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OF
THE MICHIGAN ACADEMY OF SCIENCE

CONTAINING AN ACCOUNT OF THE ANNUAL MEETING

HELD AT

ANN ARBOR, MARCH 31, APRIL 1 AND 2, 1910.

PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY
GEO. D. SHAFER

BY AUTHORITY

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TABLE OF CONTENTS.

Letter of Transmittal 1

Officers for 1910-1911. 1

Life of William Smith Sayer. 1

Life of Charles Fay Wheeler... 2

Papers published in this report:

President's Address—Outline of the History of the Great Lakes, Frank Leverett.. 3

On the Glacial Origin of the Huronian Rocks of Nipissing, Ontario, Reginald Hore. 15

The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area, Rev'd Thomas Nattress 17

Soil Stripes in Cold Humid Regions, and a Kindred Phenomenon, William H. Hobbs 19

A Waste Filled Valley (Abstract), A. E. Parkins........... 21

LETTER OF TRANSMITTAL.

TO HON. FRED M. WARNER, *Governor of the State of Michigan:*

SIR—I have the honor to submit herewith the Twelfth Annual Report of the Michigan Academy of Science for publication, in accordance with Section 14 of Act No. 44 of the Public Acts of the Legislature of 1899.

Respectfully,
GEO. D. SHAFER,
Secretary of the Michigan Academy of Science.
E. Lansing, Mich. May, 1910.

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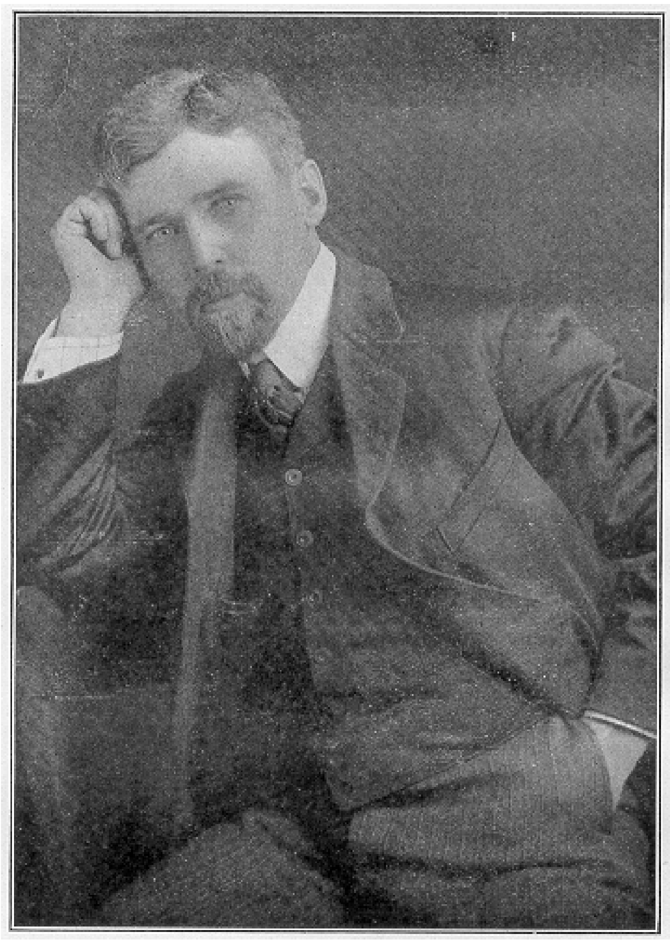
The Council is composed of the above named officers and all Resident Past-Presidents.

WILLIAM SMITH SAYER.

Mr. Sayer was born on a farm, called the "Sayer Homestead," near Wayne, DuPage county, Illinois, January 13th, 1876. From childhood to his "Academy days" he passed on the farm. He received no other schooling during the first ten years of his life than that furnished by a companionable, intelligent mother, who directed his studies. After his tenth year, he attended the country school till he entered the "Elgin Academy" in 1892. Three years later, he graduated from the Academy and entered Beloit College.

His college days proved a formative stage in his career by developing within him, a taste for the association of a college, friends, study, culture—all the features which are constituents of a college atmosphere—and a basic and intuitive love for his home. His home became the retreat for his college chums, his mother, their foster-mother. Both college and home were linked together in his mind and in his life, as inseparable supports to action. Throughout his career, these two factors were prominent, even foremost. His graduation from Beloit occurred in 1899. Ambition of a noble type was aroused in him, and instigated by his parents, he undertook special work in the University of Chicago, choosing bacteriology and chemistry for his chief lines of study. In 1901 he was placed in charge of a laboratory at Grafton, Illinois, by Dr. E. O. Jordan, for the purpose of examining the waters of the Chicago Drainage Canal. With the discontinuance of this work in January, 1902, he returned to the University to pursue the course of study, he had begun, until the autumn of 1902. At this time, he quit the University, but before leaving he had completed all of his work. Except the thesis, for his doctorate degree. He entered the employ of the Kennicott Water Softener Company as a chemist. He remained with this firm for four years, and in the spring of 1907 he was called to the Bacteriological Laboratory of the Michigan Agricultural College to undertake research work. His attention was at first centered upon the "Keeping-Qualities of Butter," and, conjointly with Dr. Otto Rahn and Miss Bell Farrand, issued the results of the first year's investigations in bulletin form from the Experiment Station.



WILLIAM SMITH SAYER.

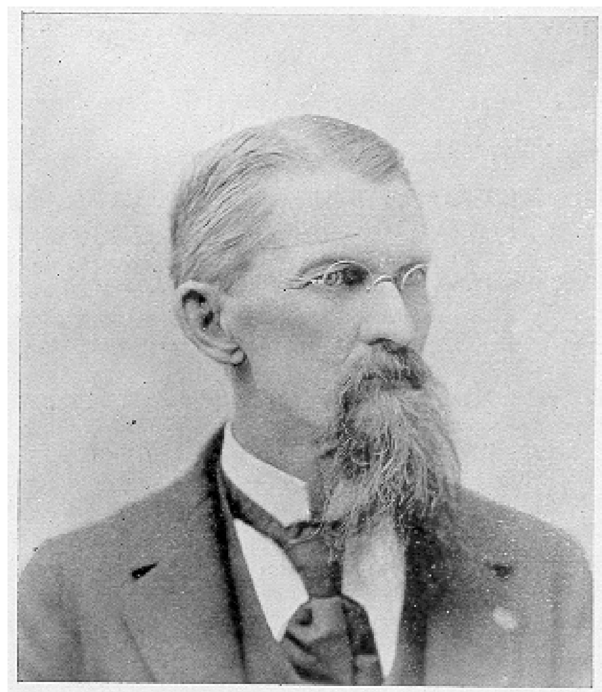
All of his training directed his tastes into the field of soil investigations. It became possible for him to satisfy his desires with the departure of Prof. Walter G. Sackett for Port Collins, Colorado. Mr. .Sayer picked up the thread where Mr. Sackett dropped it, and centered all of his force in this work.

Mr. Sackett also turned over the office of Secretary-Treasurer of The Michigan Academy of Science to him at the same time, with the consent of the council. At the annual meeting of the Academy, he was again made Secretary-Treasurer, as a recognition of his faithful and efficient services.

While canoeing on the Red Cedar river, a sport very fascinating to him, on the 30th of April, 1909, he was thrown into the river and drowned. Two weeks later, his body was found and buried from his home in "Little Woods Cemetery," Wayne, Illinois.

Mr. Sayer was careful to painstaking, very systematic, and patient. No truth was too homely for him; he wished no garnishments to cloak the facts. Therefore, what he did was honestly done and what he said was true, so far as he could determine. Such were the strong characteristics of the man.

W. J. BEAL,
CHARLES E. MARSHALL,
Committee.



CHARLES FAY WHEELER.

CHARLES FAY WHEELER.

Charles Fay Wheeler was born June 14, 1842, at Mexico, Oswego county, New York; died at George Washington Hospital in Washington, D. C., March 5th, 1910, and was buried in Arlington Cemetery.

He graduated from the Academy at Mexico, near where he was born, and enlisted in October 1861, as a private in Company B, Seventh Regiment of the New York (Black Horse) Cavalry; was mustered out in March 31, 1862. He again enlisted August 20th, 1862, in Company F. 147th Regiment of New York Infantry, to serve three years but was discharged March 21st, 1863, by reason of disability.

Unable to work, he lived in the woods, fields and marshes for a year or more and with Gray's Manual of Botany studied plants and to a great extent regained his health. In 1866-67 he spent one year in the Medical Department of the University of Michigan. He then settled in Hubbardston and for 22 years conducted a drug and. book store, spending much of his time among his beloved plants. On March 4th, 1869, he was married to Catherine T. Holbrook of Oakham, Mass.

During all these years as a merchant he continued his study of the local flora in which he became very proficient, devoting much time also to reading valuable botanical works.

In the spring of 1889, Mr. Wheeler with Professor L. H. Bailey, then Professor of Horticulture at the Agricultural College, two students and the writer, the party spent two weeks in a botanical trip, passing across the state from Harrisville in Alcona county to Frankfort in Benzie county. During his stay in Hubbardston, he had collected a herbarium of over 7,000 plants which later became the property of the Agricultural College. In 1889, he was elected instructor at this College, taking studies enabling him to graduate in 1891 with the degree of B. S., which College granted him the honorary degree of D. Sc. in May 1907. He became assistant Professor, in all spending eleven years before accepting a position in the United States Department of Agriculture where he soon found his place in identifying plants for several departments of the Government in Washington.

While at the Agricultural College, he spent much time in collecting plants for the herbarium in which he was intensely interested. Previously, in company with Erwin F. Smith, they published a Flora of Michigan in 1881 and later with Dr. W. J. Beal another edition of the Flora was published, in 1904 in the Report of the State Board of Agriculture.

At the college he was active in organizing and sustaining a botanical club and never tired of arousing interest and assisting students in his favorite pursuit. He was well read and with a retentive memory was able to impart much information on a great variety of topics. He had friends everywhere, hosts of them. He was one of the organizers of the State Academy of Science in 1892 and was chairman of the Section in Botany in 1902.

Dr. Wheeler leaves a wife and two daughters, Mrs. Dick J. Crosby of Washington and Mrs. George N. Eastman of California.

DR. W. J. BEAL.

PRESIDENT'S ADDRESS.

OUTLINE OF THE HISTORY OF THE GREAT LAKES.[1]

Frank Leverett.

CONTENTS.

Introductory Statement. 3
Great altitude preceding Ice Age. 4
Preglacial drainage. 4
Effects of glaciation in Great Lakes region. 5
Drift deposition. 5
Glacial erosion. 5
Weighting and depression by ice. 5
Glacial and interglacial stages. 6
Features characteristic of lake shores. 6
The succession of lakes. 6
Superior basin. 7
Green Bay basin. 8
Michigan basin. 9
Huron-Erie basin. 9
Lake Maumee, ... 9
Lake Arkona, ... 10
Lake Whittlesey, ... 10
Lake Warren, ... 10
Transitional lakes (Grassmere and Elkton beaches) 11
Lake Erie 11
Ontario basin. 11
Lake Iroquois, ... 11
Champlain Sea. 11
Lake Algonquin. 12
Transitional lakes (Battlefield and Fort Brady beaches). 13
Nipissing Great Lakes. 13
The Modern Great Lakes. 13
History shown by Niagara Falls. 14
Bibliographic notes 14

[1]Published by permission of the Director of the United States Geological Survey.

INTRODUCTORY STATEMENT.

Michigan is more broadly washed by the waters of the Great Lakes than any other state of the Union, and its commercial interests are greatly enhanced in value because of this situation. There are also climatic advantages which it possesses because of these water bodies. The question of the origin and history of the lakes should, therefore, be of especial interest to the people of Michigan, and particularly to such an assembly of educators and scientific students as is present this evening. The history is so complex that it can only be sketched in outline in the brief time allotted for this address.[1]

It is primarily to glaciation that we owe the presence of these great lake basins, and a sketch of their history naturally includes an outline of the leading events of the Ice Age. Accompanying the glaciation there have been deformations of the earths form that seem attributable in some measure at least to the great ice sheets that covered the land. The region occupied by the Great Lakes appears to have been weighted down and depressed during the height of glaciation, and to have risen somewhat upon the melting of the ice, yet not to its preglacial altitude. These earth movements are thus important factors in the history of the lakes, though it is not improbable that other forces independent of the weighting and disappearance of the ice have been influential in causing the changes of level here displayed.

[1]A much more complete discussion of the subject is now in preparation, for a monograph of the United States Geological Survey, by my associate in glacial investigations, Mr. F. B. Taylor.

GREAT ALTITUDE PRECEDING THE ICE AGE.

That the ice age was preceded by higher altitude than the present in eastern North America is shown by the presence of deep valleys, now submerged, in the gulfs and bays along the Atlantic coast.

From the Hudson valley northeastward the deep valleys are filled with the oldest drift of that region. Borings in the Hudson river valley near West Point, made by the New York Water Supply Commission, show that the valley floor at that place is 450 feet or more below sea level. Wells and borings in the vicinity of Boston show a rock floor 200 to 400 feet below sea level and there are similar deeply filled valleys on the coast of Maine. The coast line at that time was some distance farther out than now and much of the area of the Gulf of St. Lawrence was above sea level. The old valley of the St. Lawrence can be traced through the Gulf and out beyond the banks of Newfoundland. The ice did not cover it far below Quebec and it remains unfilled. It is 800 to 1200 feet below sea level, the depth increasing as one passes down the old channel.

The high altitude, which is easily demonstrable on the coast, is more difficult to prove in the interior of North America around the Great Lakes, for the drainage from that region had a long course to the sea, and the lakes are probably near the headwaters of the old drainage lines. It seems entirely probable, however, that the high altitude of eastern North America would have affected the Great Lakes region and given the beds of the present lakes an altitude high enough to have afforded free drainage to the sea.

It is thought that before the glacial period there were no bodies of water where the Great Lakes now stand, but instead broad lowlands bordered by belts of higher land. The condition seems likely to have been about like central and eastern Tennessee and Kentucky and southern Indiana, where the weak rock formations are marked by lowlands, and the more resistant by highlands.

PREGLACIAL DRAINAGE.

The courses of preglacial drainage from the lowlands are now concealed beneath thick deposits of glacial material and can only be partially outlined. There is as yet uncertainty whether the drainage was chiefly to the Gulf of St. Lawrence or to the Gulf of Mexico. The high altitude which affected the eastern part of the United States may have given the region along the St. Lawrence below Lake Ontario and also that along the Mohawk greater altitude than was presented by the district between the Great Lakes region and the Gulf of Mexico, thus favoring discharge of the Great Lakes region to the south. It seems highly probable that in the remote past there was a divide on the line of the present St. Lawrence below Lake Ontario, where the river now flows among the Thousand Isles, and that from it drainage passed southwestward to the central United States. But whether this divide had been cut through by headwater erosion of the St. Lawrence and part of the southwest flowing drainage had been changed to a northeast flowing system prior to the Ice Age is not known. The bed of Lake Ontario reaches now the lowest altitude of any of the Great Lakes. Whether the preglacial altitude was lower in this basin, or whether this low altitude is due to greater sinking and greater ice erosion there during the Ice Age than occurred in the neighboring basins of Huron and Erie is not yet determined. In the former case it would seem probable that the Ontario basin had a discharge through some buried channel among the Thousand Isles to the Gulf of St. Lawrence and took with it the drainage from the Erie basin if not from the Huron and the Superior and the northern part of the Michigan basin.

The most ambitious effort to restore the preglacial drainage of the Great Lakes region is that of J. W. Spencer, who some 20 years ago presented a map and discussion of the ancient drainage of the Great Lakes region in a British publication.[1] It was based on a study, (1) of the hydrography of the modern lake basins and submerged channels on the coast, (2) results of well borings which have revealed the position of buried valleys, and (3) the uplift which the Great Lakes region has experienced as shown by tilting of old shore lines. He reached the conclusion that the drainage was to the Gulf of St. Lawrence though not fully along the present lines. From the Erie basin the discharge to the Ontario basin was farther west than Niagara river so that it entered the extreme western end of the Ontario basin. He interpreted the Lake Huron basin to have had a direct southeastward drainage through Georgian Bay and past Lake Simcoe into the Ontario basin near Toronto. He outlined a drainage from the south part of the Lake Michigan basin across the southern peninsula of Michigan into Saginaw Bay and Lake Huron. The northern part of the Lake Michigan basin he interpreted to have drained through the Straits of Mackinac and east ward into Georgian Bay to join the old Huron drainage. Spencer's maps and discussion do not include the Lake Superior basin. My own studies of the district south of Lake Superior have brought to light a deep buried channel leading southward from the east end of the basin to the head of Lake Huron some distance west of the present line of discharge through Ste. Marys River.

Whether Spencer's interpretation is correct on the main proposition of an eastward drainage to the Gulf of St. Lawrence remains to be determined. It will be necessary to learn how much the level of the old rock beds have been reduced by ice weighting and differential depression and by ice erosion. The beds certainly have been sufficiently lowered to render it impossible to run the glacial drainage to the ocean over a rock floor sloping continually seaward. The amount of erosion and depression seems to decrease southwestward or toward the peripheral portion of the ice sheet. It will not be surprising, therefore, if the proper evaluation of these factors will throw the balance of probabilities in favor of preglacial discharge of much of the Great Lakes region to the Gulf of Mexico.

The data thus far collected in central Michigan favor this interpretation. The borings along the line of the buried channel that runs across Michigan from Saginaw Bay to Lake Michigan indicate, not only a fall in that direction (which is the reverse of the course outlined by Spencer), but also a widening of the channel. Deep borings in western Indiana between the head of Lake Michigan and the Wabash show a lower rock floor than any yet discovered across Illinois and suggest a preglacial drainage to the Wabash and Ohio.

[1]Quarterly Jour. Geol. Soc'y of London, Vol. XLVI, 1890.

EFFECTS OF GLACIATION IN GREAT LAKES REGION.

The Great Lakes region has been modified by glaciation in various ways, chief among which are (1) drift deposition, (2) glacial erosion, and (3) probably weighting and depression by the ice. On the first of these modifications, drift deposition, there is opportunity for definite knowledge, and no differences of opinion are held by geologists. On the second and third there are debatable questions, and in consequence a lack of uniformity of opinion.

EFFECT OF DRIFT DEPOSITION.

The drift has so completely filled the valleys which connected the several basins that the position of these valleys is known only through data from borings. Their beds lie far below the present surface of the lakes. Consequently were the drift removed from these channels the lakes would stand much lower than at present. The basin of Lake Erie, it should be noted, is rendered shallow by a thick accumulation of drift. The greatest depth of water is about 210 feet, but borings at Cleveland, near the mouth of Cuyahoga River, show the drift to extend down to within 100 feet of sea level, or more than 470 feet below lake level.

The present divide between the Great Lakes or St. Lawrence drainage and the Mississippi drainage is determined very largely by moraines and thick drift deposits. The drift has been heaped up in greatest amount at the ends and along the sides of the tongues of ice that passed over the lowlands now occupied by the Great Lakes. There is also in the southern peninsula of Michigan a remarkable amount of drift, perhaps a thicker deposit than in any other area of equal size in America. This apparently resulted from the convergence of ice movement occasioned by the trend of the bordering Great Lakes basins, there being southward movement on the west side and southwestward on the east. The northern half of the peninsula, which now rises in places 1,000 to 1,100 feet above the surface of the lakes, seems to have no rock standing more than 250 to 300 feet above the lakes, there being 700 to 800 feet of drift on its higher parts. It has been estimated by W. F. Cooper from planimeter measurements on maps showing present surface and bed rock surface, issued by the U. S. Geological Survey,[1] that the entire southern peninsula of Michigan has an average of about 300 feet of drift. The area of thick drift covers also northwestern Ohio, northern Indiana, and northeastern Illinois, and averages nearly 200 feet.

[1]Water Supply and Irrigation Paper 182, PI. II.

GLACIAL EROSION.

The large amount of drift deposited at the ends and on the borders of the ice lobes that occupied the basins of the Great Lakes calls for a similar erosion of districts over which the ice passed. Considerable material was gathered in Canada as we know from the occurrence of Canadian bowlders and pebbles in all parts of the Great Lakes region and southward to the glacial boundary. But this appears to be a less important constituent than the material derived from the softer rock formations in and around the Great Lakes basins. The examination of constituents of the drift made in Wisconsin, Illinois, Indiana, Ohio, and Michigan, have shown from 75 to 80 per cent or more of material derived from south of the Canadian boundary.

WEIGHTING AND DEPRESSION BY ICE.

That the region of the Great Lakes has experienced considerable increase in altitude on the withdrawal of the ice sheet is well shown by the tilting of the shore lines of the glacial lakes that were the predecessors of the present Great Lakes. This tilting is so closely connected with the relief of the ice covered district from its burden of ice that it seems highly probable that it came as a result of the relief from this load. As will be shown later it amounts to several hundred feet in the northern part of the Great Lakes region, where the load was heavy, and dies out entirely in the southern part where the load was light. If the unloading has given occasion for such a marked upward movement it would seem a safe assumption that the accumulation of the ice had caused a weighting down or depression from which this is a resilience. The presence of a large amount of drift in the districts bordering the Great Lakes, and especially that in the northern half of the southern peninsula of Michigan, seems likely to have had a measurable effect in preventing complete return to preglacial altitudes. It is perhaps to the great amount of drift east of the northern half of the Lake Michigan basin that the very slight rise of that region is due, a rise so slight that it is scarcely measurable south of Manistee.

It thus appears that the lake basins as we now find them are glacially modified lowlands, which have been loaded in places by drift, and in places eroded and weighted down by the ice. They are held up by rock and drift barriers to levels several hundred feet above their rock beds, the lowest, Ontario, being nearly 250 feet, and the highest, Superior, 600 feet above sea level, while the beds of all except Erie extend in places below sea level.

GLACIAL AND INTERGLACIAL STAGES.

The studies of the glacial deposits have shown that they do not consist of a single sheet but embrace three and in places four distinct drift sheets. There is evidence that these drift sheets are the product of repeated glaciation at widely separated intervals. They are separable by beds of peat and deposits made by lakes and streams. These deposits contain remains of forms of life similar to those now existing in the same regions, and thus they indicate a temperate interglacial climate.

It is probable that after the first glaciation as well as after each succeeding one there were lakes in the basins of the present Great Lakes. These would be invaded and completely filled by ice in each recurring glacial stage. Evidence of such interglacial lakes is largely destroyed by the glacial occupancy and must be at beet very fragmentary. Yet there are not wanting features that point to their occurrence. For example, at the southern end of the Lake Michigan basin, and also on the eastern side where dunes now occur, the moraines formed by the last glacial stage are found to be more sandy than their continuation on the western side of the lake basin. This sandiness it is thought may be due to the incorporation of the interglacial dune material in the drift.

The history of the lakes in connection with and subsequent to the last glaciation is so complex that it alone will be outlined at this time. The complexities here outlined are likely to be but a recurrence of those of the interglacial times. The interglacial times differ from the postglacial in that they involve a readvance of ice and extinction of any lakes that may have been present in the basins. The interglacial times were also much longer than the postglacial and there were correspondingly greater filling and modification of the lakes. We are, therefore, presenting in this postglacial lake history a succession of events lees complete than probably occurred in each interglacial stage.

In the last or Wisconsin stage of glaciation, and also in the next preceding, or Illinoian stage, the Great Lakes region was covered by ice moving southwestward from a center in Labrador. In a still earlier glacial stage, the Kansan, there appears to have been a southward movement across the Great Lakes region from a center in central Canada known as the Keewatin. At least, copper was distributed from the Lake Superior region as far southeast as central Ohio probably by ice moving southward through the Huron basin and across the western portion of the Erie basin. The lake history is likely to have been different at the withdrawal of the Keewatin ice sheet from the basin it had filled than it was at the withdrawal of the Labrador ice sheet in subsequent stages of glaciation. It would not, however, be an easy matter to unravel that part of the Great Lakes history, for any moraines or features that would throw light on the outline of the ice border have been overridden and completely concealed by the later invasions from the Labrador center.

FEATURES CHARACTERISTIC OF LAKE SHORES.

Inasmuch as the predecessors of the Great Lakes stood at higher levels than the present bodies of water and covered certain outside territory, the features characteristic of lake shores have been discovered in the outside territory and used as a basis for interpreting the extent of the ancient water bodies. These include bars of gravelly material thrown up by waves along the old shores, and abrupt banks formed where the waves cut back into the bordering land; also deposits with the delta form and structure laid down where streams entered the old lakes. The beaches of a given lake lead into the head of its outlet at a level corresponding to the ordinary stage of water in the outlet. In some cases, however, the outlet experienced considerable deepening during the life of the lake and one finds later beaches opening into it at levels corresponding to this deepening.

THE SUCCESSION OF LAKES.

It is evident that when the ice sheet extended out to or beyond the divide between the Great Lakes and the Mississippi drainage there would be a direct discharge along valleys into the Mississippi and no lakes would be present. But as soon as the ice had shrunk back inside the divide to where the land sloped toward the ice border lakes would begin forming. There would be at first small bodies of water at numerous points along the borders of the basin, either discharging directly across the rim by independent outlets or having connection by border drainage along the ice edge to some low place on the rim of the basin. With the shrinking of the ice the small lakes which at first were independent, or were connected by border drainage channels would become confluent and take the level of the lowest water level of the series.

Inasmuch as the melting of the ice uncovered the southern and southwestern borders of the lake basins earliest, it is here that we find the beginnings of the lakes. These basins extend somewhat farther out than the present Great Lakes, and it is in these extensions that the first ponding occurred; in some cases while the whole area now occupied by water was occupied by the ice.

It is scarcely possible as yet to determine in which basin the ponding of water took place earliest. Mapping of moraines has been carried far enough to indicate that there was no great difference in the dates of the beginning of the lakes in the southwest ends of the Superior, Green Bay, Lake Michigan, and Lake Erie basins, whereas the lakes formed in the Huron and Ontario basins were much later. A lake in the Saginaw basin southwest of Lake Huron was earlier than in the southern end of Lake Huron. The lake in the Ontario basin came in the latest of any in the large basins, being situated farthest northeast and consequently nearest the center of dispersion of the ice.

SUPERIOR BASIN.

The earliest part of the drainage basin of Lake Superior to be vacated by the ice seems to have been in the district now drained by St. Louis River. As noted by Winchell,[1] the ponded waters in the southwest part, of this river basin were at one time discharged southwestward to the Mississippi, from an altitude, about 700 feet above Lake Superior, as indicated in Fig. 1. The name Lake Upham has been given to this small and transient water body. With the shrinking of the ice border a lower passage, about 530 feet above Lake Superior was opened from the St. Louis River to Kettle River and thence to the St. Croix and this drew the water down below the level of the outlet of Lake Upham. To distinguish this lower lake stage in the St. Louis drainage basin it has been named by Winchell Lake St. Louis. A little further shrinking of The ice border exposed the headwaters of Nemadji River, a stream that comes into the head of Lake Superior from the west-southwest, and there was formed a small lake about 500 feet above Lake Superior level, known as Lake Nemadji. It received the melting waters from the end of the Superior lobe and discharged a large volume of water down the Kettle River valley into the St. Croix, though only 30 square miles in area. During the life of each of these lakes the ice sheet still completely covered the area of Lake Superior.

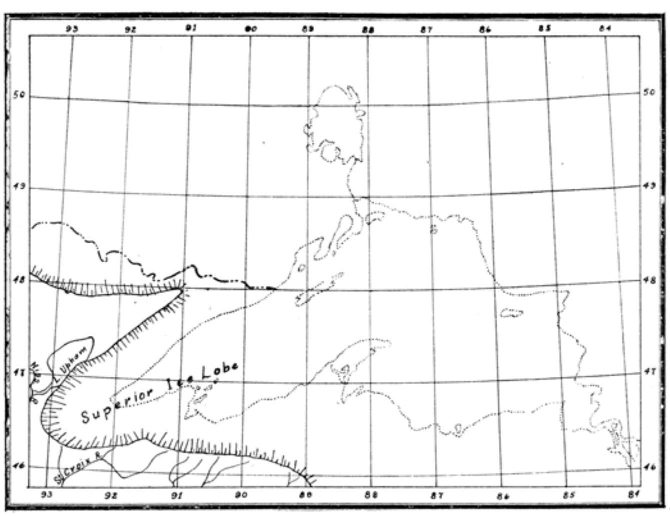


Fig. 1. Superior Ice Lobe and Lake Upham.

As the ice border shrank within the limits of the western end of Lake Superior a large body of water, named Lake Duluth (Fig. 2), came into existence. Its outlet was southward from the head of Brule River in northwestern Wisconsin into the St. Croix River. While this was still a small lake there was formed another lake farther east called Lake Ontonagon for it covered much of the Ontonagon drainage basin in the western part of the northern peninsula of Michigan. It discharged westward along or near the ice border into Wisconsin where it joined Lake Duluth in the discharge through the St. Croix valley. Its outlet made a descent between 150 and 200 feet, however, before reaching Lake Duluth. With the recession of the ice border Lake Ontonagon became confluent with Lake Duluth but at a level considerably lower. It consequently vacated much of its bed.

The St. Croix outlet served as the line of discharge for this glacial lake in the western part of the Superior basin until the ice border had receded to the eastern slope of the Keewenaw Peninsula if not beyond it (Fig. 2).

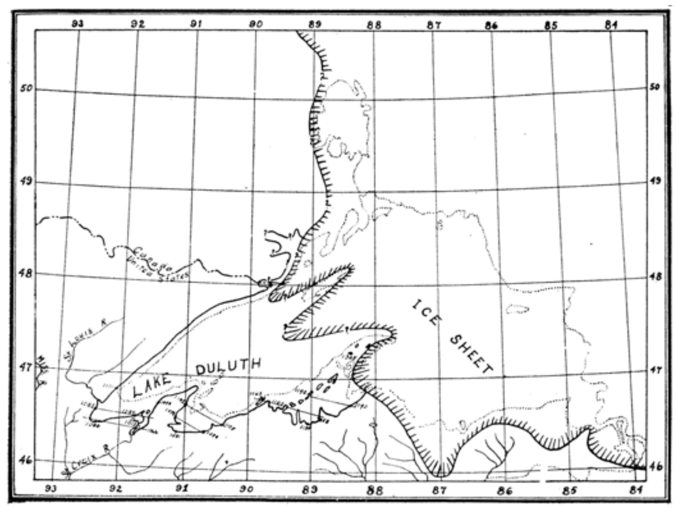


Fig. 2. Lake Duluth at greatest extent, and probable contemporary ice border. Numerals and isobases indicate altitude of the highest beach above sea level.

It will be observed that the highest shore of Lake Duluth is not at a uniform level but shows a marked rise toward the northeast. Thus at the western end it is 1,066 feet above sea level or 465 feet above Lake Superior, while at Calumet on the Keewenaw Peninsula it reaches 1,303 feet, or 702 feet above the present lake. This rise of 237 feet seems to be largely attributable to a subsequent differential uplift, though a small portion is perhaps referable to an actual higher position of the lake at the northeast end due to ice attraction. The effect of ice attraction seems unlikely, however, to amount to 37 of the 237 feet and would be mostly within a few miles of the ice border. It will be observed that the lines of equal elevation, or isobases, connecting certain points of opposite sides of the lake, trend south of east but they are not uniform in direction even in the small area covered by definite data. It appears from this that the uplift was not regular. There is need for precise levels along the whole shore to clear up the form of warping or uptilt this region has experienced. The direction of tilting, which for any given line is at a right angle to the isobase, varies on different lines from about 10° to nearly 30° east of north. It appears that the entire basin lies within the region of uplift, for there is a decrease in altitude clear to the southwest end of the lake.

It will be observed that the head of the outlet is only 1,013 feet while the lowest part of the upper shore is 1,066 feet; or a difference of 53 feet. It is scarcely to be supposed that the outlet carried a depth of 50 feet of water at its head. Instead it seems probable that it was deepened 40 to 50 feet after the lake waters were turned into it. In fact the head of the outlet is low enough to afford discharge for the lake after it had dropped to the level of its second beach.

Lake Duluth represents a, somewhat long stage in the glacial lake history. Its duration is measurable either in terms of ice recession or of work by the lake and its outlet. The recession of the ice border seems to have been more than 100 miles in the axis of the lobe and perhaps an even greater distance in the region north of Lake Superior. The time involved in such a recession must be expressed in hundreds if not in thousands of years. The work accomplished in the outlet has not been fuly ascertained for studies have been restricted to the immediate head of the outlet. At the head of the outlet there appears to have been a deepening of 40 to 50 feet in a channel nearly a mile in average width cut in sandy drift. The amount of work in this outlet seems to be less than in outlets from glacial lakes in the Michigan and Erie basins. This may be partly because of its briefer duration and partly because of its smaller volume. The beaches of Lake Duluth are strong and easily traced in all situations and indicate long duration as clearly as the outlet channel.

The occurrence of certain beaches in the western Superior basin that are too low to open into the St. Croix outlet and too high to correlate with the highest beach having an eastward outlet, the Algonquin beach, seems to demand an outlet somewhere on the north side of the basin. The ice down to the time of this supposed northward outlet probably covered the region around Lake Nipigon north of Lake Superior. A further recession would have let the waters into the Nipigon basin, and thence perhaps northward and westward into the basin of the great Glacial Lake Agasgiz. This region, however, awaits investigation to settle the course or courses of discharge for the waters. With further withdrawal of ice on the southern part of the Lake Superior basin the waters became connected with those in the Lake Michigan and Lake Huron basins to form the great Lake Algonquin, discussed below.

[1]Bull. Geol. Soc. Am. Vol. 12, 1901, p. 124.

GREEN BAY BASIN.

That there was a glacial lake in the Green Bay basin with, an outlet into the Wisconsin River near Portage, Wisconsin, is known from the well defined outlet channel, discussed by Upham in 1903[1] and by the presence of shore features at corresponding altitude at points along the borders of the Green Bay basin (Fig. 3). W. G. Alden of the United States Geological Survey has found a well defined shore east of Lake Winnebago at about 800 feet above sea level, or only 10 to 12 feet higher than the bed of the outlet, but in parts of the border the shore is very weak and ill defined.[2] The red clay of the Green Bay basin which Upham considered a deposit of the lake bed has been found by Alden to be a glacial deposit. It was on the withdrawal of the ice after depositing the red drift that the lake reached its greatest extent, and it only persisted until the ice had melted far enough back to give an eastward discharge into the Lake Michigan basin.

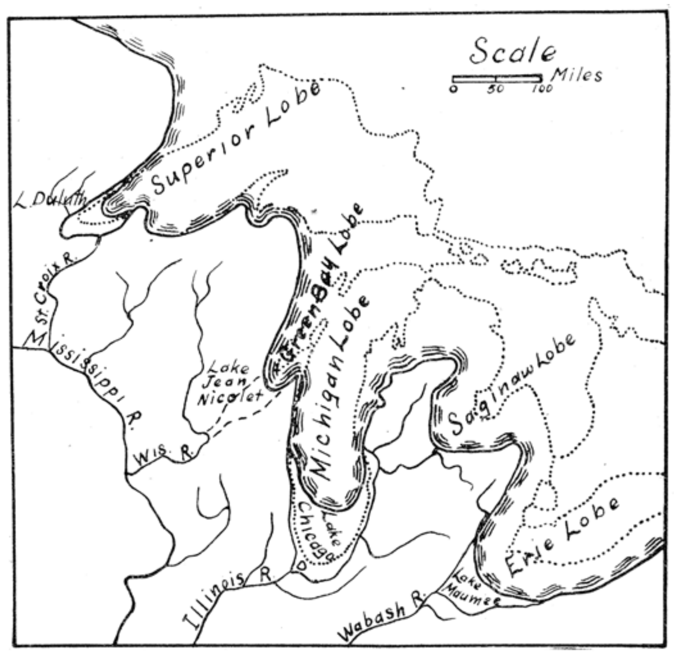


Fig. 3. Beginnings of lakes in Superior, Green Bay, Michigan, and Erie basins, with correlative ice border.

[1]American Geologist, Vol. 32, 1903, pp. 100-110, 330-381.

[2]Personal communication.

MICHIGAN BASIN.

In the Michigan basin there was at first a chain of lakes along the eastern side of the southern portion and a narrow strip of water at the south and southwest which discharged down the Des Plaines valley. The ice Ailed the basin at that time a little beyond the limits of the present lake, its border being at Blue Island ridge in Illinois, and at the narrow moraine north of Chesterton, Indiana.

From this moraine the ice border shrank within the limits of the present lake and the lake became expanded eventually over the greater part of the basin (Fig. 3). It is known as Lake Chicago, and its outlet as the Chicago Outlet. As the outlet stood but little higher than the present lake, the extent beyond the present lake was slight. The highest shore is 55 to 60 feet above lake level, so the bed of the outlet at first was about 50 feet above the lake. There are three distinct beaches differing about 20 feet in altitude, known as the Glenwood, the Calumet, and the Toleston. The highest and oldest marks the level of the lake during the cutting of a trench in the gravel formations along the outlet. The second or Calumet beach marks the level of a rock sill over which the lake outlet flowed for considerable time before cutting it away. The removal of the rock, it has been suggested by Chamberlin, was by a stoping process, there being rapids at first at the down stream end of the rock sill, which by wearing backward gradually narrowed the rock barrier until it finally gave way and let the lake drop to the level of the third or Toleston beach. The Toleston stage persisted until the ice had melted out of the Michigan basin and connection was established with Lake Algonquin in the Huron basin. It is probable, though not yet fully established, that the Chicago Outlet served for a time as the line of discharge for waters in both these basins and also of the Superior basin. But with the opening of the eastern outlet for Lake Algonquin through the recession of the ice in Ontario the lake seems to have been drawn down below the level of the Chicago Outlet. Another rise of water took place at the close of the lake stage known as the Nipissing, discussed below, the water reaching an altitude about 16 feet above the present lake Michigan. The outlet became blocked by sandbars at this stage and the lowering of the lake to the present altitude has been a result of cutting in the St. Clair outlet. The Chicago Outlet is now occupied by the small Des Plaines River, which takes a straggling course across its bed, and in its meanders scarcely touches the banks of its great predecessor.

HURON-ERIE BASIN.

The portion of the Huron basin south of Saginaw Bay lies in a lowland which is continuous with that of the Erie basin across the Canadian Peninsula. This lowland is termed the Huron-Erie basin. There were converging ice currents in the Huron arid Erie basins which became confluent and formed what may properly be termed the Huron-Erie ice lobe.

The Huron-Erie basin has had perhaps a more complicated lake history than any other of the Great Lakes basins owing to the opportunity for discharge of water at various points on its border, exposed one after another in the course of the recession of the ice. It also affects more closely the history of the southern portion of Michigan.

Lake Maumee. The first discharge was from several small lakes on the southern border of the Erie basin into the drainage of the Ohio. These eventually became connected by border drainage and led into a lake known as Lake Maumee, at the southwest end of the basin, which discharged past Fort Wayne, Indiana, to the Wabash River, along what is known as the Fort Wayne Outlet. (Fig. 3.) During and prior to the development of a large moraine, the Defiance, which forms a loop in the Maumee basin southwest of Lake Erie, and is cut through by Maumee River below Defiance, Ohio, the glacial lake Maumee had a small area in southwestern Ohio and northeastern Indiana and a narrow strip in Michigan southwest of Adrian.

As the ice melted back from the Defiance moraine the lake expanded over the low country to the east and became extended northward on the eastern slope of the Thumb of Michigan[1] as far as Imlay. Here it found an outlet across the Thumb and drained past Flint and Durand into the Grand River and thence to Lake Chicago, its course being along the edge of the Saginaw ice lobe nearly to Grand River. (Fig. 4.)

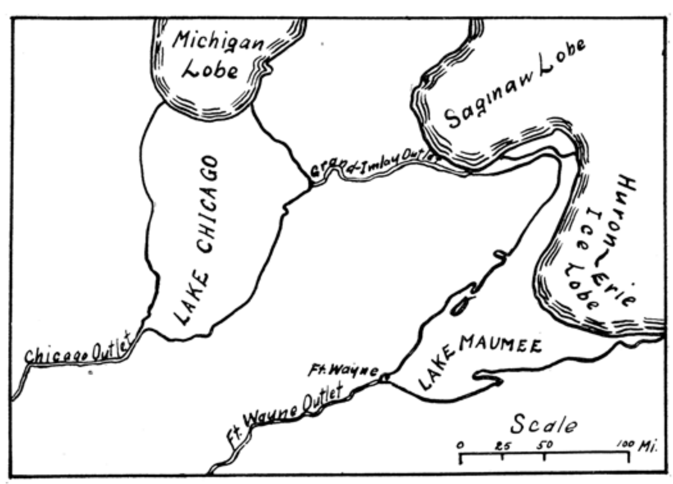


Fig. 4. Lake Maumee and Lake Chicago, with correlative ice border.

At present the bed of the channel at the head of the Imlay Outlet stands 45 to 50 feet higher than the head of the Fort Wayne Outlet largely because of differential uplift of the northern outlet. A comparison of the altitude of the highest beach of Lake Maumee with each of the outlets indicates that the Imlay Outlet probably stood about 15 feet lower than the Fort Wayne Outlet. The summit in its bed is 40 feet below the highest beach, while the summit in the Fort Wayne Outlet is only about 25 feet below the same beach. The second beach of Lake Maumee is barely high enough to have afforded discharge through the Fort Wayne Outlet, but it stands 20 feet above the head of the Imlay Outlet. The actual difference in level of the highest beach at the two outlets is 60 to 65 feet, being 785-790 feet at Fort Wayne and about 850 at the head of the Imlay Outlet. Since the ice border was near by the Imlay Outlet and remote from the Fort Wayne Outlet the water surface may have been drawn up by ice attraction to a slightly higher level at the Imlay Outlet. The amount of ice attraction must be deducted from the 60 to 65 feet to show the actual differential uplift. Another qualifying condition is found in the amount of peaty filling which each outlet contains. The amount appears to be several feet greater in the Imlay Outlet than in the Fort Wayne. It may be sufficient to counterbalance the amount that would need to be subtracted because of ice attraction.

With further recession of the ice border on the Thumb lower outlets were found across it, one near Ubly, and a lower one still farther north, and the Imlay Outlet was abandoned.

[1]The Thumb of Michigan is the peninsula between Saginaw Bay and the Huron-Erie basin.

Lake Arkona. The lowest of the three outlets across the Thumb is not now exposed to view because the ice readvanced and Ailed it. This readvance raised the lake waters to the level of the next higher or Ubly Outlet. The beaches of the lake formed at this lower stage are, however, preserved at certain places just outside the moraine of re-advance at lower levels than the beach that opens into the Ubly Outlet. The name Lake Arkona is applied to this water body that preceded the advance of the ice, and the features of this lake have been discussed by Taylor in an earlier report of the Michigan Academy.[1] Its full limits on the north are not known, but it is supposed to have extended over much of the Saginaw basin as well as the district east of the Thumb. It appears also to have extended eastward into New York beyond Buffalo to the vicinity of Alden where its beaches are preserved in a protected situation back of a moraine, thus duplicating the features noted on the Thumb.

[1]Seventh Report, 1905, pp. 29-80.

Lake Whittlesey. The stage of the lake that accompanied the readvance of the ice and utilized the Ubly Outlet has been named Lake Whittlesey. Its beach is the best defined of the whole series in the Huron-Erie basin, and was traced through much of southern Michigan some 70 years ago by Bela Hubbard. It was used as a highway or ridge road in the earliest days of settlement and still continues in use extensively. It is conspicuous as far north as the latitude of Port Huron on the east slope of the Thumb from St. Clair county to Lenawee and thence continues around the western and southern sides of Lake Erie into western New York. (Fig. 5.) Its eastern terminus in New York as well as its northern terminus in Michigan is found at a moraine that marks the contemporary ice border.

The Ubly Outlet discharged to a small lake in the portion of the Saginaw basin southwest of Saginaw Bay and thence through the Grand River outlet to Lake Chicago.

The beach of Lake Whittlesey is horizontal from near Birmingham, a few miles north of Detroit, around the western and southern sides of Lake Erie to the vicinity of Ashtabula, Ohio, but north from Birmingham and east from Astabula it shows a marked rise resulting from differential uplift. At the Ubly Outlet its altitude is about 60 feet higher than in the horizontal portion, and in western New York it reaches an altitude about 150 feet above the horizontal portion.

Lake Warren. With the recession of the ice border from the northern part of the Thumb, Lake Whittlesey abandoned the Ubly Outlet, and the waters in the Huron-Erie basin became confluent with those in the Saginaw. The lake extended so far outside the limits of the Saginaw basin that it has seemed inappropriate to call it Lake Saginaw, and the name Lake Warren has been applied. Its eastern end was in the Finger Lake region of central New York, and it covered a large area on all sides of Lake Erie (Fig. 6). During its existence the ice was still present in the Ontario basin and prevented eastward discharge. The outlet was westward through Grand River to Lake Chicago. The water level was sufficiently high to submerge the site of Niagara Falls to a depth of about 250 feet.

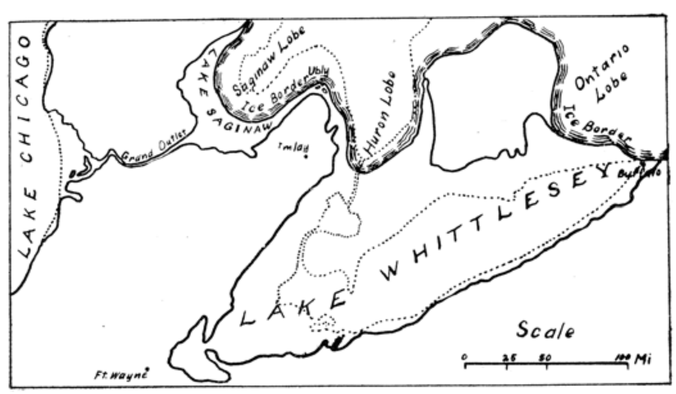


Fig. 5. Lake Whittlesey, with correlative ice border.

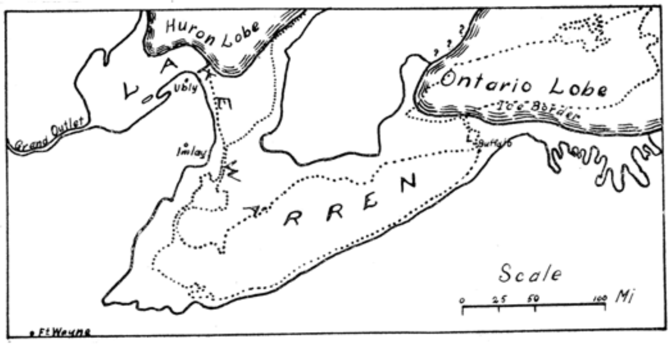


Fig. 6. Lake Warren, with probable correlative ice border.

The lake has two well defined beaches differing about 20 feet in level. These beaches have suffered differential uplift in the Saginaw basin and on the northern part of the east slope of the Thumb, and also in the eastern part of the Lake Erie basin, but elsewhere they are horizontal. In the horizontal portion the higher beach stands about 880 feet above sea level or 100 feet above Lakes Huron and Michigan and the lower one about 880 feet above sea level. In western New York the higher beach reaches an elevation of 880 feet, or 200 feet above the horizontal portion.

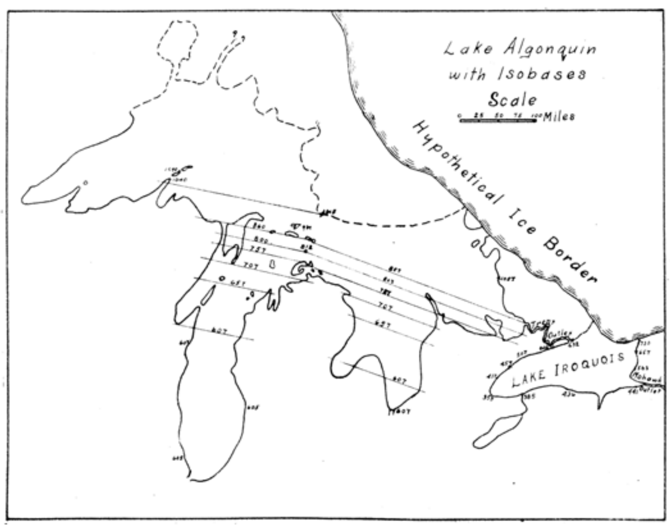


Fig. 7. Lake Algonquin and Lake Iroquois, with probable correlative ice border. Numerals and isobases indicate altitude above sea level of the highest beach of these lakes. Isobases of Michigan and Huron basins by Taylor and Goldthwaite.

Transitional lakes. (Grassmere and Elkton beaches). As the ice border shrank into the Ontario basin passages were opened for the discharge of the waters of Lake Warren eastward past Syracuse, New York, to the Mohawk valley, at altitudes low enough to draw down the lake level and cause the abandonment of the Grand River Outlet. The ultimate discharge by the new route was to the Atlantic Ocean at New York instead of to the Gulf of Mexico. Two weak beaches were formed in southeastern Michigan, known as the Grassmere and the Elkton, at levels 20 and 40 feet respectively below the level of the lower of the two beaches of Lake Warren. While full tracing has not yet been made around the entire course from Michigan to New York it seems probable that these beaches are to be correlated with two of the eastern outlets, past Syracuse.

The lowering of this eastward discharge was not at first sufficient to uncover Niagara River, but eventually the ice border shrank within the Ontario basin sufficiently to allow discharge over a low col at Rome, New York, the lake was drawn down to a level more than 150 feet below that of the crest of Niagara Falls, and the cataract came into operation.

Lake Erie. Inasmuch as the eastern part of the Erie basin has suffered considerable differential uplift subsequent to the draining of Lake Warren, the beginning of Lake Erie was as a small body of water in the eastern end of its basin, which has been extended westward with the raising of the outlet (Fig. 7). Evidence that it did not formerly cover the western part of its area is found in the submerged lower courses of the streams in the western part of the basin, especially that of Sandusky River, which has been traced by Mosely entirely across the bed of Sandusky Bay. Evidence of a rise of water is also found in submerged stalactites in the caves on Put in Bay Island in the western part of the lake.

ONTARIO BASIN.

Lake Iroquois. The lake in the Ontario basin known as Lake Iroquois (Fig. 7) began as a narrow strip of water along the front of the ice at the south side of the Ontario basin and became gradually expanded over the entire width of the basin as the ice sheet melted back. The discharge was continued through the Mohawk valley during this recession for the ice sheet completely blocked any passage down the St. Lawrence. The level of Lake Iroquois was, throughout, considerably higher than the present surface of Lake Ontario. Its beaches have suffered differential uplift and are much higher in the northeastern portion of its basin than in the southwestern. Inasmuch as the outlet is at the side of the basin, the effect of the uplift has been to raise the waters on the portion of the shore south of an isobase running through the outlet and to cause the water to recede from the portion of the shore north of the isobase. The highest beaches of the northern part of the basin can not be traced into the southern part of the basin for the rise of water in that part of the basin has effaced them almost completely. The single beach present in the southern part of the basin is, therefore, a correlative or continuation of the lowest Iroquois beach of the northern part of the basin.

Champlain Sea. When the ice had opened a passage northeast of the Ontario basin the altitude was so low that the sea came into the basin (Fig. 8) and stood at a level slightly higher in the northeastern portion of the basin than the present shore of Lake Ontario, but in the remainder of the basin the old sea level shore passes beneath the waters of Lake Ontario. The differential uplift subsequent to this invasion of the sea has given Lake Ontario its present extent and level.

LAKE ALGONQUIN.

The lake history thus far has required a separate discussion for each of the lake basins but it is now possible to consider a lake stage that involves the basins of the three upper lakes, Superior, Michigan, and Huron, for upon the extinction of Lake Warren and the withdrawal of the ice from the vicinity of the Straits of Mackinac and the Ste. Marys River, a single large lake, known as Lake Algonquin (Fig. 7), occupied the basins of the present Lakes Superior, Michigan, and Huron, and part of the intervening territory. Sometime during the life of Lake Iroquois the ice uncovered the Trent valley in Ontario and gave an outlet for the waters of Lake Algonquin into this lake in the Ontario basin. Prior to this the discharge had been either through the Chicago Outlet or the St. Clair Outlet, or perhaps through both of these outlets. The change to the Trent Outlet appears to have been due to lower altitude along that line than either of the other outlets possessed. Uplift in the region bordering the Trent outlet, however, eventually brought the lake up to a level high enough to resume discharge through one or both of the former outlets, and to cause the abandonment of the Trent outlet. The altitude of Lake Algonquin when brought up to a redischarge through the southern outlet or outlets was about 25 feet above the level of Lakes Huron and Michigan, its beach at the southern end of Lake Huron being 605 to 607 feet above sea level. In the Lake Michigan basin it came back to the level of the third beach of Lake Chicago which is 20 to 25 feet above Lake Michigan.

Fig. 8. Nipissing Great Lakes and Champlain Sea. Numerals and isobases give altitude above sea level of the highest exposed shore. Isobases of Michigan and Huron basins by Taylor and Goldthwaite.

The conditions on the north side of Lake Superior have not been determined sufficiently to afford data as to the area of the lake or the height of its beaches. Professor Coleman has noted shore features on the northeast border of the Lake Superior basin up to an altitude of about 1,400 feet above the sea or 800 feet above Lake Superior which are thought to represent the work of Lake Algonquin.[1]

The area of Lake Algonquin has suffered differential uplift throughout the Superior basin and much of the Huron basin, but uplift has affected only the northern portion of the Michigan basin, as may be seen by reference to Fig. 7. In the southern portion of the Huron basin, and as far north in the Michigan basin as the mouth of Grand Traverse Bay, and the north end of Door peninsula in Wisconsin, the amount of uplift has been but a few feet, and the slope of the beaches is therefore very gradual, with scarcely any splitting into separate members. Farther north, however, the rate of uplift is much more rapid, and the Caches are found to split up into several members. The splitting of the beaches shows clearly that the uplift was in progress during the life of Lake Algonquin. The divergence of the several members of the Algonquin shore amounts to more than the uplift which has taken place since the lowest of the beaches was formed. It thus appears that the resilience wag very rapid in the course of the departure of the ice, though there was not a complete restoration of the preglacial level, and a slow rate of uplift is apparently going on at the present day.

It is a matter of interest to note the area affected by uplift during the Lake Algonquin stage does not extend so far south in the Huron-Erie basin as that which affected the shores of Lake Whittlesey and Lake Maumee, but the cause for the lessening of the area of uplift is not as yet fully established. The features suggest a complete resilience in the southern portion of the uplifted area very soon after the recession of the ice from that area; whereas farther north complete resilience has not as yet been attained.

It will be noted that the trend of the isobases of Lake Algonquin is not uniform through all the area of uplift (Fig. 7), the trend being more nearly east to west in the Michigan basin than in the Huron and Superior basins. If we may judge by the isobases of Lake Duluth in the western Superior basin (Fig. 2), the trend of the isobases is not uniform throughout the width of that basin. The tilt lines in different parts of the Lake Algonquin region, or lines at a right angle to the isobases, have a tendency to trend in the direction of the axial movement of the ice in each of the great basins, the movement in the Michigan basin being more nearly southward than in the Superior and Huron basins. This may signify that the variations in the trend of the tilt line have been governed to some extent by the lines of heaviest ice weighting.

[1]Eighteenth Annual Report, Bureau of Mines, Ontario, 1900, pp. 286-87.

TRANSITION LAKES (BATTLEFIELD AND FORT BRADY BEACHES).

The Algonquin Lake stage was brought to an end by the opening of an eastward passage along the ice border into the Ottawa valley, just as Lake Warren was brought to an end by the opening of a passage along the ice border into the Mohawk valley. The Ottawa valley is several miles in width, and the ice border appears to have shrunk across it from south, to north so that the earliest discharge was along the face of the south bluff. It is probable also that after the main valley had been uncovered ice lobes protruded into it from northern tributaries and blocked it up sufficiently to hold the waters considerably above the level of the valley bottom. Features pointing to such a history are found in the occurrence of weak shore lines in the Huron, Michigan and Superior basins at levels too low to be included in the Algonquin beaches and too high for the Nipissing shore. There are two such shore lines, the higher of which is known as the Battlefield beach, because well developed on the battle grounds on Mackinac Island, while the lower is termed the Fort Brady beach, it being well developed at Fort Brady near Sault Ste. Marie.

NIPISSING GREAT LAKES.

The Nipissing Great Lakes began with the complete lowering of the lake waters to the level of the low pass that leads from Georgian Bay eastward past Lake Nipissing into the Ottawa valley (Fig. 8). The present small lake east of Georgian Bay, known as Lake Nipissing, lies near the head of the old outlet. The term Nipissing Great Lakes is applied because of the close association of the Nipissing shore at its latest stage with the shore of the modern lakes in the Michigan, Huron, and Superior basins.

At the outlet by Georgian Bay and in the extreme northeast part of the Superior basin uplift has been sufficient to give the beach an altitude about 120 feet above the modern lakes. It falls to only 15 feet above the lake at the southern end of Lakes Huron and Michigan and drops slightly below the level of Lake Superior in the western portion of its basin.

At the time the Nipissing Great Lakes began eastward discharge, the altitude of the outlet appears to have been considerably lower than that of the Chicago or St. Clair outlet, and the lake was drawn down to a somewhat smaller area than the present area of Lakes Michigan and Huron. As the uplift of the outlet progressed the lake became extended with the rise of the waters until it resumed an outflow through the St. Clair River. The beach known as the Nipissing beach, on the borders of the Huron and Michigan basins, and also of the portion of the Superior basin south of an isobase running through the outlet, was formed after the lake had become expanded sufficiently to have a discharge through the St. Clair as well as the Ottawa outlet. It is, therefore, the beach of a two outlet stage. The part of the Nipissing shore north of an isobase running through the head of the Ottawa outlet exposes a series of beaches formed prior to the two outlet stage, as well as the beach of that stage. The continuation of these earlier beaches is submerged in the portion of the lake area south of the isobase running through the head of the outlet.

The direction of tilting of the Nipissing shores does not coincide precisely with the tilt lines of the Algonquin shores, being in places a few degrees to the east. The amount of uplift is very much less than that affecting the Algonquin beaches. The horizontal portion of the Nipissing beach extends over about the same area as that of the horizontal portion of the Algonquin and includes the southern portion of Saginaw Bay and Lake Huron and fully two-thirds of the basin of Lake Michigan. The tilting affects the entire area of the Superior basin. There has been about 100 feet of uplift at the head of the Ottawa outlet since it was abandoned. The abandonment of this outlet marks the beginning of the modern Great Lakes. The shore of Lake Nipissing formed at the two outlet stage just preceding the abandonment of the Ottawa Outlet is everywhere a strong feature, and indicates that the duration of this stage was comparatively long. It would seem to require a length of some centuries if not some thousands of years. Its duration was such as to suggest a lessening if not a cessation of the differential uplift that led to the rising of the lake to the two outlet stage.

THE MODERN GREAT LAKES.

In view of the changes which have been experienced by the bodies of water in the Great Lakes basins as just outlined, it becomes a matter of interest to determine whether the present Great Lakes will undergo important changes in the future. There are of course processes at work on the shores of all lakes which tend toward the filling and extinction of the water bodies. Material is brought in by streams and the deltas are extended out into the lakes, while the fine material is carried on to settle over the deeper portions of the beds. The material which is cut by waves along the shores is also deposited in the deeper parts of the basins as well as on the borders of the lakes. In the course of many thousands of years, therefore, the lakes would become filled by these ordinary processes. There will also be more or less lowering of the outlets of the lakes by erosion. In this way the level of Lakes Michigan and Huron has already been lowered about 15 feet by the cutting down of the St. Clair Outlet at the south end of Lake Huron. Should the recession of Niagara Falls continue until Lake Erie is reached, the barrier over which the water from Lake Erie now discharges would be removed and the level of the lake correspondingly lowered. In opposition to the processes of erosion comes that of differential uplift and this appears to be affecting the outlets of some of the lakes and it may cause considerable shifting of the lines of discharge.

Observations on the changes in level in the Great Lakes basins undertaken by Gilbert, indicates that a tilting is still in progress, and that the direction of the tilting is about the same as that in the Nipissing shores, or in a general north-northeast direction. The portion of the Michigan basin south of an isobase running east-southeast through the head of the St. Clair outlet is apparently undergoing an extension of the lake, but the Huron basin and the portion of the Michigan basin north of this isobase show a shrinking of the lake from the present shore. The portion of Lake Superior south of an isobase running from the outlet west-northwest and striking the north shore near the line of the United States and Canada is undergoing a rise of water on the shore, while that north of the line is shrinking from the shore. This shrinking has exposed a beach known as the Sault beach which is submerged along the south shore. In the Lake Erie basin, and also in the Lake Ontario, there is an expanding of the entire shore line because the outlets are at the end where uplift is most rapid. In the course of time the uplift of the outlet of Lake Erie may be sufficient to bring that body of water up to the level of Lakes Michigan and Huron, for it now lacks only 7 or 8 feet of being as high as this higher water body. The continuation of the uplift would bring the water at Chicago to a level high enough to produce a reoccupancy of the Chicago Outlet as a line of discharge. There might then be a two outlet stage such as occurred in the case of Lake Nipissing, one outlet being as at present over Niagara Falls, and the other southwestward along the old Chicago Outlet. A further continuation of the uplift might result in the abandonment of the Niagara Outlet.

The estimated rate of uplift, as determined by Gilbert, is only .42-of a foot in 100 miles in a century, or somewhat less than 2 feet in 100 years at the opposite extremities of the Georgian Bay-Lake Michigan body of water. The contingencies above mentioned, if uplift continues at the present slow rate, lie many centuries in the future, and there is a possibility that the uplift may die out entirely before the lake reaches a stage high enough to transfer the discharge from Niagara to Chicago.

HISTORY SHOWN BY NIAGARA FALLS.

The several changes of volume in the discharge from the Lake Erie basin over the falls of Niagara are found to be clearly represented in the bed of the gorge below the falls. During the time when only Lake Erie was discharging over the falls, and Lake Algonquin had its discharge through the Trent Outlet, the bed of the gorge was excavated to a shallow depth, but when the large discharge of Lake Algonquin was united to that of Lake Erie a deeper excavation occurred in the vicinity of the whirlpool. Then when the Nipissing Great Lakes had eastward discharge and left only Lake Erie to discharge over the falls a shallow portion of the bed of the gorge between the whirlpool and the suspension bridge marks the work done by the small Lake Erie Outlet. With the return of the waters that came about in the change from the Nipissing Great Lakes to the modern Great Lakes a deep excavation of the bed of the gorge set in which continues to the base of the present Horseshoe Fall.

The rate of recession of Niagara Falls has been a subject of careful investigation in order to form a basis for an estimate of the length of time involved in the entire recession of the cataract. The American Fall, which carries only a small amount of water probably illustrates conditions which obtained during the times of small discharge, while the Horseshoe Fall shows a recession by which the measurement of the time involved in the discharge of the great volume of water can be made. By means of these studies of the recession of the present falls it is estimated that the time can not be less than 15,000 years and it may be as great as 30,000 years since the cataract came into operation, that is, when Lake Warren had given place to Lake Erie. From this it appears that the time involved in the entire lake history from the beginning of Lake Chicago and Lake Maumee down to the present can not well be less than 20,000 to 25,000 years on the basis of the lesser estimate of 15,000 years for the recession of Niagara, and it would considerably exceed 30,000 years on the basis of the larger estimate. This places the culmination of the last stage of glaciation back some 50,000 years or more. These figures, while merely approximate, serve to indicate in a rude way the order of magnitude of the time involved in the changes shown in the history of the Great Lakes.

BIBLIOGRAPHICAL NOTES.

Space will not permit a complete bibliography of the Great Lakes Region for there are several hundred titles. A few notes, however, will be presented which, may serve to put those interested in the subject on the track of the literature.

A fairly complete bibliography of North American Geology is given in Bulletins 127, 188, 189, 301, 372, and 409 of the United States Geological Survey. These Bulletins are so arranged that it is possible to find many titles under the name of the State or Province, or under certain subjects (as Pleistocene), as well as under an author's name.

A few students have given especial attention to the features of the Great Lakes, among whom should be mentioned F. B. Taylor, J. W. Spencer, B. L. Fairchild, G. K. Gilbert, Warren Upham, A. C. Lawson, W. C. Alden, E. L. Moseley, J. W. Goldthwaite and the present writer. Many others have given incidental attention to lake features in connection with other investigation. This is the case with persons who have prepared county reports of Ohio, Michigan, Indiana, Illinois, and Minnesota, and district reports in New York, Wisconsin and Ontario. Contributions of this sort have been made by Charles Whittlesey, M. C. Read, A. A. Wright, J. S. Newberry, N. H. Winchell, and G. K. Gilbert, in the Ohio geology; by W. B. Sherzer, A. C. Lane, W. F. Cooper, W. M. Gregory, and I. C. Russell, in the Michigan reports; by W. S. Blatchley and C. R. Dryer in Indiana reports, and by S. M. Bannister in Illinois reports. The old beaches of the western shore of Lake Michigan have been discussed by Goldthwaite in Bulletins of the Illinois and

Wisconsin surveys. Early descriptions of the beaches of eastern Wisconsin were made by Chamberlin in the Geology of Wisconsin. The beaches of the portion of New York bordering the Erie and Ontario basins have been made a subject of special investigation by Fairchild and have received incidental attention from several other geologists. The beaches in Ontario have been studied extensively by J. W. Spencer and also by Taylor and Goldthwaite, and have received incidental attention of Chalmers, Coleman and other members of the Canadian Survey.

The ancient shores of the Great Lakes attracted the attention of travellers and explorers in the early part of the 19th century, mention of such features being made by J. J. Bigsby in 1821, by DeWitt Clinton in 1824, and by Featherstonehaugh in 1831. The beaches on the borders of the Lake Superior basin attracted the attention of the members of the Land Survey and are mapped in many places in districts covered by W. A Burt and Douglas Houghton. Members of the First Geological Survey of Michigan, notably Bela Hubbard, and C. C. Douglas, gave attention in 1838 to 1840 to the ancient beaches of southeastern Michigan and in the vicinity of the Straits of Mackinac; while the old beaches south of Lake Superior received the attention of Agassiz and Desor about 1850. In Schoolcraft's Narrative Journal of Travels in 1820 the shore features of Lake St. Clair, the west side of Lake Huron, both sides of Lake Michigan, and part of the south, shore of Lake Superior, are described with considerable accuracy. The narrative also reviews the explorations by Marquette, Joliet, LaSalle, Hennepin, La-Hontan, and Charlevoix in the Great Lakes region.

Ann Arbor, April 1910.

ON THE GLACIAL ORIGIN OF HURONIAN ROCKS OF NIPISSING, ONTARIO.

REGINALD E. HORE.

In the early (1840 et seq.) reports of the Canadian Geological Survey there appear descriptions by Sir Wm. Logan of a series of non-fossiliferous clastic rocks found on the west shore of Lake Temiskaming and north of Lake Huron. Logan correlated the rocks of the two localities and gave them the name Huronian. He believed them to be younger than, and made up partly of detritus from, the Laurentian, and his conclusions have been verified by later observers.

Recently these rocks have attracted more than local interest on account of the discovery of rich silver veins at Cobalt. In six years this camp has yielded sixty-three million ounces of silver at a net profit of seventeen million dollars, and it is expected that the production of the coming year will be greater than that of any previous.

As a result of their economic importance the rocks have been subject to much closer examination than before, and many interesting features have been noted. Among these are peculiar characters which are strongly suggestive of the existence of glaciers in Nipissing in early Huronian times.

Dr. A. P. Coleman[1] who has made a study of these rocks from the stand point of the glacialist, has gathered evidence from which he concludes that there is no doubt of the glacial origin of the basal conglomerate of the lower Huronian.

It is purposed here to present some facts which hear on this question.

As will appear from the accompanying table the chief rocks in this district are of the Archean and Algonkian groups. These are separated by a very marked unconformity and the interval was doubtless the greatest which occurred in Pre Cambrian times. There is no good reason to doubt that for a long period of time the Archean rocks were being worn down by all or any of the erosive agents now active.

The Huronian series doubtless represent a portion of the secondary rocks thus formed, and they are entirely composed of detrital material. They are conveniently grouped into an upper and a lower series which are generally conformable but in some localities separated by a slight unconformity.

The upper aeries is made up largely of medium grained feldspathic quartzite with a little conglomerate material. It presents no unusual feature and doubtless represents the hardened accumulation of a feldspathic sand derived from siliceous holocrystalline igneous rocks of the Laurentian group.

The lower series is made up largely of conglomerate, shale, greywacke, and feldspathic quartzite. In many cases there is gradual gradation vertically from one of these types to another. Less often there is a sharp division line. The composition of one stratum is often fairly constant for some distance; but in some cases a distinct change takes place in a few feet laterally as well as vertically.

The shales are for the most part of grey color, less often greenish black. Occasionally they are inter-banded with layers of purple, green, and pale gray colors. The chief recognizable minerals are quartz and altered feldspars, minute scales of chlorite and sericite, and small grains of epidote, titanite and iron ores. In mineralogical and chemical composition they are not unlike green shales of other formations.

The quartzites are in most instances feldspathic and grade insensibly into typical arkoses. They are usually very massive, fine to medium grained and not unlike light colored granite in appearance. It is often very difficult to determine their structure, as they are seldom well marked bedding planes. There are however instances in which the bedding is indicated by variations in the size and relative proportions of the various grains and other cases in which it is indicated by horizontal jointing. The rock is very largely composed of quartz and feldspar. Sericite and kaolin are prominent in light colored varieties and chlorite in the darker. Titanite and iron ores are usually present in small quantity. The feldspar and quartz grains are often well rounded but quite as frequently angular or subangular.

ROCKS OF THE NIPISSING SILVER FIELDS.

I. Cenozoic	*Recent*	Clay, marl, peat.
	Pleistocene	(1). Coarse unstratified material—sand, gravel, bowlders; (2). Stratified clay with some sand.
Great unconformity:		
II. Palaeozoic	*Silurian*	Grey limestone with some interbedded greenish shales, and at the base an arenaceous conglomerate. Correlated with Niagara of New York State.
Great unconformity:		
III. Algonkian	*Keweenawan*	Igneous intrusives only. Chiefly quartz diabase and quartz gabbro with acid differentiation products. Some olivine diabase and diabase porphyrite dykes.
	Igneous contact:	
	Huronian	Sedimentary rocks only. (a) An upper series. Probably equivalent to Middle Huronian of Lake Superior district. Chiefly feldspathic quartzite with some conglomerate.
	Slight unconformity:	
		(b) A lower series. Probably equivalent to Lower Huronian of Lake Superior district. Chiefly greywacke, shale, conglomerate, and feldspathic quartzite. The conglomerate pebbles are mostly of holocrystalline igneous rocks, the matrix greywacke and grey shale. The rocks are seldom schistose except as the result of contact metamorphism.
Great unconformity:		
IV. Archean	*Laurentian*	Igneous intrusives only. Holocrystalline light colored siliceous rocks. Chiefly granites, diorite, syenites and gneisses.
	Igneous contact:	
	Keewatin	Igneous and sedimentary rocks. All much metamorphosed, many being chlorite, hornblende and sericite schists. The relative age of the igneous and sedimentary rocks is doubtful The agglomerates were probably contemporaneous with some of the non-clastic volcanic rocks, and may be contemporaneous with the other sediments. The igneous rocks are chiefly of *extrusive* types.
	Extrusives	(1) Dark colored basic rocks—basalts—mostly with composition and texture of altered diabases. (2) Light colored siliceous rocks—felsite porphyries—mostly quartz porphyries which have been altered to sericite schists.
	Intrusives	(1) Basic rocks, mostly diabase and gabbro. (2) Siliceous rocks, mostly quartz porphyries and porphyrites.
	Sediments	(1) The iron formation, chert, jasplite, carbonates, slates and green schists. (2) Fragmental volcanic rocks—a grey felsite agglomerate.

Closely allied to the shales and arkoses are the greywackes. The chief recognizable constituents in these are feldspar, quartz, a dark chlorite and a pale colored mica. Less abundant are small particles of iron ore and epidote, while pyroxene and amphibole are rare. With the minerals are angular and rounded rock particles of various sizes. Rock of this type in some instances is found in massive beds of uniform character, very fine grained and of grey to greenish color. Similar material forms the matrix of much of the boulder conglomerate.

The conglomerate is remarkable for its heterogeneous appearance. Not only are the boulders of a great variety of types but in many cases they show no evidence of arrangement according to size. Frequently one finds boulders a foot in diameter scattered irregularly and sparsely through an aphanitic matrix of shale or greywacke, thus simulating glacial deposits. In other cases there are thick beds of shale quite free from such erratics. There are also beds of boulders of nearly equal size packed close together and with but little of fine grained matrix, as in an ordinary water accumulation of coarse gravel. In some instances the aphanitic beds are distinctly laminated as in ordinary water lain clay, while again similar material forms a compact rock lacking in well developed bedding planes.

As a general rule the large boulders are well rounded or subangular; but there are occasional streaks containing markedly angular fragments. Dr. Coleman found some boulders at Cobalt which show striae and concave surfaces.

The matrix of the conglomerate, which is often greywacke and less often shale, contains numerous angular particles of quartz, feldspar, chert, and felsites. Particles of such shape are very characteristic of. though they are by no means found only in, glacial debris.

Where the contact of the conglomerate with underlying rocks has been found there is a noteworthy lack of alteration in the older rocks. If they were deeply disintegrated by surface weathering the material must have been removed by a very efficient agent. This again suggests ice action. In a few of the contacts the line of demarcation is less distinct, as is ordinarily the case with unconformities in water lain sediments. Naturally the contacts of the latter type are not so likely to be found as those of the former.

There has not yet been found a smooth or striated floor. The basal conglomerate, in some cases at least, has been formed in situ and is made up of detritus from the immediately adjacent rocks.

Prof. Coleman does not consider that the lack of discovery of a characteristic glacial floor precludes the possibility of the material having been placed by ice, and refers to well known instances in which such a floor is lacking.

The localities specially mentioned by Dr. Coleman are Cobalt and Temagani. Cobalt Lake, on which the town is situated, lies almost entirely in Huronian conglomerate. The conglomerate in turn lies in a deeper valley formed by rocks of the Keewatin group. It might be expected therefore that the coarser material in the conglomerates would be largely detritus from those old greenstones and cherts; but such is by no means the case. The basal portion is made up very largely of material similar to that which enclosed the old valley; but the greater portion of both boulders and matrix is quite different. There are not now exposed any nearby hills from which these materials might have been brought down, nor is there good reason to believe that such hills existed in Huronian times. The nearest outcrops of Laurentian rocks from which many of the boulders may have been derived are some miles distant. Many of the large boulders are quite unlike any rocks which have been found in place in the district. Evidently ice was the most competent agent to bring such materials to their present position, and to deposit them in such a heterogeneous manner.

At Temagami the conglomerate lies on and at its base contains numerous fragments of Keewatin schists. The conglomerate also contains numerous rounded and subangular boulders of rocks not found close by. The underlying rock presents a fairly fresh but not a smooth surface. The matrix of the basal conglomerate contains numerous well formed rhombohedra of siderite and similar crystals are abundant in shale and quartzite beds in the conglomerate. They are evidently derived by weathering from the adjacent iron formation, and the crystals were growing freely contemporaneous with the mechanical deposition of clay, sand, and boulders. It is probable therefore that the conglomerate was formed under water and that there was carbonate in solution. If the larger erratics were brought by ice it was probably not land ice.

Summary—In appearance the conglomerate-quartzite-shale series of the Huronian represents nothing so closely as compacted, glacial and glacio-fluvial debris. The finding of striated and soled pebbles confirms the supposition of such an origin. The character of the contacts thus far found do not disprove that glaciers placed the basal conglomerate, though they suggest that such was not the case.

There are some sudden transitions from shale to coarse conglomerate which suggest that the earlier deposits may have been overriden by land ice. It seems probable however that part of the material was deposited under water and that floating ice contributed its load of glacier derived material.

There is no reason for supposing that the thick boulder free beds of shale and greywacke are not ordinary water lain sediments, though they may contain glacial flour.

Michigan College of Mines, Houghton, Mich., April, 1910.

[1]The Lower Huronian Ice Age, Jour. Geol.. Vol. XVI, 1908, pp. 149-158.

THE CONTOUR OF THE SYLVANIA SANDROCK AND RELATED STRATA IN THE DETROIT RIVER AREA.

REV. THOMAS NATTRESS.

The beds exposed within the new Livingstone Channel cofferdam at Stony Island, in Detroit River, do not at first sight offer any decisive clue to their horizon such as the Devonian at the mouth of the Salt Shaft at South Detroit affords; and have, perhaps as a consequence, been mistaken by high authority for Later Silurian deposits, whereas they are older than the Sylvania Sandrock.

Stony Island itself forms a part of the wall of the cofferdam, at the west side of the dam. If we take this island as a centre we shall find Sylvania sandrock S.W., in the extreme S.E. corner of Wayne County, in Michigan; S., on the foot of Bois Blanc island; S.E., off Bois Blanc, in the east channel of Detroit river and on Elliot's Point, in the Dr. Green Shaft; S.E. x E., in the Caldwell Grove well; E. x N.E., in the Sucker Creek test hole in Anderdon; N.E., approaching Lake St. Clair; N., in the Salt Shaft at South Detroit; and N.W., in rock wells in Wyandotte.

The area unwatered inside the cofferdam falls away toward the S.W., S.E.,, N. E.; W., S., E., and N. Within this area the rock cutting for the new channel that is being made to facilitate navigation, reveals an anticlinal formation of Silurian rock.

The cap of the anticline within the cut is abreast of Stony island, the island itself being the highest part of what has been an insular uplift since somewhere in Silurian time, a part of the great Cincinnati anticline.

South from the cap of the Stony island anticline the strata bank up against it at an angle to the south limit of a block that has faulted. Southward of this the dip of the newer strata is, much greater. In a distance of 300 paces from the point where the strata begin to bank up against the *highest* elevation of the weathered anticlinal surface within the cut an additional 30 feet of strata are picked up; and in a total of 3,330 feet in length of exposure there is a depth of 55 feet of rock of higher horizon than the cap stratum of the anticline.

At the south end of the area excavated within the dam a minimum of five feet of rock required to be removed to get contract grade; at the north end, 5,500 feet from south end, 6½ feet; and 21 feet at highest elevation, about midway between.

South of the cofferdam, (and within the lower reach of its distance, before the dam was built,) dredges worked to advantage. Still southward, and west of Bois Blanc island, dredges went to grade without assistance of the drill, working in a mud bottom.

The conclusion is: this rapid southward dip of strata, traced now to the close neighborhood of the Sylvania on the foot of Bois Blanc, and on the west side of that island, contradicts the supposition advanced, figured, and made the basis of conclusions in "New Upper Siluric Fauna from Southern Michigan," issued in 1907, by Professor W. H. Sherzer of Ypsilanti and Professor A. W. Grabau of New York; conjointly, and bearing the imprimatur of Dr. Alfred C. Lane, then State Geologist for Michigan.

The ascertained fact, revealed by the Dr. Green Shaft at Elliot's Point — that the Sylvania sandrock, which is a surface extension abreast of the south third of Bois Blanc island and across the river bottom of the east channel, has disappeared *southward* in a distance of a few hundred yards till it lies under about 23 feet of Silurian strata, shows where the sandrock belongs.

Sherzer and Grabau represent it as dipping under the Stony Island anticline.

The rock in the channel immediately west of Bois Blanc has all been scraped in dredging, where mud-covered. The drill has been used to a depth of 14 feet where the rock surface rises again, 6,500 feet south-south-west from the south third of the island. No sandrock has been touched, as it would have been had it extended across Detroit river. The reason is *IT DOES NOT BELONG THERE*.

When Schuchart of the U. S. National Museum at Washington prepared his paper "On the Faunal Provinces of the Middle Devonic of America, etc," and published in The American Geologist in September, 1903, he made use of two palaeographic maps, one of Onondaga time, the other of Hamilton time. It is evident to me from study of the Stony island cut and of the Sylvania sandrock exposures and elevations, that he does not figure either the Cincinnati Peninsula in the one case or the Cincinnati island in the other, as extending as far north as they did extend. There doubtless has always been more or less of a trough—perhaps a succession of troughs—across the peninsula or island between the head of it as figured by Schuchert and the actual head of it as constituted by the pre-Sylvania anticline known as Stony island and associated area in Detroit river.

The proximity of the west and east sides of Detroit river, and the close neighborhood of the corresponding exposures of Sylvania, have hitherto blinded everybody concerned to the fact that *these respective exposures are on opposite sides of the Cincinnati anticline.*

The contour of the Sylvania sandrock follows from the Ohio state line, about where it is joined by the county line between Monroe and Adrian counties, diagonally across Monroe and into the extreme southeast corner of Wayne county. And then, (as I am persuaded,) follows approximately the line of the west or Trenton channel of the river till it rounds the head of the northern projection of the Cincinnati anticline about or beyond the head of Gross Isle; thence circling into and through Sandwich and Anderdon townships in the county of Essex, Ontario, it has its first exposure as a surface extension in Canada—and probably the only one—in the bed of Detroit river and on Bois Blanc island, at the southern limit of Amherstburg. Thence it *strikes south-eastward* and is found under some 222 feet of "fossiliferous limestone" on Pelee Island; and might be expected to show in rock wells along a line from Sandusky Bay to Adams county, Ohio, and approaching—if not crossing—the Kentucky state line.

There is an associated problem presented in the Salt Shaft at South Detroit. Down under 189 feet of Silurian dolomite there is a deposit of limestone 38 feet in thickness, carrying what have hitherto been recognized as chiefly Devonian fossil forms and not belonging to the Silurian age. These have been identified by Grabau as very similar to those of the Anderdon beds of high-grade limestone (99% $Ca\ CO_3$) to which, as a faunal zone of distinctive character, he has given the name "zone of Idiostroma nattressi."

Sherzer and Grabau have therefore concluded that this 38 feet of limestone in the shaft is the Amherstburg beds intercalated.

It may therefore be of interest to locate the rocks above the Sylvania in relation to it as a permanent base, and in relation one to the other,—at various points around the shore of the Detroit river reach of the Cincinnati anticline. As we shall be able to follow this old shore-line from drill core to rock well, shaft and test hole, the area is approximately of horse-shoe outline. The left heel of the shoe will mark the Sylvania in the extreme south-east corner of Wayne county. If there be four nail-holes on each side of the shoe, the first one from the left heel will mark Horse Island and sandrock. The second one will mark the Sibley quarry at Trenton. The third marks the Wyandotte well, the log of which is given in Vol. V., Geological Survey of Michigan, Plate LXVI. The fourth hole locates the Salt Shaft at South Detroit. Let Windsor Salt Well No. 11, (See State Board of Geological Survey of Michigan report, 1901, p. 218,) be indicated by the toe-calk of the shoe; then the second nail-hole on the right will just about mark the Sucker Creek test hole. The third one marks the Amherstburg quarries in Anderdon. The fourth marks the Caldwell Grove well. And the right heel of the shoe will mark the Dr. Green Shaft to the Sylvania at Elliots Point.

Here is the comparative statement:

At Sibleys there is a Corniferous (Dundee) deposit over a heavy stratum of magnesian limestone, immediately under which (as. shown by drill cores) is a Stromatopora "reef" associated with what Grabau has described as "calcilutite," a compact brittle limestone, precisely as in the "Anderdon beds" in the Amherstburg quarries, in Essex county.

In the Wyandotte well there is 50 feet of "Dundee," (no subdivision reported in the well record) and 105 feet of dolomite, above 60 feet of Sylvania. Presumably the Anderdon beds—the coral stromatopora "reef" and the compact calcilutite (Grabau) are present; for the distance from Sibleys is very short, and the depth recorded as Dundee is sufficient, and was so named before the "Anderdon" beds were discovered,—by comparison with both the Amherstburg and Sibley quarries.

At the Salt Shaft is 63 feet of Dundee (again sufficient depth for the Anderdon beds to be present, other things being equal;) and 189 feet of "Lucas" dolomite next under this depth of Dundee. (Evidently we are getting *off shore further* from the Cincinnati uplift.) Next below is 38 feet of limestone which Sherzer and Grabau together claim is the "Anderdon" limestone, intercalated. That is the problem.

Under the problematical 38 feet is 47 feet of Flat Rock dolomite, resting upon 117 feet of Sylvania; the increased depth again suggesting greater distance off shore from the Cincinnati anticlinal than at Wyandotte, a heavier deposit in a deeper sea.

In the C. P. R. Salt Well; No. 11, at Windsor, are "dolomites" to a depth of 300 feet, reported upon by an authority to whom it had not then become necessary in the solving of Detroit river area problems, to distinguish with precision between dolomites and limestones, for the problems had not yet developed. Below this is 25 feet of "dark petroliferous limestone." (Compare the 38 feet of problematical deposit in the Bait Shaft with this.) Then follow 210 feet of dolomites, etc., above 55 feet of Sylvania.

The question is: Is the Anderdon included in the one case? and: Is this latter the problematical limestone?

At the Sucker Creek test hole, there is 90 feet of gray limestone at the top, which effervesces briskly. The location is about six miles from the Amherstburg quarries—where is the only recognized surface extension of, and the maximum depth of the Anderdon beds. Under the 90 feet is 260 feet of brown dolomites, resting upon 30 feet of Sylvania. In the proximity of 400 feet down from surface, or toward the bottom of the dolomites which rest upon the sandrock, considerable effervescence is observable. (With this compare the "petroliferous limestone" of the Windsor salt well, and the problematical 38 feet of the Salt Shaft).

The question again is: Is the Anderdon included in the one case? and: Is this latter the problematical limestone of the Salt Shaft?

The Amherstburg quarries have already been described in contrast with Sibleys, and have been stated to be practically identical—except for the later beds of thin-bedded Coniferous (Dundee) at Sibleys, and a maximum depth of Anderdon beds at the Amherstburg quarries.

The Caldwell Grove well recorded in Brummel's "Natural Gas and Petroleum in Ontario," 1892, has 252 feet of "limestone," (compare as regards lack of precision in the use of terms, "dolomite" in record of surface deposits at Windsor salt well;) resting upon 60 feet of sand-rock.

The Dr. Green Shaft at Elliots Point has 25 feet of dolomite above the Sylvania, with no Devonian overlying. This is at about the waistline, so to say,—the narrowest part—of the Cincinnati anticline, the distance across from Elliots Point to the Huron River.

I have attempted to suggest to you—without sufficient accurate knowledge as yet being available for proof—that the contour of the "Anderdon beds" is continuous throughout the area traversed between the extreme points, Elliots Point in Essex county, Ontario, and the southeast corner of Wayne county, Michigan, in the near neighborhood of which extreme points the Anderdon is acknowledged to be present.

I have also attempted to suggest to you with some show of reason—but again with only the same limited sources of inexact but suggestive knowledge—that the supposed intercalated beds have, through at least a great part of the same area and distance, *their own independent horizon*.

Amherstburg, Ontario, Canada, April, 1910.

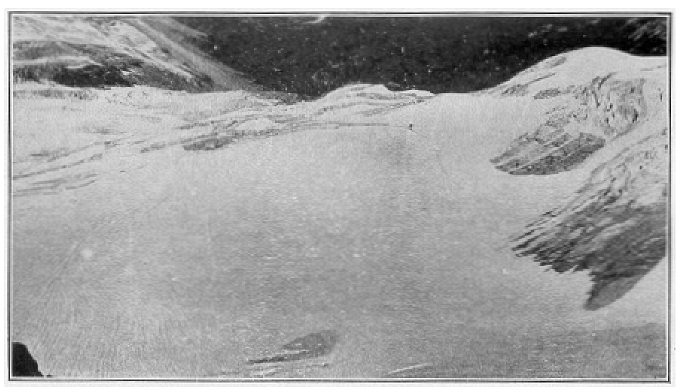
SOIL STRIPES IN COLD HUMID REGIONS, AND A KINDRED PHENOMENON.

WILLIAM H. HOBBS.

Attention was first strikingly directed to surface rock flowage as a characteristic degradational process in humid regions and high latitudes by Professor J. G. Andersson of the University of Upsala.[1] For this process, the importance of which had not before been adequately recognized, he proposed the name *solifluction* (*solum*, soil; *fleure*, to flow). Striking examples of the process he had himself studied in detail from Bear Island (74½° N. latitude), and from the Falklands (52° S. latitude), where are the famous "stone rivers." These streams of mixed rock debris and clay, while bearing considerable resemblance to the 4'mud rivers" early mentioned by Hayden from the North American Rockies and more recently described in detail by Howe,[2] are considerably longer and narrower and relatively thicker.

PLATE I.

A. Surface striping in rock debris on steep side of Asulkan Pass, Selkirk Mountains. The view looks down slope from a snowdrift.



B. Striping in the steep slope of the Asulkan névé, Selkirks. The effect is most marked in the left foreground and to the right of the center in the view.

Andersson's paper, which is a preliminary notice, discusses the larger characteristics only of these interesting streams of rock debris. In one place, however, he refers to a streakiness of the surface of the moving rock debris on Bear Island. Nordenskjöld,[3] on the other hand, has furnished us with much new and general information concerning solifluction, both as regards the localities described by Andersen and others which he has himself examined.

Speaking in general of the surface of these flows, Nordenskjöld says:

"Often there appears upon the slopes of hills a band-like arrangement of the debris. If one examines it more closely, he perceives that these bands consist of irregularly heaped up masses of angular stones, debris and clay slime, which extend almost from the summit of the hill down to the valley, where they stretch out after the manner of glaciers and push ahead of them a true terminal moraine of rock splinters which are cast aside" (page 61).

A fine example of surface striping by this process Nordenskjöld has figured from Graham Land (Pl. 2, B.), and he refers to a similar observation made long before in Greenland. Of this latter example he says:

"I found that the debris on steeply inclined slopes often had a peculiar arrangement. The slope appears as though striped, because-narrow generally parallel bands of finer or coarser debris or clay alternate in close sequence. The entire earth-mass is ordinarily well sorted, so that each band as a rule consists of equally large sand grains or stones" (pp. 62-63).

These bands continue down the slope in more or less serpentine courses becoming always fainter, however, as the gradient becomes flatter and passing finally into a peculiar net-like arrangement of the debris on the lower levels.

[1]J. G. Andersson, Solifluction, a component of subaerial denudation. Jour. Geol., Vol. 14, 1906, pp. 91-112.

[2]Ernest Howe, Landslides in the San Juan Mountains, Colorado, including a consideration of their causes and their classification. Professional paper No. 67 U. S. Geol. Surv., 1909, pp. 1-58.

[3]Otto Nordenskjöld, Die Polarwelt und ihre Nachbarlander. Leipzig, 1909, pp. 60-65.

Andersson's observation that solifluction is a phenomenon particularly characteristic of inhospitable regions, seems to be confirmed by the observation of Howe in the Rocky Mountains. The rock streams which he has described from that region are always found originating beneath the steep walls of abandoned glacial cirques in high altitudes.

Nordenskjöld has brought out the interesting fact that the debris stripes are always developed below the rim of a great snow drift, which in melting has so saturated the debris as to transform it into a thick paste, and thus allow it to slide slowly down the slope.

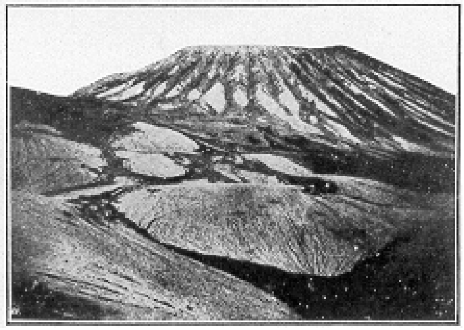
In the month of August, 1909, the writer discovered identical striped debris zones on the steeply inclined side slopes of the Asulkan Pass above the névé of the Asulkan glacier (see plate 1, A). Here, also, the stripes ran in gently curving courses in the direction of the steepest slopes, making their start at the lower edge of a drift of snow. Thus the observation is in every way confirmatory of those made by Nordenskjöld. The dark lines in the illustration are slight trenches within which no larger rock fragments are found, and they appear to correspond to lines of maximum near-surface flow of the rock paste, here largely of mud. The flat rock fragments lying between the trenches, form an imperfect plating of the intervening ridge so that it sheds the water as does a pent-house.

Upon the Asulkan névé below the pass the surface layer of the snow has been grooved by a process which perhaps has something in common with that which arranged the debris in parallel bands. The effect of this surface striping, or venation, is brought out in Plate 1, B. Starting from near the upper margin of the névé, nearly parallel ridges and grooves descend so as always to conform to the lines of steepest gradient upon the surface, eventually coalescing to form a somewhat larger trunk groove which follows the lowest line of the névé surface. Unlike a drainage system the tributaries travel beside the trunk for a considerable distance before making junction with it. This surface grooving or venation upon the névé is best shown upon the plate near the left, and also near the right-hand margin of the newer snow. That it is due to water drainage is evident from the fact that the lines do not continue beyond crevasses which intersect their course. It is suggested that the melting of the outer zone of the névé granules by filling up the spaces between them with water, affords temporary conditions similar to those of a thin layer of sand partially saturated with water and lying upon a slope. There is thus considerable resemblance between the surface venation of the névé and the striping in the rock debris on steep slopes below summer snow drifts.

This phenomenon of soil striping in debris which has been saturated with water, can hardly be considered apart from the well-known "barrancas" which develop on volcanic tuff cones after each new eruption, so soon as the first rains have saturated the material with water (See plate 2 A). Here also the stripes follow the steepest slope. A comparison of the Asulkan and Greenland soil stripes with the great barrancas, suggests that the width of the ridges which develop is in some way a function of the viscosity of the rock paste, which in turn is doubtless dependent upon the nature, form, and size of the materials, the degree of saturation, the thickness of the saturated layer, the steepness of the slope, etc. The problem here involved would appear to be one that would repay an attempt at mathematical solution based on the known laws of flow of viscous bodies. That a differentiation of the mass into alternate bands of relatively more and less fluid materials, and that the width of these bands determines the width of the visible stripes seems almost certain.

University of Michigan, March 10, 1910.

PLATE II.



A. Barrancas formed on the tuff cone of Mount Vesuvias after the rains subsequent to the eruption of 1906, (after Lacroix).

B. Stripes on the surface of rock debris in Graham Land, West Antarctica, (after Otto Nordenskjöld).

A type of waste filled valley. The fresh cliff is not found in many.

A WASTE FILLED VALLEY.

A. E. PARKINS.

(Abstract.)

From an examination of ten or twelve valleys of intermittent streams along the Huron River between Ypsilanti and Dexter, the writer found that invariably where these valleys headed in cultivated fields, the valleys are waste filled and have flat floors. This would lead one to suspect that such filling was produced by an increase in supply of material from the head waters, due to the cutting away of the forests.

The accompanying picture is an example of one of the best of such valleys. That filling has taken place is evident from the following lines of evidence:

(1) The flatness of the floor, which in a valley of such great slope should be V-shaped;

(2) The sharp angle that the sides make with the valley bottom;

(3) The partial burying of the trees;

(4) The interesting features shown by the stump and the 5 ft. cliff to the right. Just above the upper parts of the root of the stump is a line of muck, and marks the position of the valley bottom before filling. The deposits above this layer of muck are 2½ ft. thick. By a count of the rings on the stump, the tree when cut was 75 years old. Filling has taken place some time since the tree was a sapling growing in the valley bottom.

Another characteristic of all such valleys is the great number of steps, caused by stones and twigs damming the channel at various points, and, also, perhaps by the recession of the steps.

In such streams the post-glacial cycle of erosion has been interrupted by an increase in supply of waste from the headwaters. These valleys may serve then as local examples of what took place during the close of the Glacial Period in all valleys of south flowing rivers.

M. S. N. C., April, 1910.