MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

Publication 12.
Geological Series 9.

GEOLOGICAL REPORT

ON

WAYNE COUNTY

BY

W. H. SHERZER

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1911.

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1913

BOARD OF GEOLOGICAL AND BIOLOGICAL SURVEY.

1913.

EX OFFICIO:

THE GOVERNOR OF THE STATE,

HON. WOODBRIDGE N. FERRIS, *President.*

THE SUPERINTENDENT OF PUBLIC INSTRUCTION,

HON. L. L. WRIGHT, *Secretary.*

THE PRESIDENT OF THE STATE BOARD OF EDUCATION,

HON. D. M. FERRY, JUNIOR.

DIRECTOR,

R. C. ALLEN.

SCIENTIFIC ADVISORS.

Geologists—Dr. L. L. Hubbard, Houghton; Prof. W. H. Hobbs. Ann Arbor; Prof. Wm. H. Sherzer, Ypsilanti.

Botanists—Prof. E. A. Bessey, East Lansing; Prof. F. C. Newcombe, Ann Arbor.

Zoologists—Prof. W. B. Barrows, East Lansing; Prof. J. Reighard, Ann Arbor; Dr. Bryant Walker, Detroit.

LETTER OF TRANSMITTAL.

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

Gov. Woodbridge N. Ferris, President.
Hon. D. M. Ferry, Jr., Vice-President.
Hon. L. L. Wright, Secretary.

Gentlemen:—I transmit herewith a report on the geology of Wayne County by Professor W. H. Sherzer and recommend that it be printed and bound as Publication 12, Geological Series 9. This manuscript embodies the results of many years of careful study and is an adequate, interesting and valuable treatise on the geology of the most populous county in the state.

Very respectfully yours,

R. C. ALLEN,
Director.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

PLATES.

FIGURES.

CHAPTER I.

GEOGRAPHICAL AND HISTORICAL INTRODUCTION.

GEOGRAPHICAL DATA.

Location and size. The county of Wayne, as at present constituted, lies in southeastern Michigan, adjacent to the Province of Ontario, extending along the entire western bank of Detroit River from Milk River Point, Lake St. Clair, to the mouth of Huron River, Lake Erie. To the north, lie Macomb and Oakland counties, to the west, lies Washtenaw, and to the south, Monroe County. The county now covers an area of approximately 616.37 square miles, and, exclusive of the two cities Detroit and Wyandotte, is subdivided into twenty townships. Expressed in latitude and longitude, the county extends from approximately N. Lat. 42°-2′ to 42°-27′ and from W. Long. 82°-52′ to 83°-33′, or through about 25′ of latitude and 41′ of longitude.[1] From the extreme points, the county has a north and south extent of some 29 miles and an east and west extent of 35½ miles; each minute of latitude thus averaging about one and one-seventh miles and, of longitude, about seven-eighths of a mile. The county includes all the islands of Detroit River which lie west of the international boundary, two of which—Belle Isle and Grosse Isle—are of considerable size. The magnetic declination at Belle Isle in 1907 was found to be 1° 29′ *west,* and is increasing at the rate of about 3′ of arc annually. At present writing (1913) it is reported as 1° 45′ W.

Boundaries. No other county in Michigan and, probably, few others in the entire country have had such a varied geographic history as has the county of Wayne. It was originally organized

1. The following is a list of exact determinations of the geographic positions of points along the Detroit River, taken from the reports of the Coast and Geodetic Survey. (Reports for 1902 and 1903, appendix EEE and FFF.)

	Latitude N.			Longitude W.		
Windmill Point light house, Lake St. Clair	42°	21′	30.389″	82°	55′	48.525″
Belle Isle light house	42	20	24.465	82	57	36.751
City hall flag-staff, Detroit	42	19	52.145	83	02	50.749
Woodward Ave. waiting-room, Det. & Belle Isle Ferry	42	19	33.480	83	02	34.160
Dock upper end Ft. Wayne grounds	42	17	51.800	83	05	32.300
Grassy Island light house	42	13	27.655	83	07	59.556
Mamajudy light house	42	11	30.578	83	08	10.096
Gibraltar light house	42	05	25.900	83	11	14.800
Bois Blanc light house	42	05	12.770	83	07	10.310
Detroit River light house, Lake Erie	42	00	02.820	83	08	28.290

Aug. 15, 1796, by Winthrop Sargent, then secretary of the Northwest Territory, the first within the present limits of Michigan and the fifth of those counties originally carved from this Territory.[2] The seat of government was located at Detroit and the county was

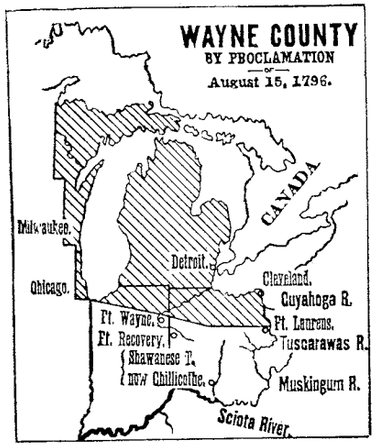


Fig. 1. Wayne county as originally organized by Winthrop Sargent, Secy. of northwest Territory.

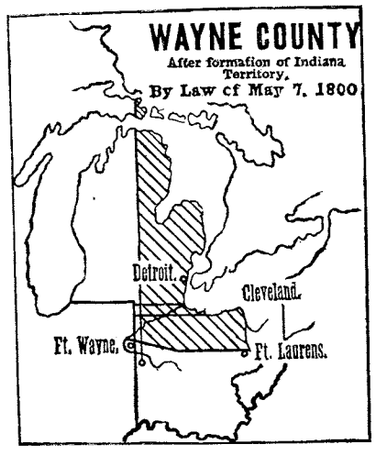


Fig. 2. As reduced after the creation of Indiana Territory.

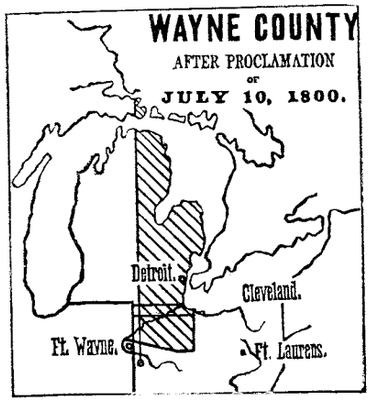


Fig. 3. After the detachment of the southeast corner in Ohio to help form the county of Trumbull.

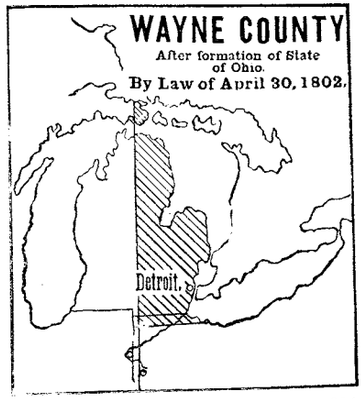


Fig. 4. As reduced at the time that Ohio was admitted to the Union.

named after General Anthony Wayne, who was then in the city, and who had recently achieved such a signal victory over the in-

2. The other counties previously organized were Washington, with seat of government at Marietta, Ohio; Hamilton, with county-seat at Cincinnati, Ohio; St. Clair, seat at Kaskaskia, Illinois; and Knox with seat at Vincennes, Indiana.

dians. As thus organized, the county included practically the whole of Michigan, the northern portion of Ohio to the west of the Cuyahoga River, northern Indiana, northeastern Illinois and a narrow strip of eastern Wisconsin (See fig. 1). The creation of

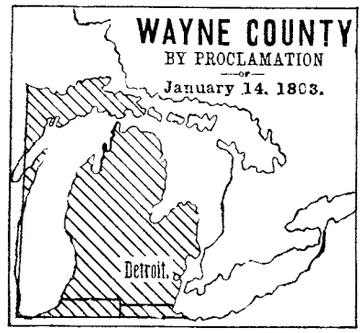


Fig. 5. The boundaries as again defined by Gen. Harrison, then governor of Indiana Territory.

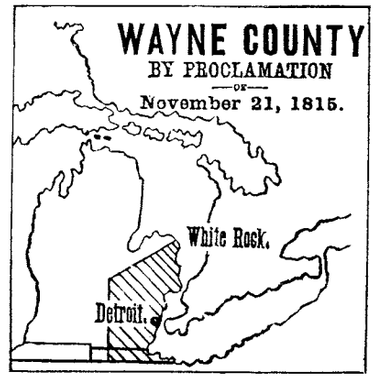


Fig. 6. As reduced by Gov. Cass to include that portion of Michigan Territory to which the Indian title had been extinguished.

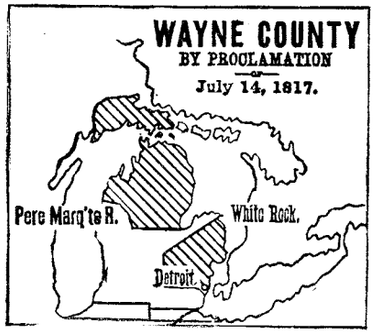


Fig. 7. With the district of Mackinac added by Gov. Cass and the separation of Monroe County.

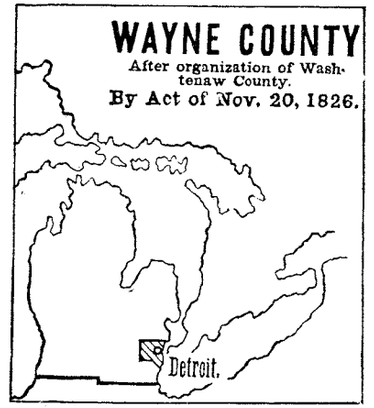


Fig. 8. The final definition of the county by Gov. Cass after the organization of Washtenaw County.

the territories of Indiana and Michigan, the admission of Ohio as a state, and the extinguishing of certain Indian titles demanded various changes in the boundaries of the county and marked reduction in its size, as shown in figures 2, 3, 4, and 6. Oct. 18, 1816, Governor Cass issued a proclamation adding to the county the en-

tirely detached District of Mackinac, as shown in fig. 7, after the county of Monroe had been detached July 14, 1817. With the organization of Macomb County in 1818, the so-called "base line"[3] became the northern boundary of Wayne and, by a proclamation of Governor Cass, the county was assigned its present boundaries Sept. 10th, 1822, but with Washtenaw County temporarily annexed. The latter was organized Nov. 20, 1826, and the present Wayne County definitely established, as shown in fig. 8. Previous to this date, four other neighboring counties had been definitely established and organized:—Monroe (July 14, 1817), Macomb (Jan. 15, 1818), Oakland (Jan. 12, 1819), and St. Clair (Mar. 28, 1820).

The proclamation of Governor Lewis Cass, of Sept. 10, 1822, defining the boundaries of Wayne County reads as follows:

"Beginning in Lake St. Clair, on the boundary line between the United States and the British Province of Upper Canada, at a point due east from the intersection of the base line with Lake St. Clair, and running thence west to the line between the seventh and eighth ranges east of the Principal Meridian; thence with the said line south to the line between the townships numbered four and five, south of the base line; thence with the said line between the said townships four and five to the middle of the said townships four and five to the middle of the River Huron of Lake Erie; thence with the said river, keeping the middle thereof, to its mouth; thence east to the boundary line between the United States and the Province of Upper Canada; thence with the said boundary line to the place of beginning."

County subdivisions. As early as 1798, four townships were created in the then unwieldy county of Wayne:—Detroit, Mackinaw, Sargent, and Hamtramck. To these were added others as the county was narrowed to its present dimensions and increased in population. With the creation of the Board of Supervisors in 1827, the county as now constituted was divided into the following nine townships:—Detroit, Springwells, Hamtramck, Monguagon, Brownstown, Plymouth, Ecorse, Huron, and Bucklin. Two years later, the township of Bucklin was divided into Nankin and Pekin, the latter in 1833, being changed to Redford. By further subdivision, eleven other townships have been organized from the re-

3. This east-west line of reference was surveyed under the direction of the General Land Office, then a branch of the Treasury Department; Edward Tiffin Surveyor General. Its survey through ranges 6, 7, 8, 9, 10, and 11 east of the Michigan Meridian was made in November, 1815, by Alexander Holmes. The line was resurveyed through ranges 9, 10, and 11 in September, 1816, and extended through ranges 12 and 13, east, by Joseph Fletcher, closing on the "west line of private grant No. 656, confirmed to Nicholas Rivan." A resurvey was made through range 7, east, in 1823, by Joseph Wampler and continued through range 5, east, in 1823 and through ranges 4, 3, 2, and 1 in 1829, closing on the Meridian.

mainder, making twenty in all since 1903. These are listed in table I, with statistical data that may prove of interest to the reader. The foreign names were selected in order to avoid the possible duplication of names then in use for postoffices.

The following information relating to the original survey of the townships of Wayne County is supplied by the State Land Office.

T. 1 S., R. VIII E. (Northville and Plymouth).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Wampler, 1815.
T. 1 S., R. IX E. (Livonia).
South and east township lines by Joseph Fletcher, 1816.
North and west township lines by Alexander Holmes, 1815.
North line corrected by Joseph Fletcher, 1819.
Subdivisions by Joseph Fletcher, 1816.
T. 1 S., R. X E. (Redford).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 1 S., R. XI E. (Greenfield).
Township lines (1816) and subdivisions (1817) by Joseph Fletcher.
T. 1 S., R. XII E. (Hamtramck and part of Gratiot).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 2 S., R. VIII E. (Canton).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Wampler, 1819.
T. 2 S., R. IX E. (Nankin).
Township lines by Joseph Fletcher and Alexander Holmes, 1815–16.
Subdivisions by Joseph Fletcher, 1816.
T. 2 S., R. X E. (Dearborn).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 2 S., R. XI E. (Springwells).
Township lines (1816) and subdivisions (1817) by Joseph Fletcher.
Line between public lands and private surveys by Joseph Fletcher, 1822.
T. 3 S., R. VIII E. (Van Buren).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Wampler, 1819.
T. 3 S., R. IX E. (Romulus).
West township line by Alexander Holmes, 1815.
North, east and south township lines by Joseph Fletcher, 1816.
Subdivisions by Joseph Fletcher; 1817.
T. 3 S., R. X E. (Taylor and part of Ecorse).
Township lines by Joseph Fletcher, 1816–17.
Subdivisions by Joseph Fletcher, 1817.
"Mammy Judy" and Grassy Island by H. Brevoort, Jr., 1845.
T. 4 S., R. VIII E. (Sumpter).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Francis, 1819.
Reserve by James H. Mullett, 1843.
T. 4 S., R. IX E. (Huron).
West township line by Alexander Holmes, 1815.
North, east and south township lines by Joseph Fletcher, 1816.
Subdivisions by Joseph Fletcher, 1816.
T. 4 S., R. X E. (Parts of Brownstown and Monguagon).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 4 S., R. XI E. (Part of Monguagon).
Township lines and subdivisions by Joseph Fletcher, 1817.
T. 5 S., R. X E. (Part of Brownstown).
Township lines (1816) and subdivisions (1817) by Joseph Fletcher.

Population. Starting with Cadillac's company of 50 soldiers and 50 artisans and traders, at the time of the first settlement within the present limits of Wayne County, July 24, 1701, the white population grew very slowly and fluctuated much for 100 years. The settlement depended at first entirely upon the fur trade and agriculture was purely incidental. The United States census of 1810 credited the Civil District of Detroit with a population of 2,227 and Wayne County, as it existed in 1820, two years before its final delimitation, with 3574. Since the final organization of the county its growth by decades is indicated in the following table, based upon the U. S. Census.

TABLE I. GROWTH OF WAYNE COUNTY IN POPULATION, BY DECADES.

Date.	Population.	Percentage of increase.
1830	6,781	.....
1840	24,173	256
1850	42,756	77
1860	75,547	77
1870	119,038	58
1880	166,444	40
1890	257,144	54
1900	348,793	36
1910	531,591	52

TABLE II.—STATISTICAL DATA RELATING TO TOWNSHIPS—(NOT INCLUDING CITY OF DETROIT).

Number.	Township.	Tier south.	Range east.	Date of establishment.	Date of original survey.	Origin of name.	Approximate area in sq. mi.	Population in 1900.	Population in 1904.	Population in 1910.
1	Brownstown	4–5	X	1827	1816–1817	From Adam Brown	40.005	2,031	2,034	2,045
2	Canton	2	VIII	1834	1815–1819	City of China	35.935	1,218	1,179	1,113
3	Dearborn	2	X	1833	1816	Gen. Henry Dearborn	34.410	2,752	2,656	2,761
4	Ecorse	2–3	X–XI	1827	1816–1817	From Ecorse or "Bark" River	35.410	6,675	8,219	9,398
5	Gratiot	1	XII–XIII	1903	1816	Col. Charles Gratiot	19.425	1,333	1,326	1,900
6	Greenfield	1	XI	1833	1816–1817	Allusion to appearance of fields	34.782	2,360	2,646	4,995
7	Grosse Point	1–2	XIII	1848	1817	Large point of land	11.310	2,933	3,010	3,579
8	Hamtramck	1	XII	1827	1816	Col. John Francis Hamtramck	16.888	3,078	3,778	7,122
9	Huron	4	IX	1827	1815–1816	Huron River from Indian tribe	35.790	1,978	1,838	1,690
10	Livonia	1	IX	1835	1815–16–19	Probably the province of Russia	35.960	1,460	1,383	1,365
11	Monguagon	4	X–XI	1827	1816–1817	Potowatamie chieftain	23.355	2,387	2,797	3,367
12	Nankin	2	IX	1829	1815–1816	City of China	35.940	3,812	3,857	3,966
13	Northville	1	VIII	1897	1815	Named from village	18.270	2,371	2,226	2,274
14	Plymouth	1	VIII	1827	1815	Probably from Plymouth, Mass	19.140	2,098	2,264	2,248
15	Redford	1	X	1829	1816	From ford of the "Rouge"	35.680	1,990	1,985	2,176
16	Romulus	3	IX	1835	1815–16–17	Founder of Rome	35.660	1,816	1,741	1,538
17	Springwells	2	XI	1827	1816–1817	From abundance of springs	9.830	13,034	16,660	1,835
18	Sumpter	4	VIII	1840	1815–1819	Gen. Thomas Sumter	37.285	1,495	1,320	1,228
19	Taylor	3	X	1847	1816–1817	Gen. Zachary Taylor	23.825	1,296	1,191	1,238
20	Van Buren	3	VIII	1835	1815–1819	Pres. Martin Van Buren	36.690	1,789	1,701	1,700
	Total	1–5	VIII–XIII	.....	.....	.....	575.590	57,906	63,811	57,538

TABLE II.—Concluded.

Number.	Township.	List of postoffices in 1913.	Remarks.
1	Brownstown	Eldredge, Rockwood	Gave portion to Monguagon in 1842.
2	Canton	Canton, Inkster	Derived from Plymouth.
3	Dearborn	Dearborn, Inkster	Reduced from larger Dearborn.
4	Ecorse	Navarre, Ecorse, River Rouge	Reduced to form Taylor in 1847.
5	Gratiot		Derived from Hamtramck and Grosse Point.
6	Greenfield	Highland Park, Howlett	Derived from Springwells.
7	Grosse Point	St. Clair Heights, Cottage Grove, Paye, Grosse Point Farms	Derived from Hamtramck.
8	Hamtramck	Hamtramck, North Detroit, Leesville	Contributed to Detroit, Grosse Point and Gratiot.
9	Huron	New Boston, Waltz, Willow	Reduced to form Sumpter, Van Buren and Romulus, and known as East Huron awhile.
10	Livonia		Derived from Nankin, formerly part of Bucklin.
11	Monguagon	Trenton, Sibley, Grosse Ile	Increased by addition from Brownstown, 1842.
12	Nankin	Wayne, Eloise	Derived from Bucklin and included Livonia.
13	Northville	Northville	Separated from Plymouth.
14	Plymouth	Plymouth	Formerly included Canton and Northville.
15	Redford	Redford, Greenfield	Name in 1833 changed from Pekin, part of Bucklin.
16	Romulus	Romulus	Derived from Huron.
17	Springwells	Springwells	Contributed to Detroit and Greenfield.
18	Sumpter	Taylor Center, Hand Station	Derived from Huron and for a time called West Huron.
19	Taylor	Taylor Center, Hand Station	Derived from Ecorse.
20	Van Buren	Denton, Belleville, French Landing	Derived from Huron.
	Total	36 offices.	

From an inspection of the table, it will be noted that the greatest relative increase in population occurred during the decade when the territory became a state, while the greatest actual increase (182,797) occurred during the last decade 1900 to 1910, it now having approximately 19% of the entire population of the state (2,810,173). This abnormal rate of growth is due, of course, to the very rapid industrial development of the city of Detroit. Although the percentage of increase was also large in the adjacent counties, between 1820 and 1840, owing to the tide of emigration from the East, their growth from decade to decade has been moderate and some of them (Monroe, Oakland and Washtenaw) have at times shown an actual loss. The population of the townships for 1900, 1904 and 1910 is given in Table I. They have suffered, (the loss during the last decade being 6,273) as well as the adjacent counties, because of their proximity to a rapidly growing city. The average density of population throughout the county, outside the two cities of Detroit and Wyandotte, is 100 to the square mile, or about one person to every 6.4 acres. If the hamlets and villages are excluded the strictly rural population would average about 50 to the square mile, or about one individual to each 13 acres.

Although founded in 1701, Detroit was not incorporated as a town until Jan. 18, 1802, and as a city, Sept. 13, 1806. In the meantime, the town had been wiped out, so far as structures were concerned, by the great fire of June 11, 1805, commemorated in the present seal of the city. As so often happens, here was a blessing in disguise as it led to a new plan of streets and parks, furnished a new basis for land titles and a revision of the local government. In 1809 this act of incorporation as a city was repealed and a new charter was not granted the city until Oct. 24, 1815. Its growth in population during the past 100 years is indicated in the following table (U. S. Census):—

TABLE III.—GROWTH OF DETROIT IN POPULATION, BY DECADES.

Date.	Population.	Percentage of increase.
1810	770	.....
1820	1,442	87
1830	2,222	54
1840	9,192	314
1850	21,019	129
1860	45,619	117
1870	79,577	74
1880	116,340	46
1890	205,876	77
1900	285,704	39
1910	465,766	63

The present area of the city is approximately 42 square miles and its average density of population hence is 11,156 to the square mile, attaining a maximum of 38,793 in the 9th ward and a minimum of 17,109 in the 2nd ward. An interesting table showing the geographic development of the city has been prepared by City Engineer R. H. McCormick and is here reproduced.

TABLE IV.—GROWTH OF DETROIT IN AREA.

Dates.	Annexed.	Total area.
1806		0.33 sq. mi.
1815	1.03 sq. mi.	1.36 sq. mi.
1827	1.20 sq. mi.	2.56 sq. mi.
1832	1.61 sq. mi.	4.17 sq. mi.
1836	1.09 sq. mi.	5.26 sq. mi.
1849	0.59 sq. mi.	5.85 sq. mi.
1857	6.90 sq. mi.	12.75 sq. mi.
1875	2.25 sq. mi.	15.00 sq. mi.
1879	1.09 sq. mi.	16.09 sq. mi.
1885	6.10 sq. mi.	22.19 sq. mi.
1891	5.95 sq. mi.	28.14 sq. mi.
1894	0.21 sq. mi.	28.35 sq. mi.
1905	0.45 sq. mi.	28.80 sq. mi.
1906	6.90 sq. mi.	35.70 sq. mi.
1907	5.08 sq. mi.	40.78 sq. mi
1912	0.97 sq. mi.	41.75 sq. mi.

The city of Wyandotte was incorporated in 1867, being set off from the township of Ecorse. At the first U. S. Census in 1870, it possessed a population of 2,731, from which it has had a steady growth; 3,631 in 1880, 3,817 in 1890, 5,183 in 1900 and 8,287 in 1910. The list of villages in Wayne County at present writing, with the date of incorporation and population data is given below.

TABLE V.—STATISTICAL DATA RELATIVE TO VILLAGES.

Number.	Village.	Township.	Incorporated.	Population.		
				1900.	1904.	1910.
1	Belleville	Van Buren	1905			486
2	Dearborn	Dearborn	1893	844	820	911
3	Ecorse	Ecorse	1903		741	1,063
4	Ford City	Ecorse	1903		1,372	1,689
5	Grosse Point Farms	Grosse Point	1893	817	615	862
6	Grosse Point Village	Grosse Point	1870	343	417	830
7	Grosse Point Park	Grosse Point	1907			290
8	Grosse Point Shores	Grosse Point	1911			
9	Hamtramck	Hamtramck	1901		1,559	6,559
10	Highland Park	Greenfield	1889	427	612	4,120
11	Northville	Northville	1867	1,755	1,627	1,665
12	Oakwood	Ecorse	1910			781
13	Plymouth	Plymouth	1867	1,474	1,663	1,671
14	Redford	Redford	1907			328
15	River Rouge	Ecorse	1899	1,748	2,474	4,163
16	St. Clair Heights	Grosse Point	1903		545	1,252
17	Trenton	Monguagon	1855	1,167	1,201	1,224
18	Wayne	Nankin	1869	1,361	1,218	1,263

The grounds for the U. S. Fort Wayne, comprising a tract of eighty and one-half acres in the western part of the city of Detroit, was ceded to the general government by an act of the state legislature, approved March 26, 1867. At present writing (March 1910), there is stationed here a garrison of 600 enlisted men and 38 officers.

Railways. With such a concentration of population along Detroit River and for years with the only ferry for heavy traffic at Detroit, it is readily understood why Wayne County is so generously supplied with railway facilities, both steam and electric. Both types of roads radiate from Detroit like a great arterial system, sustaining and supporting its industrial activity and distributing its products to even the remote corners of the earth. Rendered possible and called into existence by such industrial development, these roads, conjointly with the shipping, have had much to do with the remarkable growth and development of the county, enabling it to lead all others in the state in population, wealth and achievement. In the body of this report, it will be shown that the *geology* of the region furnished the necessary basis for this growth, the full appreciation of which fact is not, at first, easily grasped by the reader.

The first railroad charter granted in the Northwest Territory was to the Pontiac and Detroit Railway Company, July 31, 1830, less than a year after Stephenson's successful demonstration in England of the application to railroads of steam power. This line, however, was not constructed and a more liberal charter was granted March 7, 1834, to the Detroit and Pontiac Railroad Company. In the year 1835 some twelve miles of this road were in operation for horse-cars, the first locomotive being employed in the Fall of 1838.[4] This road was opened to Royal Oak, July 21, 1838; to Birmingham, Aug. 16, 1839, and to Pontiac July 4, 1843,[5] its name being subsequently changed to the Detroit, Grand Haven and Milwaukee and now a part of the Grand Trunk System.

What is now known as the main line of the Michigan Central Railroad, passing westward from Detroit to Chicago, was projected in 1830 and chartered June 29, 1832, by the Territorial Council as the Detroit and St. Joseph Railroad. Started first as a private enterprise the road was purchased by the state in May, 1837, and the name changed to that by which it has since been known. It was opened to Ypsilanti, Feb. 3, 1838; to Ann Arbor, Oct. 17,

4. The Semi-Centennial of the Admission of the State of Michigan into the Union. Address "The Railroads of Michigan" by Maj. W. C. Ransom, p. 183.
5. Farmer's History of Detroit and Michigan, p. 893.

1839; to Jackson, Dec. 29, 1841, and to Kalamazoo, Feb. 2, 1846. Owing to financial troubles, the road was resold in 1846 by the state to a private company, by which it has since been operated. In 1872 the road was "double-tracked" as far as Wayne, the next year as far as Ypsilanti; since which time it has been extended to Chicago. Branches have been constructed southward to Toledo, northward to Saginaw, Bay City and Mackinaw. In 1882 the Michigan Central leased the Canada Southern, giving them direct connection with the East. The transfer of freight from the cars to the ferry boats was the source of much delay and expense and Jan. 1, 1867, the Great Western Railroad inaugurated the plan of carrying the cars bodily across the river and this has been continued to the present writing by several roads. As early as 1871, the question of tunneling the river was agitated and considerable work actually accomplished in 1872 and 3. Opposite St. Antoine street, a shaft was sunk to a depth of 108 feet below the level of the river, from which the tunnel was started riverward 135 feet, but abandoned because of sulphur water and quicksand. In April, 1879, a start was made to tunnel across Detroit River at Stony Island, where the Great Western and Canada Southern Railroads had been maintaining a car-ferry, but the attempt made little progress because of the unfavorable condition of the lime-rock. The ferry service here was abandoned in 1883, and transferred to Detroit. The so-called "Essex-cut-off", completed in 1883, a line from Windsor to Essex, connected Detroit with the main line of the Southern and the ferry at Stony Island has been used only two or three severe winters since and then for but a short time. The old docks are now being destroyed in the construction of the Livingstone Channel, referred to later in this report. The construction of a railroad bridge across the river has always been vigorously opposed by the shipping interests and a tunnel is now in successful operation by the Michigan Central Railroad. This tunnel, carrying a double track and operated by 110-ton electric locomotives, went into operation during the summer of 1910.

The Great Western Railroad of Canada, connecting Detroit River with Niagara River, was begun in 1846 and opened through to Windsor, Jan. 17, 1854, amidst great rejoicing. In 1882 it was consolidated with the Grand Trunk System. The Detroit and Port Huron branch of this system was opened in 1859, where, in 1891, the crossing of the river was effected by means of a tunnel. This system has communication with Toledo over the newly constructed Shore Line Railroad.

The Pere Marquette System maintains a line leading northwestward from Detroit, through Plymouth, Howell and Lansing, connecting at Plymouth with the main line from Toledo for Saginaw and Ludington. Those portions in the vicinity of Wayne County were completed in 1871. A line operated by this same company extends southeastward from Windsor to Leamington, Ontario. In addition to these ten lines of railroads, included in the Michigan Central, Grand Trunk and Pere Marquette systems, four other separate lines enter Detroit:—the Canadian Pacific from the east, the Lake Shore from Toledo, the Wabash and Detroit, Toledo and Ironton railways from the southwest. The "Big Four" cars from the south enter the city over the Michigan Central line; the Cincinnati, Hamilton and Dayton cars over the Pere Marquette and the N. Y. Central trains use the Michigan Central tracks between Buffalo and Chicago. It is estimated that 76 passenger and 99 freight trains enter and leave the city of Detroit daily (December, 1911; Detroit Board of Commerce).

During the decade 1890 to 1900, there was a rapid development of electric lines, centering in Detroit and crossing the county in every direction, paralleling most of the steam lines and competing with them in passenger and light freight business. These lines have had a very marked influence in establishing business and social relations between the city and surrounding country. Most of them, constructed as independent lines, have come under the control of the "Detroit United Railway" and are now operated as a single system. The list of these lines with the dates at which they began operation is here given, the data being supplied by the railway itself.

TABLE VI.—INTERURBAN LINES COMMUNICATING WITH DETROIT.

1	Wyandotte division	1892
2	Detroit, Monroe and Toledo	1903
3	Detroit, Jackson and Chicago:	
	Ann Arbor and Ypsilanti	1890
	Ypsilanti to Detroit	1897
	Ypsilanti to Saline	1899
	Ann Arbor to Jackson	1901
4	Orchard Lake division—about	1897
5	Pontiac division	1895
6	Flint division	1898–9
7	Rapid Ry. System to Mt. Clemens	1894
	to Port Huron	1899
8	Shore Line to Mt. Clemens	1897
9	Sandwich, Windsor and Amherstburg	1902

April 4th, 1911, the Michigan United Railway secured entrance into Detroit, using the tracks of the Detroit United Railway from Jackson eastward. This arrangement gave through service, without change of cars as far as Kalamazoo and Lansing. At the time

of writing (December, 1911) there are 260 passenger cars and 40 express cars daily over these various electric lines.

River traffic. Owing to its location relative to the river and its splendid harbor facilities Detroit has become an important lake port. From data supplied by the Marine Clerk, of the U. S. Customs Office, the port of Detroit, from July 1, 1910 to July 1, 1911, shows 5,815 vessel entries and 5,705 clearances. The boats enrolled and licensed at Detroit number 250, with an average tonnage of 716. Between New Baltimore and Monroe, it is estimated that there are 3,000 motor boats and 500 small sailing vessels. Detroit River, however, is one of the great avenues of commerce of the world, exceeding that world's great thorough-fare, the Suez Canal. In 1910 there were 33,638 passages reported, with a net registered tonnage of 58,821,282 tons. The estimated quantity of freight carried was 73,526,602 tons, of an estimated value of $771,294,055. The great bulk of this trade consists of iron, copper and grains, south bound and coal north bound.

HISTORICAL DATA.

Mound Builders. The earliest known human residents of southeastern Michigan were apparently identical with, or closely related to, that industrious race of people to whom the name "Mound Builders" has been applied. This name, however, is unfortunate since it fails to distinguish them from the inferior races with which they had little in common. Being an agricultural people and relying almost entirely upon the cultivated products of the soil, they seem to have mastered the art of spinning and weaving, they manufactured pottery and a superior grade of stone weapons, utensils and ornaments. Not satisfied with the use of stone alone, they opened shallow pits in the Lake Superior copper district and systematically mined the red metal, both on the main land and upon Isle Royale. This copper was simply beaten into form and never moulded while in molten condition, so that these people can not be regarded as properly in the "age of metal".[6] Dependent directly upon the soil of a given region for their sustenance it was necessary for them to retain possession of the same, at all hazards, and elaborate and skillfully constructed fortifications were erected; connected often by a series of mounds as signal stations.

6. In the sacrificial fires of the Mound Builders copper objects are found to have been melted and it seems most probable that these people were aware of the fusibility of this metal in moderate heat. Had they had possession of *tin* articles at the same time these two metals would have formed an alloy and the superiority of bronze, over either copper or tin, would very naturally have been discovered. The moulding of the molten alloy would have been but an easy step, thus placing these people upon a much higher plane of culture than that usually acknowledged for them.

Equally elaborate enclosures, embankments and mounds were constructed, apparently for religious purposes, justifying the inference that they were made by a settled, populous and prosperous people; well advanced beyond savagism. Surprising military skill is often shown in the location and construction of these defensive works and the mathematical precision with which large squares, circles and regular polygons have been projected has led to the belief that they were very probably acquainted with the use of some simple types of surveying instruments. It would be interesting to know to what extent slave help may have been utilized in the construction of these earth works, in their mining operations and in the cultivation of the soil.

So far as may be judged from the location of their structures and other remains, this race of people was distributed mainly along the Mississippi and the fertile lands adjacent to its tributaries, from the Gulf northward to the Great Lakes and between the Appalachian and Rocky Mountain systems. The center of population seems to have been, for a long time at least, along the Ohio and the basins of its northern tributaries. In the state of Ohio alone, it is estimated that there are no less than thirteen thousand mounds and enclosures. The disposition of these structures leads to the belief that the enemies of these people lay to the northeastward and, when finally dispossessed of the region, there is evidence that they retreated southward and westward. Baldwin in his "Ancient America" (page 70) has given cogent reasons for thinking that they originally entered the United States from Mexico and that they were related to, or identical with, the Toltecs, the predecessors of the Aztecs, whom the Spaniards found in possession of the central portion of our continent. After a study of the traditionary records of the Toltecs, the Abbe' Brasseur de Bourbourg reached the conclusion that they had indeed descended from these builders of mounds whose empire is referred to as *"Huehue-Tlapalan"* and which is located far to the *northeastward.* According to these records while there they were savagely attacked by barbarous, aboriginal tribes, united under one leader and, after a terrible thirteen year struggle, were compelled to abandon their country.[7] The chronology, according to this author's interpretation, would place this event about 1,000 years B. C. Based upon another account, Payne deduces the date of this migration as 387, A. D.,[8] which date would be more acceptable to

7. From Baldwin's Ancient America, p. 203.

8. History of the New World Called America, Payne, vol. II, p. 461. This author places "Tlapallan" in the *western* part of the United States or Canada, ignoring or overlooking the fact that the migration was *southwestward* and thus destroying all connection between the Mound Builders and the ancestral Toltecs.

archaeologists who have noted the state of preservation of the mound skeletons. The Toltec record states that their new country (Mexico) was reached partly by land and partly by sea, (Gulf of Mexico?) and we may readily believe that people who could cross Lake Superior from the main land to Isle Royale would be capable of this feat of navigation.

A tradition, said to be current amongst both the Algonquin and Iroquois nations, and hence all the more reliable, is of interest in this connection because it may be an echo of the above great event. According to this tradition, these two hostile nations once formed an alliance against a formidable enemy, known to them as the "Alligewi", who lived in the region of the Ohio. After a warfare extending over a period of about one hundred years, these Alligewi were defeated and driven southward.[9] We may seek confirmatory evidence of the above accounts in a study of the remains found in and about the fortifications, since the Mound Builders and their Indian enemies were ethnologically distinct. The Toltecs and their relatives are known to have been characterized by the type of head known as *short*, or "brachycephalic"; while the Algonquins, and to a less extent, the Iroquois, possessed the *long,* or "dolicocephalic" type of head. A very extensive collection of such osteological material was made in Ohio by Warren K. Moorehead and described for him by Dr. H. T. Cresson.[10] The predominant type of skull from the mounds and fortifications is of the short kind. At Fort Ancient, a very extensive work on Little Miami River, the author states "the struggle seems to have been a bitter one * * * *. The longheads were evidently the attacking people, who besieged the earthwork and were buried apart outside of its walls under the stone heaps." Further eastward mounds were found in which, although the short type of cranium greatly predominated there was a mingling of those of the long type, as though the lower race had been partially absorbed or enslaved.

Michigan seems to have been upon the northern outskirts of the Mound Builders' domain and the evidences of their occupancy are relatively meager in the southeastern portion of the state. None are known in Monroe County although low mounds and other structures have probably often been obliterated by the plow. In Wayne County a number of mounds and, at least, one small enclosure were constructed in the vicinity of Detroit River, between Ft. Wayne and River Rouge.

9. The Iroquois Book of Rites, Hale: Library of Aboriginal American Literature, edited by Brinton, p. 11.
10. Primitive Man in Ohio, Moorehead: Chap. XVII, p. 204.

The enclosure was of oval form, about 250 by 350 feet, surrounded by a low embankment and located on a tract of firm land surrounded by a morass. It was probably prepared as a place of retreat in case of attack. The largest and most interesting of the mounds is located near the mouth of River Rouge, at Delray. This is believed to have been originally 700 to 800 feet long, 400 feet wide and possibly 40 feet in height; not all of which, however, was artificial. The top of the mound gave a commanding view of the river and may have originally carried some form of structure, long since disappeared. Some forty years ago these earth works were made the subject of study by Messrs. Henry Gillman and Bela Hubbard, both of Detroit, to the writings of whom the reader interested is referred for details.[11] The so-called "Prairie Mound," SW. corner of Sec. 4, Hamtramck township, is simply a crescent-shaped sand dune, some 9 to 10 feet high and about 500 feet in length. Upon this William A. Ennis built a house and barn about the year 1865 and came across bones associated with Indian relics,—but whether of the Mound Builder type or not is not known.

The red Indians. History opens with various tribes of the Algonquin and Iroquois nations in possession of the St. Lawrence and the region about the Great Lakes. Of the former nation, the Ottawas, Chippewas and Potawatomi claimed southeastern Michigan as their hunting ground and the site of Detroit had long been occupied by a permanent village known as "Yondotiga", or "Great Village". When Cartier, in 1535, explored the St. Lawrence he found along both banks, in the vicinity of the present sites of Quebec and Montreal, a tribe of Iroquoian stock now known to have been the Hurons, or Wyandots. They were then at war with the New York Iroquois and by the time Champlain arrived in 1603 they had apparently been defeated, their villages were deserted and they had migrated to that restricted territory at the southeastern extremity of Georgian Bay, between it and Lake Simcoe. Here they were visited by Champlain in 1615 and their number variously estimated between 20,000 to 30,000. Even at this distance, however, and in spite of their numbers, they were not safe from their New York enemies, who had procured fire arms from the Dutch, and who pursued them with relentless persistency. The destruction of their fortified villages began in 1647, was completed in

11. "The Mound Builders and Platycnemism in Michigan," Gillman: Smithsonian Report for 1873, p. 364. "The Mound-Builders of Michigan," Gillman: Read before the Detroit Scientific Association, May, 1874. Michigan Pioneer Collections, Vol. II, p. 40 and Vol. III, p. 202. "Ancient Men of the Great Lakes," Gillman: American Association for the Advancement of Science, 1875, p. 316. See also report for 1876, p. 300 and p. 311. Memorials of a Half Century, Hubbard, 1888, p. 201.

1649 and large numbers perished or were led into captivity.[12] The demoralized and disorganized remnant of the Hurons was scattered and sought the protection of friendly tribes; the one group in which we are here interested going to the "Tionontati," who dwelt to the westward of the Huron country. Still pursued, however, they retreated to Christian Island, in Georgian Bay; thence to Mackinac, Manitoulin Island, secured an asylum among the Potawatomi in Wisconsin for a short time and then moved westward into Illinois. But here encountering the hostility of the Sioux nation they returned to Michigan by way of the south shore of Lake Superior and about 1670 built a palisaded village at St. Ignace. Subsequently from here a portion of them moved to Detroit River and to Sandusky, Ohio, and became known as the Wyandots. Although not numerous, they became influential and claimed and exercised the right to light the council fire at all intertribal councils, which fire was located in Brownstown township, near the Huron. The remnants of the tribe about Detroit River were gathered into reservations by the United States and Canadian governments, with the final sale of which the Indians have been gradually absorbed by the French and English population. The last of the chiefs in this region were Joseph White and Alexander Clark. The Ohio band ceded their lands in the county which bears their name (Wyandot) in 1842 and repurchased the next year in Indian Territory at the junction of the Missouri and Kansas rivers. Tribal relations were dissolved in 1855 and their land allotted in severalty but again resumed by a portion of the tribe who purchased a small tract from their old enemies the Senecas and still reside in the northeastern corner of the territory.

Both the Iroquois and the Algonquins constructed settled villages, generally protected by strong palisades and the former are known to have thrown up mounds of earth. Both nations cultivated maize and other food plants, more or less systematically, which supplemented the fruits of the chase. They wove mats and baskets but were not known to have produced cloth and their pottery and stone implements were crude, when compared with that of the Mound Builders. They were plainly in a lower stage of culture and, separated from the latter quite sharply by the cranial differences above noted. The practice of constructing a fortified village and the cultivation of the soil to such a marked

12. For a graphic description see "The Jesuits in North America in the Seventeenth Century" by Parkman: Chapters XXVI and XXVII. See also "The Downfall of the Huron Nation," C. C. James: Transactions of the Royal Society of Canada, second series, vol. XII, section ii, 1906, p. 311.

extent is not to be expected amongst a hunting and fishing people, the pastoral stage usually intervening. It is a matter of some surprise also that they should have relied so fully upon the maize, which they must have procured from Mexico, or still further south, where the supposed ancestral plant (teosinte) is native.[13] If we grant the southwestern origin of the Mound Builders these anomalies are readily explained;—this short-headed, but more cultured race, brought the maize with them, this being their staple food. From them the ancestral Algonquins and Iroquois learned of its great value and its method of culture; learned of the advantage of fortification and got an object lesson in mound construction for religious purposes. The knowledge and manual skill necessary for the production of cloth, high grade pottery and stone utensils could not be so easily stolen. Had the Indian descended from the Mound Builders, skill in these arts very probably would not only not have been lost but would have been improved upon.[14] If we thus reject this origin for our eastern aborigines, then we have left nothing but conjecture and speculation; one view being that they reached America from northeastern Asia and the other that they navigated the Atlantic and crossed directly from Europe.[15]

13. Sargent, Corn Plants, their Uses and Ways of Life, 1899, p. 93. Harshberger, Maize; A Botanical and Economic Study, 1893. See also Cyclopedia of American Agriculture, vol. II, 1911, p. 399. Fiske, The Discovery of America, vol. i, 1892, p. 27. Fiske points out the great ease with which maize may be grown and harvested and that its yield per acre is greater than that of any other cereal.

14. Without all the evidence which we now have before us, a number of eminent authorities have contended that the Mound Builders were the ancestors of the Indians found in possession of the region, (Brinton, Carr, Nadaillac, Thomas, Moorehead, etc.) That they were racially distinct has been maintained by Bancroft, Wilson, Foster, Morgan and McLean. Maj. J. W. Powell held that, although many tribes of Indians actually constructed mounds, none of them could be accredited with having made the extensive works of the Ohio and Mississippi valleys. This view was also shared by Prof. T. W. Putnam and now appears most tenable.

15. There has recently been brought to light an extensive collection of articles which would seem to indicate that another and totally different race of people had temporary possession of this region. Chiefly through the investigations of Daniel E. Soper, Ex-Secretary of the State of Michigan; Rev. James Savage, pastor of Most Holy Trinity Church and John A. Russell, Vice-President of the Home Telephone Company and Ex-Secretary of the Detroit Chamber of Commerce, many low mounds in the vicinity of Highland Park and River Rouge have been opened. The mounds are described as being ellipsoidal in form, 10 to 30 feet in length, the longer axes placed generally east and west and about twice the length of the shorter, and one and one-half to two feet high. Upon the slightly hollowed surface of the earth a fire was built, the articles deposited and loose soil heaped up to form the tumulus. The articles found and now in the possession of the three above named citizens of Detroit consist of records in undecipherable hieroglyphic upon copper, slate and clay; pictorial records upon the same materials, mainly of Old Testament stories; caskets and urns of clay; articles of warfare, domestic use and adornment, made of copper and stone. They purport to be Assyro-Babylonian, or Egyptian, and to depict a conflict between them and the American Indian. The authenticity of these relics has been very strenuously disputed by expert authorities who have either examined the articles or photographic reproductions of the same. Such views have been taken by Dir. A. H. Griffith, formerly of the Detroit Museum of Art; Prof. F. H. Kelsey, University of Michigan; Dr. Morris Jastrow, Jr., University of Pennsylvania; Prof. Frederick Starr, University of Chicago, and Dr. James E. Talmadge, Curator of Deseret Museum, Salt Lake City. Those interested in the discussion, pro and con, may be referred to the literature cited below. The writer cannot doubt the sincerity of the men who are making the finds and believes that a careful and comparative study will certainly prove the fraudulent character of the material, if such it is. The modern manufacture of such material is attended with such difficulty that only a genius and scholar could hope to make a success of it and we shall ultimately know the truth. Dr. Talmadge made a trip from Salt Lake City to Detroit especially to investigate the finds and succeeded in excavating some of the artifacts himself, but under circumstances that did not convince him of their genuineness. Accepted as real they indicate that a race of Caucasians from southwestern Asia familiar with the book of Genesis wandered into this section of Michigan, where they came into conflict with an inferior race apparently the American Indians, who kept them moving so continuously that no time was found for the erection of enduring structures. Their records were made in pictographs and in characters

French occupation. History is unable to furnish the name of the white man who first gazed upon the placid waters of the Detroit and who first dared invade the sacred hunting-grounds of the jealous and savage Algonquins. In all probability, it was an adventurous and hardy hunter or trapper, possibly a sad and unappreciative captive from the eastern settlements, and he may never have returned to civilization to leave his name with the historian and geographer. By some, Champlain is credited with having passed from Lake Huron into Lake Erie in 1612, returning from a visit to the Sacs, near Saginaw Bay.[16] In the spring of 1670 two priests of La Salle's first expedition (Francois Dollier de Casson and de Galinée) ascended Detroit River and destroyed a stone idol which they found the Indians there worshiping. They prepared a map of the region, which, however, was not published for a number of years afterward. Between the time of Champlain's reputed visit and that of these two priests, others had explored the region furnishing the data for a map published in Paris in 1657, showing Lake St. Clair and its connection with both lakes Huron and Erie. This highly interesting map was reprinted in color, at considerable expense, by Mr. C. M. Burton, of Detroit, and used in a paper entitled "La Salle and the Griffon".[17] It shows the location of several Jesuit missions in western Ontario, but shows no connection between lakes Erie and Ontario, possibly due simply to an error in the engraving. Probably because of some confusion of the notes of the original explorers relating to the neighboring salt springs, Lake St. Clair is indicated as consisting of salt water ("Lac des Eaux de Mer"[18]). In the Fall of 1678, La Salle dispatched a party of fifteen men up the lakes by way of the Detroit, to secure furs from the Indians and were met by him, on their return, the following August. Joliet is known to have passed from Lake Huron to Lake Erie in a canoe, in 1679, to Niagara River and

16. Memorials of a Half Century, Hubbard, p. 159.
17. Read before the Society of Colonial Wars of the State of Mich., Jan., 1902.
18. In an interesting article by William L. Jenks in the Michigan Tradesman (June 15, 1910) on Michigan Counties the suggestion is made that this name is probably a French translation of the Iroquois name of the lake *Otsiketa*, said to mean salt. Upon Joliet's map of 1674 it is marked "Lac des Eaux Salees." In commenting upon this name Gallineé remarks "we saw no indication of salt in this lake."

resembling the Egyptian, Greek, Assyrian, Phoenician and Hebrew. Surely, if true, a fascinating chapter in American history.

Notes on Prehistoric Discoveries in Michigan, 1911, Rev. James Savage.

Prehistoric Discoveries in Wayne County, Michigan, 1911, John A. Russell.

Engravings of Prehistoric Specimens, 1910, Rudolph Etzenhouser.

Archaeological Forgeries at Wyman, Michigan, Prof. F. W. Kelsey: The Nation, vol. LIV, 1892, p. 71. Also letter by Morris Jastrow, Jr.

A Persistent Forgery, Prof. F. W. Kelsey: The Nation, vol. XC, 1910, p. 603.

Some Archeological Forgeries from Michigan, Prof. F. W. Kelsey: The American Anthropologist, vol. X, 1908, p. 48.

The "Michigan Relics," a Story of Forgery and Deception, Dr. James E. Talmage: Deseret Museum Bulletin, New Series No. 2, 1911.

there met LaSalle and his party who were just finishing the "Griffon," the first sailing vessel upon the upper lakes. Bound for Green Bay and fated to never return, this vessel of some sixty tons burden, fantastically built and decorated, entered Detroit River on Aug. 11, 1679, and reached Lake St. Clair the following day. The journalist of the expedition was Father Louis Hennepin, a Recollect priest, who was most surprised and pleased at the abundance and variety of the game and vegetation. Full of enthusiasm at the prospect he wrote:—"The Country between thofe two Lakes is very well fituated, and the Soil very fertile. The Banks of the Straight are vaft Meadows, and the Profpect is terminated with fome Hills covered with Vineyards, Trees bearing good Fruit, Groves and Forests, fo well difpos'd, that one would think Nature alone could not have made, without the Help of Art, fo charming a Profpect. That Country is ftock'd with Stags, Wild-Goats, and Bears, which are good for Food, and not fierce as in other Countries; fome think they are better than our Pork. Turkey-Cocks and Swans are there alfo very common; and our Men brought feveral other Beasts and Birds, whofe Names are unknown to us, but they are extraordinary relifhing. The Forefts are chiefly made up of Walnut-trees, Chefnut-trees, Plum-trees and Pear-trees loaded with their own Fruit and Vines. There is alfo abundance of Timber fit for Building; fo that thofe who fhall be fo happy as to inhabit that Noble Country, cannot but remember with Gratitude thofe who have difcover'd the way, by venturing to fail upon an unknown Lake for above one hundred Leagues."[19] So delighted was the priest with the region that he urged La Salle to establish a settlement here, but the latter had more ambitious plans and the expedition proceeded on its way.

The first attempt at white settlement in southern Michigan was made by Cadillac in 1701, the site of Detroit being selected because of the higher ground near the river and because it apparently held the key to the navigation of the upper lakes, and consequently to the fur trade of the northwest. Cadillac presented his plans in person to the colonial minister Count Pontchartrain, received the approval of Louis XIV and by way of Ottawa River and Lake Huron reached the site of Detroit, July 24, 1701; landing with fifty soldiers and fifty artisans. A stockade was at once erected, a chapel, magazine, store houses and dwellings and that autumn the first crop of wheat was sown. Owing to political intrigues.

19. "A new Discovery of a Vast Country in America," by Father Louis Hennepin. Reprinted from London Edition of 1698, by Twaites, Vol. I, 1903, p. 109.

due to the hostility of the Jesuits and jealousy of traders, combined with the ferocity of certain northern and western Indian tribes, the settlement barely held its own for a half century. The policy of Cadillac had been to group the various tribes of friendly Indians about the fort, in order to better control them and at the same time secure mutual support. The Indian allies rendered invaluable assistance at critical times in the history of the infant settlement, until through jealousies, dissensions arose and their support was withdrawn. Inter-marriage between the French and Indians was encouraged at first and is said to have been common. During the French and Indian War, between them and the English and their colonists, both settlers and troops were concentrated at Detroit. With the conquest of Canada by the English, the fort was surrendered to them by the French, Nov. 29, 1760.

English occupation. Friendly with the French for a century and a half, the Hurons and various Algonquin tribes were not pleased to see the English, who had made allies of their Iroquois enemies come into possession of the various western forts. Within less than two years Pontiac, a bold and crafty Ottawa chief, had laid the plans of his great conspiracy, which contemplated the simultaneous destruction of all the posts west of the Allegheny Mountains. Detroit being regarded as the most important one of all received Pontiac's personal attention and undoubtedly would have fallen but for the timely warning of a French maiden Angelique Cuillière (May 1763). The posts of St. Joseph and Mackinac fell easy victims to the treachery of the Indians.[20] For over two years, they continued to harrass the settlement but with the arrival of Col. Bradstreet, Aug. 26, 1764, with an army of 1,200 troops and 300 Iroquois, peace was soon declared and the English experienced but little further trouble from the Indians. During the War of the Revolution, they were the allies of the British and every possible encouragement given them to bring in prisoners or scalps. One of the best known of these prisoners was the noted scout and Indian fighter, Simon Kenton, the friend of Daniel Boone, who made his escape from the fort and cherished to the last the most bitter hatred of the Indians. The close of the war between England and the States, however, did not bring peace to the western settlements owing to prolonged dispute over the boundaries. The English and their Indian allies claimed the Ohio as their boundary and united their forces in order to hold the country to the north and west. The crushing defeats of Generals Harmer and St. Clair followed,

20. Farmer's History of Detroit and Michigan, Chap. 38. Also Journal of Pontiac's Conspiracy; translated by Ford, published by C. M. Burton, Detroit, 1912.

when Gen. Anthony Wayne ("Mad Anthony" of his troops, "Blacksnake" of the Indians) took the field and gained such a signal victory over the Indians at the Rapids of the Maumee, that they were glad to accept terms of peace. Detroit was evacuated by the British on the 11th of July, 1796, and was garrisoned by a detachment of troops from Wayne's army. During the war of 1812, following Hull's disgraceful surrender of the city, the British flag again floated over the fort from Aug. 16, 1812, to Sept. 28, 1813. The return of the Stars and Stripes marked the fifth time that the flag had been changed over the settlement. The hostility of the Indians against the Americans led to further outbreaks which started in 1806 and continued until the defeat of Proctor by Harrison at the battle of the Thames. Tecumseh, a Shawanese warrior, who seemed the reincarnation of old Pontiac in treachery and aggressiveness, with the help of his twin brother "The Prophet", who claimed supernatural powers, endeavored to unite all the Indians of the northwest against the Americans. During the War of 1812 they were the allies of the British, Tecumseh holding the rank of a brigadier-general; but the victories of Harrison on land and Perry on the lake brought peace again to the region.

Previous geological work.[21] No systematic geological work was attempted in this portion of the state so long as Michigan remained a territory, but immediately upon its admission to the union, the legislature deemed it wise to organize a geological survey. The act of the legislature was approved by Gov. Mason, Feb. 23, 1837, and Dr. Douglass Houghton was appointed director of the survey. The year following the work of the survey was extended and a geological board organized by Dr. Houghton with departments of geology, mineralogy, topography, zoölogy and botany. The work in geology and mineralogy was assigned to the assistant geologists Bela Hubbard and Columbus C. Douglas; the topography to S. W. Higgins; the zoölogy to Dr. Abram Sager and the botany to Dr. John Wright. The season of 1838 saw much activity amongst these pioneer workers, most of it expended in the southeastern portion of the state, and early in the year following reports from each were ready and were included in the Second Annual Report of the State Geologist.[22] The survey of Monroe and Wayne counties had been assigned to Hubbard and were here reported upon, the Wayne report comprising some eighteen pages

21. An account of the organization and work of the various geological surveys of the state will be found in the writer's Report upon Monroe County, which may be secured by making application to the State Geologist.

22. Senate Document No. 12, pp. 264–391, session of 1839. Also published as House Document No. 23, pp. 380–507.

and covering the following subjects:—Topographical features; soil and agricultural character; boulders, marshes or wet prairies; encroachments of the river and lakes; clay; limerock; brine springs; water, wells and springs and roads. Considering the difficulties in the way of geological exploration at this early day, this work of Hubbard and his shrewd interpretations command admiration. The map of the county, prepared by Higgins, appeared a year later in the Third Annual Report,[23] dated Feb. 3, 1840. The science of geology was still too much in its infancy and too little could then be learned of the nature of the underlying rock layers to attempt any correlations or the construction of a geological map. In the Third Annual Report, Hubbard refers the limestones of Wayne and Monroe counties to the so-called "Cliff limestones" of Indiana and recognized an eastern and western division, distinguished lithologically and palaeontologically and separated by the silicious beds which we now term the Sylvania formation. They were properly stated, further, to underlie the "black strata" which are now referred to as the Antrim shale. In the Fourth Annual Report of the State Geologist, under date of Jan. 24, 1841, Hubbard gives a geological resumé of the formations studied by him. The "Limestones of Lake Erie" included not only the true limestones of Wayne and Monroe counties but also the dolomites and sand rock lying beneath. Above this limestone series was placed the "Black, bituminous, aluminous slate", just referred to, and still higher a "Soft, coarse grained sandstone". The boulder clay mantling these rock formations was identified as "Tertiary", upon which rested the "ancient alluvions" (glacial lacustrine deposits) and the "recent alluvions" (marl, peat and bog ore.)

During the subsequent surveys of Dr. Alexander Winchell and Dr. Carl Rominger, no especial attention was given to Wayne County, except a more or less casual examination of the limestones and dolomites exposed about Detroit River. Both investigators, however, made a careful study of these same beds as seen in outcrop in Monroe County and upon these studies based their geological maps of this corner of Michigan. In his Biennial Report, published in 1861, Winchell includes all of these beds under the "Upper Helderberg" (p. 140), although he recognized important lithological differences in the strata. In his geological map of the lower peninsula of Michigan, the first to be prepared and published,

23. Senate Document No. 7, Vol. II, pp. 66-153; House Document No. 27, Vol. II, pp. 206-293; also separately No. 8, pp. 1-120.

1873 in Walling's Atlas, he still grouped the limestones and dolomites together geologically as the "Corniferous." This included the beds of the Sibley quarry, rich in lime carbonate and Devonian fossils, and the dolomites of Grosse Isle, Stony Island and Gibraltar, poor in lime carbonate and Silurian fossils. Crossing Wayne County from northeast to southwest there was represented, just to the west of the Corniferous, a narrow belt of "Little Traverse", regarded as of Hamilton age and extending northward as far as Delray. Parallel with this, across the center of the county, there is next represented a belt of the "Huron Group," some 10 to 15 miles in breadth and regarded as the geological equivalent of the Genesee, Portage and Chemung formations of the New York series. The northwestern corner of the county is covered by the "Marshall sandstone", regarded then as the lowest member of the Carboniferous. This map by Winchell is of special interest since it is the first attempt to depict the geology of the county, but is based upon data obtained almost entirely outside. The occurrence of the Waterlime division of the Lower Helderberg in Monroe County was noted by Winchell in 1870, but was not considered as extending into Wayne.

A study of the Sibley strata, with their characteristic fossils, led Rominger to correlate these beds with those on the Macon and Raisin in the northwestern part of Monroe County and to identify them with the Upper Helderberg of New York. He made the error, however, of extending them downward to the Sylvania sandstone, which he greatly underestimated in thickness, and, following the Ohio geologists, correlated with the Oriskany. The dolomites below the Sylvania, he properly referred to the Lower Helderberg, now described as the Lower Monroe Series. In his map (1876), the geology of southeastern Michigan is much simplified by the union of the Upper and Lower Helderberg under "Helderberg" and the omission of the Sylvania and Hamilton formations, the latter not believed to be present in this portion of the state. In Wayne County alone, we have represented the upper division of the Helderberg, comprising the southeastern corner; the Waverly sandstones crossing the northwestern corner and regarded as of Devonian age, while between the two, there extends the broad belt of "Black Shale", the representative of the Genesee shale of the New York Series.

During the administrations of the state geologists, Charles E. Wright (1885-1888) and Dr. M. E. Wadsworth (1888-1893), numerous well records were collected from which sections were prepared

and published during the administration of Dr. L. L. Hubbard (1893-1899).[24] With the help of these records and the work of Winchell and Rominger as a basis, Lane was enabled to much more completely and accurately represent the boundaries of the various geological formations of southeastern Michigan upon a map accompanying Vol. V and bearing the date of 1893. The course of the Sylvania sandstone is for the first time represented in the state and the Hamilton, omitted by Rominger, included under the name of the "Traverse". In Wayne County, the formations are represented as striking northeastward from Monroe and Washtenaw counties, turning to the eastward as they approach Detroit River. From the dolomites underlying the Sylvania (Lower Monroe) at the extreme southern point of the county, the formations in order of position and age are:—the Sylvania; the dolomites between the top of the Sylvania and the bottom of the Dundee (Upper Monroe); the Dundee; Traverse; St. Clair (Antrim) shale and Richmondville sandstone. The Richmondville sandstone is regarded as the geological equivalent of tne Berea sandstone of Ohio and referred to the Carboniferous, the position accorded the formation by Winchell but united with the Devonian by Rominger.

During the administration of Dr. L. L. Hubbard, the writer was commissioned to make a survey of the county of Monroe and the field studies began in July, 1896, with a careful examination of the strata of the Sibley quarry, just north of Trenton, and the natural and artificial exposures of the beds of rock along the Detroit and Huron rivers. An extensive collection of fossils was then made which has furnished the basis for the palaeontological chapter prepared for this report by Prof. A. W. Grabau. The subsequent field work in Monroe County in 1896, 1897 and Sept. 1899, with the maps and reports based upon the same, furnished the key to an understanding of the surface features and geological structure of much of Wayne County. The survey of this county was authorized by Dr. Alfred C. Lane, (State Geologist from 1899 to 1909), and portions of the field seasons of 1902 and 1903 were devoted to a detailed study of all its geological features. The final preparation of the completed report upon the county has been delayed until the U. S. topographic maps were available, covering the entire region, and until the shaft of the Detroit Salt Company had given us the long-wished-for record of the series of rock strata of southeastern Michigan. In the meantime further valuable well

24. Vol. V, Geological Survey of Michigan, 1895, pt. II; edited by Dr. A. C. Lane, then assistant state geologist.

records have been collected and much information obtained through the help of co-laborers in the territory immediately adjacent, or overlapping.

Messrs. Frank Leverett and Frank B. Taylor, of the U. S. Geological Survey, have been diligently working out the surface features and the glacial history of this region for a monograph now in preparation. In the summer of 1904, Mr. Leverett and Myron L. Fuller, also of the U. S. Geological Survey, investigated the shortage of water in the lower Huron basin, examining a strip in Wayne County and the corresponding portion of Monroe. Rev. Thomas Nattress, of Amherstburg, Ontario, has studied the strata of the Anderdon quarry and of the bed of the Detroit River adjacent and collected interesting suites of fossils from the same. In August, 1907, Prof. A. W. Grabau, of Columbia University, spent a week with the writer in a direct study of the geological formations exposed along Detroit River and about the western end of Lake Erie. To him have been submitted all the fossils collected from the dump of the salt shaft at Oakwood and to him we are indebted for the subdivisions of the geological column. The Ann Arbor Folio, No. 155, of the U. S. Geological Survey, published in 1908, contains a geological sketch map of the Ann Arbor quadrangle by the late Prof. I. C. Russell, of the University of Michigan, as well as maps of the soil and surface features by Mr. Leverett. This quadrangle includes a narrow strip of Wayne County and all that region immediately to the west, thus contributing much to our knowledge of the geology of Wayne County itself. Based upon all the data available from the work of the State and United States geological surveys, Mr. John F. Nellist, of Grand Rapids, has prepared a colored map of the entire lower peninsula of Michigan giving the soil and surface features. This map was issued in connection with the Ninth Annual Report of the State Geologist for the year 1907, published in 1908; accompanying a paper of Lane on the surface geology of the state. Since the pioneer work of Higgins in the late 30's this is the first attempt to map the surface features and soils of Wayne County, and, considering the small scale of the map, these features are very satisfactorily shown. A revision of this map has now been made which has corrected some errors and permitted the insertion of later data. The new soil map has been issued on a smaller scale but more soil details are shown than on the older and much larger map. A new text upon the surface geology with special reference to agricultural conditions has also been prepared by Frank Leverett of the U. S. Geological Survey to accompany this map.

CHAPTER II.

GLACIAL HISTORY OF THE HURON-ERIE BASIN.

THE ICE INVASION.

Present importance. The key to an understanding of the present physical features of Wayne County is found only in a study of the late geological history of southeastern Michigan and the territory adjacent. Taken by themselves, these physical features never could have been fully deciphered, but, in connection with those of the entire area, they lend themselves to clear and accurate interpretation. Improbable as it may seem to the ordinary reader, they point back, in comparatively recent geological time, to a period of ice sheets of great dimensions and glacial lakes at levels considerably above those of our present system. The rocky strata of earlier geological age and the soils resulting from their decomposition have been covered up or swept away through the agency of this ice. The old surface features, developed through the untold ages of middle and subsequent earth history, were obliterated and new ones superposed.

A farmer of the county wishes to learn why his section is rolling and another is flat, why his farm is strewn with boulders while that of his neighbor is not so encumbered; why he can raise corn and wheat, his neighbor only beans and rye; why he can have a flowing well while his neighbor must be content to do his pumping by hand, or go to the expense of installing a windmill. The urbanite may wonder what determined the site of his home city and what will be its most probable direction of growth, or why the soil of his garden or lawn is sand rather than clay or gravel. He is more actively interested in learning how deep he must go for a secure foundation for his office building or manufacturing plant, the amount and type of sewer system required and what is his share of the expense of the bond issue for good roads. To answer such inquiries fully, there must be recounted the story of the great ice invasion from the Canadian regions to the north and east.

Formation of the ice sheets. Very long ago as man reckons time;—say 300 to 400 thousand years, but geologically speaking, only yesterday, there was started in the highlands of the Labrador peninsula a great snow field, more snow falling during the winters

than could be melted during the summers. Geologists are not yet agreed as to the exact set of causes which brought about this condition in this particular region and other sections of the northern hemisphere. Numerous theories have been proposed which may be at once discarded: such as, the shifting of the earth's axis, the sliding of the earth's crust on the molten interior, the secular loss of heat by the earth or sun, or the obscuring of the sun by sun-spots or meteoritic matter. The theories which have received the most attention from geologists are based:—

1st. On a particular distribution of land and sea, causing a maximum of refrigeration and permitting favorable atmospheric and marine currents.

(Lyell and Dawson).
Principles of Geology, Lyell, 7th edition, 1847, Chapter VII, p. 93.
The Canadian Ice Age, Dawson, 1894, Chapters III and IV.

2nd. Greater elevation of the lands in the regions of accumulation.

(Dana and Upham).
Manual of Geology, Dana, 3rd edition, 1880, p. 540.
On the Cause of the Glacial Period, Upham, American Geologist, vol. VI, 1890, p. 327.
Appendix to Wright's Ice Age in North America, Upham, 1889, p. 585.

3rd. A certain shape of earth orbit by which there were produced long cold winters and short hot summers.

(Croll and Ball).
Climate and Time, Croll, 1875, chapter IV, p. 54.
Climate and Cosmology, Croll, 1886, chapter III, p. 38.
The Cause of an Ice Age, Ball, 1891, chapter V, p. 78.

4th. A diminution in the amount of the carbon-dioxide ingredient of the atmosphere, wherby there is permitted excessive radiation of heat from the earth.

(Tyndall, Aarhenius and Chamberlin).
Tyndall, Heat considered as a Mode of Motion, American revision of second edition, 1867, p. 363. Sixth edition, 1905, pp. 344 and 413.
Aarhenius, On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground: Philosophical Magazine, 5th Series, vol. XLI, p. 237.
Chamberlin, An Attempt to Frame a Working Hypothesis of the Cause of Glacial Periods on an Atmospheric Basis: Journal of Geology, vol. VII, 1899, p. 752. Geology, Chamberlin and Salisbury, vol. III, 1906, p. 432.

Geologists are disposed to believe that two or more, possibly all of these factors may have conspired to bring about glacial conditions in certain areas,[1] and are agreed that there was an uplift to the north and an increase in precipitation in the form of snow. Tyrrell, of the Canadian Geological Survey, reports finding snow in mid-summer in isolated patches of the Keewatin region to the west of Hudson Bay and concludes that a slight increase in the amount of precipitation, or a slight reduction in the annual temperature, would again mantle the region with snow and ice.[2] Once started, such a covering would tend to still further lower the mean annual temperature of that section and to assist in the establishment of conditions favorable for glaciation.

1. See Lane's paper Summary of the Surface Geology of Michigan, Report of the State Board of Geological Survey of Michigan for 1907, p. 97.
2. The Glaciation of North Central Canada: Journal of Geology, vol. vi, No. 2, 1898, p. 160.

Year after year the snow field would thicken and extend its area about the margin, gradually becoming compacted into ice through pressure, summer melting and rainfall. Owing to a peculiar and, as yet, little understood property of ice, this mass would *act* as if *plastic* under its own weight and gradually creep out in all directions from the central area of accumulation. A continuance of

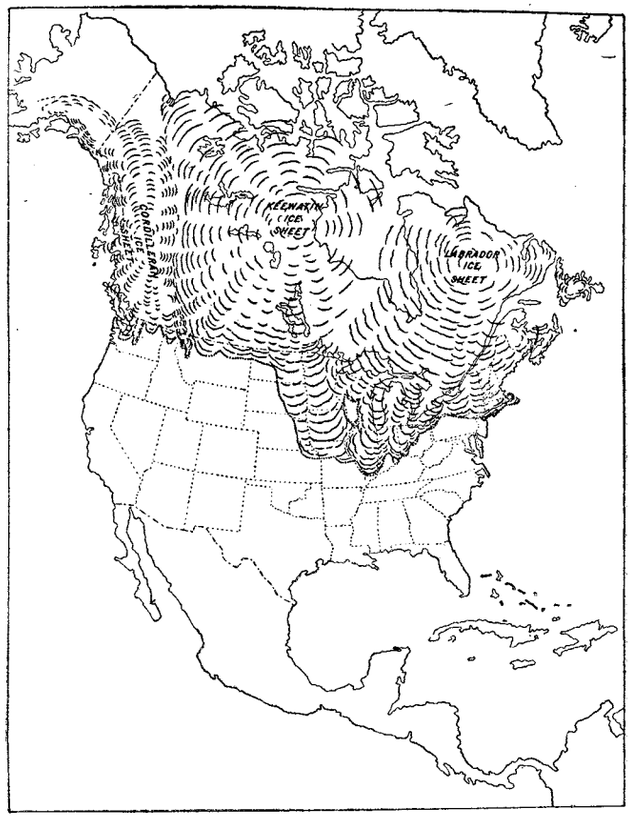


Fig. 9. Sketch map. Extent to which the ice sheet covered North America. After Chamberlin and Salisbury's Geology. Patrician center not shown.

the conditions established would compensate for the loss from this flowage, the oceans supplying the moisture and the sun the necessary heat for its evaporation and transportation by the wind, until a great continental ice sheet came into existence comparable with that of Greenland, or Antarctica. Similar ice sheets had previously formed to the west, one centering in the Keewatin region just west of Hudson Bay, another in eastern Manitoba between

Hudson Bay and Lake Superior and yet another over the Great Cordilleras of western Canada. These centers of accumulation and dispersal and their maximum extent are shown approximately in fig. 9.

Whether or not the Keewatin and Manitoban (Patrician) ice fields reached southeastern Michigan remains undecided though probable,[3] but certain it is that the Labradorean sheet spread over the region as far south as the Ohio and from the Atlantic to the Mississippi, covering an area of hundreds of thousands of square miles, attaining a possible thickness of two miles, or more, and moving out from the center some 1,600 miles. The main movement was to the southwest directly athwart which lay Michigan, at just the right distance from the center as well as from the margin to receive the full force of the attack. Thus located and, with the maximum of international boundary, Michigan was compelled to bear the brunt of this great Canadian ice invasion. The movement may have averaged no greater than a foot a day, but it was continuous over a very long period and was practically resistless in its power. The animal life was driven from the region, or destroyed, the soil and all vegetation pushed ahead of the ice, or incorporated into the basal layers and thus removed. The rock strata then exposed were planed down, fluted or grooved, scratched and in places polished. Fragments of these strata were detached and removed, some of them large enough to be mistaken for outcrops of bed rock.[4] This highly effective type of ice action is shown in Pl. I, from the Canadian Rockies. Where the topography, nature and structure of the rocks were favorable, great basins were excavated which became the sites of the Great Lakes, these being modified from preglacial erosion valleys. The final result was the production of enormous quantities of gravel, sand and rock flour, which when lodged beneath, or about the margin of the ice, gave rise to till, or when assorted more or less by running water to various forms of stratified deposits.

There is geological evidence that a general depression of the region occurred, probably due to the heavy weight of the ice mass itself, followed by an amelioration of the climate and a retreat of the ice to an unknown distance northeastward. A partial restoration of the conditions favorable for glaciation led to the formation of at least two additional ice masses and subsequent advances over southeastern Michigan, each less vigorous than the first and

3. Leverett, Review of the Glacial Geology of the Southern Peninsula of Michigan: Sixth Report of the Michigan Academy of Science, 1904, pp. 101 and 104.
4. See Winchell in American Journal of Science, second series, vol. XL, 1865, p. 331.

separated by shorter intervals of time. Each ice sheet destroyed, or modified the work of the preceding, so that the present physical features of this region are to be attributed, in the main, to the last sheet, so far as they have not since been modified by aqueous or aeolian agencies. The destructive work above noted was accomplished during the stages of ice advance, while during stages of retreat, or of marginal halt, the material transported by the ice found lodgment in sheltered places, or was built into various topographic forms to be described. It has been estimated that the Lower Peninsula of Michigan is mantled by such glacially worked material to an average depth of about 300 feet,[5] made up of preglacial soil, disintegrated local strata and similar material from the northeast. No satisfactory data are at hand for estimating even approximately the amount of denudation suffered by our state as the combined result of this ice action. It is quite probable that the material supplied to it from outside was in excess of that taken from it to help make up the deposits to the south and west.[6] Economically it will be shown that the Glacial Epoch was of vast importance to the state in its contribution of soil, lakes and water power.

Illinoian ice sheet. Owing to its extension into Illinois and the opportunity there afforded for a study of the deposits left by this ice sheet during its waning stages this, the first of the great ice masses from the Labradorean center, has been so named.[7] It represented the maximum extension of ice from this center, was presumably the thickest and was largely responsible for the ice erosion in southeastern Michigan. Had it occurred last there would probably have been no identifiable trace of the earlier ice movements. Where the direction of movement coincided approximately with the strike of the rock strata, as it did in Wayne and Monroe counties, there were excavated broad, shallow troughs and basins, in the softer beds, separated by low, rounded divides of more resistant rock, all now covered by subsequent deposits and traceable only by means of well borings. These troughs were mapped and described by the author in his report on Monroe County[8], the names used in connection with them referring to the geological strata in which they were carved. Were the covering of till removed, they would serve as the beds of streams in Monroe County, while, in Wayne, they would be permanently occupied by arms of the Great Lakes. These troughs have their axes approximately parallel, ranging from S. 40° to 47° W. and averaging S. 43° W., pointing directly to the Labradorean center of ice accumulation.

5. Cooper, Geology and Physical Geography of Michigan: Ninth Report of the Michigan Academy of Science, 1907, p. 140.
6. See paper by Lane, *loc. cit.*, p. 101.
7. Leverett, The Illinois Glacial Lobe: Monograph XXXVIII, United States Geological Survey, 1899. The name "Illinois" was first used by Chamberlin in an editorial in the Journal of Geology, vol. IV, 1896, p. 874, with credit to Leverett.
8. Geological Survey of Michigan, vol. VII, pt. I, 1900, pp. 122-124. See also a paper entitled Ice Work in Southeastern Michigan, Journal of Geology, vol. X, 1902, p. 197.

In commenting upon this view of the writer Russell questioned the soundness of the evidence that these troughs were appreciably enlarged by the ice, remarking that the weaker rock strata would have been broken down to somewhat lower levels than the more resistant layers.[9] In reply it may be said that the mere breaking up of strata without removal of the debris would lead to the reverse of a trough and the shape of these troughs precludes the idea of the material having been removed by running water. Of the two main agencies left:—ice and wind, which might have operated most in removing such debris, I would select the ice as the most probable agent. The point was overlooked further, that these troughs become well defined only as the strike of the strata swings around into parallelism with that of the Illinoian ice movement over this section. In following these continuous depressions into Wayne County it was learned from the well records that a series of well defined rock-basins mark their course, which are generally accepted as convincing evidence of ice action (see Pl. XXV).

At the Sibley quarry, just north of Trenton, a large embossment of limestone served as a minor obstruction to the general ice movement. As the ice ascended this hill of firm rock it plowed more deeply into the layers that were able to withstand the plucking action and there were excavated on the so-called "stoss-side" a series of parallel grooves and basins, some 10 to 30 feet across and from 2 to 10 feet deep so far as seen (see Pl. II, A.). The axes of these great furrows have an average trend of S. 42° W., practically identical with that of the greater troughs above noted and presumably belong to the same system. The close parallelism of these glacial features, directly across such obstructions, indicates a very steady movement and consequently a relatively large ice mass. For every 1,000 feet of thickness the pressure of such a mass upon the underlying rock was some 28.5 tons to the square foot, so that its eroding power need cause no great surprise when a great length of time is allowed for its action.

In a portion of the bed of Detroit River, laid bare in the excavation of the Livingstone Channel, opposite Stony Island, a series of shallow, approximately parallel grooves, (see Pl. II, B) two to

9. Ann Arbor Folio, No. 155, 1908, p. 2.

four inches across, were noted ranging S. 35°-45° W. Associated with these were patches of delicate striae averaging (35 observations) S. 41.8° W. These evidences of glaciation were protected from subsequent ice action, as well as that of the river, by a bed of very compact, stony, rusted till believed to be of Illinoian age (Pl. III, A.). The import of this discovery is that we have now convincing evidence that the Illinoian ice actually moved across this region in the direction indicated by these great troughs and furrows.

A diminution in the amount of snowfall over the area of accumulation, or increased melting due to an amelioration of climate, probably both these factors combined, brought about a more sluggish condition of the ice and finally inaugurated a retreat of the ice margin. The ice is to be thought of as constantly advancing at approximately right angles to the ice front owing to the weight and pressure of the greater mass behind. When the marginal melting was greater than this average forward movement of the ice mass, the margin seemed to retreat; when the average rates of melting and forward movement were equal, the margin appeared to halt, while a slight excess of movement at any time might cause a temporary advance of the ice front. Plates III, B. and IV, A. and B. from the writer's report upon the Canadian glaciers show such conditions of the ice margin. From what is known of modern glaciers there is reason for thinking that the retreat of such an ice sheet would be very slow and characterized by periods of halt and temporary advance. Taylor has presented evidences for thinking that such a movement would be periodic and hence rhythmic[10] and has endeavored to show that the procession of the equinoxes may have influenced climate sufficiently to have produced such a type of retreat and led to the symmetrical spacing of the frontal moraines formed during stages of halt. Whatever topographic features were produced in southeastern Michigan by the retreating Illinoian ice sheet, all have been destroyed by subsequent ice advances and there remain only the effects produced upon the rock surface, obscured by glacial debris but not entirely obliterated. In certain places where conditions were especially favorable, there was a deposition beneath the ice of rock fragments, gravel, sand and rock flour in a heterogenous compact mass known as "till". None of this material referable to the Illinoian was encountered in either of the two salt shafts, or in the Detroit River tunnel but so-called "hard pan" is frequently reported by well drillers of

10. Moraines of Recession and their Significance in Glacial Theory: Journal of Geology, vol. V, 1897, p. 421.

Wayne County just overlying the bedrock. This varies in thickness from a few inches to several feet and may represent fragments of the Illinoian till-sheet not removed by the later ice movements.

At the southern end of the Livingstone Channel previously referred to, overlying the supposed Illinoian glaciation, there occurs a very hard, stony and rusted till (Pl. III, A. and Pl. V, B.) which appears to be of Illinoian age. The deposit proved to be so hard that much difficulty was experienced in removing it by means of a powerful steam shovel. Pebbles from this deposit when placed alongside of those from the later Wisconsin, indicate greater age, the limestones especially showing a thin, mealy coating which has obliterated, to a large extent, the delicate scratches so often shown by limestone fragments from the younger till. An interesting relation was found to exist between this deposit and the rock topography, apparently explaining its preservation in this particular locality. At the northern end of the channel an anticlinal fold crosses the river in an east-west direction, the crest of which has an elevation of approximately 568 to 569 feet above sea level. One mile south the surface of the till deposit is 568 feet, upon either side of the channel, but the rock surface is 560 feet upon the west side and 554 feet upon the east, giving a thickness to the till of 8 to 14 feet. Towards the north, the till diminishes in thickness as the rock surface rises, forming a broad wedge in the lee of the anticline (see Pl. V, A.), from which protected position it was not removed by subsequent advances of the ice. In the vicinity of Detroit River light, Lake Erie, an unusually hard variety of till was encountered by the dredges and is also very probably of Illinoian age. At the pit of the American Silica Company, near Rockwood, some 14 to 16 feet of an exceptionally hard clay overlies the sandstone, so hard that it was at first found necessary to blast it out. Later it was found possible to remove it by means of a powerful steam shovel. The lower portion is stony, the upper not so much so and the whole probably also represents another fragment of this older till.

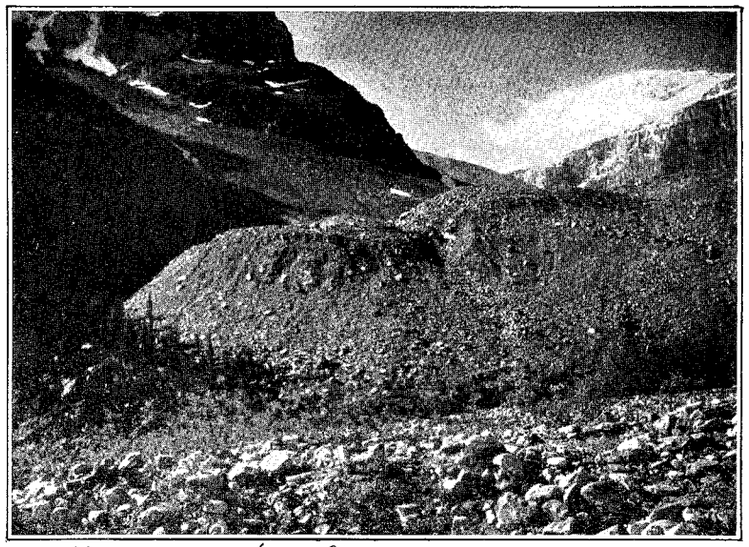
Iowan ice movement. A supposed movement from the Labradorean center has been recognized as the Iowan,[11] of much later

11. The term "East-Iowan" was first made use of by Chamberlin in the third edition of Geikie's Great Ice Age, 1901, page 759, for an extensive till-sheet developed in southeastern Iowa. This name was shortened to *Iowan* in 1895 (Journal of Geology, vol. III, 1895, pp. 270 and 273) when it was discovered by the work of the Iowa Geological Survey that the till-sheet to which it was applied was the same as the Kansan. A year later Chamberlin consented to the transference of the name Iowan to a much younger and less well developed till-sheet in the northeastern corner of the state. See—
Chamberlin, Editorial in the Journal of Geology, vol. IV, 1896, p. 872.
Calvin, Synopsis of the Drift Deposits of Iowa: American Geologist, vol. XIX, 1897, p. 270.
Iowa Geological Survey, vol. VII, 1897, p. 18.
Iowan Drift: Bulletin of the Geological Society of America, vol. 10, 1899, p. 107.

age than the Illinoian and presumably older than the Wisconsin. Michigan lying directly in the path between its center of dispersal and the state of Iowa, where the till deposits have been most fully recognized, must have been crossed by this ice movement. Recent investigations of Leverett, however, have led him to question the soundness of the evidence of such a stage.[12] In his presidential address before the Geological Society of America, December, 1908,[13] Calvin asserts the distinctness of this drift sheet from all the others, but describes it as meager in amount and scrappy in character. The movement into Iowa was from the *northwest* (p. 144), covering only the northeastern quarter of the state and it did not reach the region that had been visited by the Illinoian ice. In view of these facts it must be regarded as uncertain whether or not such an ice sheet ever crossed this section of Michigan. In studying the glacial striae of Wayne and Monroe counties, the writer has found a set having the general direction of W. SW. (S. 65 to 78° W.), older than the late Wisconsin and younger than the Illinoian, which might very plausibly be referred to the Iowan in view of their age and course. If this stage, however, is to be eliminated these striae will have to be regarded as having been made during an early phase of the Wisconsin stages.

Between the withdrawal of the Illinoian ice sheet and the arrival of the Wisconsin, there was a relatively long time interval which gave opportunity for pronounced weathering of the deposits and marked erosion by the streams. The soils were rusted to a considerable depth, the lime carbonate leached out and the rock fragments considerably decayed. The growth of vegetation in places gave rise to beds of humus and muck which when not removed, give a very distinct dividing line between the Illinoian till and later deposits. The term Sangamon soil, or the Sangamon weathered zone, has been used to designate the one formed immediately upon the Illinoian till.[14] Between the supposed Iowan till, or the loess deposit correlated with it, a second such soil, known as the Peorian, or Toronto, has been recognized. In sections, where neither till nor loess of Iowan age was present, these two soils would be superposed and indistinguishable from one another. Rather indefinite and uncertain traces of these buried soils have been found in well records in southern Wayne and northern Mon-

12. Weathering and Erosion as Time Measures: American Journal of Science, vol. XXVII, fourth series, 1909, p. 367.
13. Bulletin of the Geological Society of America, vol. XX, 1909, p. 146. See also paper "The Iowan Drift," read at the Pittsburg, 1910, meeting of the Society.
14. Leverett, Journal of Geology, vol. VI, 1898, pp. 176 and 244.
See also paper Weathering and Erosion as Time Measures: American Journal of Science, fourth series, vol. XXVII, 1909, p. 349.

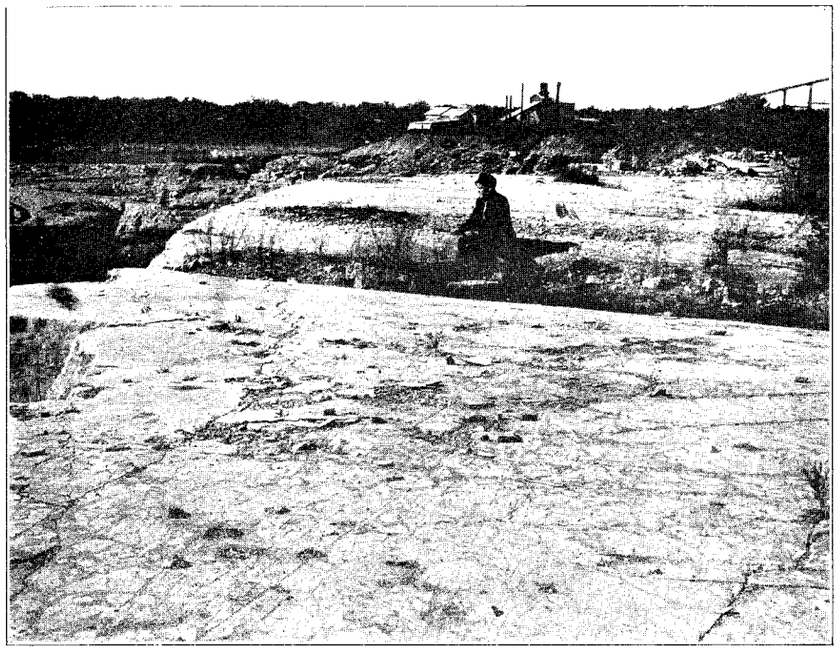


Cut of the nose of Victoria Glacier

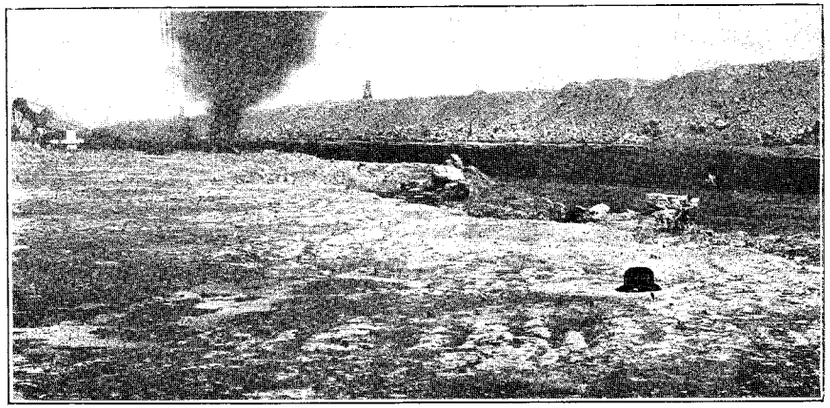
~~QUARTZITE BLOCKS DISRUPTED BUT NOT REMOVED BY ANCIENT GLACIER,~~
~~CANADIAN ROC~~KIES. (COURTESY SMITHSONIAN INSTITUTION).

ERRATA.

The cut of the nose of the Victoria Glacier, now shown upon Plate I, should have been placed upon Plate III B. The disrupted quartzite blocks called for upon Plate I are shown upon Plate IV A, while the retreating face of the Victoria Glacier appears upon Plate III B. Titles will be found to be correct as printed. For Plate XXXIX read XXIX.

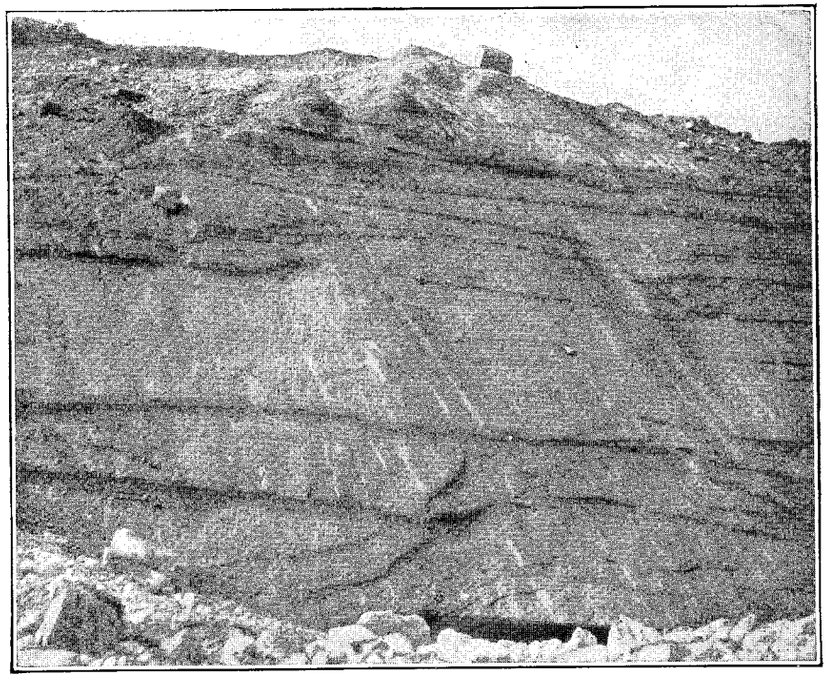


A. GLACIAL TROUGHS, ILLINOIAN AGE, SIBLEY QUARRY. IN THE FOREGROUND IS SHOWN THE GLACIATION DUE TO THE WISCONSIN ICE.



B. ILLINOIAN GROOVING AND STRIATION, LIVINGSTONE CHANNEL, DETROIT RIVER.

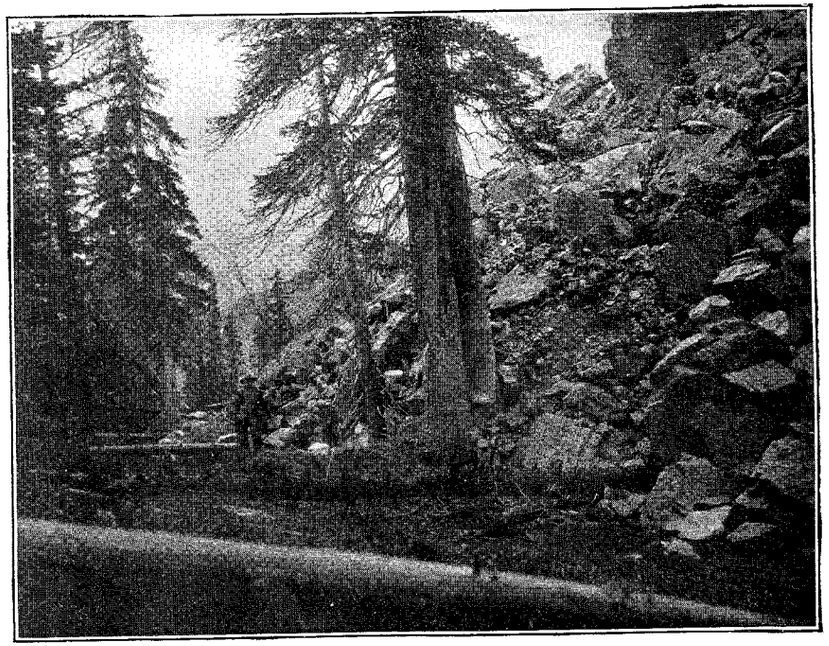
A. NEAR VIEW ILLINOIAN TILL, LIVINGSTONE CHANNEL. THE VERY STONY CHARACTER OF THIS TILL MAY BE CONTRASTED WITH THAT OF THE WISCONSIN; PL. VI, A, AND PL. VIII.



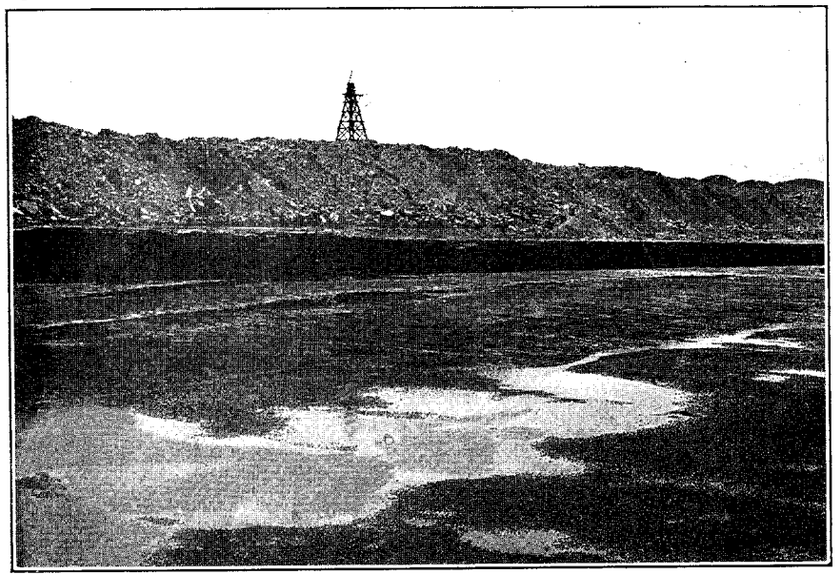
B. STATIONARY NOSE OF VICTORIA GLACIER, CANADIAN ROCKIES. (COURTESY SMITHSONIAN INSTITUTION).

Disrupted quartzite blocks (By an ancient glacier)

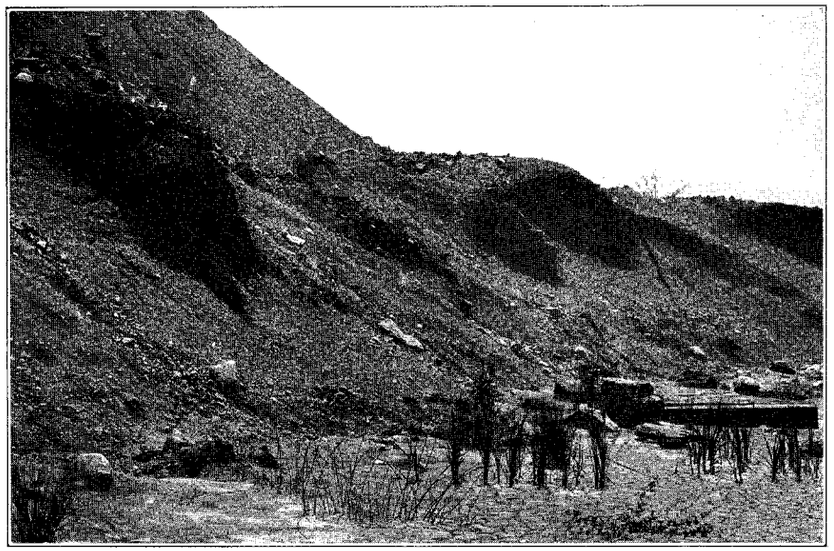
A. ~~RETREATING FACE OF VICTORIA GLACIER.~~



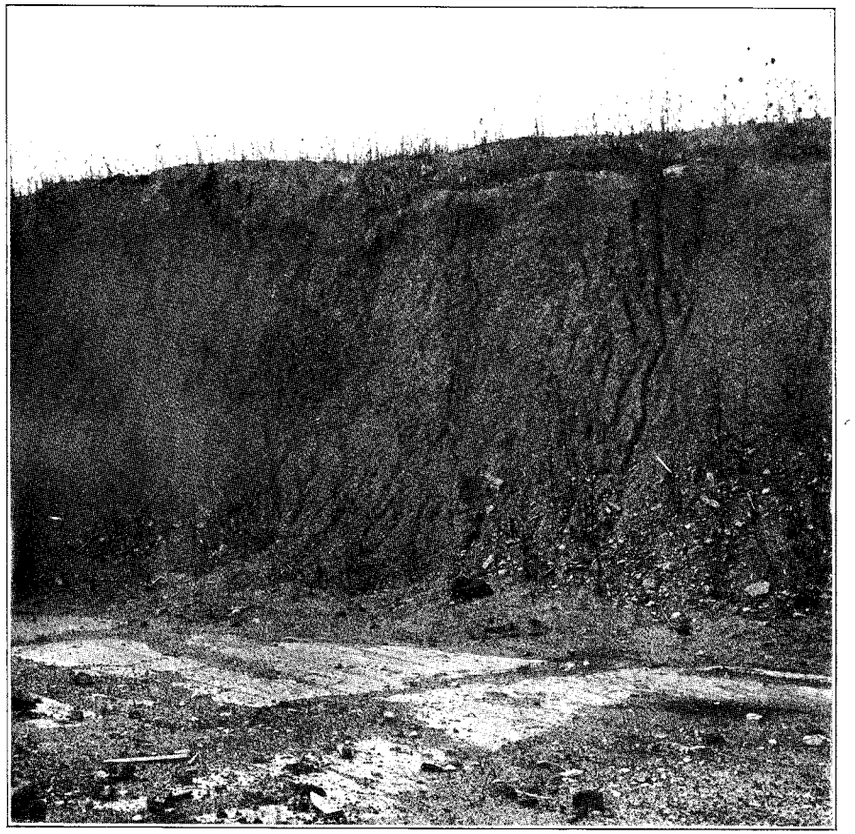
B. ADVANCING FRONT OF WENKCHEMNA GLACIER, CANADIAN ROCKIES.
(PLATE IV A & B COURTESY SMITHSONIAN INSTITUTION.)



A. DISTANT VIEW ILLINOIAN TILL DEPOSIT, LIVINGSTONE CHANNEL, DETROIT RIVER. THE UNDISTURBED WEDGE OF TILL LIES JUST BENEATH THE DUMP AND MANTELS THE BEDROCK.



B. NEAR VIEW ILLINOIAN TILL, LIVINGSTONE CHANNEL.



WISCONSIN TILL AND GLACIATED BEDROCK, SIBLEY QUARRY. NOTE THE STONY CONDITION OF THE TILL JUST OVER THE BEDROCK.

LENGTHWISE VIEW OF GLACIAL TROUGH, SIBLEY QUARRY. THE STRIAE SHOWN ARE DISCORDANT WITH THE TROUGH AND PROBABLY OF EARLY WISCONSIN AGE.

LAMINATED WISCONSIN TILL, SIBLEY QUARRY. THIS STRUCTURE IS BELIEVED TO BE DUE TO THE MOVEMENT AND GREAT WEIGHT OF THE ICE.

roe counties, suggesting that remnants of them may still be there preserved.[15] Leverett has estimated that the amount of stream erosion indicated upon the surface of the Illinoian till, where it was not subsequently covered, is five times greater than that shown by the youngest, or late Wisconsin sheet. If we postulate similarity of rainfall and drainage conditions, this would indicate that the interval from the withdrawal of the Illinoian ice to the final disappearance of the ice sheets in this region was four times as great as the time that has since elapsed.

Wisconsin ice movements. Two related movements, an early and late, have been termed Wisconsin, because of typical exposures of the various deposits in that state and their early studies there.[16] They were related in point of time, being separated by a relatively short interval, which gave but little additional time for the weathering and erosion of the earlier deposits, when not covered by the later.[17] The earlier was the more massive and vigorous, extended farther westward and southward and, upon its retreat to an unknown distance, left behind its characteristic till-sheet, moraines, etc. Its distribution did not entirely coincide with the Illinoian, but, wherever such was the case, the topographic features left by the Illinoian, or developed subsequently, were obscured or entirely obliterated. In many places, the bedrock was entirely denuded and received a new set of glacial striae or furrows. The detritus which the Early Wisconsin found in its path was mixed in with that which it was able to manufacture, or acquire anew, and the whole worked into a much younger and fresher till-sheet, which it deposited during its waning stages with more or less regularity (see Pl. VI).

The interval between the retreat of the Early and the advance of the Late Wisconsin permitted the introduction of factors which caused a deflection of the general direction of movement more to the westward. This effect may have been brought about by a shifting of the main center of snow accumulation, a change in topography due to the work of the Early Wisconsin itself, or by a relief of pressure of ice masses to the north. This second movement fell short of the first both toward the south and west, but so far as they covered the same territory the effect was the same as that noted above. Where one till-sheet still overlaps the other, there

15. See writer's Geological Report on Monroe County: Geological Survey of Michigan, vol. VII, pt. I 1900 p. 126.

16. The term "East-Wisconsin" was first proposed by Chamberlin (third edition of Geikie's Great Ice Age, 1901, p. 763) for these till-sheets so well exposed in this state. At the suggestion of Upham the name was shortened to *Wisconsin*. (Journal of Geology, vol. III, 1895, p. 270.)

17. See Leverett, American Journal of Science, vol. XXVII, fourth series, 1909, p. 351.

is no practical way of distinguishing between them, based either on the nature of the material present, its condition, or on any line of demarcation, such as that noted between the Illinoian and Early Wisconsin. A study of the glacial striae of southeastern Michigan shows that the last recorded movement was *northwestward*, pronouncedly so at the Sibley quarry, swinging around toward the west over the northern half of Monroe County and to west-southwest in the southwestern corner. These striae were without doubt made by the lobe of ice which filled the Huron-Erie basin, after it had separated from the neighboring lobes upon either side, this region lying upon the northwestern side of the lobe and the motion being approximately at right angles to the ice margin. At the Sibley quarry the average bearing of the striae was found to be about N. 29° W.,[18] with a range of some 43°. This rather wide range (N. 43.5° W. to N. 0.5° W.) would indicate that the ice lobe at the time was free from its neighbors and subject to minor disturbance. The next oldest set of striae studied at the Sibley quarry gave a range of but 20° and averaged about S. 31° W., giving an angle of 120° with the later movement. If these striae are referred to an early phase of the Late Wisconsin, we should expect them to be connected with the later set by an entire series of striae having an intermediate course and produced, as the Huron-Erie ice lobe was being separated from the main body of ice. Such intermediate striae were not found, however, although a more thorough search might have revealed them. The present inference then is that the set of striae to the S. SW. should be connected with the Early Wisconsin movement, while the still older series, having the general bearing W. SW., should be regarded as due to an earlier, more westerly direction of movement of the same ice mass.

The general effect of the Wisconsin ice sheets upon the bedrock about Detroit River and the western end of Lake Erie seems to have been relatively slight, even at the Sibley embossment, where we should expect to find the maximum effect. The upper surfaces of the limestone and dolomite were planed down and smoothed, but received at the same time innumerable parallel, or slightly diverging, scratches and gouges caused by sand grains, pebbles and boulders held in the basal layers of the ice (see Pls. II, A., VI, and VII). The criteria for determining the direction of ice movement have been most satisfactorily described and figured by Chamberlin,[19] to whose very complete paper the reader, interested, is referred. At the Sibley quarry, although 80 acres of beautifully glaciated limestone surface have been destroyed, all these various criteria may still be found by the investigator who knows just what to look for. The glimpses of the rock surface here afforded and at other isolated patches in this corner of the state, lead us to infer that the entire rock surface of the region was similarly affected by the Wisconsin ice, except where protected sufficiently by the Illinoian till-sheet, as at the Livingstone Channel and elsewhere.

18. A table of the bearings of glacial striae in Monroe County is given in the author's report on this county, *loc. cit.*, p. 131.

Although interesting from a geological standpoint the destructive work of the Wisconsin ice masses is far overshadowed in importance by their constructive work. Spread over the rock surface, filling the hollows and subduing the general relief of the entire region, was a heavy mantle of bluish-gray till, similar in character to that left by the Illinoian ice but much fresher and less indurated. Formed beneath the ice while still in motion this deposit is often referred to as the "ground moraine", while the even surface imparted to the deposit gave rise to a "till plain." This deposit ranges in thickness from zero, in southeastern portions of Wayne County to 170 to 180 feet in the northern part of Hamtramck and the northeastern corner of Van Buren townships (see Pl. X). Spread evenly over the surface, it might average from 70 to 80 feet in thickness. The deposit consists, in the main, of a compact, bluish, and unstratified clay, charged with pebbles and boulders, nearly all of which show facets, striae or give other evidence of glacial abrasion. A majority of these pebbles and boulders in this region consists of limestone, or dolomite, well fitted for receiving these evidences of glacial action. Although the till is unstratified, there has been developed at times in it a lamination, the result of ice pressure and movement, best seen when the vertical face has dried somewhat and shrinkage cracks have developed. This structure is shown in Pl. VIII taken at the Sibley quarry in August, 1911. Compared with the Illinoian till, the Wisconsin is characteristically soft, it being sometimes difficult to force a knife-blade into the former and exceedingly difficult to penetrate it in wells. A large body of Wisconsin till will creep, or flow under its own weight, which phenomenon caused the abandonment of the salt shaft of the Michigan Rock Salt Company, at Ecorse, in 1902. In general, the surface of the Wisconsin till shows some evidence of weathering, more or less rusting of the iron present having taken

19. The Rock-Scorings of the Great Ice Invasions: Seventh Annual Report of the Director of the U. S. Geological Survey, 1888, p. 244 to 248.

place. The greatest amount of such discoloration reported was in the vicinity of Windsor, Ontario, where it is said to extend to a depth of 25 feet. Tested with acid there is little recognizable leaching of the lime carbonate from the till, which is interpreted as indicating a relatively short exposure to atmospheric action. In this respect it does not differ essentially from the Illinoian till which may be due to the fact that the upper, more leached portions of the latter were swept away by the Wisconsin ice.

During periods of halt, or temporary advance, the retreating Late Wisconsin, built up along its broad front ridges and mounds of till deposit, resting upon the main till-sheet and forming the so-called frontal moraines. Boulders and cobbles carried on, or within the ice were brought to the margin of the ice by its continuous forward movement and strewn over the morainic features there formed. In contrast with the rock fragments found in the ground moraine, these consist very largely of the crystallines;—granites, gneisses, greenstones, etc. and very few of them show signs of glaciation. In retreating across Wayne County, there were apparently two periods of halt (see Pl. X) of the ice front, during which no morainic features were built up, and indicated only by a concentration of these boulders and cobbles. A uniform retreat of the ice from the pronounced morainic structures in the northwestern portion of the county to the more subdued morainic features of the eastern section would have strewn the boulders, that happened to be carried by the ice, somewhat uniformly over the intervening till plain.

Running water, resulting from the melting ice or from rainfall, carried from beneath the ice sheet quantities of clay, sand and gravel. The easily transported clay was carried to considerable distances before it could find favorable conditions for lodgment, but the sand and gravel were often deposited in the vicinity of the ice margin, frequently forming mounds, more or less elongated, known as kames, (Pl. IX A. and B.) at the time that the frontal moraines were in process of formation; sometimes filling and clogging the subglacial tunnels, giving rise to eskers, or spreading out in a broad sheet beyond the ice margin and thus forming outwash plains, or aprons. An advance of the ice over such deposits, or similar ones that may have formed locally beneath the ice, sometimes resulted in their being covered with a sheet of till and their being thus incorporated in the general ground moraine. Such deposits being porous and permeable by water become of great economic importance to the inhabitants of the region, as will appear in the chapter on water supply.

LACUSTRINE HISTORY.

Formation of the lakes. When the ice had withdrawn northward from the low divide separating the Erie drainage from that of the Ohio basin, the water began to be ponded back between this divide and the ice front, which served as a dam, preventing the water from following its present course of drainage. Small, isolated bodies of water would first be formed along the ice front, which would gradually combine as the water level rose and a single lakelet would result. When the supply of water from the melting ice sheet and that supplied by ordinary precipitation was sufficient to raise the level of the lake to that of the lowest rim of the divide, or of the ice dam itself, an outlet would be formed and the drainage of the lake would begin. As a result of wave action about the land-locked portion of the lake, a beach would begin to take form, the gravel and sand from the previously formed glacial deposits being washed into a low ridge about the water line, while the finer materials would be transported lakeward and there allowed to settle in the deeper and more quiet water. If the ice front remained stationary for a length of time, the bed of the drainage channel, especially if of ice or till, would be deepened by erosion and the level of the lake thus gradually lowered until the channel found a more resistent sill. A succession of rather poorly defined beaches would mark the stages in the lowering of the lake level. With sufficient time and water supply the bed of the drainage stream would be cut back to the lowest part of the lake bed, the lake would be drained and the additional water would be taken care of by a system of drainage channels flowing over the bed of the now extinct lake. Long before this could occur, however, the ice front had retreated until a lower outlet was uncovered, when the lake level would fall rather rapidly and without opportunity for a *succession* of beaches. If this second outlet was higher than the bed of the first outlet, there would be a stage during which both outlets would serve and this would continue until the bed of the second outlet was lowered by erosion sufficiently to draw off the entire discharge from the lake. Although the level, size, depth, shape and location of the lake might thus be subject to change it would be regarded as the *same* lake until a new outlet had been opened, when it should be designated by a new name. It is now proposed to trace the series of these glacial lakes, the predecessors

of our present Great Lakes, so far as they covered southeastern Michigan and made their beaches and clay deposits within the limits of Wayne County. Reference will be made to the writings of those who have had the most to do with deciphering this interesting history.

Lake Maumee. This, the first of the series, the oldest, the smallest and the highest, occupied at the beginning the present basin of Maumee River. It came into existence when the ice first began to retreat from the Fort Wayne moraine, which served as a restraining wall on one side, while the ice front served upon the other.[20] It soon assumed the shape of an arrow-head, the point

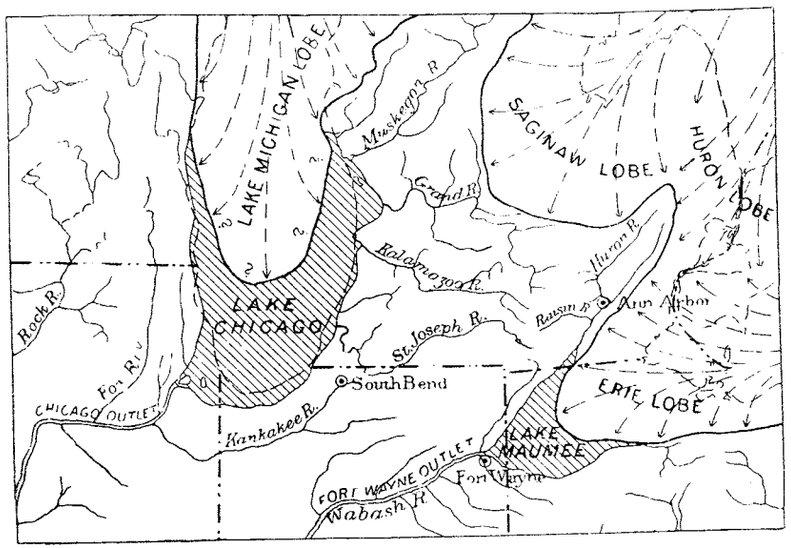


Fig. 10. Glacial Lakes Chicago and Maumee, first stage. After Frank Leverett.

being at the present site of the city of Fort Wayne, Indiana, one barb extending northward along the ice-lobe toward and into Michigan, the other eastward across northwestern Ohio. After leaving the Fort Wayne moraine the next place of halt for the ice front was the Defiance moraine, extending from Findlay, Ohio, by Defiance to Adrian, Michigan, giving a stretch of about 100 miles of ice wall, and a fairly definite size and shape to the lake. The water had risen to the level of the moraine at Fort Wayne and there found an outlet to the Wabash and thence to the Ohio. The lake

20. Dryer, The Erie-Wabash Region: Studies in Indiana Geography, 1897, p. 50. See also Geology of Allen County: Sixteenth Annual Report of the Department of Geology and Natural History of Indiana, 1889, p. 107.

at this stage of development is shown in fig. 10. It was some 40 miles wide in an east-west direction, 75 miles from Fort Wayne to Adrian and Findlay[21] and was 60 feet deep at Defiance. The elevation above present sea level was about 795 to 805 feet, the crest of the beach formed standing some 5 to 7 feet higher. Different sections of this beach in Ohio and Indiana were termed the Van Wert[22] and Hicksville ridges, from places located directly upon them, which names have been discarded and Upper Maumee beach substituted.[23] The two sections of this beach running from Findlay and Adrian respectively to Fort Wayne lead into the old channel which passes through the city and continues for 25 miles to Huntington, there entering the Wabash. According to Taylor this old outlet channel averages about a mile in width, is strewn with boulders and cobbles and represents a cut into the drift of some 20 to 80 feet, dropping very gradually down stream except in the last three miles where there is a more rapid descent over a sill of limestone.

When the time arrived for the ice to finally withdraw from the Defiance moraine, the water of the lake moved in between it and the retreating ice front and the barbs of the arrow-headed lake were extended eastward in Ohio towards Cleveland and northeastward across the northwestern corner of Wayne County. The beaches were thus extended at the original level, the outlet remaining the same, but, being younger and developed in relatively narrow arms, they do not show the strength of those portions lying between the Fort Wayne and Defiance moraines. The waters of the lake were thoroughly chilled by the great ice front as well as by floating ice bergs and the beach gravels show no signs of molluscan life. In Michigan, the main tributaries were the Raisin and Huron rivers, the latter entering the lake and building a conspicuous delta at Ann Arbor. When the retreating ice front had reached the site of Imlay City, in the eastern part of Lapeer County, a lower outlet than the Fort Wayne was uncovered and the waters of the glacial lake fell rapidly some 10 to 20 feet. This new outlet was from one-third to one mile wide, averaging

21. Taylor, The Great Ice-Dams of Lakes Maumee, Whittlesey and Warren: American Geologist, vol. XXIV, 1899, p. 23.

22. They were described by Klippart, without any names being assigned in his early Agricultural Survey of Ohio: Report of Progress of the Geological Survey in 1870, pp. 321 to 323; published in 1871.

For "Hicksville" see Dryer in Geology of Allen County, 16th Annual Report of Department of Geology and Natural History of Indiana, 1888, p. 109.

By each of the above writers, they were regarded as true beaches, but by N. H. Winchell as a peculiar type of *moraine* formed from "an unusual amount of water precipitated from the ice on the already deposited drift along its margin." Proceedings of the American Association for the Advancement of Science, Dubuque meeting, 1873, p. 175. The "Belmore Ridge," the beach of Lake Whittlesey, was believed to have had a similar history (page 179).

23. Taylor, *Loc. cit.*, p. 24. Leverett, Glacial Formations of the Erie and Ohio Basins: Monograph XLI, U. S. Geological Survey, 1901, p. 710.

about one-half mile, and being floored with sand and gravel indicates no great vigor of the drainage stream.[24] It led by Flint and Durand to Grand River, which discharged into glacial Lake Chicago, then forming at the head of the Lake Michigan ice-lobe (See fig. 11). This lake had its discharge southwestward to the Illinois and thence to the Mississippi.[25] The Imlay channel seems to have been neither low enough nor wide enough to have drawn the full discharge of the expanded lake and the Fort Wayne outlet also continued in commission for a time. The ice of the Huron lobe retreated eastward to the Imlay and Yale moraines, while the position of the ice front of the Erie lobe is not definitely known, being possibly represented by the Scofield and Grosse Isle halts of the ice margin. A new beach was formed at this lower level which was designated in Ohio the Leipsic beach,[26] but which is now generally referred to as the Second Maumee. The level of this lake may be given as 775 to 785 feet, above tide; the crest of the beach formed being a few feet higher. The full size, shape and location are made out by mapping the beach and locating the ice dam as shown by the course of the correlative moraine. This has been done and the result is shown in fig. 11.

Traces of a still lower beach, at an elevation of about 760 to 770 feet above tide, have been noted by Leverett east of Plymouth and Ypsilanti and described as the Third Maumee. This beach was also traced by the writer during the past summer northeastward from Plymouth into Oakland County lying just above the 760 foot contour, generally as a sandy belt and only exceptionally as a well defined ridge. South of the Huron, the beach, although faint, may be traced[27] but has the appearance of having been submerged after its formation and suggesting that it may have been formed before the completion of the Second Maumee. Future investigations may show that the ice had temporarily uncovered a lower outlet than that at Imlay City, forming a new member of the series of glacial lakes, and then by an advance had closed it and brought the level of the waters back again to that of the second stage of Lake Maumee. A gravelly deposit just east of Ypsilanti is believed by Leverett to represent the delta deposit of the Huron during this stage.

24. Taylor, Surface Geology of Lapeer County, Michigan: Annual Report of the Geological Survey of Michigan, for the year 1901, p. 114.
25. For a description of this outlet see paper by Davis, The Ancient Outlet of Lake Michigan: Popular Science Monthly, vol. XLVI, 1895, p. 217. Also Leverett, The Pleistocene Features and Deposits of the Chicago Area: The Chicago Academy of Sciences, Bulletin No. II of the Geological and Natural History Survey, 1897, p. 57.
26. Leverett, On the Correlation of Moraines with Raised Beaches of Lake Erie: American Journal of Science, third series, vol. XLIII, 1892, p. 291.
27. Leverett, Ann Arbor Folio, No. 155; Atlas of the U. S. Geological Survey, 1908, p. 7.

Lake Arkona. By the still further retreat of the ice margin toward the northeastward, there was developed a much larger water expanse, but at a lower level than the lowest stage of the Maumee lakes above described. In uncovering the "thumb", from the position of halt near Imlay City, lower ground than that of the Imlay channel was encountered and a new outlet or possibly a series of such outlets, opened to Grand River and Lake Chicago, giving rise to a lake now known as Lake Arkona.[28] The position of these outlets is not yet definitely known nor of the ice margin itself because

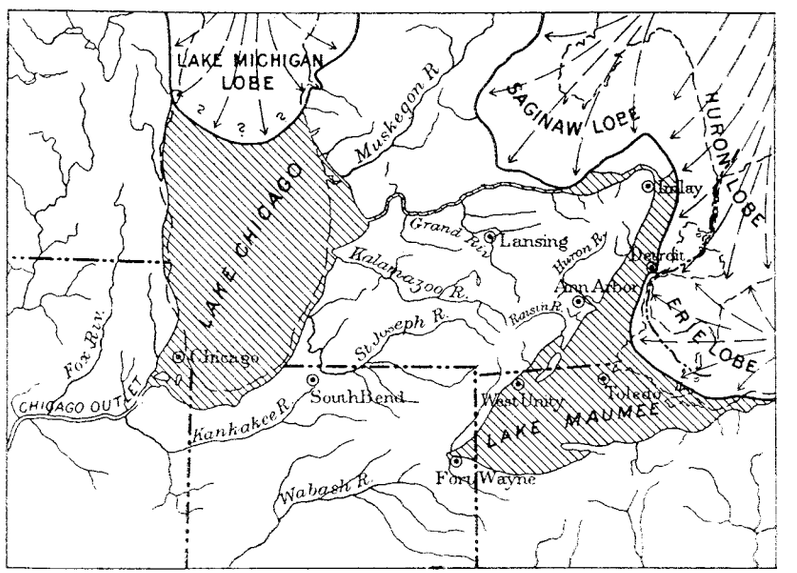


Fig. 11. Glacial Lakes Chicago and Maumee, second stage. After Frank Leverett.

of the partial destruction of the beaches and the correlative moraine by a re-advance of the ice, thus making it impossible to map the lake as has been done for the other stages.[29] The ice margin probably crossed the "thumb" and the bed of Lake Huron in a loop to the north of Port Huron. Three beaches may be recognized, with evidence of even a fourth, in the western part of Wayne County lying between 690 and 710 feet above sea level, or

28. Lane, Summary of the Surface Geology of Michigan: Annual Report of the Geological Survey for 1907, p. 128. The beach of this lake was given the name "Arkona" in 1891 by Spencer, from the village in western Ontario: American Journal of Science, third series, vol. XLI, 1891, p. 204. This beach was located at Denton, Wayne County, by Spencer himself and given an altitude of 694 feet above tide (p. 206), which elevation corresponds with that of the Third Arkona.
29. Taylor, Relation of Lake Whittlesey to the Arkona Beaches: Seventh Report of the Michigan Academy of Science, 1905, p. 29.

117 to 137 feet above the general level of Lake Erie. Taylor believes that the outlet was of the nature of a *strait* (*loc. cit.* p. 35) around the ice at its reëntrant angle between the Saginaw and Huron-Erie lobes, thus bringing Lake Arkona and so-called Lake Saginaw to the same level. As ingeniously worked out by this investigator, the beaches from Applegate and Croswell, on the eastern side of the "thumb" (Sanilac County) around to Cass City of the western slope, were overridden by the ice when it advanced from the position that it had held to that of the Port Huron moraine. He believes that these destroyed beaches were originally formed across the crest a little to the south of Bax Axe, Huron County. In thus advancing the ice closed up the strait, or other outlet and raised the level of the water to that of a channel crossing the crest of the "thumb" at Ubly and thus submerging those portions of the Arkona beaches lying to the south of Applegate and Croswell. Had this submergence of 20 to 30 feet taken place rather rapidly the beaches would probably have experienced but little alteration, but as the water rose somewhat gradually up to the level of the new outlet those portions of the beaches exposed to wave action were reduced in height and in places almost obliterated. This makes the tracing of the Arkona beaches in southeastern Michigan rather difficult and uncertain.

Lake Whittlesey.[30] The village of Ubly, Huron County, is located upon the floor of an old drainage channel which crosses the crest of the "thumb" and leads southwestward to Cass City. This channel varies from a half to one mile in width, descends some 70 feet in its length of 22 miles and is floored with boulders and gravel (Taylor, *loc. cit.* below, p. 41). Two smaller channels enter the main one from the village of Tyre, some four miles southeast of Ubly. These channels carried the waters of Lake Whittlesey, the successor of the fluctuating Lake Arkona, into Lake Saginaw and thence by way of Grand River to Lake Chicago. The Huron and Erie ice lobes had separated from one another to a distance of about 50 miles in southern Ontario, the Huron ice front standing at the Port Huron moraine in some 150 feet of water and having a frontage of nearly 200 miles.[31] The Erie lobe probably had its apex somewhere in Ontario on a line between Port Huron and Buffalo.

---

30. This lake was named by Taylor for Col. Charles Whittlesey, of the early Ohio Geological Survey, an explorer of old shore lines. Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan: Bulletin of the Geological Society of America, vol. Viii, 1897, p. 39. For description see also Leverett, Monograph XLi, U. S. Geological Survey, 1901, p. 741. Folio No. 155, U. S. Geological Survey Atlas, 1908, p. 7.

31. Taylor, The Great Ice-dams of Lake Maumee, Whittlesey and Warren: American Geologist, vol. XXIV, 1899, p. 19.

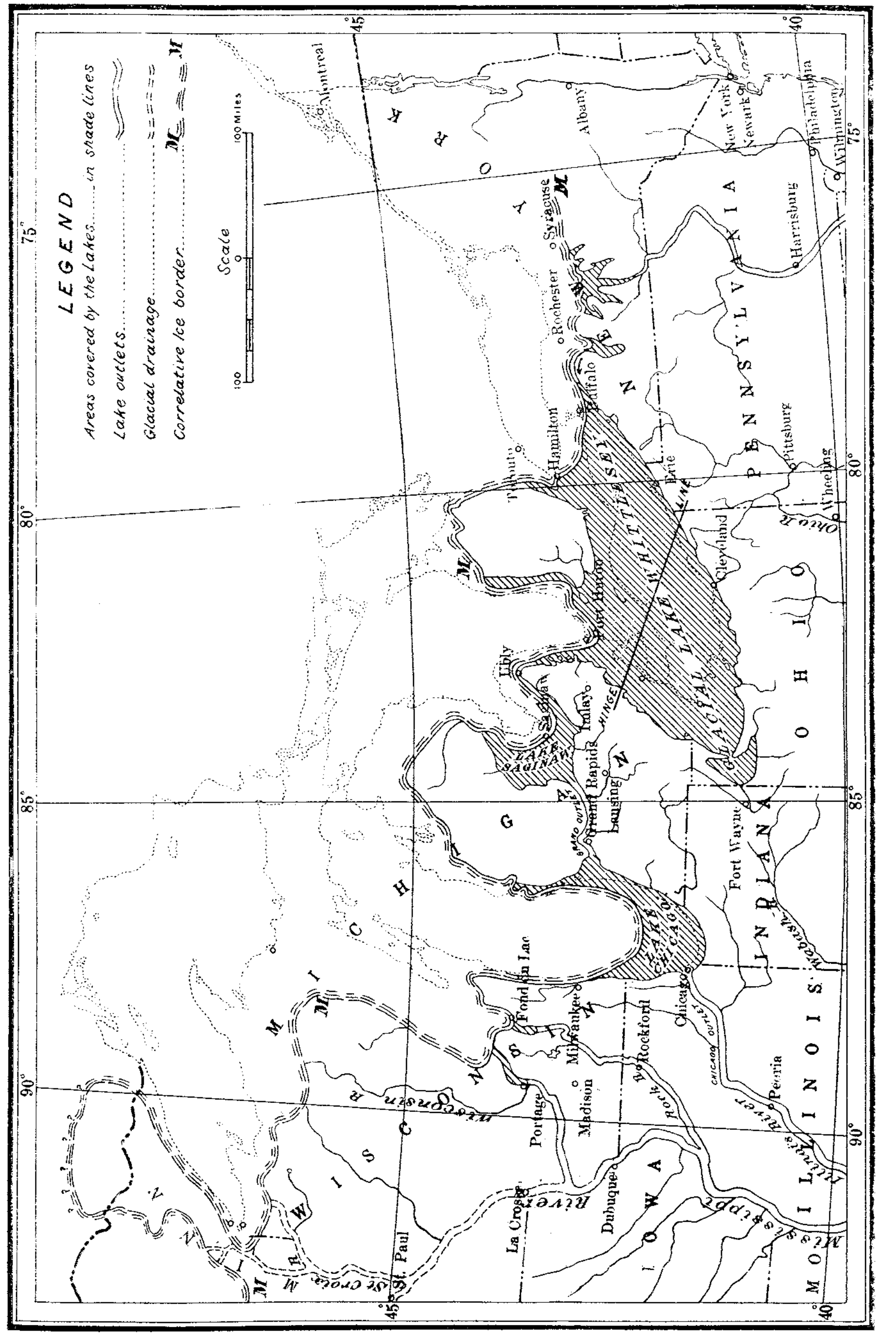


Fig. 12. Glacial Lake Whittlesey and correlatives. By Frank Leverett and Frank B. Taylor of the U. S. Geological Survey.

The lake thus impounded had approximately the form and extent shown in fig. 12, being about twice the area of Lake Erie. Its southern margin followed closely the present southern shore of Lake Erie from Buffalo to Sandusky, thence extended up the Maumee valley nearly to the Indiana line, turning abruptly to the northeast, across the northwestern corner of Wayne County and thence to the outlet at Ubly. The lake seems to have been held rather steadily at approximately the same level and for a considerable length of time, if we may judge from the development of the beach. Rather unfortunately this beach has been designated the "Belmore" from a small town in Ohio,[32] but it will simplify the study, already sufficiently complicated, and lead to no ambiguity, if we refer to it as the Whittlesey beach. As seen in southeastern Michigan it is a conspicuous gravel ridge, standing some 10 to 15 feet above the general level of the adjacent country, often deflecting the drainage streams, determining the location of the highways and furnishing an inviting site for farm buildings. It was generally recognized in an early day by the settlers, possibly also by the Indians, as marking an ancient shore line and received attention from the early Michigan and Ohio geological surveys.[33] Bela Hubbard had traced it for some 60 miles in southeastern Michigan and it was located on the map of Wayne County prepared by S. W. Higgins and published in 1840 in the Third Annual Report of State Geologist Houghton, p. 35.

In this section of the state, the elevation of the beach is now known very accurately from the work done by the U. S. topographical survey and is found to range from 735 to 740 feet above mean sea level, or say about 165 feet above the general level of Lake Erie. When traced northward it is found not to be horizontal, as we might reasonably expect it to be, but to gradually rise, and here we may stop to explain a phenomenon found in connection with the entire series of glacial lake beaches. From just beyond the "base line", the northern boundary of Wayne County, the rise is very gradual as far as Armada, in the northern part of Macomb County, amounting to about a half foot to the mile. From Armada northward to the outlet at Ubly the average rise is about three-fourths of a foot to the mile. With no recognizable tides in

32. N. H. Winchell: Proceedings of the American Association for the Advancement of Science, Dubuque meeting; 1873, p. 177.

33. Whittlesey, Second Annual Report of the Geological Survey of Ohio, 1838, p. 55..
Hubbard, Third Annual Report of the State Geologist of Michigan, 1840. House of Representatives, document No. 8, p. 102.
A. Winchell, Geology of Washtenaw County: History of Washtenaw County, Michigan, 1881, p. 161.
An interesting historical account of the work done upon the beaches of the Great Lakes region will be found in Goldthwait's The Abandoned Shore-Lines of Eastern Wisconsin: Bulletin No. XVII, Wisconsin Geological and Natural History Survey, 1907, p. 9.

our present system of great lakes this agency may be dismissed in seeking an explanation of this anomoly. Fluctuating stages of the lake level due to wind action, or to periodicity in the amount of rainfall, would give no such gradual rise in the elevation of a single beach or in the correlative uplift of the entire series. Col. Whittlesey had noted the phenomenon in Ohio, and previous to the year 1838. Observations about the mouths of the streams entering the Great Lakes have also indicated such a movement, either a subsidence toward the southwest, an elevation toward the northeast, or a combination of the two movements, leading to what is termed a "canting" of the lake basin. In order to discover whether the lake gauges might show any evidence of such a movement still in progress, Gilbert made an investigation with rather limited and unsatisfactory data and reached the conclusion that such a movement is indicated, amounting to .42 foot (5 inches) per century in a line 100 miles long, having the bearing S. 27° W.[34] About the same time Moseley was collecting botanical data to show that the islands opposite Sandusky, Ohio, had in recent geological time been connected with the main land.[35] Later detailed studies on the sand ridges of Sandusky Bay and Cedar Point, Lake Erie, led him to conclude that the level of the water is rising at an average rate of about 2.14 feet per century,[36] presumably from this same canting effect.

Although a gradual depression of the region to the southwest would bring about the same result, the view generally held is that to the northeastward a gradual elevation is in progress, continuing a movement started just at the close of the Glacial Epoch and inaugurated very probably by the disappearance of the ice sheet from the region. If the weight of this vast mass of ice had caused a subsidence of the underlying crust, it is fair to suppose that its withdrawal would lead to at least a partial recovery of the original elevation, starting first at the southwest and proceeding gradually in the direction of ice retreat. The beaches in the southwestern portion of the Huron-Erie basin should show the least amount of differential uplift, upon this theory, and the earliest formed beaches should show more than the younger ones. Such is indeed found to be the case[37] and the theory receives correspond-

34. Gilbert, Recent Earth Movement in the Great Lakes Region: Eighteenth Annual Report of the U. S. Geological Survey, part II, 1898, p. 635.

35. Moseley, Modification of the Great Lakes by Earth Movement: National Geographic Magazine, vol. VIII, 1897, p. 233.

36. Moseley, Formation of Sandusky Bay and Cedar Point: Presidential address, Ohio Academy of Science, vol. IV, part 5, 1904, p. 238. Abstract in Seventh Report Michigan Academy of Science, 1905, p. 38.

37. Gilbert, *loc. cit.*, page 603. Goldthwait, *loc. cit.*, page 21. See also recent paper by Hobbs, The Late Glacial and Post Glacial Uplift of the Michigan Basin: Publication 5, Geological series 3, 1911, p. 11.

ing support. This canting, or warping of the basin of the glacial lakes will be shown essential to a clear understanding of their history, amounting in some cases to as much as four to five feet to the mile in the Georgian Bay region.

An attempt has been made to account for some of this rise in the beach line by referring it to the attraction which the ice mass had for the adjacent body of water. A solution of this problem has been furnished us by Woodward, who finds that to produce an average rise in the water surface of five feet to the mile for a distance of 69 miles from the ice front would require the ice mass to be 24 miles thick about the center.[38] An ice front 10,000 feet high, exceedingly improbable during the waning stages of the ice sheet when the glacial lakes were forming, would cause an average slope towards the ice of 1.8 feet to the mile. It thus appears that the attraction of the ice for the water cannot be assumed to account entirely for the rise of the beaches toward the northeastward, although it was probably appreciable near the ice wall and should now be observed, if at all, where the beaches approach their correlative moraines.

Lake Wayne. The withdrawal of the ice entirely from the "thumb" of the Lower Peninsula of Michigan allowed the waters of the Erie-St. Clair basin to become confluent with those of Lake Saginaw, lowering the level of the combined lake some 80 to 85 feet. This lowering of the level contracted its area somewhat in Ontario, Ohio and Michigan, which loss, however, was more than compensated for by the incorporation of Lake Saginaw and the extension of the lake waters eastward into New York so as to include the Finger Lake region. The present site of Niagara was deeply buried in over 200 feet of water, drainage down the St. Lawrence being still prevented by the presence of the great ice wall. In thus falling to the lower level, the waters dropped beyond that of the next beach in the series, the Forest, or Warren beach, just as the Maumee had previously done. This was due to the temporary opening of an outlet believed to have been located just to the south of Syracuse, New York, allowing drainage into the Mohawk. In Michigan, the ice dam is believed by Taylor to have been located some 25 to 30 miles to the northeast of Bad Axe. The beach formed at this stage is very sandy in southeastern Michigan and the water line not well defined. It will be traced in some detail in the succeeding chapters. It has been generally known as the "Lower Forest" with an elevation in this region of some 655 to

38. Woodward, On the Form and Position of the Sea Level: Bulletin No. 48, U. S. Geological Survey, 1888, p. 68.

660 feet and was believed to mark the lower stage of Lake Warren. The more recent studies of Taylor have shown, however, that its level was not high enough to have permitted drainage through the Grand River outlet and in the forthcoming monograph the beach will be termed the Wayne, owing to its development at that village and the lake responsible for its formation will carry the same name. He found the evidence of submersion by the waters of the subsequent lake quite marked in the vicinity of the "thumb."

Lake Warren. A temporary advance of the ice in the region of the outlet of Lake Wayne closed that direction of escape and raised the level of the glacial waters some 25 to 30 feet, causing discharge westward by Pewamo, Ionia and Grand Rapids to Lake Chicago and thence to the Mississippi. The channel leading to Grand River is described by Taylor as 50 miles long, from three-fourths to one mile in width and descending to the southwestward at an average rate of about one foot to the mile.[39] The position of the ice dam during this stage is placed by this investigator a little to the west and south of Alpena and just south of Rochester, New York. The Erie lobe had retreated far to the northward in Ontario leaving a broad gap between the Lake Huron and Lake Ontario lobes.

The outline of this body of water is shown approximately in fig. 13 and to it the name Lake Warren has been applied by Taylor (*loc. cit.*, pp. 48 and 56.) The term "Lake Warren" had first been proposed by Spencer in 1888,[40] in honor of Gen. G. K. Warren, "the father of lacustrine geology in America," for the general expanse of waters covering the basin of the Great Lakes and believed by him to be marine in character. Used thus indefinitely and referred to later as "Warren Gulf" and "Warren Waters", it seemed desirable to restrict the name to a definite member of the series of glacial lakes. This Warren beach has an elevation of about 680 feet, is more gravelly and generally better defined than the Wayne, which is sandy and more or less obscured by wind and water action. These two beaches have been found to extend about the western and southern margins of Lake Erie, holding approximately the same interval and extending into New York, where they have been described as the "Crittenden beaches.[41] Only the lower mem-

39. Taylor, Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan: Bulletin of the Geological Society of America, vol. VIII, 1897, p. 52.

40. Spencer, The Iroquois Beach: A Chapter in the History of Lake Ontario: Science, vol. XI, 1888, p. 49.

41. Gilbert, Surface Geology of the Maumee Valley: Geological Survey of Ohio, vol. I, 1873, p. 554.
Newberry, Geological Survey of Ohio, vol. II, 1874, p. 59.
Sherzer, Geology of Monroe County: Geological Survey of Michigan, vol. VII, 1900, p. 140.
Leverett, On the Correlation of New York Moraines with Raised Beaches of Lake Erie: American Journal of Science, vol. L., third series, 1895, p. 10.

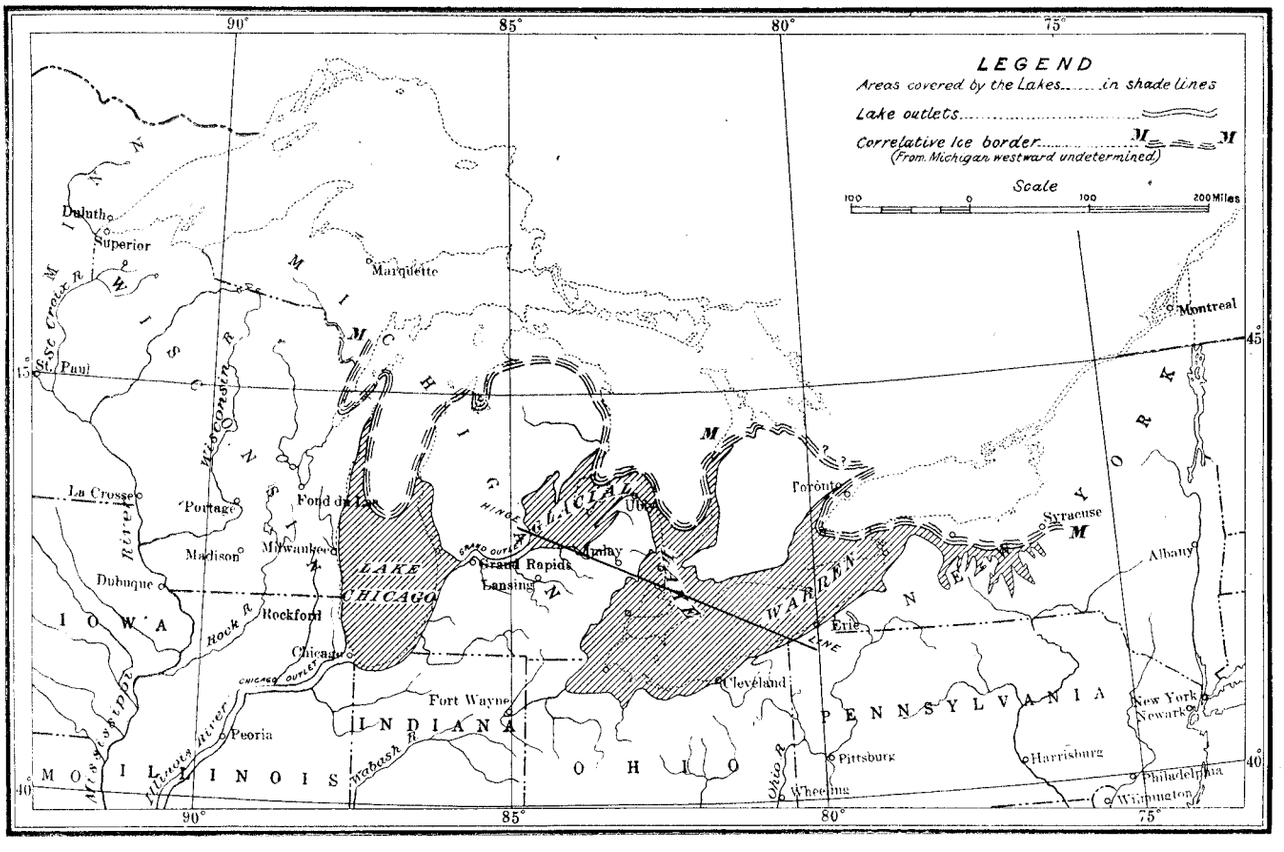


Fig. 13. Glacial Lake Warren and Lake Chicago. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

bers of the series reach as far as Crittenden, Erie County, New York, and continue to Lima; the upper beach stopping at Alden. The interval between the Whittlesey beach (in N. Y. the "Sheridan") and the highest Warren ("Crittenden") in western New York is about 50 feet and in southeastern Michigan about 56 feet.

Lake Lundy. In a paper recently read before the Michigan Academy of Science[42] Leverett disposes under the heading "Transitional Lakes" of two stages whose beaches were described in Huron County by Lane in 1900 and the uppermost of which was recognized by the present writer in Monroe County at the same time as lying between the Forest and Algonquin beaches.[43] At this time, they were regarded as marking still lower stages of Lake Warren than those indicated by the Upper (Warren) and Lower Forest (Wayne) beaches. In Huron County, the higher was termed the "Grassmere" from the small village of that county and was found to consist of a series of ridges reaching from 672 to 692 feet above sea level. The lower was named the "Elkton" and marked a stage of the water some 25 feet lower than the lowest of the above series (647 ft. above sea level, in Huron County). In Wayne County, two belts of sand dunes and ridges mark the location of these two beaches at elevations of 635-640 and 610-615 feet respectively, the differential uplift to the north accounting for the higher elevation of the beaches in Huron County. Wind action has apparently obliterated the triple character of the Grassmere, in case it was originally present. The vertical interval from the Wayne to the Grassmere is about 20-25 feet in Wayne County while in Huron County it measures 70 to 75 feet, apparently indicating that between the formation of these two beaches there was a time interval sufficient to allow a deformation of some 50 feet to take place.

These beaches have not been followed continuously to their outlets and correlative moraines and hence our knowledge of the lakes producing them is of a very indefinite character. Lane in his paper, previously referred to, included the Grassmere beaches with the Lake Warren series[44] and the Elkton beach with a lake of the Finger Lake region of New York, described by Fairchild and named Lake Dana.[45] The latest disposition of these two beaches is

42. Presidential address; Outline of the History of the Great Lakes: Twelfth Report, 1910, p. 34.
43. Lane, Geological Report on Huron County: Geological Survey of Michigan, vol. VII, pt. II, 1900, p. 74.
Sherzer, Geological Report on Monroe County: Same volume, p. 141.
44. Geological Survey of Michigan, Report for 1907, p. 130.
45. Fairchild, Glacial Waters in the Finger Lakes Region of New York: Bulletin of the Geological Society of America, vol. X, 1899, p. 56. See also American Journal of Science, Fourth Series, vol. VII, 1899, p. 260.

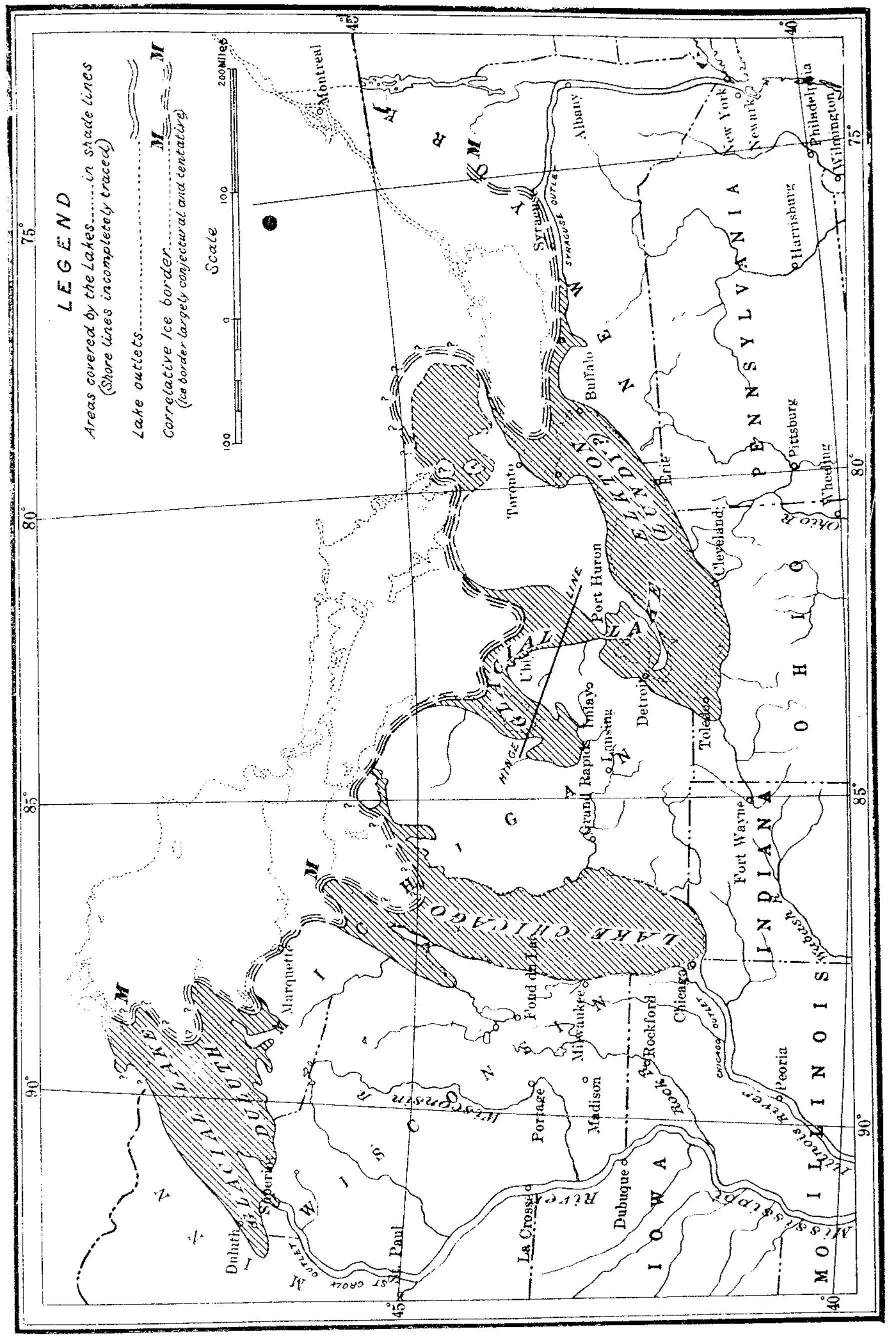


Fig. 14. Glacial Lake Lundy and correlatives. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

by Taylor who regards this lake as the western extension of Spencer's Lake Lundy of western New York and southern Ontario, the two stages of which we may recognize as the Grassmere and Elkton (See fig. 14).

Lake Algonquin. The withdrawal of the ice from the Straits of Mackinac to an unknown distance into Canada allowed the waters that had been accumulating in the basins of the three upper lakes to become confluent and a single vast water expanse resulted, known as Lake Algonquin.[46] This lake had a complicated history, the full discussion of which has been prepared by Taylor for the monograph previously cited. Starting with a theoretical stage covering the southern half of Lake Huron and draining southward by the St. Clair outlet, with the ice front near Alpena, Michigan, and Port Elgin, Ontario, the waters extended themselves into the basins of the three upper lakes. The withdrawal of the ice to the northeastward opened a passage way through the Trent River valley, at Kirkfield, Ontario, into Lake Iroquois, the predecessor of Lake Ontario.[47] The studies of Goldthwait in 1905 showed that the highest beach of Lake Algonquin in the Lake Michigan region skirts the head of the lake as the "Toleston beach,[48] which indicates that the lake, at its highest stage, made use of the old drainage channel of glacial Lake Chicago into Illinois River and thence to the Mississippi. The sill of this old outlet has an elevation now of eight feet above the present level of Lake Michigan, or about 590 feet above sea level. The use of these three outlets;— St. Clair, Chicago and Trent, conjointly, or separately, rendered possible a very complicated history, the stages of which may eventually need to be distinguished by separate names. Sometime during the early life of the lake the Mohawk valley became clear of ice sufficiently to allow the waters of the Ontario basin to drop, causing the separation of Lakes Erie and Iroquois and giving birth to Niagara. The presence of abundant molluscan life in Lake Algonquin is indicated by shell remains in the beach deposits, reported from several localities, and suggests that the waters were no longer of glacial temperature.[49] This change in temperature was ap-

46. This name was proposed by Spencer in 1888 for the lake, the beach and the river by which the lake was drained through the Trent valley, Ontario. Notes on the Origin and History of the Great Lakes of North America: American Association for the Advancement of Science, vol. XXXVII, 1889, p. 199.
47. Gilbert, The Algonquin River: American Geologist, vol. XVIII, p. 231.
48. Goldthwait, The Abandoned Shore-Lines of Eastern Wisconsin: Wisconsin Geological and Natural History Survey, Bulletin No. XVII, 1907, page 42. Leverett, Chicago Academy of Sciences: Bulletin No. II, 1897, p. 74.
49. Marcy, Geological Survey of Illinois, vol. III, Geology and Paleontology, 1868, p. 250.
Alden, Chicago Folio, No. 81, U. S. Geological Survey, 1902, p. 10.
Lane, Geological Survey of Michigan, vol. VII, 1900, p. 248.
Goldthwait, Bulletin No. XVII, Wisconsin Geological Survey, 1907, p. 118.
Leverett, Chicago Academy of Sciences, Bulletin No. II, 1897, p. 77.

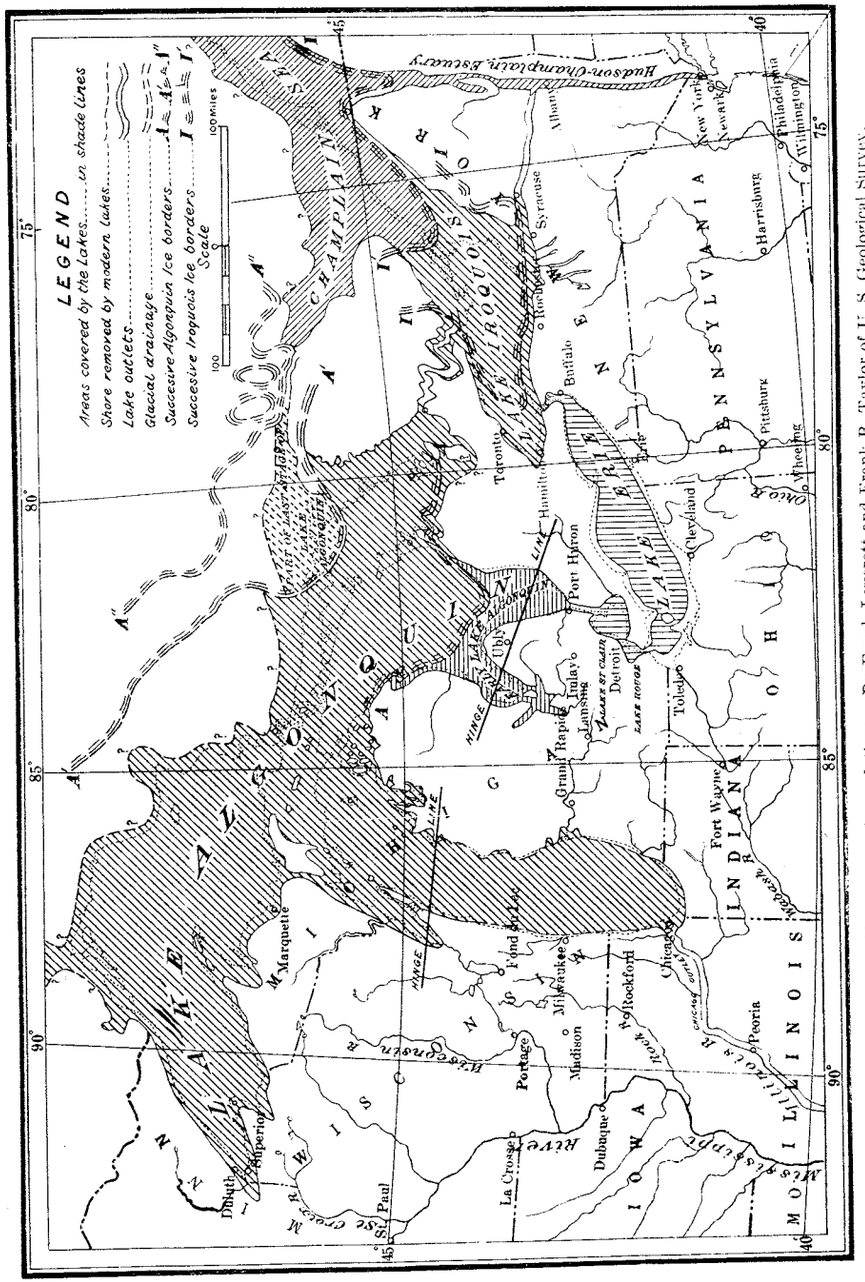


Fig. 15. Glacial Lake Algonquin and correlatives. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

parently due to the reduction of ice frontage as the ice wall withdrew into the Mattawa and Ottawa valleys of the Georgian Bay region. One stage of Algonquin history is shown in fig. 15 during the life of the Trent and St. Clair outlets.

The differential uplift to the northeastward, to which previous allusion has been made, is believed to have been responsible for the elevation of the bed of the Trent outlet sufficiently to cause the waters to escape southward at the present site of Port Huron, through the St. Clair and Detroit valleys into Lake Erie. It has been suggested that both the Chicago and St. Clair outlets may have served at the same time, supposing that Lake Iroquois was then in existence. Lake Erie was deprived of the drainage from the three upper lake basins, was considerably smaller than at present (elevation 560 feet), but the beaches then made by which its size and depth could be determined are now submerged by its own waters. St. Clair and Detroit rivers carried simply the water from their own, comparatively small, drainage basins and were correspondingly reduced in size. Their tributaries flowing to this lower level cut channels considerably below what is now the normal depth for these streams. Since Lake Algonquin did not reach as far south as Wayne County only its correlative beaches are there represented, encircling the present margin of Lake St. Clair and that of the extinct Lake Rouge (see below). These are the bodies of water through which the Algonquin drainage took place during certain stages and hence they stand at a somewhat lower level, about 590 feet above tide, or 15 feet above the present water level. Owing to the relatively limited size of these bodies of water and the consequent weak wave action, these correlative beaches, to be termed by Taylor the First St. Clair and First Rouge, respectively, are generally poorly defined. In places a slight cut in the clay, or a faint gravel ridge is all that marks the former water line.

Lake Rouge. During the later phase of Lake Algonquin and simultaneously with the existence of First Lake St. Clair, there was an embayment of water covering the lower Rouge basin to which the name "Lake Rouge" will be given by Mr. Taylor in a forthcoming monograph of the U. S. Geological Survey (The Pleistocene of Indiana and Michigan) now in preparation by Messrs. Taylor and Leverett.[50] This lake covered the present site of the

50. Through the kindness of these authors, the writer has had access to those portions of their manuscript dealing with the physical features of southeastern Michigan and has had the benefit of their personal explanations and advice. The lake stages reproduced in this chapter are also from this source and here used through the courtesy of the U. S. Geological Survey.

Woodmere and Delray additions to the city of Detroit, the southern half of Springwells township, the eastern two-thirds of Ecorse and the northern point of Grosse Isle. In Essex County, Ontario, it extended some one to four miles east from the river, the heavy sands obscuring the features of the Grosse Isle moraine described later. The lake was some 10 to 12 miles in length and 8 to 9 miles broad, the upper beach standing from 588 to 590 above sea level, but with sand ridges rising to 595. The lake was a shallow one and the bottom was subjected to wave action throughout the greater part of its extent. The lower, or Second Rouge beach, was formed during the life of Lakes Nipissing at an elevation of 580 to 582 feet above sea level. In places it is represented by a well defined sand ridge, again as a cut terrace, but owing to recent steam action can not be continuously traced.

Nipissing Great Lakes. Modern Lake Nipissing lies in an east and west trough, leading across the highlands north of Georgian Bay to the valleys of the Mattawa and Ottawa rivers in Ontario. Here a comparatively narrow ice dam had sufficed to hold back the waters of Lake Algonquin for many centuries. Finally a weakening of the ice along the southern margin of the valley allowed some of the water to escape and the level was gradually lowered, with halts sufficiently long to permit the formation of a succession of weak beaches. At first, the discharge from the receding lake was through both outlets, but was gradually shifted to the Nipissing, and thence through the Mattawa and Ottawa valleys to an arm of the ocean (Champlain Sea) then covering the Ontario and St. Lawrence basins. When the ice and its deposits had been cleared away the cutting down of the outlet was very slow and the water level was fairly constant for a relatively long period, so far as may be judged from the strength of the beach formed. The lake at this stage occupied the basins of the three upper Great Lakes (Superior, Michigan and Huron), reaching slightly beyond their present limits, as is shown in fig. 16. To this body of water, already differentiated into our present lakes, and their immediate predecessor, Taylor gave the name Nipissing Great Lakes.[51]

The gradual differential uplift to the northeastward slowly brought the Nipissing outlet to the approximate level of the bed of the St. Clair and drainage through both outlets is believed to have taken place for a considerable time. Finally the drainage was completely shifted to the St. Clair-Detroit outlet, into Lake Erie, and lakes Huron, Michigan and Superior may be said to have

51. A short History of the Great Lakes: Studies in Indiana Geography, first series, 1897, p. 105. See also The Second Lake Algonquin: American Geologist, vol. XV, 1895, p. 100.

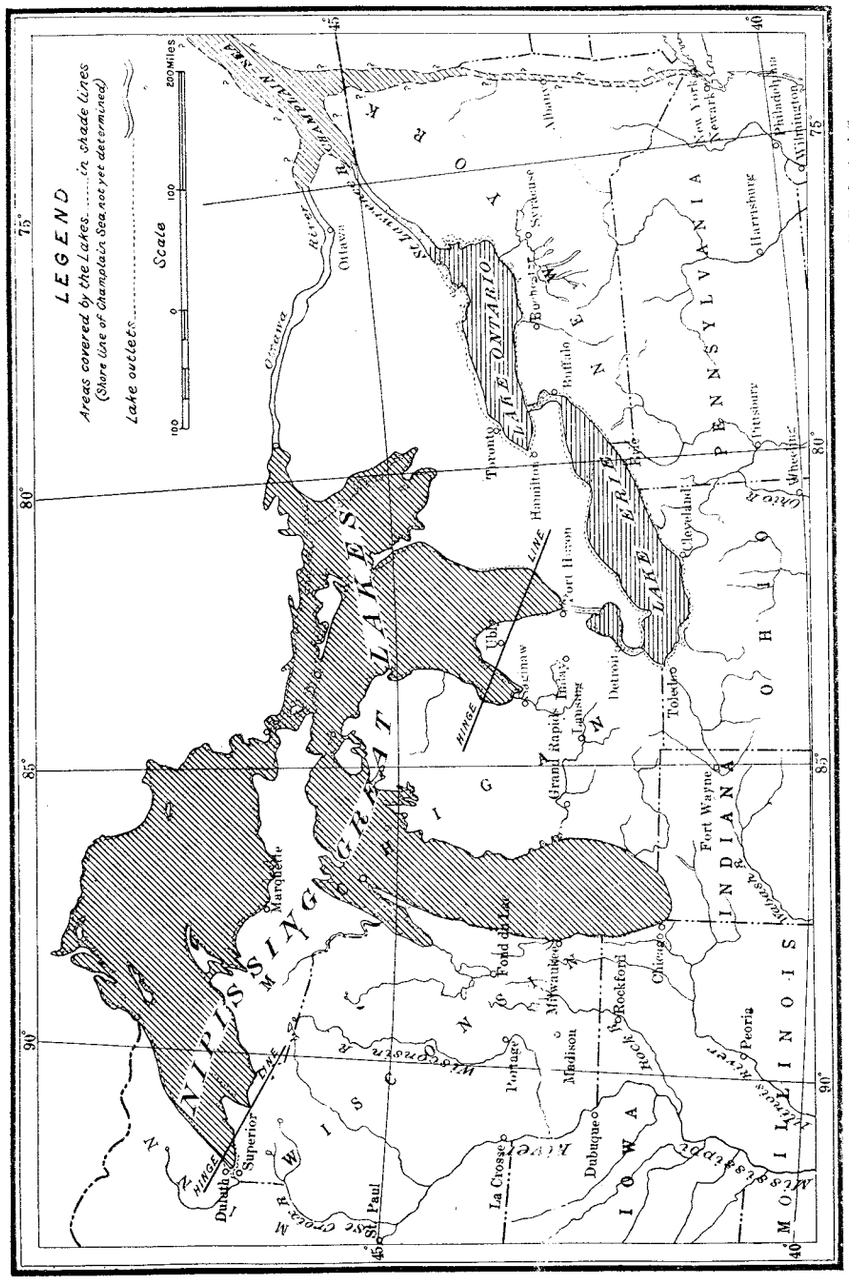


Fig. 16. Nipissing Great Lakes and correlative marine waters. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

come into existence. The northeastward uplift has continued until the old Nipissing outlet now stands about 100 feet higher than when it was abandoned, giving the beaches a gradual tilt in that direction. As previously noted the correlatives of the Nipissing beaches are represented in Wayne County by the Second St. Clair and Second Rouge beaches, some 6 to 7 feet above the present level. They consist in places of a cut bench close to the present water line or of a sand ridge, removed to a greater or less distance by the surface slope.

Time estimates. Reference has been made to the relative time involved in the various lake stages described in this chapter and every student of the subject grasps eagerly at any opportunity offered to translate this time into actual years. Based upon the amount of cutting done by the waters of Niagara since it came into existence, various observers have made estimates of the time that has elapsed since the waters of the Ontario basin separated from those of the Erie basin.[52] There are so many factors of uncertainty, however, that these estimates are at wide variance with one another. Chamberlin and Salisbury give 25,000 years as the mean of all such estimates.[53] Leverett considers that the time can not be less than 15,000 years and may as great as 30,000.[54] Based upon the amount of weathering that has taken place along the walls of the gorge of Niagara, Wright has made an estimate of its age independently of the rate of stream erosion and places this at 10,000 years.[55] These estimates, it should be noted, cover the time that has elapsed since the early life of Lake Algonquin. In order to reach back to the beginning of Lake Maumee, they should probably be doubled.

In his report on Huron County (*loc. cit.*, 1900, p. 79), Lane has furnished us an estimate of the time involved in this lake history since the birth of Lake Warren, based upon the volume of the beaches and dunes derived therefrom and upon the amount of cutting of the land by the waves during the various stages. He considers that some 4,000 years have elapsed since Lake Algonquin came into existence and that the wave action since more than equals that which preceded. If we note that the amount of such action, in a given time, would be considerably greater in the more expanded, later lakes than in the earlier, smaller ones we may double this estimate of 4,000 years, and perhaps extend it to 10,000.

52. Wright, Ice Age in North America, 1889, p. 448.
53. Geology, vol. III, 1906, p. 419.
54. Twelfth Report of the Michigan Academy of Science, 1910, p. 40.
55. New Method of Estimating the Age of Niagara Falls: Popular Science Monthly, vol. LV, 1899, p. 145.

Some 30 years earlier than this work of Lane's, Andrews had similarly based time estimates of the beaches about the head of Lake Michigan upon the action, both destructive and constructive, now taking place at the present level.[56] His estimate is some 6,000 years since Lake Chicago came into existence, one-half of which is to be assigned to the present Lake Michigan. Since Lake Chicago was the contemporary of Lake Maumee, this estimate would apply also to the series of glacial lakes of the Huron-Erie basin. Lane calls attention to the fact that since the Nipissing beach is not represented in the region studied by Andrews his estimate of 6,000 years would need to be considerably extended.

Still another method of gaining some idea of the length of time involved in this geologically recent history of this region may be based upon the rate of uplift now believed to be in progress. Lane has estimated that if this rate has been continuous for a sufficient time, to bring the present water-plane up to that now indicated by the Nipissing beach would require about 14,000 years.[57] It is very probable, however, that the rate of uplift was considerably more rapid as we pass back to the time when the ice was just withdrawing from the region and that any estimates based upon the present, supposed rate of uplift would need to be considerably reduced. This discussion is sufficient to show the reader that the factors involved in all such estimates are as yet very uncertain quantities, but that the glacial lake history is to be reckoned in *thousands* of years, rather than centuries and that it may fall within the period of human occupancy of the continent.

If estimates of the age of the series of glacial lakes are found to be so divergent and uncertain, still more so will be those formulated to express the ages of the various ice sheets themselves. Consequently, these data will need to be expressed in hundred-thousands of years, instead of simple thousands, and they are founded upon the relative amount of stream and atmospheric erosion, combined with weathering and leaching, that has affected the surfaces of the various till-sheets in those regions where they were not covered or modified by subsequent ice invasions. From an intimate acquaintance with the various areas suitable for such comparative study, Leverett has estimated that in the case of the Late Wisconsin fully nine-tenths of the till plains still stand at the original level,[58] while, in the case of the Illinoian, only one-half

56. The North American Lakes Considered as Chronometers of Post Glacial Time: Transactions of the Chicago Academy of Sciences, vol. II, 1870, pp. 1 to 23. See also American Journal of Science, vol. XCVIII, 1864, p. 172.
57. Huron County report; *loc. cit.*, 1900, p. 84.
58. Leverett, Weathering and Erosion as Time Measures: American Journal of Science, vol. XXVII, 1909, p. 354.

remains. The Kansan till-sheet, produced by one of the great movements from the Keewatin center, is similarly estimated to have only *one-tenth* of the original glacial deposit left at the original level. Bain has estimated that the capacity of the post-Kansan valleys in Iowa is 10 to 15 times greater than that of the post-Wisconsin valleys,[59] and apparently nearer the larger figure. In 1896 Chamberlin, after consultation with various individuals familiar with the field phenomena, made up a table showing the age ratios of the various glacial stages then recognized. Calling the time interval unity that has elapsed since the culmination of the Late Wisconsin, the age of the Early Wisconsin is expressed by 2½; the Iowan by 5; Illinoian 7 and Kansan 15.[60] The latest contribution to this discussion has recently been made by Leverett and presented to his class in glacial geology at the University of Michigan (1909). Taking 25,000 years as a fair estimate of the time involved in the formation of the gorge of Niagara he constructs the following table.[61]

TABLE VII.—ESTIMATED AGE OF GLACIAL EPISODES (LEVERETT).

	Years.
Culmination of Late Wisconsin	50,000
Culmination of Early Wisconsin	100,000
Beginning of Wisconsin	150,000
Culmination of Illinoian	300,000
Beginning of Illinoian	350,000
Culmination of Kansan	750,000
Beginning of Kansan	800,000
Culmination of pre-Kansan (Nebraska)	950,000
Beginning of pre-Kansan	1,000,000

The chief value of such a table is to convey to the reader the probable great age of this geologically recent episode in our earth's history and to furnish a basis for the comprehension of the relative times at which the various events occurred.

59. Bain, Relations of the Wisconsin and Kansan Drift Sheets in Central Iowa, and Related Phenomena: Iowa Geological Survey, vol. VI, 1897, p. 474.
60. Chamberlin, Journal of Geology, vol. IV, 1896, p. 876.
Table of estimates slightly revised, Chamberlin and Salisbury's Geology, vol. III, 1906, p. 414.
61. See also table given by Chamberlin and Salisbury in Geology, vol. III, 1906, p. 420.

TABLE VIII.—GLACIAL LAKES OF THE HURON-ERIE BASIN.—(BASED UPON A TABLE PREPARED BY FRANK B. TAYLOR, MARCH, 1913.)

Name of lake.	No. of stages.	Names of beaches.	Elevation of beach south of "hinge line."	Location of ice dam.	Location of outlet.	Location of beach in Wayne County.
Maumee	3	Highest or Van Wert	800 to 812	Defiance and Birmingham moraines. Scofield boulder belt.	Ft. Wayne channel.	Series crowded together between Plymouth and Waterford.
		Middle or Leipsic	775 to 785	Imlay to Yale moraines.	Mainly Imlay channel, also Ft. Wayne.	
		Lowest	770 ±	Unknown	Probably north of Imlay City.	
Arkona	3–4	Highest	708 to 710	Some 25 miles to the northeast of Bad Axe.	All stages by Grand River channel.	Denton and Nankin.
		Middle	698 to 702			
		Lowest	690 to 694			
Whittlesey	1	Whittlesey or Belmore	735 to 740	Port Huron moraine.	Ubly channel to Lake Saginaw.	Plymouth.
Wayne	1	Wayne or Lower Forest	650 to 657	Nearly same as for Arkona.	Probably south of Syracuse, N. Y.	Romulus, Wayne, Livonia.
Warren	1	Warren or Upper Forest	675 to 680	Somewhat to the west and south of Alpena.	Grand River channel to Lake Chicago	Canton.
Lundy	2	Grassmere	635 to 640	Slightly farther north than for Warren.	Probably south of Syracuse, N. Y.	New Boston, Sand Hill, Highland Park, Hand, Dearborn, North Detroit.
		Elkton	615 to 620			
Algonquin	4	Early Algonquin	607 ±	Across bed of Lake Huron north of "thumb."	Port Huron outlet.	Not recognizable.
		Main or Upper	603 to 607	Superior, Huron and Georgian Bay.	Kirkfield, Ont., Port Huron and Chicago.	Correlative only, shown by the First St. Clair and First Rouge.
		Battlefield	?	Same but farther north.	Port Huron mainly, also Chicago.	
		Ft. Brady	?	Northeast of Georgian Bay.	Same as for Battlefield.	
Nipissing	2	Nipissing, one-outlet	596	No ice dam for either stage.	North Bay, Ont.	Correlative shown in Second St. Clair and Second Rouge, skirting present shore line.
		Nipissing, two-outlets			North Bay and Port Huron.	
St. Clair	2	First St. Clair	593	Same as main Algonquin.	Upper early Detroit River.	St. Clair Heights. Milk River Point, Cottage Grove, Fairview.
		Second St. Clair	582	No ice dam.	Next stage upper Detroit River.	
Rouge	2	First Rouge	593	Same as main Algonquin.	Lower early Detroit River.	Flat Rock, Wyandotte Heights, Woodmere Cemetery.
		Second Rouge	582	No ice dam.	Next stage lower Detroit River.	Ft. Wayne, Brady Island, River Rouge.

CHAPTER III.

PHYSICAL GEOGRAPHY OF WAYNE COUNTY.

SURFACE CONFIGURATION.

General topography. The surface features of Wayne County readily fall into two main divisions, easily distinguished and clearly understood in the light of its recent geological history. There is first the rough, morainic area covering only the northwestern corner of the county and the broad, flat lake plain; which, were it not for subsequent stream, wave and wind action would appear remarkably even. As noted by Hubbard in his early geological report, the dividing line between these two areas is the Whittlesey beach, the location of which was determined by the eastern slope of the morainic area itself while the waters of this and the subsequent lakes subdued any elevations that may have been left by the ice sheet and filled in with clay or sand any depressions. Between the Whittlesey and Upper Maumee beaches there is an intermediate strip, quite narrow in Wayne County, but broadening to the southwestward, which partakes somewhat of the character of either main area. Throughout this strip the morainic knolls were originally low, the depressions shallow and wave action and deposition slight although plainly noticeable when looked for. Along the entire eastern margin of the county, morainic features may also be detected but they are more or less obscured and disguised, owing to the conditions of their formation and subsequent history, and they blend very naturally with the features of the lake plain itself.

The highest point noted in the county by the U. S. Topographic Survey is the extreme northwestern corner, 975 feet above sea level, or 400 feet above the ordinary level of Detroit River at Detroit. A few hundred yards to the southeastward a slightly higher ridge places the county below the plane of vision and serves as a narrow water-shed for the surface drainage of this region. The general slope from this level is southeastward and averages about 16 feet to the mile, but from the base of the inner slope of the Whittlesey beach to the river level is only one-half this amount, or but 8 feet to the mile, a slope imperceptible to the eye. This slope of the

surface of the till imparted to the streams of the county their general southeasterly direction, gave the beaches their northeast-southwest trend and, as will be pointed out later, projected itself forcibly into the subsequent history of the region.

Moraines and boulder belts. If one stands on the "base line", at this extreme northwestern corner of the county, where by moving a step he may bring himself into Wayne, Washtenaw or Oakland counties, and casts his eye from north around to the southwest he notes an elevated tract made up of numerous knolls and ridges, extending in a northeast-southwest direction across Oakland and Washtenaw counties. Although he is now on a relatively level gravel and sand tract, nearly a thousand feet above the sea, broad knolls to the north and west may be seen from one-half mile to two miles distant rising to an additional height of 150 feet. To the northeastward this rough belt of country extends into St. Clair and Sanilac counties and in the opposite direction into Ohio and Indiana and constitutes the Ft. Wayne moraine. It was formed by the Late Wisconsin ice sheet, during a temporary halt of the ice front, when the Huron-Erie lobe of ice completely covered the county of Wayne as a broad tongue with a northeast-southwest axis. Historically, this moraine is of interest since it was one of the first to be recognized in the country, being described by Gilbert in 1871.[1] Owing to its relation to the St. Mary's River, in Ohio, it was named the "St. Mary's ridge"[2] and because of its subdued character in that region was believed to represent a moraine buried in lake clays. This moraine is figured by Chamberlin in his paper the Terminal Moraine of the Second Glacial Epoch,[3] but is there undescribed and unnamed. The term "Ft. Wayne" was first applied to it by Taylor in 1897 in a paper entitled "Moraines of Recession and their Significance in Glacial Theory" (Journal of Geology, vol. V, p. 433). A description of that portion lying in Ohio and Indiana will be found in Leverett's Monograph (No. XLI) of the U. S. Geological Survey[4] and a further description of the Michigan portion of this moraine has been prepared by Leverett and Taylor for a forthcoming monograph on the glacial features of southern Michigan. The crest of this moraine in Washte-

1. Gilbert, On certain Glacial and Post-glacial phenomena of the Maumee Valley: American Journal of Science and Arts, Vol. I, 3rd series, 1871, p. 340. Also Geological Survey of Ohio, Vol. I, 1873, p. 540.
2. N. H. Winchell, The Surface Geology of Northwestern Ohio: Proceedings of the American Association for the Advancement of Science; Dubuque meeting, 1873, p. 168. By Dryer in 1889, it was referred to as the "St. Mary's and St. Joseph Moraine:" Sixteenth Annual Report of the Department of Geology and Natural History of Indiana, p. 114.
3. Third Annual Report of the Director of the U. S. Geological Survey, 1883, pl. XXXI.
4. Glacial Formations and Drainage Features of the Erie and Ohio Basins, 1902, pp. 566 to 578. See Also Ann Arbor Folio, No. 155, U. S. Geological Survey, 1908, p. 6.

naw and Oakland counties forms the water-shed between the basins of the upper Huron and Rouge rivers.

The ice sheet finally withdrew from the Ft. Wayne moraine, uncovering the extreme northwestern corner of the county and making a comparatively brief halt. The ice margin fluctuated over a strip about a mile broad, pushing up ridges and knolls, separated by sags and "kettle-holes", the general course of which was parallel with the previously formed moraine. In places, the glacial drainage streams left the ice under "head" and the sand and gravel carried by these torrents built up knolls and ridges of irregularly stratified deposits of these materials about the margins of the ice, partly beneath and in the reëntrant angles of the irregular ice front. These deposits are known as *kames* and they are so numerous in secs. 4, 5, 6 and 7 of Northville township as to constitute a "kame-moraine", a term suggested by Salisbury for similar moraines seen in New Jersey.[5] A detailed study of 2,000 pebbles from the kames of northwestern Wayne and the adjacent portion of Oakland county indicates that from 40 to 50% of them are limestone or dolomite and but about 19% are of the crystalline type. This indicates that the supply of rock fragments for these kames was derived, in the main, from the till deposits rather than from the ice itself and suggests that the streams were of the subglacial type, instead of being englacial, or supraglacial. Of the 1,000 pebbles from a single kame, the property of the Detroit United Railway, at Northville, 506 were calcareous, of which 216 (43%) were limestone and 290 (57%) were dolomite. About 1/7 of the pebbles were found to be quartzite (15%) and about the same (13%) proved to be chert, derived originally from calcareous strata. The subangular to rounded condition of these pebbles, when compared with those from the till, indicates that they have been subjected to considerable stream action by the glacial currents. Owing to its position between the Ft. Wayne and Defiance moraines and its apparent distinctness from either in this region, this moraine was referred to by Leverett in the Ann Arbor Folio (p. 6) as the "middle moraine" but may best be designated as the Northville from its relation to that village. Southwestward towards Ann Arbor, it unites with the Ft. Wayne, indicating little or no retreat of the ice front here from its former position. From Ann Arbor southward, it is distinct from the Ft. Wayne but becomes united with the Defiance and indistinguishable from it. The roughest portion of this moraine in Wayne County is found in

5. Report of the State Geologist of New Jersey for 1892, p. 93. The Glacial Geology of New Jersey, 1902, p. 117.

section 5 of Northville, where the knolls rise to 940 and 960 feet above sea level. Boulders are scattered sparingly over the surface of the moraine where they were dropped as the ice melted from beneath them.

After another slightly more pronounced retreat of the ice front to the southeast and a fluctuating halt, there was formed the Defiance moraine, a belt two to three miles broad of knolls and irregularly disposed ridges, mostly of till but occasionally also of gravel and sand, having a northeast and southwest course across Canton, Plymouth and Northville townships. The knolls rise to a height of 840 to 860 feet very generally but reach the 900 foot contour in SE. ¼ sec. 11 and 920 in the NW. ¼ sec. 16, Northville township (see Pl. X). Toward the northeastward, this moraine extends parallel with those previously formed, curving to the northward and then westward in Lapeer County. In the opposite direction, it stretches across Washtenaw and Lenawee counties, curving to the southward and eastward in the Maumee valley. This portion was first figured by Gilbert in 1871, at the time of the mapping of the Ft. Wayne moraine, and it was then regarded as a terminal moraine deeply buried in lake clay.[6] Although Gilbert assigned no name to it the name "Blanchard Ridge" was used by N. H. Winchell in his paper upon "The Surface Geology of North-Western Ohio" (*loc. cit.*, p. 175) this name being derived from one of the streams, the course of which it governs. This name was subsequently changed to "Defiance", from the name of the city located thereon.[7] Where the moraine is crossed by the Pere Marquette Ry., west of Plymouth, the profile shows a ridge crest in the NW. ¼ sec. 20, at an elevation of 852 feet, a sharper and higher crest (862 feet) lying 1,100 feet to the eastward, with the bottom of the sag 837 feet. In the SE. ¼ sec. 20, there occurs the highest crest (866 feet) along the line of the railway. Along the eastern slope of the moraine, into section 21, the fall is rather rapid, dropping below the 800 foot contour, rising to 834 feet in SE. ¼ sec. 21, showing three minor ridges and dropping to the level of the Maumee beaches in SW. ¼ sec. 22, Plymouth.

The steepest slope is upon the eastern side of the moraine from the 800 to the 760-foot contour and this strip is dissected by short, parallel streams and was considerably eroded by the waves of the Maumee lakes. Between the Upper Maumee beach (812 feet) and that of Lake Whittlesey (736 feet), the morainic ridges and

6. On certain Glacial and Post-Glacial phenomena of the Maumee Valley: American Journal of Science and Arts, third series, vol. I, 1871, p. 341. See also Geological Survey of Ohio, vol. I, 1873, p. 542.

7. Leverett, Monograph XLI, U. S. Geological Survey, 1901, p. 581.

mounds gradually die out, some of them exhibiting signs of wave cutting while submerged in Lake Maumee. Throughout this morainic surface boulders are rather sparingly displayed, and none of considerable size were observed. The wells on the moraine are too shallow to reach bedrock, or reliance is had upon the numerous springs of the region so that the actual thickness of the morainic deposit is unknown. The nearest records are from Plymouth and Northville and indicate a probable thickness of 150 to 250 feet.

Subsequent to the formation of the Defiance moraine just described the ice front withdrew for a distance of one to ten miles, shortly beyond the present sites of Plymouth and Denton, and there appears to have made a quiet and relatively brief halt, depositing a line of cobbles and boulders which can be traced continuously across the NW. ¼ Livonia, the SE. corner of Plymouth and southward across the center of Canton and Van Buren townships to Belleville. Here the course appears to be westward, parallel to the river, crossing it at Rawsonville, where the boulders have been concentrated by stream action, as noted in 1838 in the field notes of Hubbard. The boulder belt continues westward into Washtenaw County and appears to join the Defiance moraine in the southwestern corner of Ypsilanti township. From Belleville westward the surface boulders have been largely obscured by subsequent delta deposits and are seen mainly in the valley of the Huron and its short tributaries. In Livonia and Plymouth townships the boulder belt lies between the 700 and 720-foot contours, dropping in Canton township to the interval between the 700 and 680 foot contours and again rising to the former level as the belt passes into Washtenaw County (see Pl. X). In many places along this boulder belt, the rock fragments have been collected and utilized for foundations and, as this goes on, traces of this stage of halt of the ice will be gradually obliterated. At only a few places were they originally abundant enough to be obtrusive. It may appropriately be designated the "Rawsonville boulder belt" to distinguish it from the two subsequently formed.

A second boulder belt, apparently entirely independent of any of the previously described moraines, has been traced by the writer across Wayne, Monroe and Lenawee counties into Ohio (Pl. X), and believed by the writer to indicate another stage of halt of the

ice margin in its retreat from the western to the eastern part of the county. From the village in Monroe County near which it passes, this may be distingnished as the "Scofield boulder belt". The halt seems to have been accompanied by no minor advances in Wayne and Monroe counties whereby a set of ridges might have been produced in the underlying ground-moraine and the rock fragments embedded in the ice, or resting on its surface, were brought to the margin and there dropped. Granting that these were fairly abundant, the time involved in the halt may have been short, but if we may judge of their abundance by the number present in the next older (Defiance) and next younger Grosse Isle moraines, the time allowed for the formation of the boulder belt must be correspondingly increased. The boulders consist of subangular fragments of granites, gneisses, schists, greenstones, conglomerates and quartzites. Limestones are rare and sandstones and argillites still more so. Only occasionally is one found with traces of glaciation, quite in contrast with the rock fragments of the till.

The belt is a narrow one, from one to two miles broad and, in places, is completely obscured by subsequent deposits of beach and delta sands and gravel. It is less well defined, where it enters Wayne from Oakland County, crossing Livonia and Nankin townships somewhat eastward of the central meridian. In sec. 15 of Livonia, the boulders and cobbles are not much in evidence but there is a suggestion of morainic topography there indicated. The rock fragments become more numerous in passing southward, being noticeable between Wayne and Eloise and abundant in the northern part of Romulus township, but obscured by sand in the SW. ¼. Southward across the western strip of Huron township, the belt may be followed, leaving at the SW. corner and entering Monroe County, crossing Exeter township near Scofield, Maybee, between Raisinville and Grape to Federman, where it disappears again under a heavy deposit of sand. The general course leads one to expect the reappearance of the belt just north of Ottawa Lake and here again it is seen, passing into Lenawee County and entering Ohio from three to four miles west of the SE. corner.

Across Wayne County, this boulder belt drops from 680 feet above sea level to about 620, entering Monroe County between the contours of 620 to 630 feet. South of Maybee the belt turns upon higher ground instead of following the contours, or dropping to

lower level.[8] A similar and parallel boulder belt, the Grosse Isle, lying in the eastern part of the county, shows the same anomalous behavior at the same latitude, suggesting that, at both stages of ice halt, an extra pressure to the westward was being exerted from the direction of the Erie basin.

Protected somewhat by the Detroit moraine, this pressure from the east would become greater opposite the axis of the Erie basin and might be expected to cause such westerly deflection of the ice margin. Entering Ohio, both boulder belts swing around parallel with the contours but have not been followed for any considerable distance. If they do really indicate an ice margin, during a temporary stage of halt they will be found looping around the Maumee valley inside of the Defiance moraine. In the opposite direction, from the NE. corner of Livonia township, there rises a flat, wave-washed ridge which may be a continuation of the Scofield boulder belt, although not absolutely connected with it. It has a breadth of one to two miles, rises rather rapidly from 640 feet to 780 at Birmingham, deflecting the North Branch of River Rouge to the southwestward and passing without break into the Birmingham moraine.[9] According to one interpretation this strip of moraine, and the boulder belt which appears to be its continuation, were formed by the ice margin of the Erie lobe; while the correlative moraine, that from Birmingham to the northeastward, was formed simultaneously by the Huron lobe. During and previously the Detroit moraine was in process of formation beneath the ice along the line of junction of the two lobes, extending backward into the ice and inclined at a rather high angle to the ice margin.

From the neighborhood of Birmingham, there swings into Wayne County across the NE. corner of Redford and NW. corner of Greenfield townships a broad swell in the till to be known as the

8. This anomalous behavior for a boulder belt which marks an ice margin has led Mr. Taylor to question this interpretation of the writer and to suggest, as an alternative hypothesis, that these boulders may have been concentrated in drainage channels upon the surface of the ice. Although the Labradorean ice sheets probably carried few boulders upon their surfaces, in their waning stages, the englacial boulders must have been concentrated upon the surface by melting and may be assumed to have worked their way into neighboring ice channels. However, it is difficult to believe that such channels could have had a breath of two to three miles, that their streams could have flowed for many miles so nearly parallel with the theoretical margin of the ice lobe and that three so nearly parallel great channels could have existed upon the same lobe as are necessary to account for the Rawsonville, Scofield and Grosse Isle boulder belts (see pl. X). In view of these difficulties, of the relation of these belts to the recognized moraines, that they seem to mark what must have been the approximate ice border at certain stages of retreat and that a halt or two of the ice margin was to have been expected between the Defiance and Grosse Isle positions, the writer has been induced to accept the view that these boulders were dropped at the margin of the ice during a stage of halt or during a relatively sluggish condition of the ice front.

9. This moraine was located on the Nellist map, published in the 1907 Annual Report of the Michigan Geological Survey. It will be named and described in the monograph of the U. S. Geological Survey, "The Pleistocene of Indiana and Michigan," by Messrs. Leverett and Taylor.

Detroit moraine.[10] As a physiographic feature it is very inconspicuous, being unrecognizable when one stands upon it, and still it controls the drainage and is indicated by the contours and beach ridges (see Pl. X). As it enters the county, it is some seven miles broad, having an elevation of 660 to 670 feet and carrying surface swamps in sections 4 and 5 of Greenfield which are drained to the north, southeast and southwest. Passing southeastward across Greenfield township, it crosses the city of Detroit, dropping more or less gradually and narrowing to a point about one mile east of the City Hall upon Champlain Street. In Highland Park, the elevation of the crest is 640 + feet, about 595 at the City Hall, then descending rather rapidly to the river. It is believed by Taylor and Leverett to have been formed *subglacially*, between the Huron and Erie ice lobes, the former lying on the northeastern, the latter upon the southwestern side, and thus to represent a *subglacial-interlobate* moraine. This theory of its formation accounts very satisfactorily for its broad, smoothed and poorly defined character, squeezed in between the two lobes and being constantly overridden by the marginal portions. The moraine was followed by the writer across Essex County, southeastward towards Leamington and a study was also made of the various railway profiles available. Throughout this portion of its course, it possesses the same general characters seen in Wayne County, both strips being characterized by the absence of boulders, except upon the western slope, north of Ruthven, where they seem to have been concentrated by wave action. In the city of Windsor, the elevation ranges from 600 to 620 over the higher portion of the moraine, the slope dropping to 608 feet eastward along the line of the Canadian Pacific Railway, in a distance of three miles. The branch of the Michigan Central from Amherstburg, northeastward across Essex County, gives a good section of the moraine although it is cut obliquely and its breadth thus increased. From the north-south township line between Anderdon and Colchester North townships to the middle of Rochester, a distance of 16 miles, the profile of the

10. This name was first used by Taylor in 1897 (Bulletin Geological Society of America, vol. VIII, p. 39), for the Mt. Clemens moraine and that portion of the present Detroit moraine lying in Essex County, Ontario. It was further described and figured in 1899 (American Geologist, vol. XXIV, p. 18 and pl. II) as marking an ice front and was correlated with the Euclid moraine of Leverett in northern Ohio. In his Monograph XLI, of the U. S. Geological Survey, published in 1901, Leverett figures this moraine as marking the position of the ice front during the second stage of Lake Maumee and assigns it a "probably subaqueous or subglacial" origin (plates II and XXI). Fig. 5 of the Ann Arbor Folio (U. S. Geological Survey, No. 155, 1908) indicates the same course for this moraine. More recent studies of these two investigators, however, have led to the extension of the Detroit moraine northwestward to Birmingham, as described in this report, the separation from it of the Mt. Clemens moraine, and the belief that it was formed *subglacially* between the Erie and Huron ice lobes.

railway shows a very regular swell rising from 608 to about 646 feet, above sea level, and dropping again to the former level, thus giving a relief of 38 feet and an average slope upon either side of the crest of about 5 feet to the mile. Parallel with the Lake Erie shore, the profile of the Lake Erie and Detroit River Railway, furnishes another slightly oblique section of the moraine, with a breadth of eight miles and a relief of 126 feet, with the much more pronounced average slope of 32 feet to the mile. The profile of the branch of the Michigan Central from Windsor to Essex and the proposed line of the Windsor, Essex and Lake Shore Rapid Railway, both of which follow the crest of the moraine for several miles, show an even contour gradually rising toward the southeastward to an elevation of 735 to 740 feet. This moraine at present writing is being made the subject of study by Taylor from whom we shall learn its exact course. It is now believed by him to turn eastward just north of Leamington, passing through Wigle into Romney township.

Within the limits of Wayne County this moraine is strewn with beach and dune sand and carries very few boulders. The thickness of the drift composing it is 80 to 90 feet, where it enters from Oakland County, increases to 120 to 130 feet in the western part of the city and 130 to 150 feet in the eastern part. "Hard-pan", by which term the drillers refer to a very compact, stony till, was encountered in a number of wells sunk into this moraine, but these records were not sufficiently numerous to suggest a core of pre-Wisconsin till. In Detroit and Windsor, there seems to be conclusive evidence that the Detroit moraine was overridden by the ice as it was gradually being uncovered from the northwest to the southeastward, permitting the formation across it of a younger frontal moraine and repeating again what seems to have occurred at Birmingham.

Taylor recognizes in his studies of the region a moraine, which he designates as the Mt. Clemens and regards as of the frontal water-lain type, passing directly northward from Detroit, through Hamtramck township into Macomb County. So far as Wayne is concerned, it is poorly defined and practically unrecognizable, except for a sprinkling of boulders and cobbles in the township which might have been referred to the Detroit moraine. It must have been formed by the Huron ice lobe, just previous to the formation of the Emmet and if there was a correlative of the Erie lobe, it must have been overridden by the ice and destroyed by a temporary advance to the position of the Gross Isle moraine.

The youngest moraine within the limits of Wayne County skirts the eastern margin, following the course of Detroit River and consisting of a number of approximately parallel and remarkably regular till ridges, or gentle undulations. The belt of country thus involved is strewn, more or less abundantly, with boulders, cobbles and coarse pebbles, which in the bed of Lake Rouge have been completely obscured by deposits of sand. These ridges and undulations lie mainly between the contours of 580 and 600 feet and hence are not well indicated upon the topographic sheets (see Pl. X). The level of 600 feet and over is attained in the SW. corner section 4, Monguagon township, in the SE. portion of Grosse Point and also in Detroit, Windsor and Sandwich. The general course of the moraine is from 35° to 40° east of north and shows a maximum breadth of eight to nine miles in the vicinity of Trenton and Amberstburg. Westward and southwestward from Trenton, the parallel ridges are especially well defined.[11] The profile of a proposed railway line from Ypsilanti to Trenton (Detroit office of the Michigan Central Ry.) shows a series of thirteen crests in the two miles west of Trenton, the vertical distance from crests to troughs of the largest amounting to 12 to 13 feet. The drainage of Taylor, southwestern Ecorse and Monguagon townships is deflected to the southward by the SE. ridges. Upon Grosse Isle, Sugar Island and Hickory Island, in Detroit River, similar ridges are much in evidence following the general direction of the moraine, rising to a height of approximately 600 feet. A strip in Detroit River for 2½ miles alongside of Stony Island is shown by the river chart to have boulders in the bed which have been a serious menace to navigation at the "Lime Kiln Crossing." During the construction of the Livingstone Channel at this place, some 150 to 200 acres of the river bed have been laid bare by means of a cofferdam and a belt of boulders thus brought to view (see Pl. XI, A). East of Amherstburg, for a distance of four to five miles in Anderdon township, similar morainic swells may be observed gradually dying out eastward and northeastward. In the village of Amherstburg itself, the ground has an elevation of about 595 feet above sea level, or some 21 to 22 feet above the river level, rising slowly northward and eastward to 605 to 608 feet.

The western margin of the moraine crosses the river just south of Wyandotte and reappears again at Detroit. Northward from Amherstburg, upon the Canadian side, the boulders are quite abundant for a distane of two to three miles from the river, until

11. The portion of this moraine from Wyandotte to Brest was mapped in 1902 (Journal of Geology, vol. X, p. 195), as far as it had been traced at that time.

obscured by the Lake Rouge sands. East of Sandwich and south and southeast of Windsor, the ridges and boulders are again in evidence. In Windsor, four distinct ridges are to be seen, the crests of which range from 598 to 602 feet, and a broad swell two miles in width, reaching an altitude of 620 feet, is *superposed on the crest of the Detroit moraine*. In Detroit, these gentle morainic ridges are very noticeable as one looks along the streets running back from the river, giving them a fluted, corrugated appearance. The profile of the Michigan Central Railway shows a ridge on Howard Street 550 feet broad, with a depression 300 feet across, and then a gradual rise from Baker to 20th Street, where the elevation is 600 feet, with a gradual drop beyond. Some 15 to 16, more or less well defined crests, may be counted within a distance of two miles. Upon the eastern slope of the Detroit moraine, a very regular series of these till flutings is seen just northwest of Elmwood Cemetery, between Hunt and Willis streets, where seven may be counted, spaced almost exactly two blocks apart and dying out to the east and west. Similar low ridges are seen at the Detroit Water Works, in the eastern part of the city and upon Belle Isle. The bed of Detroit River opposite the city shows a series of ridges, having the same general trend as those upon the land and the islands themselves in the river are found in the two localities where crossed by this moraine (see Pl. X). Along the Lake St. Clair shore, Grossepoint township, a conspicuous ridge is seen just NE. of Windmill Point, forming there a bluff 12 to 14 feet high (Emmet moraine). Indeed, it seems probable that the *grosse pointe* here developed owes its existence to the presence of this moraine, which has thus enabled the land to better resist the encroachments of the lake. Just north of Milk River Point the *L'Anse Creuse* results from the destruction of the morainic ridge, the waves opposite the broader portion of the lake having gotten in their work behind the moraine (see Pl. XI, B). The chart of Lake St. Clair shows that a clay ridge, stony in a few places, extends slightly east of north, for some three or four miles across the western margin of the lake, the remnants of this destroyed moraine. The point of land just east of Mt. Clemens, although delta-like upon the map, is *reported* to be *till* and seems to owe its existence also to this morainic ridge. From the general trend of the moraine it appears probable that the narrow ridge shown on the Nellist map, running northeastward from near Anchorville toward Port Huron, is the continuation of this moraine, beyond which it is closely associated with the Port Huron moraine.

From Trenton southward, the ridges become faint as Huron River is approached and in places boulders are abundant. South of the Huron, the ridging is very indistinct but the former ice margin is still indicated, the writer believes, by a boulder belt which passes east of Newport, near Brest, north and west of Monroe and southwestward across Monroe County. It is obscured in places by the sands of the Elkton, Grassmere and Wayne beaches, but appears in force east and south of Ottawa Lake and has been followed into Ohio four miles, as far as Glantown. From the Huron, the topographic contours are followed by the boulder belt, until it comes opposite the Erie basin, as in the case of the next older belt, the Scofield, when it mounts the contours from 580 to 680 in a distance of 25 miles, or at the average rate of 4 feet to the mile. Entering Ohio, the belt swings around again parallel with the contours and has not yet been followed through the Maumee valley. The name Grosse Isle is suggested for this boulder belt and for the moraine, of which it seems to be a continuation, both having been deposited in deep water. From the present site of the Huron southward, the ice margin was sluggish; northward to Detroit it exhibited a very regular, rhythmic series of advances and retreats, pushing up the till into regular and often very evenly spaced ridges parallel with the front. Theoretically the Gross Isle moraine extends to Detroit only and was formed by the Erie ice. Its direct extension northward along the western margin of Lake St. Clair was formed by the Huron lobe and is named by Taylor the Emmet moraine in the forthcoming monograph. Both were formed simultaneously and extend to the crest of the Detroit moraine with no recognizable line of demarcation, indicating a perfect blending of the Erie and Huron lobes so far as the ice margin was concerned.

The hypothesis that the Detroit moraine is of the nature of a subglacial interlobate receives much support from the field evidence; its general direction, poorly defined character and breadth being out of harmony with the other moraines of the region. It has the appearance of having been overridden by the ice, its ridges smoothed out and swept clean of boulders, which would almost certainly have been deposited while an ordinary frontal moraine of such magnitude was being formed. In Oakland County, Leverett found evidence in the distribution of the flowing wells that the beds of gravel included in the moraine slope in *opposite* directions from the crest, suggesting that it might have been formed as the

joint work of the ice lobes upon either side of the morainic ridge.[12] Moraines of this type have been observed by the writer in the Canadian Rockies and described by Wilcox as the joint work of a trunk glacier and its tributary.[13] An alternate hypothesis, however, would be that the Detroit was a *frontal moraine* of Early Wisconsin age, that it was overridden by the Late Wisconsin ice advance without being completely destroyed and that the frontal moraines formed during the retreat of the latter were deposited directly across its back without break in their continuity. Upon the former hypothesis we expect, but do not find, any indication of a *notch* just where the two great lobes united along the crest of the moraine. The moraines to the north and south of the Detroit moraine seem perfectly continuous and give no line of separation such as we may often observe in modern glaciers of much smaller size. A detailed study of the glacial striae of southeastern Michigan and western Ontario shows that just previous to the last northwesterly advance of the ice, there was a general and more powerful movement south-southwest,[14] the direction needed to have formed the Detroit moraine, if of the type now assumed and to bring it into harmony with the Early Wisconsin moraines of southwestern Ohio and eastern Indiana.[15] Still another line of evidence that seems to favor this alternative hypothesis is the direction of the striae at the Amherstburg quarries (Anderdon). In order to have formed such a massive, sub-glacial interlobate moraine as the Detroit it is fair to suppose that there must have existed a general movement of the ice from the axis of each lobe toward this common margin beneath which the morainic matter was accumulating. Since the Anderdon quarries are only some 9 to 10 miles from the crest of the moraine we might expect some indication of a northeasterly movement of the bottom ice to have been recorded upon the embossment of limestone at this locality. Instead, however, the striae indicate, as at Trenton, a late northwesterly movement of the ice, which was preceded by a more vigorous one in the direction of south-southwest. The evidence from the striae is thus more favorable to the alternative hypothesis of the Early Wisconsin age of the Detroit moraine, while at the same time it satisfactorily explains its greatly subdued character, the general absence of boulders and the fact that it carries upon its back, at least, two continuous moraines of younger age.

12. Flowing Wells and Municipal Water Supplies in the Southern Portion of the Southern Peninsula of Michigan, 1906, p. 190. Water-supply and Irrigation Paper No. 182, U. S. Geological Survey.
13. A certain Type of Lake Formation in the Canadian Rocky Mountains: Journal of Geology, vol. VII, 1899, p. 255.
14. Sherzer, Ice Work in Southeastern Michigan: Journal of Geology, vol. X, 1902, pp. 207 and 215.
15. Leverett, Glacial Formations and Drainage Features of the Erie and Ohio Basins: Monograph XLI, U. S. Geological Survey, 1902, p. 304.

Till plains. Crossing the extreme northwestern corner of the county, in a northeast-southwest direction, lying between the Ft. Wayne and Northville moraines, there occurs an elevated till plain, having a general elevation of 970 to 980 feet above sea level. A low crest serves as a divide to deflect the surface drainage to the north or south. In sec. 6, Northville, the plain is largely strewn with sand and gravel, the remainder being clay.

From the Defiance moraine eastward to the Grosse Isle moraine above described, there was formed a very broad till plain, remarkably even and regular were it not for the beaches, dunes, deltas and subsequent stream erosion. The general direction of the surface slope is southeastward in the direction of ice retreat, and averages six to eight feet to the mile. This is too slight to be detectable by the eye but is enough to control the surface drainage strongly, except where barriers have been interposed. This deposit is the ground-moraine, formed between the bedrock and the ice sheet, with its surface subdued and smoothed by the last ice advance. After leaving the Defiance moraine, during the first two stages of halt described, there was practically no disturbance of the till plain while the boulder belts were forming. This till deposit is thinnest in the southeastern portion of the county, Brownstown and Monguagon townships, where in a few places the rock is actually bare, but thickens in all directions. Over most of the county, it ranges from 40 to 100 feet in thickness. In the northwestern portion of Canton township, a depression in the rock surface gives a thickness of 140 feet and, in the northeastern corner of Van Buren, 180 feet. In Hamtramck and Grosse Point townships, deposits 170 to 180 feet thick are noted in the well records.

Although the great body of this deposit is a bluish till, rather sparingly charged with pebbles, there are irregular seams and lenticular masses of sand and gravel embedded in it and the problem of getting water for farm use consists in locating these. Although thus of great economic value in furnishing a pure and abundant water supply these "quicksand" deposits are a menace to the stability of tall buildings in the cities. Their occurrence can not be predicted and only a series of borings can be relied upon to prove their absence. In securing a safe foundation for the Penobscot Building, in Detroit, this quicksand embedded in the till entailed an extra expense of $20,000.

The most complete examination of the structure of this glacial deposit ever attempted in this region was in connection with the Michigan Central tunnel across Detroit River. This, upon the Detroit side, (east bound track) started with an open cut of 1540.07 feet; an approach tunnel 2128.89 feet; subaqueous tunnel trench 2622.56 feet; Windsor approach tunnel 3192.14 feet and an easterly open cut of 3300 feet. This gives a continuous section of 12783.66 feet, or 2.42 miles, through the till and to a depth of nearly 500 feet above sea level, or about 72 feet below the level of the river. A very extensive preliminary set of borings was made as a basis for estimates of cost of construction and these with their records are shown in Pl. XII. An examination of these boring records, which in the river portion were continued to bedrock, shows that the great bulk of this rock cover consists of glacial clay, with irregular and disconnected masses of sand and gravel. The clay was classified as *hard* and *soft*, but genuine hard-pan was not encountered and boulders and pebbles were rather scarce. Much of the clay was sliced out with U-shaped knives, operated by two men, the long strips cut into short sections with the spade and handled in the hands. The cross-section of the tunnel was made more nearly circular than at first planned in order to better withstand the pressure from the soft clay. It was this tendency of the clay to "creep" or flow that caused the failure of the Michigan Rock Salt Company to reach the rock near Ecorse in 1902. A hollow brick cylinder, 12 inches thick and 15 feet in diameter, was constructed at the top and allowed to settle as the excavation proceeded. At a depth of 55 feet the clay was forced in at the bottom almost as rapidly as it could be removed and it was found necessary to increase the thickness of the brick casing to 30 inches. At a depth of about 75 feet, when within six feet of bedrock it was found impracticable to proceed and the project of mining the rock salt was temporarily abandoned. This condition of the deeper till deposits leads to the inference that we have in the Detroit region only the Wisconsin till.

The iron constituent of the till-sheet has been very generally oxidized to a brown, or yellow, and to a depth of a number of feet, testifying to a considerable period of exposure since the withdrawal of the ice. In a few places, the blue clay comes very close to the surface but generally is overlain by from 5 to 15 feet of the yellow or brown variety. In the very complete tunnel series of borings of the 155 observations made the average thickness of this layer is 10.45 feet, the maximum thickness noted being 25 feet upon

the Canadian side, near the river. Beneath the river, this discoloration of the till is slight in amount, or absent, due very probably to the scarcity of oxygen necessary for the alteration of the iron. When the vertical surface of a bed of till is exposed the material dries, contracts more or less and a system of fine vertical joints makes its appearance. At a number of localities a bright blue discoloration of brownish till was observed along the surfaces of these joint-planes, penetrating the clay to a depth of a tenth of an inch. The effect appears to be due to water making its way along these fine seams, carrying some ingredient (possibly carbon dioxide gas) which has a tendency to restore the original color of the till. Owing to its ordinary very compact nature, however, and fine texture, this type of clay is quite impervious to water, allowing only relatively small quantities to enter and for only a slight distance. The more soluble ingredients of the soil, such as calcium and magnesium carbonate, are slowly dissolved and removed from the surface portion and the depth and completeness of this leaching effect are regarded as an indication of the length of time that the till surface has been exposed. Various factors, however, must be considered in all such estimates; such as, the amount of precipitation, the surface slope, the nature of the subsoil, the covering of sand or water, the amount of carbonate originally present, etc. The simple test for these carbonates that may be applied is to place a few drops of dilute hydrochloric acid[16] upon a lump of the clay to be tested and noting the amount of effervescence that takes place. When so tested, the Wayne County till deposits will be found to have been more or less perfectly leached to a depth of 6 to 18 inches, just below which depth the effervescence is often more vigorous than at the greater depths. This result is probably due to the concentration of the carbonates removed above through redeposition from the solutions which have difficulty in escaping from the deeper layers of soil. A similar concentration of iron oxide may often be observed between the soil and subsoil layers.

Glacial outwash. When the precipitation over the ice sheet occurred as rain and when the superficial ice or snow was rapidly melting, especially during the waning stages, quantities of water collected in the surface channels on the ice forming powerful torrents. These eroded and melted their way into the ice, forming channels (see Pl. XIII, A.), the water of which uniting into systems, was able to work more deeply into the body of the ice, and to seize and transport whatever debris came within its reach or

16. This is made by taking four parts of water and one part of the commercial acid.

was delivered to it. Sand, pebbles and boulders even, were often thus hurried along to the margin of the ice. When crevasses, or moulins, were encountered, the surface streams found their way to the inside, or bottom of the ice mass and englacial, or subglacial tunnels were formed (see Pl. XIII, B.) through which often coursed mighty torrents, charged with all kinds of rock debris. In some cases, the discharge from the lobe was of a more general character and might extend for a considerable distance along the ice front. Issuing from the ice under more or less pressure, the velocity of the water would be checked, the coarsest material dropped first, the finer next and the finest sediment retained until a quiet body of water was reached. Small marginal lakes were often formed where the topography permitted, sometimes the turbid streams coursed along the margin of the ice, gaining in volume until an opportunity for escape was afforded when they left the ice to follow the general course of drainage for that region.

The sand and gravel deposited along these valleys often extended for several miles, forming so-called "valley trains", the finer sediment reaching the quiet bodies of water and giving rise to deltas and lake deposits. Under exceptional circumstances, the subglacial tunnels became clogged and more or less filled with irregularly stratified sand and gravel, from which the ice melted without destroying the deposits, forming ridges known as eskers. Broad expanses of sand and gravel, spread by the escaping waters in front of the ice, gave rise to "outwash aprons". Owing to the original angular condition of the sand grains and pebbles and the relatively slight opportunity for erosive action before deposition takes place, the materials of which these deposits are composed are generally imperfectly rounded and may show signs of glaciation.

The glacial outwash partially covering the till plain in sec. 6, Northville township and the kame formations associated with the "middle moraine" have already been noted in the preceding chapter. Between this moraine and the Defiance, there is an old drainage channel (see Pl. XIV) floored with sand and gravel, about a mile broad which carried the drainage, during the Defiance halt, southwestward across Salem and Superior townships, in Washtenaw County, to the Saline River. This channel involves mainly sections 3, 4, 7, 8, 9, 17 and 18 of Northville and 19 of Plymouth townships. The bed now has an elevation of 830 to 865 feet above sea level, rising to 880 feet, is more or less swampy and the direction of drainage has been reversed, now flowing northeastward into

the Middle Rouge. In places the banks rise to a height of 100 feet above the floor of the channel. Where crossed by the Pere Marquette Railway (SW. corner of Northville and the NW. Corner of Plymouth townships) the channel has a breadth of 5,200 feet, the lowest level of the valley floor 834 feet, the crest of the eastern bank 852 feet and that of the western bank 891 feet. During all the subsequent stages of halt, within the county limits, the ice front stood immersed in the waters of some one of the glacial lakes, giving no opportunity for the formation of definite recognizable deposits by direct glacial drainage.

Beaches and associated dunes. The entire series of glacial lake beaches, or their correlatives, mentioned in the preceding chapter is found within the limits of Wayne County, beginning upon the eastern slope of the Defiance moraine and reaching down to the very edge of Detroit River. The upper members of the series contain considerably more gravel and are practically free from dunes, the lower members consist mainly of sand and are often disguised by dune deposits and confused by sand bars, making their tracing often difficult and uncertain.

The three Maumee beaches enter the county from Washtenaw in sec. 7, Canton township, and pass northeastward across Plymouth, Northville and Livonia townships. The uppermost of the three is moderately well defined and consists of a low gravel ridge resting upon the steep slope of the moraine which served as a barrier to the waters of the lake. Just west of Plymouth (SW. ¼ sec. 22), the profile of the Pere Marquette Railway shows that it is about 200 feet broad and that it rises about 4 feet above the general slope of the moraine. In places it is represented by a wave cut shelf at a somewhat lower level than the beach itself. It is interrupted frequently, is often obscure and difficult to follow with any degree of certainty, owing, apparently, to the relatively short time that the waves were operative in this region, or to their weak action. It has had only a slight effect upon the drainage, the short rapid streams down the eastern slope of the moraine being able to break through without undergoing much deflection. The crest of the beach in this section is about 810 to 812 feet above sea level. The second, or middle of the three Maumee beaches, pursues a more direct course, from a quarter to an eighth of a mile east of the upper, its distance depending upon the rapidity of slope of the moraine. Its general elevation is given by Leverett for the Ann Arbor quadrangle, which extends into Wayne County, as 20 feet below the upper beach, making its elevation about 790 feet

above tide. The Lower Maumee has the appearance of having been submerged and this is interpreted as meaning that it was formed before the Middle and that a readvance of the ice cut off the temporarily lower outlets and raised the level to that of the Middle beach. This subjected the lowest beach to more or less wave action, during the period of rise and subsequent fall of the waters and gave opportunity for depositional covering during the life of the second stage of the lake. The interval between the Middle and Lower beaches is about the same as that between the Middle and Upper, namely about 20 feet, making the approximate elevation of the Lower beach in Wayne County about 770 feet above tide. Just west of Plymouth (SE. ¼ sec. 22 and NE. ¼ sec. 27), there is a pretty well defined section of this beach, but it can be followed only with difficulty throughout its course (see Pl. X).

If all the beaches were as well defined as the Whittlesey, there would be no trouble whatever in mapping them and thus determining with certainty the form and size of each of the various glacial lakes. It was first described in this section by Hubbard in 1840[17] as consisting of a gravel ridge, several hundred feet broad, with an average height of 12 to 15 feet above the level lands upon either side and as plainly representing a former beach line. Before the country had been drained, the advantage of this elevated gravel ridge as a roadway was appreciated and some of the highways along its crest are still retained in Canton, Plymouth and Northville townships. The elevation assigned to the beach at that time was about 680 feet above sea level (107 to 108 feet above the level of Lake Erie), but our more accurate topographic survey gives it an elevation of 736 to 740 feet. Several railway profiles give the beach a breadth of 300 to 900 feet and a height above the general surface of the country of 7 to 8 feet, sloping more rapidly upon the westward, or landward side, and more gently toward the former lake. Owing to its elevation, drainage, soil and ease with which water may be procured from it, the ridge is very generally utilized as the sites for homes, barns (see Pl. XV, A.), schools, churches and cemeteries. Well records indicate a thickness of the gravel layers of 10 to even 25 feet. A splendid section of what is in part beach and in part delta is seen just east of Plymouth (see Pl. XV, B and Pl. XVI, A.) where the Pere Marquette Railway has been utilizing the gravel (SW. ¼ sec. 24). At the time of its examination in 1902, there was shown one foot of yellow, gravelly

17. Third Annual Report of the State Geologist, House Document No. 8, pp. 102 to 108.

loam; 15 inches of fine, stratified gravel dipping westward; 15 inches of horizontally stratified sand; and about 20 feet of cross-bedded sand and gravel, embedded in which at one place were the remains of a log as reported by the workmen. At one other locality a similar find was reported in a well dug upon the beach.

The beach enters the county from Washtenaw in the SW. ¼ sec. 19, Canton township and pursues a very direct northeast course across the northwestern corner of the township and southeastern corner of Plymouth. About a mile northeast of Plymouth, it was deflected a half mile to the eastward in crossing the old delta of the Middle Rouge, thus introducing a slight curve into its otherwise direct course. The ridge crosses the northwestern corner of Livonia township and leaves the county from the NE. ¼ sec. 5, passing into Oakland.[18] Throughout this section the beach is everywhere a built ridge and indicates rather long continued and vigorous wave action.

In secs. 7 and 8 of Livonia the cobbles have been concentrated in front of the beach, in places so thickly as to almost form a boulder pavement. Without a knowledge of the possible function of ice dams as great restraining walls, Hubbard in his early report (*loc. cit.* p. 106), speculated upon the great extent of territory covered by this lake and the possible source of the water, suggesting a depression and marine invasion. Finding evidence that, at least, a portion of the water was fresh, he considered the possibility of the Appalachians serving as the barrier across the Mohawk and St. Lawrence basins, thus deflecting the drainage to the Mississippi.

"That the lakes once discharged their waters in this direction, such additional evidence is furnished by the appearance of the country, that in this our argument but serves to add confirmation to the general opinion."

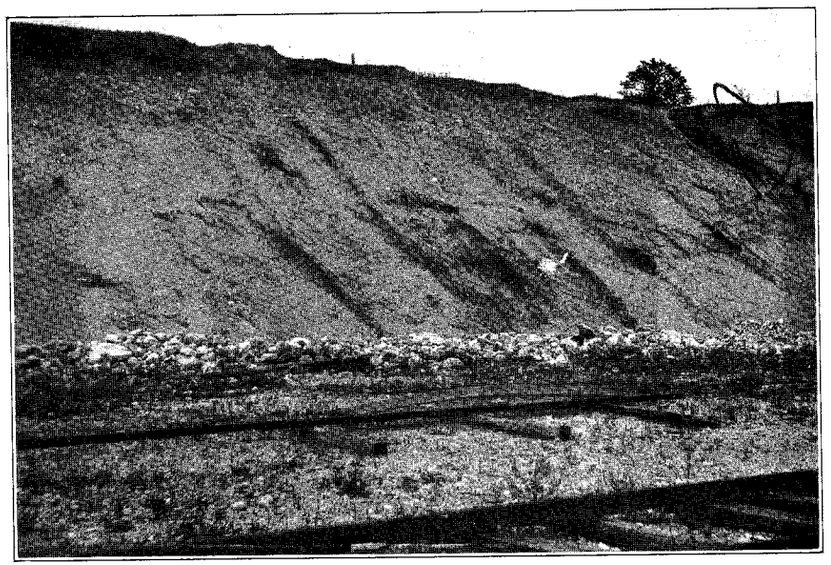
For reasons previously assigned the Arkona beaches are very generally poorly defined and at times difficult to recognize. Sometimes they consist of broad, low built sand ridges scarcely over a foot high; sometimes the sand appears to have been swept away and there remains only a narrow belt of pebbles resting upon the clay to mark its position. In places lake sediments have been introduced, thereby obscuring the beach materials. Where sand and gravel were abundant, opposite the mouths of the rivers, stronger ridges were formed and these better withstood the action of the

18. Upon the Higgins' map of Wayne County published in 1840 with the third annual report of the state geologist, the beach is correctly located until the town line between Northville and Livonia is reached when it turns suddenly to the north and follows this town line.

waves. Within the limits of Wayne and Washtenaw counties two, and in places three beaches, may be recognized, a mile or more apart, depending upon the rapidity of the surface slope. Farther north Taylor has indentified four distinct ridges of Arkona age. The two lower enter the county from Washtenaw in the southwestern corner of Van Buren township (sec. 31), being deflected eastward by the old Huron delta. The highest ridge enters sec. 18, just north of Rawsonville, and with the other two, turns northward through western Van Buren and Canton townships, swinging to the northeastward and continuing roughly parallel with the Whittlesey beach across Canton, Plymouth and Livonia townships. As in the case of the previously formed beaches, in crossing the delta of the old Middle Rouge, the ridges become better defined and are displaced to the eastward. They leave the county in NE. ¼ sec. 4 and NW. ¼ sec. 3, Livonia, the upper ridge showing the best development during the last mile and containing considerable gravel.

At Denton, the ridges are rather close together and contain considerable sand, ranging in elevation from 693 to about 707 above sea level, furnishing the site for the village cemetery. In the NW. ¼ sec. 1, Canton, there occurs a gravel ridge 900 feet across and 4 to 5 feet above the general level, having an elevation of 696 feet, apparently the lowest beach. East of Plymouth the profile of the Pere Marquette Railway gives a section of Arkona beaches that were built upon the Rouge delta. A very broad crest carrying several minor ones, some 2,600 feet across and about 5 feet above the general level, passes from the SW. ¼ sec. 24, Plymouth, into sec. 25. According to the railroad elevations, the altitude is 713 feet above sea level. Some 4,000 feet eastward, near the town line between Plymouth and Livonia, another 700-foot crest occurs on a broad swell which is 2,000 feet across and rises 6 to 8 feet above the general level. Upon the eastern slope, in sec. 30, Livonia, ridges are shown at 695, 689 and 683, the latter probably representing the Warren beach. The presence of these well defined ridges of Arkona age, resting upon the old deltas of the Huron and Middle Rouge, seems to prove that these deltas were formed during the Arkona stage of the glacial lakes, rather than during the Whittlesey stage, since if of latter age, the beaches would have been buried in the delta deposits. The conclusion seems justified also that the rise and fall of the waters over these ridges must have been rather rapid, otherwise the waves would have leveled them more completely.

A. KAME UTILIZED AS DWELLING SITE AND GRAVEL SUPPLY.



B. SECTION OF KAME AT NORTHVILLE. OWNED BY D. U. RY.