-wells 20 to 40 feet in depth. A stream flows through the edge of the town, and from this some water is taken for use in boilers.

CASS RIVER VALLEY REGION.

Cass City. This village, with a population of 1,212, has for its site a broad gravel terrace about 40 feet above the bed of Cass river and has behind it, to the north, a well-marked morainal ridge. The gravel gives abundant water in dug wells about 20 feet deep, some going deeper, and these are the common sources of supply for domestic use.

Caro. This town, with a population of 2,268, is located at the foot of a well marked morainal ridge upon a gently sloping or nearly flat gravel terrace of the river valley. It is well situated for the development of a system of waterworks, depending on gravity for distribution of the water from a properly located standpipe. For several years such a system, owned and operated by a private company, has been in use, the water being pumped, in part, at least, from springs located across the stream, opposite the town. Recently the supply has been augmented by drilling wells in the rock. The standpipe is situated in the northern part of the town upon morainal ridge about 100 feet above the principal business street. The water is of good quality and that from the springs is relatively soft. The springs have their catchment areas to the east of the river in the gravel and sand terraces, the town standing on the west bank, the water percolating through the gravel and sand down to a dense substratum, upon which, it finds its way until it reaches some place where the streams cut this in running to the river, when it flows out as springs. The water is used for all purposes, including domestic and drinking, but there are many dug wells in the town from 16 to 20 feet deep which, upon the gravel flat, reach through the gravel to the top of the clay and intercept some of the water moving along upon it. This water is reported as soft and pure, but unless care is taken to dispose of sewage, eventually the gravel will become so contaminated that the wells in the more thickly settled parts of the town may be unsafe to use and will afford breeding places for the germs of various diseases.

The following is the record of the deep well of the Peninsular Sugar Company; the altitude of the mouth is 15 feet above Cass river, and about 645 or 650 feet above the sea level:

RECORD OF PENINSULA SUGAR COMPANY'S WELL, CARO.

	Thickness, feet.	Total feet.
Drift (sand, gravel, hardpan and boulders)	113	113
Limestone	7	120
Shale (blue)	25	145
Sandstone (very soft; first flow of water, 50,000 gal. in 24 hours, soft; rose 5 feet above derrick floor)	40	185
Limestone	5	190
Sandstone	50	240
Shale, black	2	242
Sandstone	10	252
Shale	1	253
Sandstone	29	282
Streak of sandy limestone.		

At 275 feet a flow yielding 350,000 gallons in 24 hours was struck. The water has a slight mineral taste, leaving a sweet aftertaste, probably of magnesium sulphate. The well is 8 inches in diameter; temperature, 47 degrees F.

Vassar. This village, with a population of 2,032, is the third important valley town to be considered, and like Caro is located on the terraces of Cass river, but unlike that town reaches across the stream to the eastern bank. A considerable part of the town also lies upon the morainal ridge, here relatively low and inconspicuous. The ridge is covered with gravel, and hence is more permeable than such ridges usually are.

The village owns its waterworks system, the water being derived from seven drilled flowing wells, which average about 200 feet deep. The deepest well is 230 feet, but it is cut off at 200 feet. At the depth of about 125 feet a small flow was struck, and this increased with the depth until it reached its greatest volume at 175 feet, when the flow was about 100 barrels an hour. The total depth of one of the other wells is 207 feet, with the rock surface at about 50 feet. The water rises about 4 or 5 feet above the surface and is pumped to a standpipe on the ridge, from which it is distributed. It is relatively soft, giving only a slight powdery scale after prolonged use in boilers. The following analysis by Dr. R. C. Kedzie, of the agricultural college, was made about the time the system was installed:

ANALYSIS OF VASSAR PUBLIC WATER SUPPLY.[1]

	Parts per million.
Total solids	271.43
Volatile at red heat	71.43
Total mineral matter	200
Mineral compositions:	
Calcium (Ca)	65.49
Carbonate radical (CO_3)	100.82
Sulphate radicle (SO_4)	20.16
Magnesium (Mg)	6.17
Chlorine (Cl)	4.32
Sodium (Na)	2.82
	199.78
Nitrates and nitrites	None
Free ammonia	0.05
Albuminoid ammonia	0.04
Hardness by soap test	85.71
Permanent hardness	57.14
Total hardness	142.85

The amount of water yielded by these wells is about 110,000 gallons a day. Two deep wells were put down in Vassar; one near the railroad junction, which has a depth of about 600 feet, flows a considerable quantity of brackish water, which has been bottled and sold for medicinal purposes; the other, which was put down as a test well about the time the waterworks were established, is 467 feet deep, and gave salt water of 6 degrees saltness. This well was reported to be plugged and abandoned.

Dug wells from 20 to 30 feet deep are frequently used, furnishing sufficient water for domestic use, and private drilled wells from 45 to 200 feet deep are not uncommon. Most of the latter flow when located on the lower terraces of the river. The rock water is generally softer than that from the drift, especially that from sandstone, the most common source.

[1]Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Tuscola. This village, with a population of 275, lies a few miles southwest of Vassar, on the lower terraces of the river valley, here somewhat sandy and relatively narrow. The town is spread over both banks, the parts being connected by a narrow bridge. The general sources of water for domestic use and for stock, are shallow dug wells from 12 to 40 feet deep, the most common depth being about 20 feet. The water usually comes from gravel strata in the clay which underlies the shallow surface sand, and rises within 6 feet of the surface in some of the wells. It is hard and the supply constant and sufficient in most cases for the needs of the owners.

A few drilled wells on the higher slopes of the valley yield excellent supplies of somewhat brackish water from the rock at a depths of about 175 feet. A drilled well at the north side of the village is reported to be 175 feet deep, in sandstone, the rock surface being struck at 49 feet. This well flows several gallons a minute, with a head of 2 feet. It is situated on land 30 feet above the level of the river, higher than most of that on which the village is located, hence it would seem probable that other flows could be developed by going down into the rock. The rock surface was reported as 70 feet down in another well, but as it appears in the bed of the river, a short distance north of the town, it is probable that this well was on the higher ground than the flowing wells above cited.

Wilmot. This small village is situated on the southern edge of the broad sloping plain which rises to the morainal region on the south. The generally sandy or loamy character of the soil, and the fact that it is underlain by clay at moderate depths, makes the water supply good and easily obtained. The wells average about 20 feet in depth and give a good supply of hard water, which is not easily exhausted. No rock wells have been put down in this vicinity.

Deford. This is the next station north of Wilmot on the Pontiac, Oxford and Northern Railroad, and is in much the same situation as Wilmot. The plain is slightly flatter and somewhat sandier. Water is obtained from shallow dug wells at about the same depth as at Wilmot.

Silverwood. This is a small village on the Pere Marquette railroad, on the southern border of the county, and is interesting from the fact that a part of the water supply is obtained from flowing wells from the drift. The area extends southward into Lapeer county, forming a good sized district. A few wells that flow in the village are about 40 feet deep. Dug wells from 15 to 30 feet deep are also common sources of water for domestic uses. The water tank at the railroad station is filled with water from a flowing well 40 feet deep.

SYSTEMATIC CATALOGUE OF WELLS AND TEST BORINGS.

The following records have been collected from many sources, among which are the personal, detailed study of the wells and waters by the writer, who also gathered many records of depth and other pertinent facts from the owners of wells by a house-to-house canvas, carried on as a part of the field work. A most important contribution has been made by the well drillers, among whom may be mentioned Mr. John Russell of Unionville, and his brothers and Mr. Charles Van Wormer of Millington, who. permitted their carefully kept records to be used and cheerfully answered numerous questions relating to their borings. Mr. Charles Montague of Caro and Handy Brothers of Bay City and a number of other land holders, who have sunk exploratory test holes in various parts of the county, in search of coal and other minerals, have kindly permitted the use of their records, some of which are here published, and which, in the aggregate, have involved the expenditure of thousands of dollars. Mr. Alfred C. Lane procured most of the data from Elmwood and Elk land townships, and has also rendered much assistance at other points. The order of description of wells is usually as follows:

(1) Location.
(2) Name of owner, when known.
(3) Depth of well, in feet.
(4) Depth to rock, or length of casing, in feet.
(5) Quality of the water, including notes on the mineral matter found in it.
(6) Head, or height to which the water rises.
(7) Elevation above sea level or tide. (A. T.) (Lake level 581 ft. A. T.)
(8) Remarks.
(9) Driller's record and name of driller.

The records are given by townships and locations by section quarters and more accurately when possible.

Regarding the quality of the water it may be said that during the field investigations, chemical tests were made of nearly every flowing well and many of the pump wells, to determine the mineral constituents of the water.

These tests were simple but reliable, and were qualitative, although in a measure they became quantitative as well, since the promptness with which the reactions took place and the amount of the precipitate which appeared, were indicators of the quantity of the mineral sought, which was present in the sample. Hence, a rough system of classification was possible and the same one was adopted as that used in Huron county.[1] The tests made included a search for common salt, sodium chlorid, (NaCl), sulphates, or sulphuric acid, in composition (H_2SO_4 or SO_4) calcium in composition or "lime," (Ca.); magnesium in composition, (Mg) and iron, (Fe.) The tests were made at the well, by means of a pocket testing outfit, using concentrated solutions of the reagents employed. The results were recorded as follows: Where the mineral matter was present in large quantity, it was said to be strong (str.); where in moderate amount, it was called medium (med.); and when present in small quantity the record is (low), or still less, traces (tr.). If no precipitate was formed, the record was (0).

The reagents used were identical with those with which tests were made in Huron county, and the methods of work the same and are fully described in the passage already referred to above.

Where the elevation of the ground at the mouth of the well is given "A. T." it will be remembered that generally this has been determined by barometric observations and is only approximate, the difference between sea level and the level of Saginaw bay is about 581 ft, so that the latter number must be subtracted from the figures given to obtain the elevation above the bay.

The townships are given in order beginning with the northeastern, thence westward, across the county, and this order is continued throughout the list. In general no special order was observed in the given section of a township, but the wells are listed about in the order visited.

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[1]Lane, A. C., Loc. cit., pp. 138-142.

CHAPTER VIII. THE NATIVE VEGETATION OF TUSCOLA COUNTY.

NOTES ON THE FACTORS AFFECTING PLANT DISTRIBUTION.

Introduction. The study of plants in relation to their environment to determine the effects of the peculiar combinations of the factors encountered by them that influence their growth in the places they inhabit, is a most interesting phase of the science of Botany, and one that has many practical applications. In a limited political area, such as that forming the subject of this series of studies the chief causes for the grouping together of the native plants into the societies in which they are found, are not local, but have their origin in remote regions, or are cosmic, so that it will not be possible to go far into the reasons for the observed facts, from local investigation, even if it were desirable to do so in a discussion of this kind.

It is hoped, however, that the observations recorded will, perhaps, enable some of those who read the report to take up the work where this discussion leaves off and carry it on to a satisfactory conclusion.

On the factors affecting plant life that must be taken into account in considering the distribution of the native plants in Tuscola county, some have already been discussed in the section devoted to the origin of peat, and these will scarcely require more than mention in this place.

The most important of these factors are the complicated resultant of atmospheric and solar forces called climate, the soil, the amount of water in the soil and its permanent position in relation to the surface of the ground, the exposure of the soil to winds and the direct rays of the sun, or what is sometimes termed its aspect, and the amount and length of insolation or exposure to the sun's rays during the growing season.

Under climate are included the daily and average temperatures of the air, precipitation of meteoric water, the amount of cloudiness and the force and direction of the winds, in fact the sum of all these external and atmospheric phenomena which, taken day by day, we call weather.

Temperature. In another place will be found the records of weather observations made within the limits of the county, while records of temperature observations made at Bay City and Saginaw have been published by Cooper[1] and Lane[2] in previous reports of this Survey. These show that the average annual temperature at Bay City for the period covered by the record, 1896-1903 inclusive, was 46.3° F., that July is the warmest month and February the coldest, of the mean year with an average temperature of 71.1° F. for the former and 20.4° F. for the latter; the growing season is from early May to late September or early October, varying from year to year, this period being measured from the last killing frost in the spring to the first one in the fall. It is largely the temperatures of this growing season which have effect in controlling the distribution of plants, as while they are dormant, even very severe freezing does little injury to many species which would be killed by moderately low temperatures when they are active. For this reason localities subject to very late or very early freezing, or to summer frosts, are occupied by frost-resistant or northern species, while the more frost sensitive kinds are confined to sheltered areas, or to districts which are visited by hard frosts only during the dormant, or resting period of the plants.

The depth and kind of soil, the form of the land surface, the exposure to certain kinds of winds, and nearness to large bodies of water tend to locally modify the air temperatures in a given district, so as to produce local, unseasonable frosts, and also to give exemption from them. Thus shallow and sandy soil, while usually warmed up quickly during the day radiate heat more rapidly at night than clay, and killing frosts may occur on sandy land, when surrounding clay lands escape entirely. It is also a well known fact that cold air flows down hill and accumulates in depressions often causing them to become filled with mist or fog on warm still nights in summer, when the air in the hollows is full of moisture, which the cold condenses by lowering the water holding capacity of the air. Depressions without good air drainage are often the coldest spots in a given region and for this reason often support "islands" of northern plants, in a sea of more southern species, which are kept from overflowing the "island" chiefly because of summer frosts. On the other hand, ridges or hills, unless very high, are not subject to such frosts and rarely support northern plants except where the soil is very thin, and underlain by rock, or is very sandy, when apparently nocturnal radiation and dryness together produce a cold environment.

[1]Cooper, W, F., Report on Bay county, Mich. Geol. Surv., Ann. Report, 1905, pp. 356-358.

[2]Lane, A. C., Report on Huron county, Mich. Geol. Surv., Vol. VII, Part 2.

Temperature effects of Saginaw Bay. Water absorbs heat from and gives it back to the air very slowly, hence it is usually cooler than the air above it in the spring and early summer, and warmer in the fall and winter; therefore the air flowing over large bodies of water has its temperature modified to such an extent, that it exerts a considerable influence in equalizing the temperature of the adjacent land masses over which it passes after leaving the water. Thus the great general air currents or winds of the northern hemisphere of the earth are from west to east, and in passing over the oceans, these currents are warmed and give the western coasts of the continents a considerably milder and more uniform climate than is possessed by the eastern ones of the same continents in the same latitudes.

In less degree smaller bodies of water have a similar effect, and the records from year to year show that the western part of Michigan has a considerably milder winter climate than eastern Wisconsin, and a cooler summer temperature, because the cold winter winds from the west and northwest are warmed and the hot southwest ones of July and August are cooled to an appreciable extent in their passage across Lake Michigan.

To a much less extent the small area of water in Saginaw Bay must have modifying effects on the parts of Tuscola county that are near it, although since the water is frozen over for the greater part of the winter, the effects are most manifest in late summer and in the fall when the season of frosts is probably somewhat postponed in the vicinity of the Bay, because of the nearness of this body of water. The direct effect of such modification or prolongation of the growing season would be to make the district over which it extends habitable to plants of more southern range than could otherwise exist in it. Such an effect apparently may be seen in the extension northward along the western shores of Michigan of a considerable number of species of plants of distinctly more southern distribution than those found a few miles inland in the same latitude, and in a like manner the "prairie" flora of the area immediately adjacent to the marshes of Saginaw Bay is far to the north of any similar group of plants known to exist in the region, and it seems more than probable that the modifying effects of the Bay are responsible for this extension of range.

Cooper's[1] observations, while covering but a short period, and made on the west side of the Bay, indicate quite clearly the general summer condition of the relations of land and water temperatures; the effects noted by him doubtless would be emphasized on the eastern shore, as the prevailing winds are westerly, and air currents have their temperature more or less modified by passing across the Bay.

Effects of exposure, or aspect, on temperature. The main ridges in Tuscola county run generally northeast and southwest, which makes them face the northwest and southeast. Their low altitude and gentle slopes make the effects of the direction which the slopes face of minor importance although it is probable, even under the existing feeble character of these factors, that careful observation would show that the average temperature was higher during the growing season on the southeastern side of the ridges than on the northwestern, and that this would be reflected in a slight difference in the flora of the two sides. The effect would be indicated in a practical way, now that the greater part of the land is under cultivation, by the somewhat earlier dates at which crops can be planted on the southeast aspect, as compared with the other, while in the fall the cold northwesters shorten the season on the slopes which are fully exposed to their biting touch. These effects were probably reflected to some extent in the native vegetation, but if they were, the records are now practically all gone.

Precipitation. The rainfall of the region is generally ample for the needs of most kinds of plants that grow in it, and averages not far from 32 inches, quite evenly distributed throughout the year. There are, however, here, as elsewhere in the region of the Great Lakes periods of several years at a time when the rainfall is less than the average by several inches, and at such times the soil in the sandier districts becomes very dry and only the most drought-resistant or xerophytic plants are able to persist. Such dry times are uncommon, however, and generally the amount of rain and snow falling through the year was enough to make the region in its primitive condition a well-watered one and capable of supporting on most kinds of soil a dense, or at least fairly good, growth of vegetation.

During the growing season there is an abundance of sunshine for all of the needs of plant life. The relation of light to growing vegetation is so well known as to need but little consideration here; it may be said that many kinds of plants are now so used to growing in the shade of taller kinds that they are confined to such places as are partly shaded, while others must have full light, and they soon become enfeebled and finally die when over shaded. All gradations of types of plants are found from those which only grow where they receive the full light of the sun, to those which are always found in the shade of other plants; but the number of kinds which will grow in the deepest shade is few compared with that found only in the open.

[1]Cooper, W. F., op. cit., pp. 358-363.

Soil. The influence of soil on the distribution of trees and other plants is a very marked one, and is exerted in several ways, the most important of which are the following:

(1). The capacity of the soil to hold water. This in turn is governed by the depth of the soil, by the coarseness and uniformity in size of the grains of mineral matter which it contains, and by the character, uniformity and compactness of the subsoil.

(2). The kinds of mineral matter which are abundant in the soil, and whether these are beneficial or injurious to plants.

(3). The degree to which the rock particles composing the soil are broken up so that they hold the water in contact with them and permit enough of the minerals which they contain, and which are essential to the growth of plants, to be dissolved and taken by the vegetation as it is needed.

(4). The relation of the ground water level, or the top of the zone of permanent ground water, to the surface of the soil is also of great importance, and the position of this is largely determined by the size and shape of the soil particles and their relation, or position with regard to each other. Thus in deep, sandy soils the ground water surface is generally far below the surface of the soil, while in clay, or fine silty soils it may be just below the top of the ground. In the sandy soil the spaces between the grains are large and the size of the grains is also relatively uniform and large, so that the water falling as rain on the surface is quickly absorbed and usually sinks as quickly down into the deep layers of the ground out of the reach of the roots of plants. In times of drought, the water level in such soils is lowered still farther, and, air filling the interstices gives still greater dryness to the soil.

In clayey soils not only are the grains of mineral matter of uniformly small size, but the spaces between them are correspondingly small so that water neither penetrates nor flows through them as readily as it does through the sand. The result is that such soils retain water in quantity near the surface of the ground and are commonly much less affected by subsidence of the level of the ground water during droughts. If, however, air once gets into clay soils in abundance it remains much more stubbornly than in sandy soils, and may prevent to a considerable extent the entrance of water from above when rains begin again.

Since the interspaces of the soil are practically continuous, they form capillary tubes through which the soil water rises from below, as it is evaporated from the surface, and as water rises much farther by the force of capillarity in small tubes than in larger ones, the fine grained soils are much moister from this cause than coarser ones; a factor which gives vegetation growing on clay soils a large supply of available water long after that which can be used by plants located on sandy soils is entirely unavailable.

Effect of elevation and relief. The mean elevation of Lake Huron is not far from 581 feet above the average or mean tidal level of the Atlantic Ocean, and at no point in Tuscola county is the surface of the land much over 400 feet higher than the lake level, since in but a few small areas in the southeastern part of the county is the elevation of 1,000 feet above sea level reached, while the average elevation is probably less than 100 feet above the lake or below 700 feet above tide.

The primary effects of elevation are to reduce the temperature of the air as higher altitudes are reached, and by careful comparison of many observations it is known that the average temperature of the air decreases one degree Fahrenheit for each 300 feet, approximately, in elevation as one goes from the sea level upward. Hence the total average elevation of the county above the sea level is not enough to produce effects on its temperature that would be significant.

The principal prominent relief features of the county are the two morainal ridges on either side of the Cass valley, running nearly northeast and southwest. Between these is the shallow valley now occupied by the Cass river, and to the west of the lower ridge is the broad, gently sloping plain, extending to Saginaw Bay, with very insignificant and scarcely noticeable breaks in the form of slight ridges or undulations and very shallow stream valleys. None of those relief features give sufficient differences in altitude to cause any marked variations in average temperature during the year, as already shown and if they were all composed of a uniform type of soil they would affect the distribution of the plants growing on them but little, except so far as they controlled the movements of the surface water.

Distribution of soils in relation to plant distribution. They are not uniform in their soils, however, as is apparent when the chapter on the soils of the county is consulted, or the following brief resumé is examined. The dominant soils of the morainal ridges on either side of the Cass river valley are typically a stoney or gravelly loam, in places nearly pure gravel, in others more nearly true clay. In the valley between these ridges are great tracts of sand or light sandy loam, while across it run low, irregular ridges of light, fine grained sand, or well sorted gravels, the wind and wave formed dune and beach lines marking former levels of the water of lakes which preceded Lake Huron.

The same types of ridges of sorted soils occur in numbers on the plain between the western ridge, the Saginaw-Port Huron moraine, and the bay, but here the surrounding soil is principally clayey loam or near Saginaw Bay nearly pure clay, although stones scattered through it gave indications of its glacial origin. Parts of this plain, where for any reason the drainage is poor, are covered by shallow layers of organic matter, muck or peat, and over quite extensive areas the soil was formerly of this character. Smaller tracts of the same sort are found scattered in the valley of the Cass river and to the south of the moraine forming its eastern border.

These differences in soil constitute the most strikingly variable features of the environment of plants that may be found in this county and they are still farther accentuated by the differences in surface drainage and in the downward percolation of water, which are to be considered with them as making the important and significant differences of plant habitat. Thus sandy soils on steep slopes, or of considerable depths, make dryer conditions for plants to overcome than loams or clays under the same conditions, because the water penetrates them more quickly than it will other kinds and to greater depths; the sand is of such coarse texture that it absorbs the rainfall rapidly and permits it to sink so far below the surface that its permanent level may be beyond the reach of even the deepest rooted plants.

In general it is true that the ground water level or surface of the zone of saturation in the soil follows the irregularities of the surface of the ground, but its contours are flatter, and its slopes more gentle than those of the soil itself, so that while the ground water level is higher under the crest of even a narrow ridge than it is in the adjacent plains it is not proportionately high when the altitude of the ridge is compared with that of the plains, and it will generally be found that permanent ground water is considerably farther from the surface on the crest of the ridge than it is on the adjoining low land. If the ridge is of sand or gravel, moreover, the difference is much more marked than where it is of clay or glacial till. It thus happens that the ridges are not only dryer than the plains because the water in them is normally farther from the surface, even when the soils are the same on both ridges and plains. On the other hand a plain of deep sand may be more arid than a ridge of clayey loam, which, while it does not absorb water so quickly as the sand, retains it near the surface longer because percolation takes place in it more slowly.

Since water is of paramount importance to all plants, and without it they either cease to grow and become dormant, or die, and also since practically the whole flora of the temperate regions of the earth gets the water necessary for its existence from the soils which support it, it seems clear that those soils which are best watered should support the greater number of plants, both of species and individuals, provided that it is understood that, with the abundance of water there is enough air supplied the roots to keep them healthy and vigorous, enough of the essential mineral foods for healthy growth, and no substances that are poisonous dissolved in the water. The most favorable soil condition seems to be that which enables plants to get all the water they require, but does not permit the saturation of the zone in which their roots spread out. This is expressed in another way by the statement that those soils in which the ground water level is very far from the surface of the ground, or very near or at it, are unfavorable for the growth of most kinds of plants.

It must also be considered that almost daily our knowledge of the interdependence of the more highly organized plants and of the lowest types is being extended, and that in most very wet or very dry soils the bacteria and similar plant organisms find unfavorable conditions and are few in numbers, and it is not improbable that the absence of such forms in places of these kinds may, in some degree, account for their apparent sterility, the higher kinds of plants being absent because the low ones on which they depend for the preparation of parts of their food, are unable to exist there. Whether this is so or not, more species and individual plants flourish on the moist, well-drained loamy soils, than on any other kind. Moreover the plants of the given region can be classified according to their normal relation to the soils, and especially to the ground water level in the soils, as: (1) Hydrophytes, or water plants; those whose roots, and even their stems and leaves grow normally below the water level and which seem to require, or at least tolerate, an excess of water about their roots and other vegetative organs. (2) Mesophytes, or intermediate plants; those requiring a well watered, but not too wet, soil, and whose roots are usually, if not invariably, found above the ground water level, but do not thrive far from it. (3) Xerophytes, or drought plants; those which are capable of getting along with small amounts of water and can flourish where the ground water level is far below the surface, in arid climates, in dry places, or during times of little rainfall.

As in other cases in nature, however, these lines of differentiation are not drawn as sharply as would be desirable for convenience in classifying, for as every gradation of habitat is found between water of the maximum depth to which the light can penetrate to enable plants to grow, and soil so shallow that it is very dry the greater part of the time, or sand so coarse and deep that little water stays near enough, to the surface to be within the reach of plants, so plants are found that will grow in each of the great variety of conditions thus presented, and many kinds are known that can not be closely brought into either of the three great groups mentioned, but more properly might be classed as intermediate between two of them.

Generally speaking, however, the vegetation of moist climates which grows on sand dunes, and on deep sandy soils, or on very thin ones underlain by rock or impervious subsoils, and in regions of small rainfall, that growing in any kind of soil, is properly classed with the xerophytes, and on examination will be found to be provided with some of many devices to protect it from loss of water, or to enable it to gather water from wide areas, or even to store water in times of plenty, against the periods of less abundance.

In the area under consideration the dryest soil conditions are found on the sandy soils and especially on the exposed tops of some of the sand ridges which are of too recent formation to be covered and protected by trees and other enduring types of vegetation.

The conditions favoring the growth of mesophytes were found most often on the loamy soils of the slopes of the ridges and on the better drained parts of the plains where the soils were not so fine grained that swamp conditions developed from lack of downward percolation and surface drainage. Habitats suitable for the growth of aquatic types of hydrophytes were found in the river and other permanent streams, in the numerous ditches in which water stood during long periods, in the ponds and lakes scattered in various townships, and, on a much greater scale, in the shallow water of Saginaw Bay adjacent to the western shores of the county. The hydrophytes of the marsh and shallow water types were also found widely distributed over the county but were most noticeable in the western part of the county in Akron and Wisner townships, in the so-called prairie district, where there were formerly many hundreds of acres of nearly treeless, flat, marsh land, most of which was very wet throughout the growing season. The region is well named prairie because of the flatness and the absence of any heavy tree growth.

This district is rarely more than three miles wide, is bordered on the side toward the bay by low sand dunes bearing a sparse growth of trees, and on the landward side by a dense forest of tall, old, hardwood trees, while scattered over it are low sandy islands which are sometimes several acres in area, and often but a small fraction of an acre, but arranged in lines which run somewhat irregularly parallel the shore of the bay. The water level on the prairies was so near the surface the greater part of the time that marsh conditions prevailed over the greater part of them and they are still often wet enough to be termed marshes, although drainage has been provided by an extensive system of artificial drains.

At this point attention may again be called to the fact that a most notable feature of the surface deposits, the soils, of the county is the arrangement of different soil types into a series of long narrow strips, often very sharply defined, extending side by side in such a way that their long axes run in a northeasterly and southwesterly direction parallel to the shore of Saginaw Bay and to the higher morainal ridges. In these strips will be found many types of soil, from coarse bouldery gravel to fine clay, and from dry, barren, porous sands through rich, black loams, high in organic matter and mineral plant food, to wet clay and the pure organic soils, built up by the growth and decay of generations of plants in places too wet to permit thorough oxidation and destruction of vegetable matter.

This peculiar arrangement of the different soils in strips and ridges across the normal slope of the land affected the drainage materially by creating swamp conditions between low ridges of porous soils, and often made the ground water level in more permeable types of soil higher than it would have been under other conditions, and gave to them a better vegetation than they should have had from purely theoretical considerations.

Before its settlement the whole region, except the low-lying prairies already mentioned, was heavily timbered. A dense forest of elm, black ash, soft maple, with some sycamore, swamp oak, white ash, basswood and other water, tolerant trees, occupied the heavy undrained, or poorly drained clay soils adjoining the prairie region near the bay and extended inland nearly to the foot of the Saginaw-Port Huron moraine. This type of forest is still poorly represented by several tracts reserved for wood lots and by large ones which occupy swamps that are still undrained and uncleared. It is characterized by the large size of the white elms growing on the wet soil and by the sparseness of undergrowth and herbaceous plants growing beneath the dense shade of the trees. This may be termed the broad leaved swamp forest, and was the most impressive as it was apparently the most extensively represented type of plant association found within the limits of the county.

Penetrating this type of forest on the ridges and in such places as the soil drainage was good, as on the strips of sandy loam crossing the higher parts of the swamps, as well as occupying the greater part of the higher morainal ridges, was the beech and maple forest, the beech often dominant, or associated with elms, bur and red oaks on the moister areas, and the hard maples more numerous on the dryer ones. In general, however, these two species were found in quite uniform mixture and with their associates, the basswood and hop hornbeam or ironwood, made a type of forest distinct from that of the swamps, and which formed the broad leaved forest of the moist uplands, or the mesophytic forest.

Where the coarser soil constituents, such as, sands and gravels appeared in the areas occupied by this type of forest, it became mixed with white and black oak, or more frequently with white pine, which became the dominant tree when the sandy elements of the soil were present in excess. The great body of the pine forest disappeared before the ax of the lumbermen before the county was thoroughly settled, and now but few small groves remain. On many of the old beach ridges and dune lines at the time the region, was examined were to be seen the still undecayed stumps left by the lumbermen, the sole reminder of the great forest which formerly covered the land.

While there is probably not a township in the county where some white pines did not grow, so thoroughly distributed throughout the region are the soils suitable for its growth, the sandy plains and ridges which cover the townships in the Cass valley, supported a pure white pine forest, which was the nearest approach to a xerophytic coniferous forest occurring in the region.

The other forest types occurred over more limited areas, the swamp, coniferous type, represented by relatively small tracts of tamarack, arbor vitae and black spruce which were found here and there in springy or very poorly drained places, such as wet swamps and the margins of lakes. The tamarack was most often found and in the largest tracts, while the spruce was noted but once or twice in the central part of the county in morainal depressions. The arbor vitae or white cedar formed nearly pure growth along one of the older beach lines from which a large number of springs issued, and in other places around small lakes. It was of frequent occurrence also as undergrowth in swampy wood lots in the vicinity of the prairies, most of the individuals observed in such places being but a few feet high and evidently but recently established, although some old trees were still left. The last distinct type of forest to be considered was that in which oaks were dominant, the xerophytic, broad-leaved forest. The best examples of continuous forest of this type were found in western Watertown and southern Dayton townships and were made up chiefly of small trees which had established themselves on cut-over pine lands. The type may never have been able to maintain itself in competition with the white pine and form the forest cover over extensive areas in this region as it does in the southern part of the state. Oak groves were common on the dunes along the bay and on the larger "islands" of sand and gravel on the prairies but these were too small in area to give forest conditions.

On the cut-over and burned pine lands was a dense growth of shrubs and a lighter one of small oaks and poplars, but these were not of sufficient density or size to be considered forests.

As has been pointed out, the forest types are now represented by rapidly decreasing and much mutilated remnants of the original woods and at the present rate of cutting it will be only the matter of a few years before even these remnants will have vanished.

The second great type of plant associations represented in Tuscola county is that found on the prairies, and is essentially a meadow, or grass-land type, as the dominant plant forms are all grass-like, herbaceous, with marked slender stems, and long narrow leaves. The plants of these associations are characteristically turf formers, spreading from point to point in their habitat by means of long, tough, fibrous, horizontal underground steins, which interlace and mat together, and together with the roots that grow from them, form a dense firm structure that entirely covers the ground. The aerial parts of the plants, both stems and leaves, die down to the ground at the end of each season's growth, and by disintegration and partial decay, are added to the soil. This they enrich, and at the same time increase its water holding power by adding humus and by forming a protecting cover that prevents evaporation, thus tending to keep wet soil wetter than it would be if without such protection. In the region under consideration such a type of vegetation indicates either very wet or very dry soil conditions, that is, the soil is either too wet to permit trees to grow, or so dry that they are unable to establish themselves, and in this prairie district the high ground water level and the frequent spring overflows made the habitat a very wet one.

Several causes may have combined to prevent trees from invading the prairies but the paramount influence was undoubtedly water, because the forest came down to a perfectly clear sharp border of tall old trees to the edge of the grass land with no zone of scattered trees and of young trees intervening. Shrubs grew under the shade and about the roots of the trees along the border, but they too did not invade the marsh. The limit of the tree growth seemed to be marked by the upper limit of the winter and spring floods. It seems probable that these floods acted as the controlling factor to prevent the growth of the trees on the prairies by drowning such seedlings as appeared and by destroying the seeds which must have found their way to them in great numbers during spring and fall, for as is well known, several of our forest trees mature their seeds before putting out their leaves.

The conclusion that the high water of winter and spring was the important agent in inhibiting tree growth is strengthened by observations made before the ditching of the prairies had proceeded far, and again five years after the main drains across them had been completed. In 1897 there were few shrubs, and no young trees along the borders of the prairies, and only here and there a shrub in the open parts, but in 1902, shrubs had appeared in numbers not only on the borders of the woods but were abundantly scattered over the prairies, and considerable tracts of the most open parts had become covered with dense thickets of young poplars and willows, the pioneer trees largely because of the fact that their downy, light seeds are borne far and wide by the winds at the season when soil, moisture and temperature conditions are most favorable, that is, the spring. At the same time these notes were made, it was observed that in the parts of the prairies adjacent to the forest border, great numbers of young seedling trees of the kinds most abundant in the woods, elms, ashes and similar species, had started up and formed a well marked zone several hundred feet wide along the margins of the woods.

There were several types of habitat on the prairies despite the fact that to casual observation they presented a dead level and an exceedingly monotonous surface. This came about from the genetic history of the area, which may be briefly outlined here, as it has a clearly defined bearing on the distribution of the plants growing on the area, as well as explains the variations in the kinds of habitat mentioned. These flat areas were formerly bay bottom and have been recovered from the bay by natural processes, among the most important of which may be mentioned: (1) the cutting down of old, or opening new channels for the outlet of the lake; (2) the deposition of material in the bay by the streams flowing into it, and the accumulation of this in the shallows by the action of wind and wave formed currents; and (3) the action of plants and the formation of deposits from their remains.

The irregularities in soil structure and composition, reflected and indicated by the plants now growing on the prairies doubtless came about somewhat in the following way:

At some distance from the existing shore, waves and currents formed a submerged reef of sand. The same forces built the reef to the surface and the winds then took hold of the work, and, aided by stranded drift material, built it higher. As the height was increased, the other dimensions were also added to. After a time the little, island thus formed would be connected with the main shore, and perhaps form a sand point or spit by landward extension, and the enclosed bay thus cut off from the main .body of water would relatively soon fill up with sand and finer debris that would sink to the bottom in the quiet water under the protection of the point. Before very long the water would become shallow enough to favor germination of seeds and the growth of plants and these, ever ready to occupy new ground, would establish themselves and greatly aid in the filling of the bay by their own growth and decay, and by entangling and holding such suspended matter as is brought to them by waves and currents; they would also act to retard the water movements and would thus diminish its carrying power and in this way deposition of transported sediments would be favored. That such action actually occurs can be demonstrated by the examination of any mass of plants growing in moving water.

Through such agencies the small bay assumed to be formed above would, in time, become a wet marsh, and as vegetable debris accumulates rapidly in such places, and other conditions are favorable, peat would quickly form and the wet marsh would become a dry one. In places in the bay more exposed to winds :and to consequent wave action, and bars and sand flats would form where inequalities of the bottom favored, and when these were appearing above the surface, either by being built up or by recession of the water, even when they were covered by plants, but little or no peat would be formed, because the porous character of the soil permitted rapid draining away of the water and dessication of the surface.

Even if the supposed bar did not connect with the main land, or if, as is often the case, the bar began to build at the shore behind some point, the results of the protection afforded the space behind it are the same, and shoaling will inevitably follow behind it, so that if a supply of wind and. other suspended material is constantly available, parts of the shores of any body of water are likely to develop such deposits as those described, their extent depending on factors which need not be discussed here, but among them vegetation is important, both because it mechanically hastens sedimentation and also contributes directly to all deposits.

If added to these actively constructive agencies, we have the slow subsidence of the water level, or periods of more sudden lowering the outlet, or even a Ions period of diminished rainfall producing temporary lowering of the water level and attendant active building by the plants, it is apparent that parts of the bottom of the lake affected by these agencies will become reclaimed and made into land.

As the result of the combined action of these agencies, there may be differentiated three kinds of habitat in the prairies that correspond to three soil types with the following general distribution: (1) Black vegetable accumulations of variable depth and underlain by clay or clayey gravel and forming the greater part of the prairie soil. (2) Broad, more or less extensive tracts of sand, or sandy loam, slightly higher than the general level, but usually, not more than two or three feet above the general level and often not exceeding 1 foot. (3) Ridges of light sand, often continuous for considerable distances, and varying from a few inches to three or four feet in height above the general level, and rarely more than a few rods in width. These ridges are often discontinuous and sometimes two will join, but more frequently they are roughly parallel with each other and with the dunes of the present bay shore.

These sandy strips often have small groves of trees upon them and form the "islands" in the prairies. In the light of the history just discussed, they evidently represent dune and sand spit, or temporary shore lines of the days of former bay occupation, at the time when the areas of sandy loam were shallows and submerged bars, and the peat and black soils were the deeper places that were filled up by the growth and partial decay of generations of plants.

The main and most positive evidence that these different types of habitat are really unlike, must be gathered from the study of the plants growing in them, and no amount of theorizing will convince an observer that such conditions as they present are efficient in limiting the growth of plants, if he finds upon careful study that the same plants, in about the same relative numbers and in the same grouping with regard to each other are found on all of the soils and over all types of surface formations that have been described.

With this point in mind, and in spite of the fact that it is common knowledge, widely spread in the agricultural regions of Michigan, that the kind of timber growing on a piece of land is good indication of its fertility and general quality, the writer made a few studies of the plant associations found on typical soil areas in portions of the western side of the county. It was the original plan to continue this work to include all of the important soil types throughout the county in this examination, but this plan could not be carried out; the results here given are furthermore incomplete because they give only those plants that are practically permanently present in the localities visited including the more enduring perennial herbs, the shrubs, and the trees, while many of the annual plants and those whose activities are limited to the spring and early summer are not noted because the work was done in the late summer and fall.

The method of making the notes was simple, consisting in reporting in the briefest possible manner the names of the species of plants seen in the tract visited, their relative abundance, their relations to each other, and their location with regard to light and shade. Care was taken to select such places as furnished the nearest approach to the natural conditions that could be found, but in all but a few of the places visited there was abundant evidence of the removal of timber, of pasturing or of fires, and on the prairie of the disturbance of the relation of the ground water level to the surface of the ground by ditching.

In spite of the fact that it was evident that all of these factors of destruction of the primitive conditions had been operative in most cases for some time when these studies were made, there was no good evidence in the sites selected for study of any very considerable disturbance in the balance established between the significant plants. Even if no allowance is made for these disturbances, the records show that there is a marked difference in the dominant or leading species of plants to be found on the different kinds of soil, and that the accompanying species are also usually different.

What can not be expressed, in a report of this character is also true, namely, that often where the same species are present in a given association of plants, the numbers of individuals in the two associations will be so very unlike that the type of the association and its significance will be quite different. For example the arbor vitae, *Thuya occidentalis*, L., and white elm, *Ulmus Americana*, L. may grow together in the same habitat; in one case the conifer forming the major part of the tree growth with the deciduous tree growing isolated here and there on the margin of the area; in the other, as was sometimes the case in Akron township, the elm would be the characterizing species, forming a forest of tall, large trees, while the arbor vitae appeared as scattered undergrowth.

Another feature of the study of the plant associations should not be overlooked, namely, that in examining them the fact that none of them is more permanent than the conditions which brought it into being-is constantly enforced on the attention. This is manifested in many ways, but in no place so clearly as on the prairies, where conditions were rapidly changing because of man's interference in draining out the water from the soil, and where the record of significant change in the plant associations would naturally be so conspicuously recorded. Attention is called to this in other places, however, and only mention need to be made of it here. Another feature of scientific interest to which the records of the plant associations call attention, is the fact that the sand ridges nearest the bay have simpler plant associations with fewer species than those more remote and that even the same ridge, if it is not so accessible to a varied flora in one part as another, will have a larger number of species on the most accessible part than on that farther away. This is especially well shown in the list of species found on the outer dune line at Fish Point, as compared with that 3 miles farther south, where the islands bring the forest flora much nearer the shore.

With these preliminary remarks the following typical plant associations are presented:

Mesophytic type of forest. A beech and maple woodlot in Aimer township. This area was somewhat disturbed by the removal of some of the older trees for timber and firewood, and by having from time to time served for pasture. The damage done by cattle was not large, however, as the number pastured had evidently been small in proportion to the amount of food available and many parts of the area were in practically an undisturbed condition. The removal of some of the large trees had had the effect of encouraging the reproduction of some species by giving an abundance of light and young trees were more numerous and more vigorous than in the undisturbed forest.

The dominant species were the hard maple, *Acer saccharinum*, Wang., beech, *Fagus ferruginea*, Ait, white pine, *Pinus Strobus*, L., American elm, *Ulmus Americana*, L,. black cherry, *Prunus serotina*, Ehrh., hop hornbeam, *Ostrya Virginica*, Willd., basswood, *Tilia. Americana*, L., hemlock, *Tsuga Canadensis*, Carr., and white birch, *Betula papyrifera*, Marshall. The old trees were chiefly maples and beeches, but mixed with them there were a few tall, old. white pines, three feet or more in diameter four feet; from the ground, and numbers of stumps of the same species. A freshly cut stump of this species, cut off three feet from the ground was 33 inches in diameter inside the bark, and had 120 rings, outside of a hollow 1½ inches wide in the center, so that the age of the tree was not far from 150 years when it was cut two or three years before. In open spots were large numbers of young pines which, however, formed dense clumps even in the shade of the maples. These young trees were 20 to 30 feet high and were making good growth in spite of the shade. With them were also young hemlocks and, in places where the conifers were not too dense, very numerous young hard maples, while young beeches were rather infrequent.

Seedlings of the white oak, *Quercus alba*, L., white ash, *Fraxinus Americana*, L., red maple, *Acer rubrum* L., and more rarely of the red oak, *Quercus rubra* L., and of the swamp white oak, *Quercus bicolor*; Willd. were also seen occasionally.

Associated with these forest trees were many lesser plants, shrubs and herbs, most of them characterized by their broad thin leaves, and spreading branches which may be considered as adaptations to suit the plants to the dim light under the canopy of the dense crowns of the broad leaved trees. Some of the most common of these shade loving species were the mandrake, or May apple, *Podophyllum peltatum*, L., wild sarsaparilla, *Aralia nudicaulis*, L., sweet cicely, *Osmorrhiza brevistylis*, DC., wild geranium, *Geranium maculatum*, L., early meadow rue, *Thalictrum dioicum*, L., partridge berry, *Mitchella repens*, L., wild liquorice, *Galium circaezans*, Michx., Hepatica, *Hepatica acutiloba*, DC., sweet-scented bed-straw, *Galium triflorum*, Michx., blood-root, *Sanguinaria Canadensis*, L., golden rod, *Solidago latifolia*, L., wild ginger, *Asarum Canadensis*, L., small wild strawberry, *Fragaria vesca*. L. avens, *Geum album*, Gmelin., small enchanter's nightshade, *Circaea alpina*. L.. white snakeroot, *Eupatorium ageratoides*, L.f. common blue violet, *Viola palmata*, L., var. *cucullata*, Gray, wild lily of the valley, *Maianthemum Canadensis*. Desf., sedges, *Carex communis*, Bailey, *Cares gracillima*, Schwein. A few shrubby plants were also growing in the woodlot, but some of these were clearly just beginning to occupy the small clearings and open spots. The most abundant species were the thorns, *Crataegus Spp*., the red raspberry, *Rubus strigosus*, Michx., which were numerous In open spots, the elderberry, *Sambucus Canadensis*, L., was found as seedling plants near the paths, while another shrub, the leatherwood, *Dirca palustris*, L., grew in the deeper shadows. The Virginia creeper, *Ampelopsis quinquefolia*, Michx., was a representative of the climbing plants, that by the aid of their short tendrils are able to climb into the tops of the trees and there spread. their leaves in better light than was available on the ground below. Several ferns, characteristic plants of the mesophytic forest associations grew in profusion in the moist rich shaded soil, and included the maidenhair fern, *Adiantum pedatum*, L., the Christmas fern, *Aspidium achrostichoides*, Swartz., the crested shield fern, *Aspidium cristatum*, Sw., the spinulose wood fern, *Aspidium spinulosum* Swartz, the sensitive fern, *Onoclea sensibilis*, L., the common brake, *Pteris aquilina*, L., and the rattlesnake fern, *Botrychium Virginianum*, Swartz.

One other flowering plant grew here that merits special notice, since it was one of the peculiar degenerate plants that had lost the green leaves and with them the power of carbon assimilation possessed by most plants and was parasitic on the roots of the beech. This was the peculiar brownish beech drops or cancer root, *Epiphegus Virginiana*, Bart., which could grow in abundance in the densest shade of the beeches, because it had no need for light.

The soil in which this association of plants grew was clayey loam which was covered in undisturbed places with a two-inch layer of black humus, on top of which, to further add to its water-holding power was a covering of fallen leaves.

In another pastured wood lot in Akron township a mile north and a quarter of a mile west of Unionville a similar association was noted. The wood lot was a part of the old forest and had not been cut into enough to destroy the balance of the species as they had established themselves, after a long struggle for supremacy. The growth was a dense one lying on a slight elevation, and running down into the clayey valley of Craugan creek. At the top of the low, flat ridge the dominant trees were: Hard maple, *Acer saccharinum*, Wang., and beech, *Fagus ferruginea* Ait., while on the slope and at the foot of it were the following species: Red oak, *Quercus rubra*, L., white oak, *Quercus alba*, hop-hornbeam, *Ostrya Virginica*, Willd., common thorn, *Crategus sp*., prickly ash, *Xanthoxylum Americanum*, Mill., white elm, *Ulmus Americana*, L., black cherry, *Prunus serotina*, Ehrh., cottonwood, *Populus monilifera*, Ait, white ash, *Fraxinus Americana*, L., shadbush, *Amelanchier Canadensis*, slippery elm, *Ulmus fulva*, Michx., black ash, *Fraxinus sambucifolia*, Lam. In the clayey stream bottom, besides the elms and the cottonwoods, were the bur oak, *Quercus macrocarpa*, Michx., the swamp white oak, *Quercus bicolor*, Willd.. and the butternut, *Juglans cinerea*, L. The herbs noted here were wild liquorice, *Galium circaezans*, Michx., rattlesnake root, *Prenanthes altissima*, L., wild aster, *Aster paniculatus*. Lam., self heal, *Brunella vulgaris*, L., fire weed, *Erechtites hieracifolia*, Raf., besides a scant growth of sedges and. grasses.

A plant association on the old dune line near the county line road between Tuscola and, Huron counties, north of Unionville. The trees here were red, white, black and swamp white oaks, *Quercus rubra*, L., *Q. alba*, L., *Q, coccinea*, Wang., var. *tinctoria*, Gray, and *Q. bicolor*, Willd., white ash, *Fraxinus Americana*, L., black ash, *F. sambucifolia*, Lam., young white pine, *Pinus Strobus* L., American elm, *Ulmus Americana*, L., red, or slippery elm, *Ulmus fulva*, Michx., shadbush, *Amelanchier Canadensis*, T. & G., black cherry, *Prunus scrotina*, Ehrh., thorn tree, *Crataegus tomentosa*, L., and wild crabapple, *Pyrus coronaria*, L. The shrubs noted here were prickly ash, *Xanthoxylum Americanum*, Mill., sweet wild rose, *Rosa blanda*. Ait., high bush blackberry, *Rubus villosus*. Ait., black raspberry, *Rubus occidentalis*, L., red raspberry, *Rubus strigosus*, Michx., witch hazel, *Hamamelis Virginiana*, L., round-leaved and silky cornels, *Cornus circinnata*, L'Her., and *C. sericea*, L., and the wild grape, *Vitis riparia*, Michx. The herbs accompanying these were equally mixed in their relationship to habitat but were, however on the whole, those of the mesophytic forest, adapted to endure, or to need shading and moist soil. The more prominent species were wild columbine, *Aquilegia Canadensis*, L., small flowered crowfoot, *Ranunculus abortivus*, L., hooked crowfoot, *Ranunculus recurvatus*, Poir., early meadow rue, *Thalictrum dioicum*, L., mandrake or May apple, *Podophyllum peltatum*, L., blue violet, *Viola palmata*, L., var. *cucullata*, Gray., chickweed, *Stellaria media*, Smith, wild geranium, *Geranium maculatum*, L., wild strawberry, *Fragaria vesca*, L., and *F. Virginiana*, Mill., common agrimony, *Agrimonia Eupatoria*, L., and many flowering agrimony, *A. parviflora*, Ait., common cinquefoil, *Potentilla Canadensis*, L., small enchanters nightshade, *Circaea alpina*, L., common enchanter's nightshade, *Circaea Lutetiana*, L., sweet cicely, *Osmorrhiza brevstylis*, DC., black snakeroot, *Sanicula Marylandica*, L., northern bedstraw, *Galium boreale*, L., three flowered bedstraw *Galium triflorum*, Michx., fleabane, *Erigeron annuus*, Pers., and daisy fleabane, *Erigenon Philadelphicus*, L., shin leaf, *Pyrola elliptica*, Nutt., catnip, *Nepeta cataria*, L., wild lily of the valley, *Maianthemum Canadense*, Desf., false Solomon's seal, *Smilacina racemosa*, Desf., carrion flower, *Smilax herbacea*, L., trillium, *Trillium grandiflorum*, Salisb, sedges, *Carex rosea*, Schkuhr. *C. Deweyana*, Schwein, *C. straminea*, Willd., and the June grass, *Poa pratensis*, L.

A swamp conifer association was noted in the northeast part of Aimer township, in the last remnant of what had formerly been a cedar or arbor vitae swamp of considerable size. When visited the ground was not wet and swamp conditions no longer existed. The trees noted were arbor vitae, *Thuya occidentalis*, L., tamarack, *Larix Americana*, Michx., black ash, *Fraxinus sambucifolia*, Lam., red maple, *Acer rubrum*, L., American elm, *Ulmus Americana*, L., and aspen, *Populus tremuloides*, Michx. With these species grew the shrubs, smooth sumac, *Rhus glabra*, L., willows, *Salix spp.*, alder, *Alnus incana*, Willd., winter berry, *Ilex verticillata*, Gray, common elder, *Sambucus Canadensis*, L., red osier dogwood, *Cornus stolonifera*, Michx., and black raspberry, *Rubus occidentalis*, L. The herbaceous plants were wild strawberry, *Fragaria vesca*, L., Joe Pye weed, *Eupatorium purpureum*, L., throughwort, *Eupatorium perfoliatum*, L., *Aster sp*., golden rods, *Solidago Canadensis*, L., and *S. rugosa*. Mill., common milkweed, *Asclepias Cornuti*, DeCaisne, swamp milkweed, *Asclepias incarnata*, L., vervain, *Verbena hastata*, L., bugle weed, *Lycopus Virginicus*, L., June grass, *Poa pratensis*, L., red top, *Agrostis alba*, L., meadow muhlenbergia, *Muhlenbergia Mexicana*, Trin., royal fern, *Osmunda regalis*, L., and marsh shield-fern, *Aspidium Thelypteris*, Swartz.

Swamp type of forest. As conditions were most favorable for the study of the hydrophytic type of forest in Akron township and especially since the contiguity of this type of forest and the open prairies made their examination most interesting to the student of plant distribution, several studies were made in then uncleared areas northwest of Unionville where the land was still incompletely drained. These woods were not quite in their original condition because they had been used for pasture, but because the density of the crown cover of the trees was so great there was but little temptation for cattle to go into them except for shade. The trees had not been thinned, and were crowded in a rather dense stand. The following species were dominant: White, slippery and rock elms, *Ulmus Americana*, L., *U. fulva*, Michx., *U. racemosa*, Thomas, cottonwood, *Populus monilifera*, Ait., bur, swamp—white and red oaks, *Quercus macrocarpa*, Michx., *Q. bicolor*, Willd., *Q. rubra*, L., black and white ash, *Fraxinus sambucifolia*, Lain., and *F. Americana*, L., white maple, *Acer dasycarpum*, Ehrh., basswood, *Tilia Americana*, L., white birch, *Betula papyrifera*, Marshall, butternut and black walnut, *Juglans cinerea*, L., and *J. nigra*, L., shagbark hickory, *Carya alba*, Nutt, black maple, *Acer saccharinum*, Wang., var. *nigrum*, T. & G., black willow, *Salix nigra*, Marsh, and blue beech, *Carpinus Caroliniana*, Walt. The shrubs, noted here were gooseberry, *Ribes oxyacanthoides*, L., red currant, *Ribes rubrum*, L., and prickly ash, *Xanthoxylum Americanum*, Mill. The herbs were found chiefly in small openings in the wood around places so poorly drained that pools of water stood in them until late in the summer; besides there were scattered clumps of grass and sedges, and sparse, broad-leaved, herbaceous plants in the shade of the trees and often growing best on the low elevations formed around their roots. The most abundant herbs noted in the openings were smartweed, *Polygonum hydropiper*, L., false nettle, *Boehmeria cylindrica*, Willd., plantain, *Plantago Rugellii*, Decaisne, blue flag, *Iris versicolor*, L., beggar-ticks, *Bidens frondosa*, L., bugle weed, *Lycopus Virginicus*, L., nightshade, *Solanum nigrum*, L., selfheal, *Brunella vulgaris* L., wild strawberry, *Fragaria Virgina*, Mill., wild aster, *Aster sp*., and bittersweet, *Solanum Dulcamara*., L. A wild grape, *Vitis riparia*, Michx., the poison ivy, *Rhus toxicodendron*, L., and Virgin's bower, *Clematis Virginiana*, L., were also noted climbing the trees and over shrubs.

The tension zone, between marshy treeless prairie and heavy swamp forest was, as has been stated, very narrow, and the grass land came close up to the forest with practically no intergrading area. In one of the places northwest of Unionville where the timber line was examined, the woods covered a low sandy ridge rising two or three feet above the marsh level, with a pebbly clay below. The ridge was one of the ancient shore lines of the bay and was covered with red, white and bur oaks, *Quercus rubra*, L., *Q. alba*, L., and *Q. macrocarpa*, Michx., basswood, *Tilia Americana*, L., and among these a single small white pine, *Pinus Strobus*, L. On either side of the ridge the forest was made up of white elm, *Ulmus Americana*, L., black ash, *Fraxinus sambucifolia*, Lam., white or soft maple, *Acer dasycarpum*, Ehrh., shagbark hickory, *Carya alba*, Lam., and basswood, *Tilia Americana*, L., with an undergrowth of shrubs including the blue beech, *Carpinus Caroliniana*, Walt., swamp wild rose, *Rosa Carolina*, L., prickly ash, *Xanthoxylum Americanum*, Mill., elder, *Sambucus Canadensis*, L., round-leaved dogwood, *Cornus circinnata*, L'Her., and young arbor vitae, *Thuya occidentalis*, L. The characteristic herbs of the association were small-flowered crowfoot, *Ranunculus abortivus*, L., blue violet, *Viola palmata*, L., var. *cucullata*. Gray, yellow violet, *Viola pubescens*, Ait., wild geranium, *Geranium maculatum*, L., wild aster, *Aster macrophyllus*, L., and *A. paniculatus*. Lam., several species of sedges, *Carex spp*., selfheal, *Brunella vulgaris*, L., Wild liquorice, *Galium circaezans*, Michx., night shade, *Solanum nigrum,* L., and rattlesnake root, *Prenanthes altissima*, L. These plants are called characteristic because they usually form a part of the plant associations, growing in rich moist soil under the shade of dense tree growth; a. few of the species mentioned grow in the open when the conditions are favorable.

Marshward of the margin of the woods, was another low sandy ridge somewhat lower than the one just described, probably not exceeding 3 feet above the marsh at its highest point and having sedgy areas oil both sides. Here the trees were much less numerous and formed groves, while shrubs constituted an important part of the plant association; the herbaceous plants were chiefly species that are seldom, if ever, found growing in moist shady places.

The trees noted were growing along the broad low top of the ridge and some of them were of large size, 2½ to 3½ feet through. The largest trees were bur oaks, *Quercus macrocarpa*, Michx., and black oaks, *Quercus coccinea*, Wang., var. *tinctoria*, Gray. Other trees were white oak, *Quercus alba*, L., at the top of the ridge, and aspen, *Populus tremuloides*, Michx., and black willow, *Salix nigra*,. Marsh., near the prairie level. There were also numbers of young ashes, elms and white birches along the edge of the prairie where the sand ran down into the muck. The shrubs, which formed thickets of considerable extent, were staghorn sumach, *Rhus typhina*, L., red osier dogwood, *Cornus stolonifera*, Michx., panicled dogwood, *Cornus paniculata*, L'Her., low willow, *Salix humilis*, Marsh., huckleberry, *Gaylussacia resinosa*, T. & G., low blue berry, *Vaccinium Pennsylvanicum*, Lam., scarlet fruited thorn, *Crataeous coccinea*, L., black raspberry, *Rubus occidentalis*, L., frost weed, *Helianthemum Canadense*, L., in dry sandy soils that constitute its usual habitat.

Other herbaceous plants found in the plant association under discussion, were the smooth aster, *Aster laevis*, L., low golden rod, *Solidago nemoralus*, Ait., wild bergamot, *Monarda fistulosa*, L., wild strawberry, *Fragaria Virginians*, Mill., many flowered agrimony, *Agrimonia parviflora*, Ait., fern-leaved foxglove, *Gerardia pedicularia*. L., yarrow, *Achillea millefolium*, L., yellow pimpernel, *Pimpinella integerrima*, Gray, hog peanut, *Amphicarpaea monoica*, Nutt., and colonies of rush, *Juncus Balticus*, Dethard, var. *littoralis*, Engelm. This, and the silverweed, are usually characteristic plants of the associations found along the strand just above the high water mark, and their presence so far from the present shore is worthy of remark, and may be taken as an indication that the conditions existing on the abandoned shore lines are comparable with those of the present day.

Intermediate association. At the base of the ridge was a zone of soil rich in organic matter, but slightly higher than the general prairie level, in which an association of plants had developed of quite different aspect from that on the ridge. The trees were entirely wanting, or represented by very young specimens of swamp species, and shrubs were not common, although the red osier dogwood, *Cornus stolonifera*, Michx., and panicled cornel, *Cornus paniculata*, L'Her., were growing in the more open, sterile places on the highest parts of the ridge, with the pin weed, *Lechea major*, Michx., and the sweet wild rose, *Rosa blanda*, Ait. On the gentle slopes grew dense patches of the shrubby cinquefoil, *Potentilla fruiticosa*, L., while the grape, *Vitis riparia*, Michx., and Virginia creeper, *Ampelopsis quinquefolia*, Michx., in some places festooned the trees and bushes.

The ground was covered with a thin turf of dry ground sedges and grasses, which grew in tufts or bunches after the habit of the xerophytic species of these types. The grasses noted were Canadian blue grass, *Poa compressa*, L., the wild oat grass, *Danthonia spicata*, Beauv., *Koeleria cristata*, Pers., and the forked beard grass, *Andropogon furcatus*, Muhl. There were also considerable patches of the silver weed, *Potentilla Anserina*, L, with its fern-like leaves densely covered with shining white hairs on both surfaces where it grew exposed to the full light of the sun, but in places where it was shaded the upper surfaces of the leaves were distinctly greener and less hairy. The dense white tomentum or silky hairs covering the leaves of this plant are apparently an adaptation to enable it to live in the exposed situations. The hairy covering of the leaves entangles the air, which acts as a blanket and becoming saturated with moisture prevents excessive transpiration, as well as tempers the heat and light which pours down upon the plant in the entirely unshaded places in which it usually lives.

Many plants growing in very dry exposed situations have similar hairy coverings to leaves and steins and this is perhaps the most common and easily recognized adaptation to the xerophytic habitat. Low willows, *Salix spp*., and the shrubby cinquefoil, *Potentilla fruticosa*, L., occurred in the zone.

Herbs were the dominant plants here, as elsewhere on the prairies, many of them tail, branching, strong-growing plants quite different in habit of growth from the forms found on the top of the ridge or in the shade of the mesophytic and low ground forests already described. Here grew the tall sunflower, *Helianthus giganteus*, L., several golden-rods, *Solidago Canadensis*, L., *S. Ohioensis*, Riddell, *S. Riddelli*, Frank., and *S. serontina*, Ait., thoroughwort, *Eupatorium perfoliatum*, L., purple-stem aster, *Aster puniceus*, Ait., sneeze-weed, *Helenium autumnale*, L., blazing star, *Liatris spicata*, Willd., black-eyed Susan, *Rudbeckia hirta*, L., grass of Parnassus, *Parnassia Caroliana*, Michx., tall meadow rue, *Thalictrum purpurascens*, L., wild bergamot, *Monarda fistulosa*, L., New England aster, *Aster Novae-Angliae*, L., fringed gentian, *Gentiana crinita*, Froel., self heal, *Brunella vulgaris*, L., blue flag, *Iris versicolor*, L., bindweed, *Convolvulus sepium*, L., purple gerardia, *Gerardia purpurea*, L., var. *paupercula*, Gray, purple loose strife, *Lythrum alatum*, Pursh., silver weed, *Potentilla Anserina*, L., nerved manna grass, *Glyceria nervata*, Trin., and a few other grasses, and the marsh shield fern, *Aspidium Thelypteris*, Swartz.

A small area of sandy soil in the prairie at some distance from the edge of the forest was found to have but a slight elevation, 1 to 2 feet, above the general level, but was an excellent example of the small islands that are scattered over the prairies as already described. There were but two trees of any size, both black oaks, *Quercus coccinea*, Wang., var. *tinctoria*, Gray, about 2 feet in diameter, although there were large numbers of small oaks, as well as young aspens, *Populus tremuloides*, Michx., and willows, *Salix spp*.

A number of species of shrubs grew here including the red osier dog-wood, *Cornus stolonifera*, Mx., panicled cornel, *Cornus paniculata*, L'Her., service berry, *Amelanchier Canadensis*, T. & G., sheep berry, *Viburnum Lentago*, L., choke cherry, *Prunus Virginiana*, L., sweet wild rose, *Rosa blanda*, Ait., tall blackberry *Rubus villosus*, Ait., running blackberry, *Rubus Canadensis*, L., dwarf cherry, *Prunus pumila*, L., and shrubby cinquefoil, *Potentilla fruticosa*, L. A notable thing about all these shrubs with the exception of the last is the fact that they have edible fruits, or at least such as are attractive to birds, which accounts in a very large measure for their presence on the island, since in the marshy parts of the prairies are the breeding places of great numbers of redwing and crow blackbirds, as well as the haunts of great flocks of crows in the fall and spring. It is well known that the redwing blackbird after the breeding season gathers in flocks and lives largely on the fruits of shrubs of species found on this and similar islands, and the fact that the trees and shrubs on the islands serve as their resting places accounts in large measure for the abundance of the fruit-bearing shrubs in such places, and especially of those with seeds having a hard resistant seed coat.

The herbaceous plants found on this island were round-headed bush clover, *Lespedeza capitala*, Michx., hawkweed, *Hieracium Canadense*, Michx., wild bergamot, *Monarda fistulosa*, L., goldenrods, *Solidago nemoralis*, Ait., *S. lanceolata*, L., and *S. Canadensis*, L., prairie dock, *Silphium terebinthinaceum*, L., smooth aster, *Aster laevis*, L., yarrow, *Achillea Millefolium*, L., plantain-leaved ever-lasting, *Antennaria plantaginifolia*, Hook., black-eyed Susan, *Rudbeckia hirta*, L., strawberry, *Fragaria Virginiana*, Mill., tall sunflower,, *Helianthus giganteus*, L., blazing star, *Liatris spicata*, Willd., tall meadow-rue, *Thalictrum purpurascens*, L., tick trefoil, *Desmondium Canadensis*, D. C., Kentucky blue grass, *Poa pratensis*, L., Canadian blue grass, *Poa* *compressa*, L., rough hair grass, *Agrostis scabra*, Willd., tall panic grass, *Panicum virgatum*, L.. fresh water cord grass, *Spartina cynosuroides*, Willd., Indian grass, *Chrysopogon nutans*, Benth., forked beard grass, *Andropogon furcatus*. Muhl., and blue joint grass, *Calamagrostis Canadensis*, Beauv.

It will be noted that there is a considerably larger number of grasses present in this association than in any of the others described. This was apparently due to the nearness of the entire surface to the level of the prairie and to the fact that the area was only slightly shaded, so that the grasses had not been displaced of other plants more tolerant of shade.

In the vicinity where these observations were made, drained parts of the prairie became quickly covered by thickets of aspens, *Populus tremuloides*, Michx., and willows, *Salix spp*., while in the ridges of earth thrown out from, the ditches the white elm, *Ulmus Americana*, L., and the black ash, *Fraxinus sambucifolia*, Lain., often appeared in great numbers, and even more quickly these banks grew up to a dense growth of goldenrods, *Solidago spp*., asters, *Aster spp*., thoroughwort and Joe-pye weed, *Eupatorium perfoliatum*, L., and *E. purpureum*, L., and milkweeds, *Asclepias spp*. as tall as a man's head. Areas that had been drained and plowed also became covered by similar temporary associations, which eventually would be displaced by more stable tree growths.

On another island a long distance out in the prairie, the basswood, *Tilia Americana*. L., and white elm, *Ulmus Americana*, L., were the principal old trees, with a single black ash, *Fraxinus sambucifolia*, Lam.; associated with these was a growth of sumach, *Rhus typhina*, L., and the cock-spur and scarlet-fruited thorns, *Crataegus Crus-galli*, L., and *C. coccinea*, L. var. *macracantha*, Dudley, one tree of the former species being 38 inches in circumference 2 feet above the ground, which is very large for a thorn tree. Another shrub noted here was the red osier dogwood, *Cornus stolonifera*, Michx. The herbs seen were June grass, *Poa pratensis*, L., yarrow, *Achilles Millefolium*, L., blue vervain, *Verbena hastata*, L., Canada golden rod, *Solidago Canadensis*, L., common mullein, *Verbascum Thapsus*, L., the tall thistle, *Cnicus altissimus*, Willd., var. *discolor*, Gray, Canada thistle, *Cnicus arvensis*, Hoffm., and pasture thistle, *Cnicus lanceolatus*, Hoffm., white basil, *Clamintha clinopodium*, Benth., tall sunflower, *Helianthus giganteus*, L., silver weed, *Potentilla Anserina*, L.

Still another island one mile north of the south line of the upper half of Akron township had a large area and there was a good grove of the following trees growing on it; bur oak, *Quercus macrocarpa*, Michx., white oak, *Quercus alba*, L., swamp white oak, *Quercus bicolor*, Willd., red oak, *Quercus rubra*, L., black oak, *Quercus coccinea*, Wang., var. *tinctoria*, Gray, white elm, *Ulmus Americana*, L., white ash, *Fraxinus Americana*, L., aspen, *Populus tremuloides*, Michx., cottonwood, *Populus monilifera*, Ait., and thorn trees, *Crataegus spp*. Below these and in the open spaces between the groups of trees were thickets of shrubs, among which the most important were panicled cornel, *Cornus paniculata*, L'Her., the red osier dogwood, *Cornus stolonifera*, Michx., the silky cornel, *Cornus sericea*, L., sumach, *Rhus glabra*, L., elder, *Sambucus Canadensis*, L., common hazel, *Corylus Americana*, Walt., swamp wild rose, *Rosa Carolinina*, L., and the sheep berry, *Viburnum Lentago*, L. There were also numbers of grape vines, *Vitis riparia*, Michx., either clambering over the shrubs or climbing high into the trees. A much greater variety of herbs were noted here than in either of the other island associations, the most abundant of which were iron weed, *Vernonia altissima*, Nutt. var. *grandiflora*, Nutt., prairie dock, *Silphium terebinthinaceum*, L., mountain mint, *Pycnanthemum lanceolatum*, Pursh. swamp lousewort, *Pedicularis lanceolata*, Michx., *Aster junceus*, Ait., *Aster laevis*, L., *Aster Novae-Angliae*, L., low golden rod, *Solidago nemoralis*, Ait, tall lettuce, *Lactuca hirsuta*, Muhl., tall sunflower, *Helianthus giganteus*, L., closed gentian, *Gentiana Andrewsii*, Griseb., wild bergamot, *Monarda fistulosa*, L., hog peanut, *Amphicarpœa monoica*, Nutt., agrimony, *Agrimonia Eupatoria*, L., wild geranium, *Geranium maculatum*, L., pearly everlasting, *Anaphalis margaritacea,* Benth. and Hook., tall anemone, *Anemone Virginia*, L., columbine, *Aquilegia Canadensis*, L., grasses and sedges and common brake, *Pteris aquilina*, L.

It will be seen by comparing this list with those made in the same type of habitat at other points that the species are nearly the same, the chief difference being that the larger area has a more extensive series of plants, as might be expected.

Prairie Associations. In the broad area of marshy prairie forming the northern part of Akron township, the following notes were made. The upper levels that could be considered as a part of the prairie were covered with silver weed, *Potentilla Anserina*, L., low golden rod, *Solidago nemoralis*, Ait., rush, *Juncus Balticus* Dethard, var. *littoralis*, Engelm., red top, *Agrostis alba*, L., June grass, *Poa pratensis*, L. This, level was so little above the prairie proper that the line of change was expanded into a broad zone in which plants of both habitats intermingled and in about equal numbers. In what was undoubtedly the prairie association the most conspicuous plants were the blazing star, *Liatris spicata*, Willd., sneeze weed, *Helenium autumnale*, L., asters, *Aster junceus*, Ait., *A. Novæ-Angliae*, L., self heal, *Brunella vulgaris*, L., bugle weed, *Lycopus sinuatus*, Ell., basil, *Pycnanthemum lanceolatum*, Pursh., narrow leaved golden rod, *Solidago lanceolata*, L., rush, *Juncus nodosus*, L. var. *megacephalus*, Torr., Canadian June grass, *Poa compressa*, L., red top, *Agrostis alba*, L., sedges, *Carex spp*., spike rush, *Eleocharis spp*., and the shrubby cinquefoil, *Potentilla fruticosa*, L. The level slightly lower or less drained than this was a grassy marsh in which blue joint grass, *Calamagrostis Canadensis*, Beauv., fresh water cord grass, *Spartina cynosuroides*, Willd., a panic grass, *Panicum sp.*, sedges, *Carex spp.*, spike rush, *Eleocharis spp.*, rushes, *Juncus nodosus*, L., and *Juncus Canadensis*, J. Gay., narrow-leaved golden rod, *Solidago lanceolata*, L., Indian hemp, *Apocynum cannabinum*, L., and purple loosestrife, *Lythrum alatum*, Pursh, were the characterizing plants.

A sandy ridge running across this lower area was from 12 to 18 inches above the marsh level and was well turfed with Canadian blue grass, *Poa compressa*, L., and red top, *Agrostis alba*, L., while growing with the grasses were the low golden rod, *Solidago nemoralis*, Ait., very abundant, ladies tresses, *Spiranthes cernua*, Richard, rush, *Juncus Balticus*, Dethard, var. *littoralis*, Engelm., wild rose, *Rosa humilis*, Marsh., shrubby cinquefoil, *Potentilla fruticosa*, L., Florida milkweed, *Acerates longifolia*, Ell., purple gerardia, *Gerardia purpurea*, L. var. *paupercula*, Gray, and small St. John's wort, *Hypericum Canadense*, L.

Intruding into this association as indicated by the limited areas occupied and the small size of the plants, were the fresh water cord grass, *Spartina cynosuroides*, Willd., tall panic grass, *Panicum virgatum*, L., Canada thistle, *Cnicus arvensis*, Hoffm., the staghorn sumach, *Rhus typhina*, L., wild strawberry, *Fragaria Virginiana*, Mill., basil, *Pycnanthemum lanceolatum*, Pursh., and the Indian grass, *Chrysopogon nutans*, Benth. Along the borders of the marsh was a faintly defined zone in which the white heath aster, *Aster ericoides*, L., was a common plant, while in the slightly wetter marsh along the sides of this ridge there were added to the association the sedges, *Carex flava*, L. var. *viridula*. Bailey, and *Seleria verticillata*, Muhl., rush, *Juncus sp*., Kahn's lobelia. *Lobelia Kalmii*, L., fringed gentian, *Gentiana crinita*, Froel, silver weed, *Potentilla Anserina*, L. sneeze weed, *Helenium autumnale*, L., very abundant, rough hair grass, *Agrostis scabra*, Willd., panic grass, *Panicum scoparium*, Lam., a few plants of marsh coreopsis, *Coreopsis trichosperma*, Michx., var. *tenuiloba*, Gray, purple gerardia, *Gerardia purpura*, L. var. *paupercula*, Gray, here very abundant, and the mermaid weed, *Proserpinaca palustris*, L. The presence of the last named species shows conclusively that in the zone where it grew wet marsh or shallow water conditions prevail during the early part of the growing season, as the plant is a semi-aquatic or palustrine species and may be seen in the early summer standing half submerged in the shallow water in which it grows, and on examination the submerged leaves will be found to be finely dissected, while those above the water are merely toothed along the edges; apparently these differences in leaf form are adaptation to enable the plant to live in the peculiar habitat in which it grows.

A vertical section cut in the bank of a ditch in the vicinity where the last given plant association was found showed:

Turf of matted rootstocks and roots	6 to 8 inches.
Stiff bouldery clay till to bottom of ditch	2 ft. 6 inches.

Water level in September about two feet below the ground surface but the ditch had been dry during the summer as shown by the condition of the bottom; surface of the soil wet.

The rootstocks of the lake bulrush, *Scirpus lacustris*, L., were common in the turf, but the plant was only sparingly present on the marsh, at the time it was visited, clearly indicating that there had been a change from wet to dryer conditions.

The wetter parts of the marsh in this vicinity were covered by a dense growth of the slender sedge, *Carex filiformis*, L., or where it was slightly less wet, a mixture of this plant and blue joint, *Calamagrostis Canadensis*, Beauv., and where there was more water the lake bulrush took the place of the blue joint.

Some interesting observations were made in the shallow bay 6 inches to 1½ feet deep, where crossed between Fish Point and the main shore, and along the dunes forming the point southward nearly to Bay Park, and in the course of the examination the sequence of plants in occupying newly available ground space was worked out.

In the water was a quite dense growth of lake bulrush, *Scirpus lacustris*, L., growing a long distance out into the bay, while nearer shore the species was mixed with the three square, *Scirpus pungens*, Vahl., another bulrush which formed a nearly pure growth in the shallower parts of the small inlet.

Growing in the water below the taller plants were stoneworts *Chara spp*., and a sparse growth of a small pond weed, apparently a stunted form of *Potamogeton heterophyllus*, Schreb. On approaching the shore on the west side of the inlet it was found that the plants were arranged in zones, or broad belts, beginning several hundred feet from the margin of the dryer part of the marsh. In the water the three square, *Scirpus pungens*, Vahl., gave place to the lake bulrush, *S. lacustris*, L., which in turn was bordered near the shore by a zone of nearly pure twig rush, *Cladium mariscoides*, Torr., and this where the soil was still saturated with water, to a dense broad zone of the tall reed grass, *Phragmites communis*, Trin., growing to a height of more than six feet, and so thickly were the individual plants placed that but little other vegetation was growing in company with it, the only plant at all conspicuous in the zone being the blue joint, *Calamagrostis Canadensis*, Beauv. After passing through the zone of reed grass which extended along the shore as far as it was examined, some hundreds of yards at least, a narrow zone of "islands" of young aspens, *Populus tremuloides*, Michx., and willows, *Salix spp*. that had apparently needed in during the dry period of a few years earlier, when the level of the bay had been more than a foot lower than at the time when these studies were made. Westward of this was a broad sedge marsh extending nearly or quite over to the dune lines along the shore of Fish Point.

The plant covering of this marsh was chiefly the slender sedge, *Carex filiformis*, L., with spaces between the areas of denser growth, that were covered with moss. Other plants were growing scattered over the marsh, often forming small islands in the places where they had become established, or where slight elevations or depressions favored their growth. These plants were small willows, *Salix spp*., three square, *Scirpus pungens*, Vahl., reed grass. *Phragmites communis*, Trin., both scattered and covering large tracts of the marsh; the Canada rush, *Juncus Canadensis*, J. Gay, marsh St. John's-wort, *Elodes campanulata*, Pursh., and bugle weed, *Lycopus sinuatus*, Ell., were frequent but as scattered individuals. On the other hand blue joint grass was quite as common, but grew in islands, that could be distinguished some distance away, as they were approached. Other plants noted as occurring frequently in this association were *Aster paniculatus*, Lam., fire weed, *Erechtites hieracifolia*, Raf., northern willow herb, *Epilobium adenocaulon*, Haussk., marsh bell flower, *Campaula aparinoides*, Pursh., skull cap, *Scutellaria galericulata*, L., and golden rod, *Solidago Canadensis*, L. The soil was wet, soft and spongy over most of the marsh, and the water level was a foot below the surface in the broad ditch across the marsh.

The plants that had established themselves on the bank of earth thrown out from the ditch within a year or two were chiefly weeds or plants of the species which belong to plant associations found on the higher parts of the marsh; one species, *Lobelia Kalmii*, L. was apparently a survival from the time before the ditch was dug but it grew unusually large on the embankment. Other species were bugle weed, *Lycopus sinuatus*, golden rods, *Solidago Canadensis*, L. and *S. lanceolata*, L., ragweed, *Ambrosia artemisiaefolia*, L., fire weed, *Erechtites hieracifolia*, Baf., and blue joint grass, *Calamagrostis Canadensis*, Beauv. The last named species showed considerable adaptability in the degree of wetness which it could endure, but in the places in which the water level was estimated to be from 18 inches to 2 feet below the surface it grew best and most vigorously. In the wet prairie the plants were short and slender and may well have been survivals from the dry time when the level of the bay was lower by more than a foot.

After crossing the marsh and the low sand ridge bordering the main bay, the plant associations of the beach from the water to the dune line was examined and later the relationship between this flora, and that of the dunes and the marshes behind were studied, and many of the species seen were noted. In the water and extending out from the shore a long distance was a growth of lake bulrush, *Scirpus lacustris*, L., and large numbers of its culms, some of which had evidently grown in 4 or 5 feet of water, were piled in windrows along the shore. About the level of. the water both in and out of it were the few flowered spike rush, *Eleocharis pauciflora*, Link., which formed a dense carpet in many places, the little green sedge, *Carex flava*, L. var. *viridula*, Bailey, the arrow grass, *Triglochin palustris*, L., and the rush, *Juncus nodosus*, L. While there were extensive areas where these were the principal plants, there were other -places where they were wanting, or entirely replaced by other species.

The next group of plants of interest was that found about the storm-wave line, where there was an accumulation of drift material, some of which as it decayed added organic matter to the soil. Here were the bugle weed, *Lycopus sinuatus*. Ell., silver weed, *Potentilla Anserina*, L., the rough hair grass, *Agrostis scabra*, Willd., panic grass, *Panicum* scoparium, Lam., narrow leaved golden rod, *Solidago lanceolata*, L., blue vervain, *Verbena hastata*, L., Canada thistle, *Cnicus arvensis*, Hoffm., blue flag, *Iris versicolor*, L., thoroughwort, *Eupatorium perfoliatum*, L., three square, *Scirpus pungens*, Vahl., and here and there a small plant of smooth sumach, *Rhus glabra*, L. This association is manifestly a temporary one, brought together largely by the accumulation of seeds about the storm wave line, by the combined action of the winds and waves. Thus the plants are not especially significant in their grouping, as there was little competition for space, water or light, although an interesting study might be made of the probable way in which these plants established themselves to the exclusion of others whose seeds might have been brought here by the same agencies. The elevation of this wave formed association was about 2 feet above the ordinary water level.

Back of the storm-wave line, in a slight depression, was a more permanent association of plants, but one made up of several types, some of which would certainly become the leading ones if they persisted, since they would eventually become trees. The plants noted in this moist, or in parts wet, depression, were false nettle, *Boehmeria cylindrica*, Willd., fire weed, *Erechtites hieracifolia*, Raf., red osier, *Cornus stolonifera*, Michx., goldenrods, *Solidago Canadensis*, L. and *S. nemoralis*, Ait., touch-me-not, *Impatiens fulva*, Nutt., wild asters, *Aster junceus*. Ait., and *A. Nora-Angliae*, L., marsh coreopsis, *Coreopsis trichosperma*, Michx., var. *tenuiloba*, Gray, wild strawberry, *Fragaria Virginiana*, Mill., silver weed, *Potentilla Anserina*, L., young elms, *Ulmus Americana*, L. and peppermint, *Mentha piperita*, L.

In the marsh shoreward from this area, the following association was found: Twig rush, *Cladium mariscoides*, Torr., spike rush, *Eleocharis pauciflora*, Link., beaked rush, *Rhynchospora capillacea*, Torr., low nut rush, *Scleria verticillata*, Muhl., beach rush, *Juncus Balticus*, Dethard, var. *littoralis*, Engelm., little green sedge, *Carex flava*, L. var. *viridula*, Bailey, marsh spike rush, *Eleocharis palustris*, R. Br., var., *glaucescens*, Gray, marsh arrow grass, *Triglochin palustris*, L., panic grass, *Panicum scoparium*. Lam., Kalm's lobelia, *Lobelia Kalmii*, L., Ohio golden rod, *Solidago Ohioensis*, Griseb., willows, *Salix spp*., shrubby St. John's wort, *Hypericum Kalmianum*, L., purple gerardia, *Gerardia purpurea*, L. var. *paupercula*, Gray, and Aster sp.

Flora of Fish Point. The low wind-formed sand ridge which made up the greater part of the little peninsula distinguished on the map as Fish Point, represents the most recently formed, and at the same time the least disturbed portion of Tuscola county, since it is only accessible by boat, or by a long walk or drive across the prairies and the soft unattractive beach. A distant view of it across the prairies shows only a line of low trees and shrubs, seeming taller than they are because of the entire lack of other objects of known size with which to compare them in the field of view, and doubtless also in the summer time frequently owing to the effects of mirage.

The tree flora at the end of the peninsula is remarkably simple considering the length of time which the land must have been above the water level enough to permit trees to grow on it, and the relatively short distance that very complicated forest associations exist on much the same kind of soil, and where other conditions of growth are not essentially different. Indeed the studies on which this report is based show that the plant associations on the same shore line a few miles south are more complicated and have greater variety of trees and other types of plants than this more isolated area, although the ridges are continuous and in direct line, and there is no apparent difference in their maturity, although of this there can be no certainty because of the nature of the formation. The most acceptible hypothesis to account for few kinds of trees on Fish Point and for two miles south, is that the winds and the birds are the two principal agencies that can deposit seeds on such a place where they have a chance to grow. The waves and currents doubtless bring seeds of some species of trees that germinate in places where they are unable to establish themselves. The considerable distances across the bay, however, and the thick growth of bulrushes in shallow water probably, reduce the number of such seeds that reach the shore with vitality enough to grow, while the infrequency at the right season of the year of winds from the east, having force enough to blow the heavier kinds of seeds such a distance, accounts for the failure of the invasion of trees from the swamp and mesophytic forests east of the prairies.

The trees which were found on Fish Point and the low dunes for at least a mile south of it were the cottonwood, *Populus monilifera*, Ait., balsam poplar, *Populus balsamifera*, L., aspen *Populus tremuloides*, Michx., and two native tree willows, *Salix amygdaloides*, Anders, and *S. nigra*, Marsh, and the white ash, *Fraxinus Americana*, L. The last named species was producing seed, and many seedlings and young trees were seen in the neighborhood of the older trees. This was the only species whose seeds could not have easily been brought by the winds from long distances, but it is not impossible the species was introduced by the winds, because its seeds remain on the trees until winter, and might easily have drifted and been blown across the prairies, or across the bay on the ice, or crusted snow by some winter-gale.

The following shrubs were found here: Staghorn sumach, *Rhus typhina*, L., panicled cornel, *Cornus paniculata*, L'Her., dwarf cherry, *Prunus pumila*, L., sweet wild rose, *Rosa blanda*, Ait., and willows, among which was the prairie willow, *Salix humilis*, Marsh.

Woody vines were noted on the lakeward face and top of the dune line, which was low, seldom reaching a height of more than 8 or 10 feet, and sometimes less than 6 feet, as follows: running blackberry, *Rubus Canadensis*, L., wild grape, *Vitis riparia*, Michx., climbing bitter sweet. *Celastrus scandens*, L., poison ivy, *Rhus Toxicodendron*, L., all of which were found commonly present for a mile or more south from Fish Point. The shrubs were accompanied on the lakeward face of the dune, by a number of grasses and other herbaceous plants, frequenting dry ground, and a few of these were characteristic sand dune plants. The common grasses found were the forked beard grass, *Andropogon furcatus*, Muhl., fresh water cord grass, *Spartina cynosuroides*, Willd., wild rye, *Elymus Canadensis*, L., tall panic grass, *panicum virgatum*, L., and the sea sand-reed, or dune grass, *Ammophila arundinacea*, Host., a plant found on the exposed sand beaches and dunes of the shores of the Atlantic ocean in Europe and America, as well as those of the Great Lakes, and a most important agent in keeping the sand back of the beach from blowing, and in building the dunes. Associated with the grasses, which grew chiefly in stools or isolated clumps, were other herbs, the most abundant and characteristic of which were the wormwood, *Artemisia caudata*, Michx., a common dune plant, but growing in sandy soil elsewhere, *Potentilla Anserina*, L., both of which are conspicuous for their silky, hairy covering, which as already noted, is a protection against loss of moisture from the transpiring surfaces.

Two herbaceous vines are common, spreading out in wide patches over the sand, or climbing over the shrubs, the hog peanut, *Amphicarpœa monica*, Nutt., and the wild morning glory, or bindweed, *Convolvulus septum*, L. Other herbs seen were the coast joint weed, *Polygonella articulata*, Meisn., another plant common to both sea coast and the shores of the Great Lakes and adapted by its extensive root system and small thickened leaves to very dry soil conditions, crosswort, *Lysimachia quadrifolia*, L., false Solomon's seal, *Smilacina stellata*, Desf., germander, *Teucrium Canadense*, L., wild bergamot, *Monarda fistulosa*, L., Canada golden rod, *Solidago Canadensis*, L., and two species of scouring rush, *Equisetum hiemale*, L. and *E. arvense*, L.

Plant Associations of the Dunes and Marsh South of Fish Point. On the marshward side of the sand dune ridge the same plants which characterized the bay side were everywhere dominant down to a level about 3 to 4 feet above the level of the marsh at which they were replaced entirely by a zone of tall panic grass, *Panicum virgatum*, L., associated with the forked beard grass, *Andropogon furcatus*, Muhl., and the fresh water cord grass, *Spartina cynosuroides*, Willd. At a level a foot or so lower the panic grass gave place to the *Andropogon furcatus*, with a small admixture of *Spartina cynosuroides*, Willd., and at a slightly lower level, about that of the dryer parts of the marsh, these in turn are replaced by a well marked zone of blue joint grass, *Calamagrostis Canadensis*, Beauv., and golden rod, *Solidago Canadensis*, L., with a. narrow fringe of tall reed grass, *Phragmites communis*, Trin., near the marsh level where the lake bulrush, *Scirpus lacustris*, L., covered the ground. In places along the ridge where they had become established, the zone of Canada golden rod and blue joint grass was found to have some tall bush clover, *Lespedeza polystachya*, Michx., the field thistle, *Cnicus altissimus*, Willd., var. discolor. Gray, the tall sunflower, *Helianthus giganteus*, L., and the fragrant sumach, *Rhus Canadensis*, Marsh. By the orderly arrangement of these plants at definite distances above the level of the marsh, into nearly or quite pure zones there seems plainly indicated their preference for, or tolerance of, certain soil moisture conditions, that they grow best in places where these conditions are most nearly met, and that they are not distributed in a disorderly fashion without definite law.

The barest dunes in this series had an association made up of poison ivy, *Rhus toxicodendron*, L., wild grape, *Vitis riparia*, Michx., sweet wild rose, *Rosa blanda*, Ait., sea sand-reed, *Ammophila arundinacea*, Host., tall wormwood, *Artemisia caudata*, Michx., false Solomon's seal, *Smilacina stellata*, Desf., and coast joint-weed, *Polygonella articulata*, Meisn.; this association was so constantly found in these bare, dry dunes that it is safe to infer that its members are the most fully protected by their structure and power of adaptation to unfavorable conditions, of all the species observed in this habitat.

Many minor modifications of the principal plant associations were observed in passing back and forth from the bay to the marsh, but few of these were more significant than the ones which have been described, and repetition would only serve to emphasize the observations already recorded. A few more striking examples of the especially interesting facts that were noted need to be recorded here. A most interesting and significant plant association was. found around and under a solitary white pine, *Pinus strobus*, L., standing somewhat more than a mile south of the end of Fish Point and with a few others, some distance south was the only representative of the conifers occurring on the shores for a long distance in any direction. This naturally would make these trees much used roosting places for the great flocks of blackbirds, crows, red wing blackbirds and robins that either live on the marshes or visit them at certain seasons of the year, or that pass across them and the bar in moving from one point to another in their migrations. T he first of these trees were entirely surrounded by a grove of choke cherry bushes, *Prunus* Virginiana, L., with numerous other shrubs growing among them, including the panicled cornel, *Cornus paniculata*, L'Her., the red osier dogwood, *Cornus stolonifera*, Michx., the tall blackberry, *Rubus villousus*, Ait., roses, *Rosa spp*., etc., while the wild grape, *Vitis riparia*,. Michx., the Virginia creeper, *Ampelopsis quinquefolia*, Michx., and the climbing bitter sweet, *Celastrus scandens*, L., were growing over the bushes and up into the tree. In the immediate vicinity of this tree also grew the interesting evergreen, trailing shrub, the bear berry, *Arctostaphylos Uva-ursi*, Spreng., which spread out its stems over the bare sand forming dense green mats, covered at the season the observation was made, with bright red fruits. The plants of this association possessed the character in common of having fleshy colored fruits, and their presence under and around the pine tree affords a good illustration of the influence which birds have on the distribution of plants, for the seeds from which these plants had sprung could have found their way in such numbers to this tree in no other way than by means of birds.

Farther southward the trees on the dune line nearest the bay became mainly oaks, 2 and 3 feet through, and with branches and tops much broken on the side towards the bay apparently from the force of the winds which sweep down on them from the open bay. With the oaks were a few old white pine trees. The plant association in this part of the dune line was more extensive and complicated than nearer Fish Point, but it was still somewhat simple. The following plants were noted: Red oak, *Quercus rubra*, L., black oak, *Q. coccinea*, Wang. var. *tinctoria*, Gray, swamp white oak, *Q. bicolor*, Willd., bur oak, *Q. macrocarpa*, Michx., white birch, *Betula papyrifera*, Marsh., balsam poplar, *Populus balsamifera*, L., cottonwood, *Populus monilifera*, Ait., aspen, *Populus tremuloides*, Michx., and basswood, *Tilia Americana*,. L. The undergrowth below the trees was choke cherry, *Prunus Virginiana*, L., stag-horn and fragrant sumach, *Rhus typhina*, L. and *R. Canadensis*, Marsh, and wild grape, *Vitis riparia*, Michx. The herbs were not noted except the abundant forked beard grass, *Andropogon furcatus*, Muhl., tall panic grass, *Panicum virgatum*, L., and the Indian grass, *Crysopogon nutans*, Benth., which all had the same general relations here as noted in other places. These plants grew chiefly in open ground, not under the shade of trees or bushes.

The marsh bayward of the oak covered dunes was less wet than farther north, and was covered with the slender sedge, *Carex filiformis*, L., the brown sedge, *Carex fusca*, All., and other less abundant forms, mixed with grasses, of which the tall reed-grass, *Phragmites communis,* Trin., and blue joint, *Calamagrostis Canadensis*, Beauv., were the most noticeable. In September, when this area was last visited, it was covered with the Ohio and Riddell's golden rods, *Solidago Ohioensis*, Riddell, and S. Ridellii, Frank., and other showy flowered herbs of the *Compositae*.

Where there were slightly elevated areas on the surface of the prairie, the real prairie association of plants appeared, consisting of the prairie dock, *Silphium terebinthinaceum*, L., smooth aster, *Aster laevis*, L., New England aster, *A. Novae-Angliae*, L., arrow-leaved aster, *A. sagittifolius*, Willd., low golden rod, *Solidago nemoralis*, Ait., slender golden rod, *S. lanceolata*, L., iron weed, *Vernonia altissima*, Nutt. var. *grandiflora*, Nutt, blazing star, *Liatris spicata*, Willd., brown eyed Susan, *Rudbeckia hirta*, L., golden ragwort, *Senecio aureus*, L. var. *balsamitae*, T. & G., Indian plantain, *Cacalia tuberosa*, Nutt., basil, *Pycnananthemum lanceolatum*, Pursh., fringed gentian, *Gentiana cirinita*, Froel., spiked lobelia, *Lobelia spicata*, Lain., shrubby cinquefoil, *Potentilla fruticosa*, L., purple loosestrife, *Lythrum alatum*, Pursh., (in marshy places) prairie moneywort, *Steironema longifolium*, Gray, green milkweed, *Acerates longifolia*, Ell., purple milkweed, *Asclepias purpurascens*, L., Sullivant's milkweed, *Asclepias Sullivantii*, Engelm., common milkweed, *Asclepias Cornuti*, Decaisne, painted cup, *Castilleia coccinea*, Spreng., ladies tresses, *Spiranthes cernua*, Richard, tall panic grass, *Panicum virgatum*, L., and Indian grass, *Crysopogon nutans* Benth.

Conclusions. The value of such studies from the practical aspect is not difficult to see when it is pointed out that many of the plants mentioned in the last list are southern in their distribution, several of them reaching their northernmost known locality in the country in this prairie region of Saginaw Bay, where they are more than a hundred miles north of the nearest stations known for them. It seems indicated by this very local occurrence of such southern plants that the climatic conditions are favorable for southern plants, and that in the prairie region crops too tender to grow in other parts of the county might be given a trial here with fair chances of success. Such trials, however, should be conducted with care and on a small scale until it is actually proven, by trial, that the conditions are as favorable for tender crops as the native vegetation seems to show.

The lessons to be learned from the distribution of species in zones along the sand ridges according to vertical elevation above the water level in the marsh, are that plants may be quite restricted in their habitat by unfavorable soil water conditions, and to types of soils, because of their water holding capacity. Draining may, therefore, render soil that was too wet before the ditches were dug too dry for the plants it was hoped to cultivate on the drained soils, so that is well to know something of the water requirements of plants that are to be grown on a piece of ground to be drained before ditches are dug.

Of the kinds of plants growing native in an undisturbed area of wild land the trees are the best indicators of the character and drainage of the soils, since they live the longest. They show plainly that in their lifetime conditions have never been so poor that they could not persist, and that they have always found moisture and mineral food enough for their needs. On the other hand a type of land that supports only a sparse growth of trees, that are not thrifty, even if it seems well watered when examined, is to be regarded with suspicion and avoided for farming, as it is certain to prove dry and sterile in the long run, and will require much more careful handling than the soil type with good original tree growth.

Again if an old dry ground forest is found with an undergrowth of herbs and shrubs forming an association such as is commonly found in the mesophytic or moist ground forest, it may be safely inferred that the upper layers of soil have plenty of moisture for the time being, but in the long lifetime of the trees, the soil is likely to become very dry. A part of the moisture of the existing state of the soil may be due to the shade and the humus accumulations furnished by the trees, both of which will disappear with the trees and leave the soil dry again.

The scientific end aimed at in a paper of this sort is the portrayal of the conditions as they existed at the times the observations were made, and this has been done as accurately as possible, in view of the relation which this phase of the work bore to other parts of it economically of greater importance. The record is incomplete, even where most carefully made, but it will enable future students of the flora of this interesting region to reconstruct in some degree the less disturbed conditions of the plant societies in the early days of the draining. Perhaps also it will render the task of accounting for the distribution of the plants after they have adjusted themselves to the improved conditions easier and more satisfactory, for even a few years makes a very marked change in the composition of the plant societies made up wholly of short lived shrubs and herbs. It is chiefly with this end in view that the record is submitted.

ANNOTATED LIST OF PLANTS FOUND IN TUSCOLA COUNTY.

Introductory Note. The following plants were noted chiefly in the course of other work, no attempt being made to go out of the roads, for the purpose of compiling a complete list of the species which grow within the limits of Tuscola county. In general it may be said that the roads present the least favorable part of the region for observing native plants, as the weeds and cultivated grasses following man take possession of the frequented places and practically exterminate such of the native plants ;as the traffic and the live stock do not destroy. At the time when the field work was done upon which this report is based, many new roads were being built, and in the districts which they penetrated some of the unusual plants given in the following list, were noted. It should be remembered also that but a single day was spent in. the county before July 1st, hence many of the conspicuous spring flowering plants were not seen at all, or only after they were in fruit.

The localities given are generally not significant as to the limits of distribution of a species, but give the townships and kind of habitat in which the occurrence of the given species was noted for the first time, and second notes of location for most types were seldom made, because the times at which the different townships were visited were not all equally favorable for observing the species. It is obvious that if a district was traversed in early July the conspicuous plants would be quite different from those that would be found in the latter part of August, so some townships which were visited in favorable seasons are credited with many more kinds of plants than those that were gone over in less favorable times, although in fact the same types may be equally abundant in one as the other.

The fact should not be overlooked, however, that there are definite groups of plants peculiar to the parts of the county that have soil waters and climatic conditions so different that they constitute areas of limited occurrence. This is pointed out in the discussion of the distribution of plants in the county.

Nomenclature. It should be noted that the nomenclature is that of the period when the field work was done, about 10 years ago. Since that time there have been several revisions of the then existing names of the plants, in some cases the name of a given plant having been changed five times in the 10 years, so that it is apparent that stability and uniformity are not yet reached. This is enforced by the fact that since this report has been in preparation, a new edition of the manual from which the names given were taken, has appeared and varies radically from the work upon which the last revision of the Michigan Flora by Dr. W. J. Beal was made in 1904; since this appearance of the revised edition of Gray's Manual (7th) it is reported that Britton's Illustrated Flora and probably his Manual are also in the process of revision, and with the revision will appear many new names to adapt the nomenclature to the latest changes of the code of revision, or to the author's latest fancies, as to what is right.

In consideration of these facts and in view also of the fact that no specimens of most of the species were saved to check up the identification of forms that have since been split up into two or more species, it is deemed best to use the names under which the original identifications were made, namely those found in the 6th Edition of Gray's Manual of Botany.

In order that this list may be compared with the last edition (1904) of the Michigan Flora, and through that with Britton's Manual of Botany of the Northeastern United States, the numbers given the species in the Michigan Flora[1] are enclosed in brackets after the name of the plant. By means of these cross references it will also be possible to learn something of the general distribution of the species given in the State at large.

[1]By W. J. Beal, Sixth Report Michigan Academy of Science, Lansing, 1904.

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