The Glacial Lakes around Michigan

By William R. Farrand, University of Michigan

Bulletin 4, revised 1988

Geological Survey Division
Michigan Department of Environmental Quality

Bulletin 4 - **Glacial Lakes Around Michigan**

By William R. Farrand, University of Michigan, 1967 revised 1998

Illustrated by Kathline Clahassey, University of Michigan

Published by Michigan Department of Environmental Quality. Geological Survey Division

Contents

Preface

The Great Lakes are incomparable. They could have been named “The Greatest Lakes?? because no other body of fresh water in the world rivals them in size. Great size, however, is but one of many attributes. Consider also their strategic continental interior location, temperate climate, unique shoreline configuration, great depth, and perhaps above all, their lucid beauty. Furthermore, have you ever noticed how readily they can be spotted on a globe?

Many of us are prone to underestimate the importance of these vast inland seas. As intensive exploitation of land and water resources becomes increasingly necessary, respect for this magnificent natural resource will increase. Today many persons are earnestly wondering how these lakes were formed.

The purpose of this pamphlet is to show general readers, whoever they may be, how the lakes were formed. Although technical literature on geologic history of the Great Lakes is familiar to geologists, the scientific terminology often poses problems for the non-specialist.

This report covers only the highlights of a fascinating geologic story. For many years, students of glacial geology have been puzzling the evolution of these lakes. Leverett and Taylor compiled the original comprehensive work in 1915. In 1958*,* Hough completed a revision of the geology of the lakes. Contributions of several other investigators are also listed in the selected references at the rear.

For the most part, students of Great Lakes geology agree on the fundamental pattern of events. Interpretation of details, however, is quite another matter: Complete agreement on all phases can hardly be expected. A lot of the record is lost or unknown. It is surprising so much of the history has already been worked out with reasonable certainty.

The present edition is a completely revised version of *A Glacier Passed This Way* and *The Glacial Lakes Surrounding Michigan* issued by the Michigan Department of Conservation in 1960 and 1967.

Lansing and Ann Arbor, October, 1966,
Robert W. Kelley, Geologist MI Geological Survey Division
William R. Farrand, Geologist University of Michigan

Revised, 1987 William R. Farrand, Geologist University of Michigan

Abstract

Michigan is situated in the midst of one of the world’s unique natural resources -- the Great Lakes. Geological information reveals they evolved as the most complex succession of freshwater lakes known to geologists. This information, however, is not widely available and the technical terminology sometimes poses problems for non-specialists.

This is a summary of the fascinating geologic history of the Great Lakes for the general reader. Basic concepts of glacial geology are discussed briefly. Several prominent lake stages associated with major glacier re-advances during Wisconsinan time are described and illustrated. Also, the names, levels, outlets, and geologic dating of the entire sequence of glacial and post-glacial stages are listed in a handy reference table.

Introduction

Just a few years ago, geologically speaking, a glacier passed this way, and that's why North America has a unique 1,200 mile wide lake chain, containing about a third of the world's freshwater area (figure 1). The sequence of geologic events resulting in the formation of these Great Lakes is an interesting though very complex story. Probably we'll never know the complete history. Only the highlights are included in this booklet. The interpretation of the landscape of the northern United States has been evolving for more than a century. Once it was thought that a great flood from the north washed debris of clay, sand, and gravel southward, and that the large erratic boulders were rafted in by drifting icebergs. Hence, the origin of the term ***drift***--which now denotes all materials deposited by a glacier. Today available geologic information allows a fairly comprehensive understanding of glacial geology, but many questions remain unanswered. As in any scientific endeavor, each new discovery prompts new questions hitherto unsuspected. Doubtless, present ideas will be improved upon. One of the foremost riddles of the Great Lakes today concerns their basic geologic structures. Until the bottoms are thoroughly explored, we can only speculate as to the nature of the underlying bedrock foundation. Information on the shape of the lake bottoms and the nature of the sediments and glacial materials deposited in them is also quite limited. Specific knowledge of the deeper parts is indeed meager, but advances are being made, especially in the upper Great Lakes where oceanographic techniques, formerly restricted to the deep sea, are now being employed.

Was There A Glacier?

Can we be sure a glacier passed this way? Today's glaciers are hundreds of miles away from the Great Lakes. The ice fields of North America are mostly in the mountain ranges in the Northwest. Let's examine the evidence. Studies of existing glaciers reveal the nature of glacial deposits. A thorough investigation of Michigan soils has proved their glacial origin.

For example, one of the most distinctive deposits left by a glacier is an ice-deposited material called ***till**.* Till is a mixture of rock materials of all sizes from boulders to clay with few characteristics of sediments deposited in water, such as stratification or size-sorting of particles. Till is a dominant surface deposit in the Great Lakes region. Another characteristic of glacial drift is that it is comprised of a great variety of rock materials obtained from widely scattered geographic areas. If these materials are boulder-size, they are called ***erratics*** and become excellent markers for re-tracing the glacier's path. A good example is jasper conglomerate, a distinctive pudding-stone rock formation exposed at the surface only in Ontario north of Lake Huron. Yet fragments are scattered in the drift throughout eastern and central Michigan, and elsewhere. On the other hand, in southwestern Michigan we find erratics that originated in the copper and iron formations of the western Upper Peninsula.

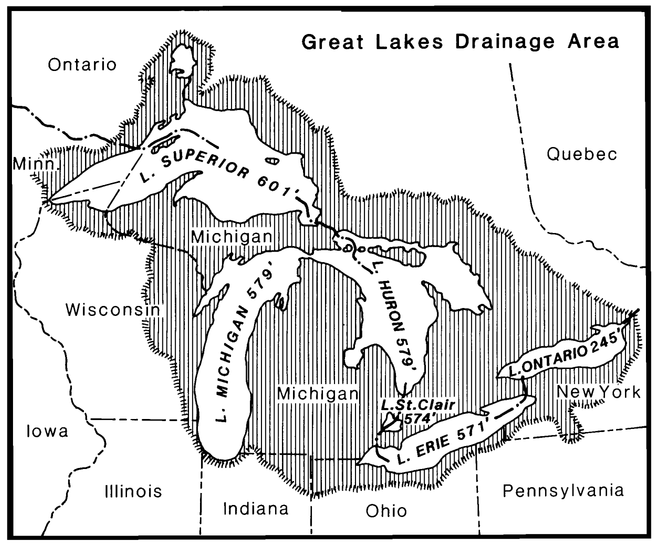

Figure 1: The modem Great Lakes have a water surface area greater than 95,000 square miles, a total drainage area of about 295,000 square miles, and a shore line 8,300 miles long.

In non-glaciated regions, weathering and decomposition of local bedrock formed soils in place*.* Thus, the bedrock is covered by its own soil, and this combination is so marked that the soil is the key for mapping the underlying bedrock. This relationship, however, does not prevail in Michigan, or in any other glaciated region where soil materials are carried in from 100's of miles away. The ancient bedrock formations in Michigan are generally covered with an average of 200 to 300 feet of drift--in places, more than 1,200 feet. Michigan soils are relatively young and their occurrence so scrambled, only a gross pattern is apparent on a soils map. The drainage pattern is also very haphazard and immature, another characteristic of glaciated regions.

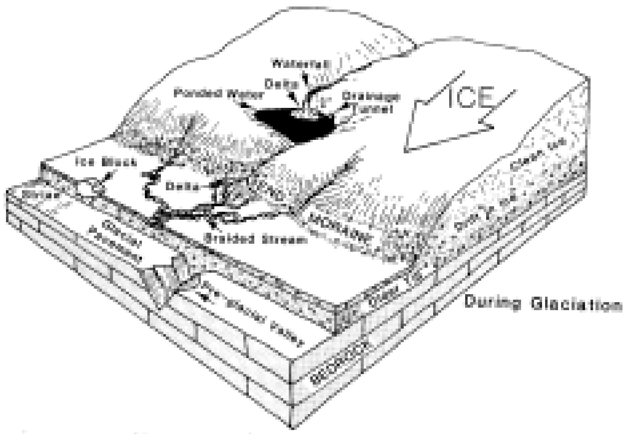

Figure 2: Features originating at a glacier front occur in a definite order.

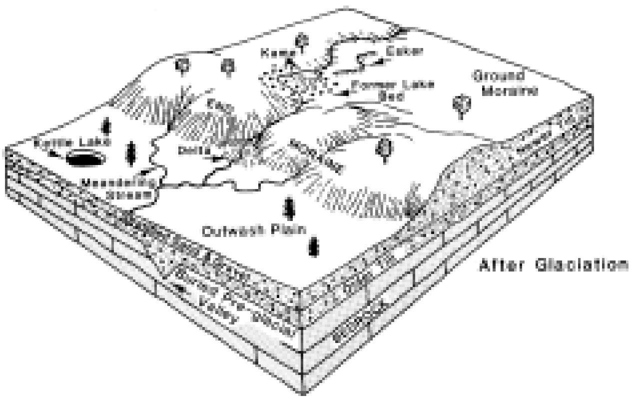

Figure 3: Landforms of continental glaciation are unmistakable. Compare with figure 2

Continental glaciers leave behind a unique hilly terrain (figures 2 and 3). The most prominent features of a glaciated landscape are ***end moraines**,* or, simply ***moraines**.* Moraines are systems of hills traceable for many miles across the countryside. Frequently the land surface is characterized as ‘knob and kettle." Most moraines originate at a stabilized front of an active glacier, when forward movement of the ice equals melting, or when drift is deposited in ridges along the ice margin. Morainic relief varies because the drift materials were unequally distributed in the ice and the glacier front shifts irregularly from place to place and from year to year. Boulders are numerous.

Closely associated with the end moraines are other deposits and features of lesser import in the actual development of the Great Lakes. Usually behind the moraine (in the direction of ice retreat) is ***ground moraine**,* a gently undulating, hummocky deposit of till. This topography is characterized as ***sag and swell**.* In front of the moraine is a flat expanse of stratified sands and gravels called an ***outwash plain**.* It is formed by sheet runoff of meltwaters flowing out and away from the ice front at the moraine. Outwash commonly extends out to and overlaps the older ground moraine associated with the preceding ice halt. On the ideal outwash plain, very coarse sediments near the moraine grade perceptibly to finer sands and silts farther out. The finest sediments are carried farthest away because they are held in suspension longest. Clays settle out only upon reaching relatively quiet ponded water, such as a lake. Perhaps the most obvious evidence of glaciation is the abraded bedrock surface scratched and scoured by the advancing drift-laden glacier. One need not be a glacial geologist to appreciate the significance of these markings. They are most prominent on freshly exposed surfaces as in stone quarries. Frequently this ***glacial pavement*** is polished to a luster. Directional scratches, called ***striae**,* and gouges, called ***chattermarks**,* are most always present. Flutings and groves are common, some attaining depths of several feet. In places in the Upper Peninsula, small protruding irregularities in the ancient igneous rock formations were sculptured and streamlined into what appear to be elephant backs" partially buried in drift.

The Ice Advances

About 2 million years ago, at the beginning of the Pleistocene Epoch, the climate in the northern part of the continent changed. Snowfall increased and did not entirely melt in the cool summers. Many theories have been advanced to account for this change, but none are entirely adequate. At any rate, great masses of ice accumulated in the Hudson Bay region forming a continental glacier similar to the two-mile thick ice caps on Greenland and Antarctica. Altogether during the Great Ice Age, glaciers came and went perhaps twenty times. Between ice invasions, moderate climates like the present prevailed and soils developed. In Michigan, more recent glaciation has obliterated or buried records of earlier stages. The evidence we see relates mostly to the last major advance and retreat of the glaciers, called the Wisconsinan Glaciation (figure 4).

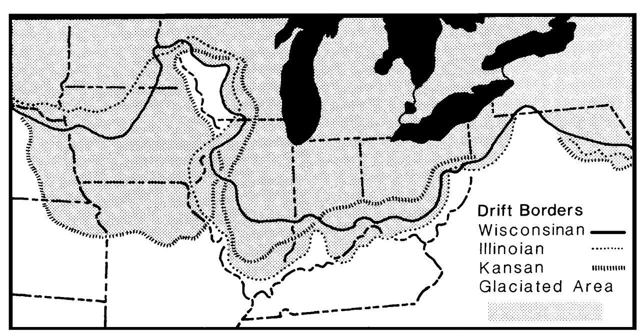

Figure 4: Glaciers of the Wisconsinan Stage did not advance as far south as earlier glaciers.

During this episode, ice fanned out from the Laurentian Highlands, east of Hudson Bay, and pushed southward to central Illinois, Indiana, and Ohio. Earlier stages reached as far south as the Ohio River. As the Wisconsinan glacier pressed forward, it either picked up or overran loose surface materials developed previously. It also worked around exposed ledges and into breaches in the bedrock, and plucked off chunks. By the time the Wisconsinan glacier reached Michigan, the lower zone of the ice was heavily loaded with a variety of rock debris largely derived from Canada.

The geologic history of Michigan immediately prior to the Pleistocene Epoch remains almost a total mystery. There is practically no record at all for the entire 200 million years comprising the Mesozoic and Cenozoic eras. The situation is somewhat like a book in which some of the chapters have been removed. About the only thing that can be said now is that the area may have been above sea level much of the time, allowing rivers to erode great valleys that have been widened and deepened by glaciers to form our present lake basins.

Our knowledge of the Great Lakes basins indicates much of their deep areas bottomed in comparatively soft Paleozoic shales, salt beds and sandstones. When the glacier reached this region, it took the course of least resistance, moved into the old river valleys, and divided into lobes or ice tongues as it continued to advance. The ice was thickest and moved fastest along the axes of the main valley depressions, broadening and deepening the valleys. On the other hand, many of the tributary valleys were obliterated.

The ice pushed over and deeply buried Michigan. Continuing southward and overriding the preglacial drainage divide, it moved into the ancient Mississippi watershed. Changes in climate, however, brought up its maximum advance just short of the Ohio River.

The Ice Front Retreats

Then started a grand retreat giving rise to the most complex succession of freshwater lakes known to geologists. The retreat was not continuous, but was marked with many halts and occasional re-advances. Drift was released from the glacier in a rather orderly disorder. This is the record from which geologists have worked out their interpretations of continental glaciation in North America.

When the glacier front was still within the old Mississippi drainage system (figure 5), meltwaters were free to escape southward away from the ice front. They transported considerable volumes of fine silt and clay to the Gulf of Mexico. The position of the ice margin just before the origin of the first lakes is illustrated in figure. 6. When the ice front moved back into the preglacial Hudson Bay watershed, however, meltwaters no longer had an unrestrained flow southward. The next morainic systems to be deposited also became effective natural dams and their lobe-shaped patterns (centerfold) are clear evidence of the former glacier tongues.

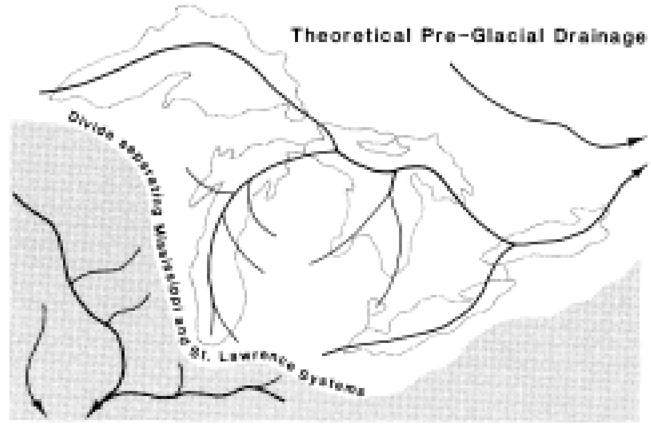

Figure 5: The drain age divide separating the old Mississippi and the preglacial St. Lawrence watersheds was probably situated near its modern counterpart'.

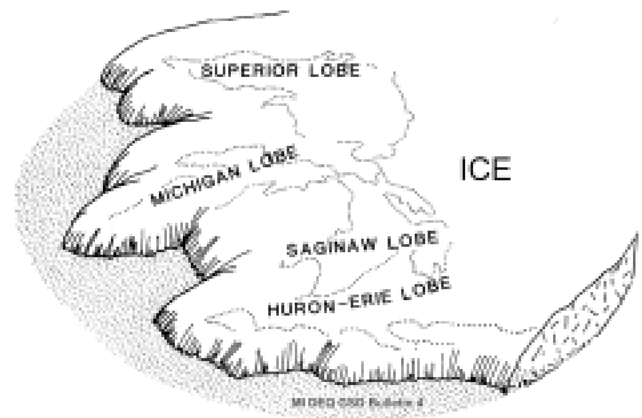

Figure 6: The retreating ice front halted and built the Valparaiso-Charlotte-Ft. Wayne Moraine. As the ice left this position the first known lakes began to form. (about 14,500 years ago)

The Lakes are Born

As the ice lobes melted back into the great basins that had channeled their earlier advance, tremendous volumes of meltwater were ponded between the glacier and the inner, or northerly, sides of the Valparaiso and Fort Wayne moraines.

Thus were born Early Lake Chicago and Early Lake Maumee, the first known stages of the modern Great Lakes. More than twenty other distinct stages followed during glacial and postglacial time. Most of them are listed in the table inside front and back covers. For the purpose at hand, only the major lake stages will be discussed.

The next major halt of the ice front was at the position of the morainic system called the Lake Border (figure 7). The glacier had retreated farther north only to readvance to the position illustrated. Lake Chicago in the Michigan basin and Lake Maumee in the Erie basin, therefore, had several different stages. Drainage was to the Mississippi through gaps in the Valparaiso and Fort Wayne moraines. Lake Maumee discharged through an outlet at Fort Wayne to the Wabash River most of the time. But for a while it also drained north through the Imlay outlet and west across the "Thumb" of Michigan to the old Glacial Grand River that flowed west to Lake Chicago. During Lake Border time, Lake Chicago was practically forced out of its basin by the temporary re-advance of the glacier.

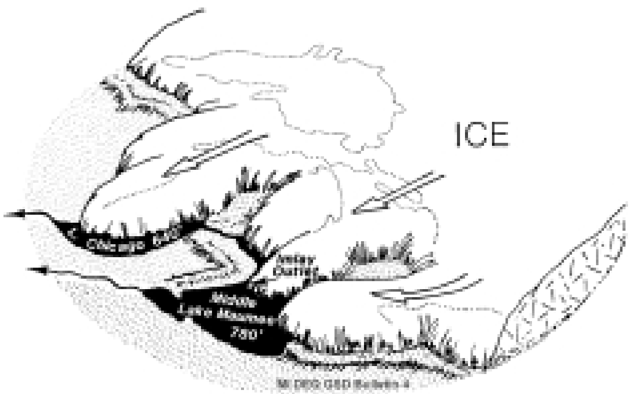

Figure 7: Advancing temporarily, the glacier almost forced Early Lake Chicago out of its basin. The Lake Border Moraine was built at this time. (about 14,000 years ago)

Another retreat (not illustrated) temporarily freed parts of the lake basins of glacier ice, and Lake Arkona developed throughout the connected lowlands of the Erie, Huron, and Saginaw basins. It continued to discharge through the Glacial Grand River to Lake Chicago, which was still draining through the Chicago outlet to the Mississippi via the Illinois River. During this retreat the glacier retreated at least to the Straits of Mackinac, ultimately allowing lake levels to fall even lower than Lake Arkona before they rose again to subsequent high levels.

*Note on Radiocarbon Dating — *Dates are taken from radiocarbon investigations. Living organisms accumulate a fixed proportion of a special unstable isotope of carbon, called C-14, which is constantly being created in the atmosphere by cosmic radiation. Upon death, C-14 intake ceases but disintegration of the accumulated C-14 continues at the rate of half the remaining amount every 5,600 years. Comparing the change in ratio at a later date, therefore, one obtains an approximate date of death of the organism.*

Port Huron Time

The Port Huron, the last major re-advance and long halt of the ice front, built the most prominent morainic system of all. The system may be traced, with few breaks, from Minnesota to New York (figure 8). The Huron lobe advanced across Lake Arkona separating it into two lakes, Lake Whittlesey and Lake Saginaw. Lake Whittlesey was the largest and most prominent of the glacial lakes in southern Michigan. Lake Saginaw was a shallow, but extensive lake in the Saginaw lowlands with shore lines about *50* miles inland and about 115 feet above present Lake Huron. Lake Whittlesey discharged through the Ubly outlet across the Thumb into Lake Saginaw which, in turn, discharged westward through the Glacial Grand River to Lake Chicago.

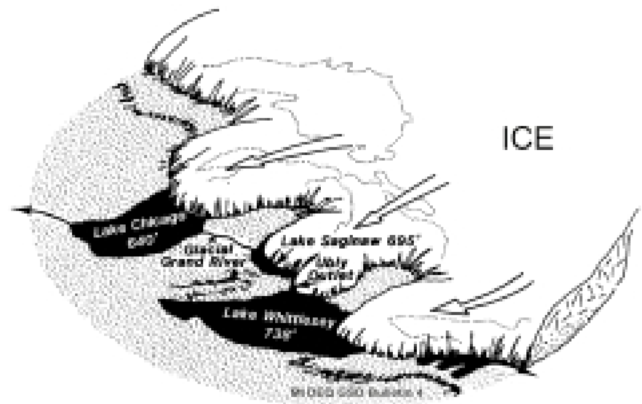

Figure 8: After making one last strong re-advance, the ice front halted and built the most prominent topographic feature in the region, the Port Huron Moraine. (about 13,000 years ago)

As the ice front retreated from the Port Huron Moraine the waters of Lake Whittlesey and Lake Saginaw merged to form a single water body named Lake Warren. Continued oscillations of the ice front, especially in the western New York sector, opened and closed new and lower outlets. This produced in succession three Lake Warren levels, Lake Wayne, Lake Grassmere and Lake Lundy. Lake Warren drained through the Glacial Grand River,

but the other, lower lakes found an outlet through the area of Rome, New York, into the Mohawk and Hudson rivers. Lake Chicago, then at 620 feet, continued to drain southward at Chicago. In the Lake Huron basin the water level dropped also to *605* feet (early Lake Algonquin) toward the end of this period.

Two Creeks Interval

The ice front continued its retreat in the Upper Great Lakes area ultimately moving north of and freeing the Straits of Mackinac and also uncovering a lower outlet at Kirkfield, Ontario, leading into the Trent Valley, across southwestern Ontario from Georgian Bay to Lake Ontario. The water bodies in the Lake Michigan and Lake Huron basins were, therefore, drained to a low level, somewhat below the present 579 foot level of Lakes Michigan and Huron. The Two Creeks Interval is named after a rather unusual fossil forest deposit at Two Creeks, Wisconsin. Field evidence at this site indicates that the trees were overrun and sheared off by the subsequent ice advance. Lake Keweenaw formed during this interval when at least two-thirds of the Lake Superior basin was free of ice.

Last Re-Advance

One last re-advance (not illustrated) built the Two Rivers-Manistee Morainic System that extends across the northern part of the Southern Peninsula, the middle of Lake Michigan and just south of Green Bay in Wisconsin. As the Two Rivers ice sheet advanced southward across the Straits of Mackinac, the water bodies in Lakes Michigan and Huron were separated once again and rose again to the levels of the abandoned outlets at Port Huron and Chicago. The Port Huron outlet was at *605* feet, the Lake Algonquin level, but the Chicago outlet was initially still at the 620-foot

Calumet level but quickly eroded down to 605 feet. The ice then retreated northward, uncovering once again the Straits of Mackinac, allowing the waters of the Michigan and Huron basins to merge and form the main stage of Lake Algonquin (figure 9) discharging at Chicago and at Port Huron both at 605 feet. Lake Algonquin may have flooded most of the Lake Superior basin, although its traces were obliterated by the subsequent Marquette ice advance, except in the southeast corner of the Superior basin (Whitefish Bay).

Niagara Falls

Lake Erie was the first modern Great Lake to form. As the ice sheet was retreating during the Two Creeks Interval, it withdrew from northern New York State and freed the Niagara Falls escarpment from its icy grasp. Glacial Lake Iroquois then formed in the Ontario basin, discharging at Rome, New York, into the Mohawk and Hudson valleys. Since the Rome outlet and Lake Iroquois were well below the level of the Niagara escarpment, the modern Niagara Falls and Lake Erie were born.

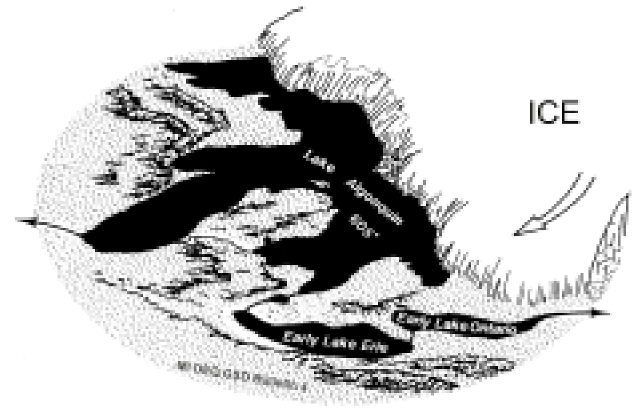

Figure 9: Lake Algonquin stage was initiated when the Trent valley outlet was dammed by a local readvance. (about 11,000 years ago)

Last Stand of Ice

As the ice front retreated northeastward across Ontario, the Port Huron outlet was abandoned and lower eastern outlets were progressively uncovered, resulting in a series of low-water stages (figure 10). The culmination was the extreme low-water interval dating about 10,000 years ago when Lakes Chippewa and Stanley discharged via the North Bay outlet and the Ottawa River into the salty St. Lawrence Sea--an Atlantic embayment that encroached into the St. Lawrence lowlands and into the Ottawa River valley. Discharge from Lake Chippewa into Lake Stanley cut a gorge now deeply submerged below the Straits of Mackinac. This gorge is in the lake floor between the towers of the “Big Mac” bridge.

Figure 10: The lakes were drained down to extreme low levels when the retreating ice front uncovered a sea level outlet at North Bay. (about 9,500 years ago)

In contrast to the events to the east just described, other portions of the ice front behaved differently. The glacier lobe that had freed much of the Lake Superior basin in Lake Algonquin time now rushed back south just far enough to reach the Michigan shore near Grand Marais. It nearly filled the basin, except for the extreme southeastern and southwestern corners. This ice melted away almost as fast as it had advanced, leaving in its place Lake Houghton, the lowest level lake of the Superior basin. Lake Houghton drained through the Sault area into Lake Stanley, but the St. Marys River of that time was considerably longer and steeper than the present Saint Marys Falls.

Postglacial Lakes

The Wisconsinan glacier then permanently retired from the Great Lakes region, returning to the area where it originated about 70,000 years ago. As the ice mass dissipated, the earth's crust began to rise slowly, a process called crustal rebound. The tremendous force exerted by the weight of the glacier ice had depressed the crust. For example, the North Bay outlet was once near sea level, whereas today it is about 700 feet above sea level. This phenomenon was not operative along the southern area of the glaciated region. Though much diminished in rate, rebound is still proceeding in the northern Lake Superior region at about foot per century and may not cease until the surface has returned to its altitude prior to glaciation.

All during the initial period of crustal rebound, the North Bay outlet rose gradually but continued to handle the discharge during the transition to the last main postglacial lake, the Nipissing Great Lakes, the largest of all the Great Lakes stages. Rebound also forced the St. Lawrence Sea to recede to the Atlantic thus creating the modern St. Lawrence River. The main Nipissing stage (figure 11) was attained when uplift raised the North Bay outlet to 605 feet, the level of the outlets at Port Huron and Chicago, neither of which had been functioning since Algonquin time. These three simultaneous outlets provided stability that allowed the Nipissing Great Lakes to endure for perhaps 1,000 years--enough time to form the strongest and most spectacular shore features in the entire region. In the northeastern Lake Superior area, Nipissing shore features are found up to 700 feet above sea level whereas in the southwest, they occur at 605 feet.

About 4000 years ago, the Nipissing Great Lakes began to wane. The North Bay outlet had been abandoned because of continued rebound, thus forcing the full discharge through the Port Huron and Chicago outlets. The Chicago outlet, having a limestone sill, resisted down cutting. The Port Huron outlet, channeled in unconsolidated glacial drift, yielded to steady erosion. When the lake surface dropped below the Chicago outlet, Lakes Michigan and Huron were born, and the St. Clair River at Port Huron began to handle the entire discharge of the upper lakes--as it does today. About 2000 years ago Lake Superior was separated from Lake Huron by a combination of factors. The sandstone sill in the St. Marys River was rising due to rebound, and the water level of Lake Huron was falling due to erosion at Port Huron.

Figure 11: With the ice burden gone, the earth's crust in the northern part of the region began to rise. When the North Bay outlet rose to the same level as the Port Huron and Chicago outlets, the Nipissing Great Lakes were born. (about 6,000 to 4,000 years ago)

The Lakes Today

The extensive belt of sand dunes along the east shore of Lake Michigan was formed mostly during the interval of lowering levels following the Nipissing stage, although some of these dunes certainly originated during the Chippewa low stage. Sands that had accumulated along the shores were exposed on now dry beaches. The prevailing westerly winds, fetching across Lake Michigan, then winnowed, lifted, bounced, and heaped the quartz grains onto the adjacent upland.

Will discharge be restored naturally at Chicago? Perhaps in a few thousand years -- if crustal rebound continues. However, both the Port Huron and the Chicago outlets are south of the region of crustal rebound. Thus, the St. Clair River seems destined to remain unrivaled as the outlet for the upper Great Lakes.

And Tomorrow...

Will another glacier pass our way? It is very likely, but we cannot be sure. Most geologists believe the ice ages are not finished, but we will have to wait at least a few thousand years to see the next ice sheet in Michigan.

Further Reading

Bretz, J H., *1955,* Geology of the Chicago Region, Part II - The Pleistocene, Illinois Geological Survey, Bulletin No. *65.* (Great Lakes regional history covered in pages 99-132 in Chapter 4.)

Farrand, W. R., 1982, Quaternary Geology of Southern (& Northern) Michigan, Michigan Department of Natural Resources, Geological Survey Division, 1:500,000, 2 sheets.

Farrand, W. R. and Drexler, C. W., *1985,* Late Wisconsinan and Holocene history of the Lake Superior basin, p. 17-32 in Geological Association of Canada, Special Paper 30. (A major revision of the history of the Superior basin.)

Flint, R. F., 1971, Glacial and Quaternary geology, 892 pages, Wiley and Sons (standard text).

Geological Association of Canada, Special Paper 30, “Quaternary Evolution of the Great Lakes,” P.F. Karrow and P.E. Calkin, Eds., 1985. (The most recent papers summarizing the glacial history of each of the Great Lakes.)

Geological Society of America, 1959, Glacial Map of the United States East of the Rocky Mountains, scale 1:1,750,000, 2 sheets.

Hough, J. L., 1958, Geology of the Great Lakes, 313 pages, University of Illinois Press. (A comprehensive volume on the bedrock and the glacial history of the Great Lakes, but somewhat out-of-date.)

Leverett, F. B. and Taylor, F., 1915, The Pleistocene of Indiana and Michigan and the history of the Great Lakes, United States Geological Survey, Monograph 53, 529 pages. (First comprehensive geological study of the Great Lakes.)

Mason, R. J., 1981, Great Lakes Archaeology. New York, Academic Press, 426 pages. (A good summary of the migration and development of prehistoric peoples in the Great Lakes area.)