Research overview: Holocene development of Lake Erie

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ABSTRACT. This paper reviews and summarizes research on the Holocene evolutionary history of Lake Erie. New bathymetric data published in 1998 and more recently by the National Geophysical Data Center reveal lake-floor features indicative of former, now inundated, shorelines. These data combined with other recent research, permit a detailed reconstruction of Lake Erie's complex history since the Wisconsinan ice sheet retreated some 12,000 years ago, ending a series of glacial lakes and initiating a series of post-glacial lake stages. The lakes that have occupied the Lake Erie Basin are grouped into three phases. The oldest phase, 14,400 to 12,000 years ago, had lake stages associated with glaciers in the basin and were higher than present Lake Erie. The middle phase, 12,000 to 4,700 years ago, had lake stages isolated from Upper Lakes drainage during a dryer climatic period and were below the present level of Lake Erie. In the last phase, from 4,700 to present, the Lake Erie Basin received Upper Lakes drainage and the water level rose to a slightly higher stage before establishing the present elevation through outlet erosion.

DATE OF PUBLICATION: 23 May 2013 **OHIO J SCI 112 (2): 24-36**

INTRODUCTION

The geological sequence known as the Holocene Epoch (formerly called "Recent") spans about 12,000 years ago to the present. In the Great Lakes region this sequence is generally thought of as that period immediately following Pleistocene glaciation (Neuendorf and others 2005). This paper reviews the evolutionary history of the water bodies that have occupied the Lake Erie Basin during the Holocene Epoch. Dates are in approximate radiocarbon years.

In a relatively short span of geologic time, Lake Erie and the other Great Lakes have undergone dramatic changes in water levels with attendant shifts in shoreline configuration. These changes are related to fluxes in global and regional climatic conditions. Currently the Great Lakes are experiencing fluctuations in water levels, which are having serious consequences for commercial navigation, recreation, and consumptive uses of lake water. Understanding the complex lake-level dynamics that have taken place in the past can help predict the fate of Lake Erie in this current period of change.

Lake Erie, the shallowest and southernmost of the Great Lakes, has had the longest and perhaps most complex glacial and postglacial history of any of the Great Lakes. Recent detailed bathymetric data (National Geophysical Data Center 1998; Holcombe and others 1997, 2003, 2005) and seismic/sedimentologic data (Pengelly and others 1997; Lewis and others 2012) reveal lake-floor and shoreline features indicative of former, but now, in most cases, inundated shorelines, demonstrating that relatively modest rises and falls in lake level caused significant changes in the paleogeographic outline of the water bodies within the basin.

LAKE ERIE GEOMORPHOLOGY

Lake Erie is narrow and relatively shallow for its size. With a surface area of 25,657 km^2 (9,906 mi^2) and a volume of 484 km^3 (116 mi^3), it ranks 11th in area and 17th in volume of the large lakes in the world (Herdendorf 1990a). Lake Erie is 388 km (241 mi) long, but at its widest point only 92 km (57 mi) separate the Canadian and American shores. This narrowness, together with the fact that the lake's long axis parallels the prevailing southwesterly winds, causes Lake Erie to function as an enormous wind tunnel. Violent storms, some powerful enough to sink a large freighter, sweep the lake each year. At a maximum depth of only 64 m (210 ft), Lake Erie is by far the shallowest of all the Great Lakes and the only one whose bottom does not extend below sea level (Bolsenga and Herdendorf 1993). The mean water level of Lake Erie is 174 m (571 ft) above sea level.

Based on bottom topography, Lake Erie is divided into three distinct basins: western, central, and eastern (Figs. 1 and 2). The western basin, lying west of a line from the tip of Point Pelee, Ontario, to Cedar Point, Ohio, is the smallest (13 percent by area) and shallowest (five percent by volume), with most of the bottom at depths between 7 and 10 m (23 and 33 ft). In contrast with the other basins, a number of bedrock islands and shoals are situated in the western basin and form a partial divide between it and the central basin. The bottom of the western basin is flat except for several steep-sided islands

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and shoals in its eastern part. The deepest sounding is 18.9 m (62 ft) in a small depression north of Starve Island Reef, off the south shore of South Bass Island (Herdendorf and Braidech 1972). Several passages in the chain of islands provide water circulation channels.

The central basin is the largest of the three basins, containing 63 percent of the lake's area and volume. This basin is separated from the eastern basin by a relatively shallow sand and gravel bar between Erie, PA and the base of Long Point, Ontario. This basin has a mean depth of 18.5 m (60 ft) and a maximum depth of 25.6 m (84 ft). Except for the rising slopes of a sand and gravel bar extending south-southeast from Point Pelee, Ontario, the bottom of the central basin is extremely flat. This bar isolates a depression in the bottom between it and the islands to the west that is known as the Sandusky Sub-basin.

The eastern basin is relatively deep and bowl-shaped, with a considerable portion of the bottom below 30 m (100 ft). The deepest sounding, 64 m (210 ft) is located 13 km (8 mi) east-southeast off the tip of Long Point. This basin comprises 24 percent of Lake Erie's area and

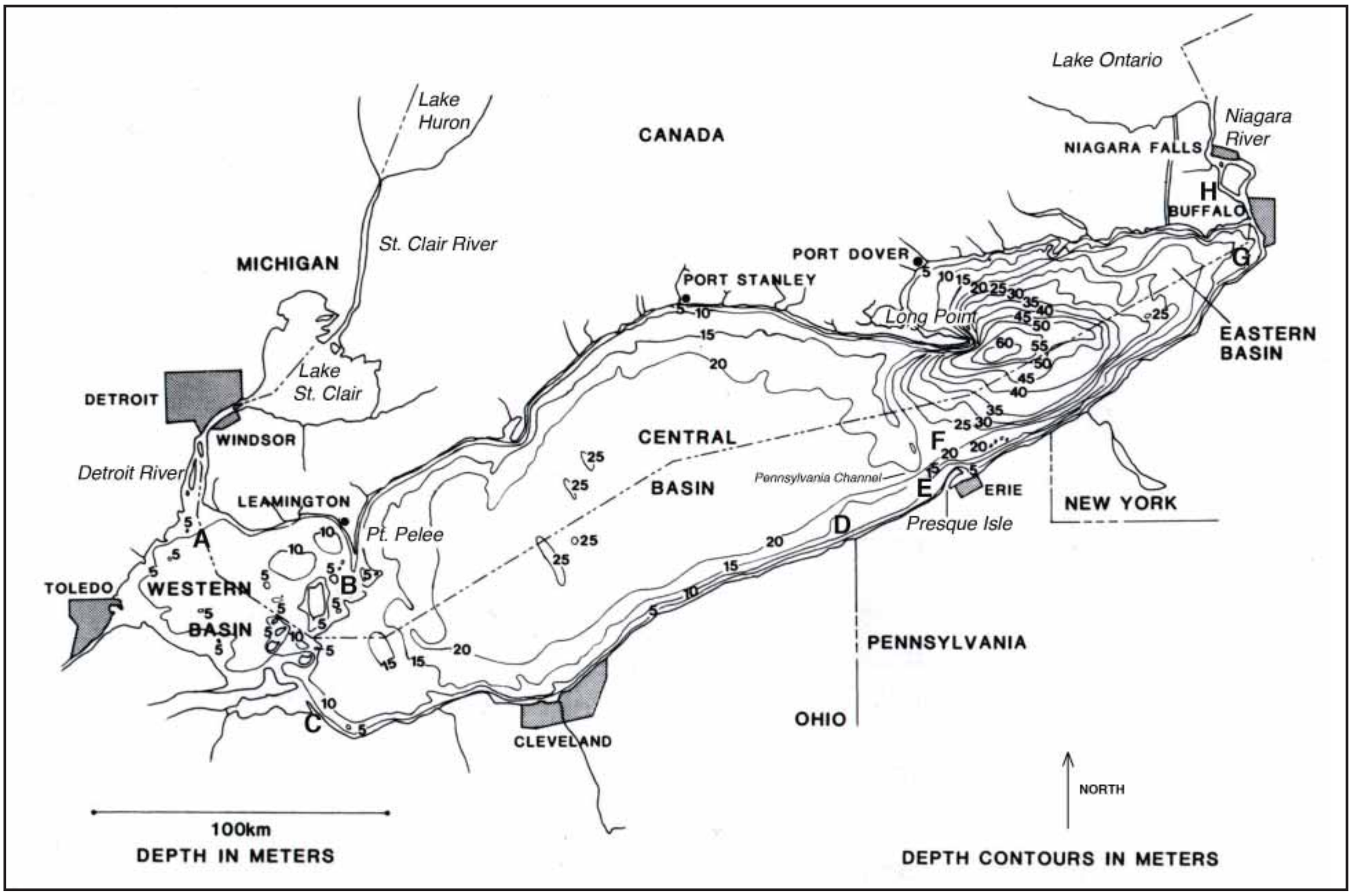

FIGURE 1. Bathymetry of Modern Lake Erie showing some of the place names referenced in this paper: A–Detroit River Delta, B–Pelee Passage, C–Cedar Point and Sandusky Bay, D–Conneaut Bank, E–Presque Isle Bank, F–Norfolk Moraine, G–Buffalo Ridge, and H–Niagara River Outlet.

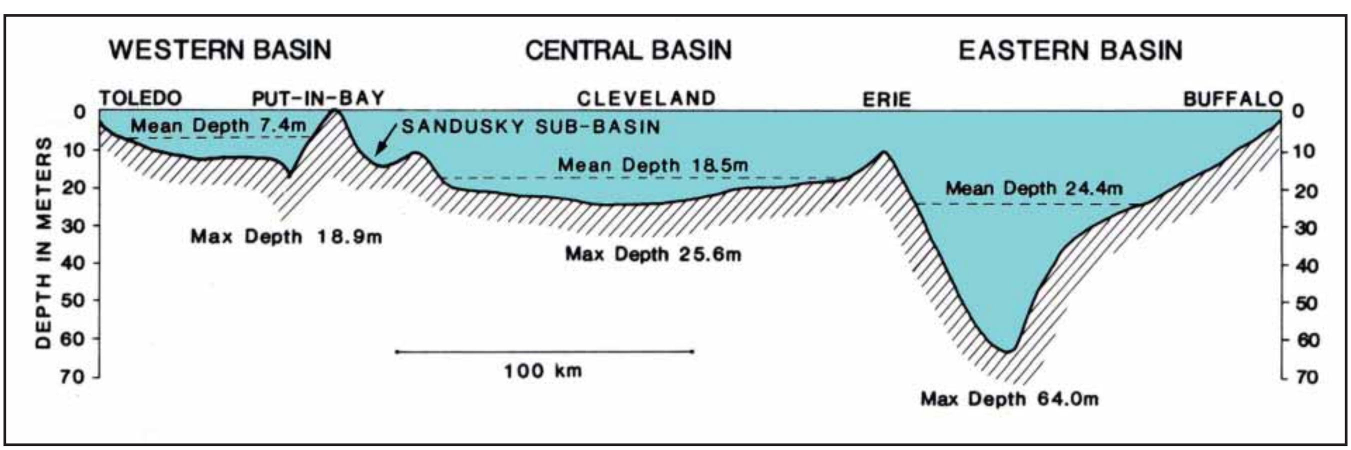

FIGURE 2. Cross-section of Modern Lake Erie.

32 percent of its volume. The glacially deposited ridge north of Erie, PA (Norfolk Moraine) contains a notch, known as the Pennsylvania Channel, which provides a subsurface connection for water circulation between the central and eastern basins.

PRE-GLACIAL AND GLACIAL HISTORY OF THE LAKE ERIE BASIN

Lake Erie is underlain by middle Paleozoic sedimentary rock, composed of limestones, dolomites, shales, and sandstones (Bolsenga and Herdendorf 1993). These rocks were deposited some 430 to 300 million years ago under conditions ranging from tropical barrier reef habitats to deltaic and deepwater clastic environments associated with mountain building episodes and tectonic plate collisions taking place to the east. Uplift following these episodes initiated a long period of erosion that resulted in excavation of deep stream valleys and a mature drainage system along the longitudinal axis of the present lake. Continental glaciers during late Cenozoic Era (Pleistocene Epoch beginning about 2.5 million years ago) further sculptured this valley system by overriding the Niagara Escarpment and excavating most deeply in the shale at the eastern end of the lake, moderately deeply in the shales of the central portion, and least deeply in the limestone/dolomite bedrock at the western end of the lake. This process formed the distinctive three basins that characterize Lake Erie (Fig. 2). During the most recent glacial advance (Wisconsinan Stage), ice extended nearly as far south as the Ohio River ~21,000 years ago. Thereafter, the ice margin receded in pulses with several ridges of glacial debris (moraines) being deposited under what is now the bed of Lake Erie (Lewis and others 2012). Prominent end moraines occur at the junctions of Lake Erie's basins, further separating them from one another.

Thus, Lake Erie owes much of its geomorphic character to changes induced by the Pleistocene glaciers. As advancing or retreating ice sheets paused, moraines composed of glacial till clay and gravel were built up at the ice margins, which at places dammed earlier drainage systems. Large glacial lakes formed between the earlier moraines and the ice front for 2,000 years beginning about 14,400 years ago. Lake Erie and its estuarine embayments, such as Sandusky Bay, are remnants of a series of these lakes that, at its earliest and highest stage, extended as far southwest as present day Fort Wayne, Indiana and drained in that direction via the Mississippi River system (Herdendorf and Krieger 1989).

POST GLACIAL HISTORY OF THE LAKE ERIE BASIN

For about 2,000 years (~14,400 to ~12,400 years ago) several high-water glacial lake stages and a low-water stage existed in the Lake Erie Basin (Herdendorf and Krieger 1989). The high-water stages (known in sequence as Lakes Maumee, Arkona, Whittlesey, Warren, Wayne, Grassmere, and Lundy) ranged in elevation from about 70 m (229 ft) to 15 m (49 ft) above modern Lake Erie, while a low-water stage (Lake Ypsilanti) fell to ~89 m (292 ft) below current lake level during a short-lived ice retreat following Lake Arkona (Table 1). Once the last glacier retreated from the Niagara Escarpment the Niagara River Outlet was opened for drainage, but was greatly depressed from the weight of the ice. Most of the lake drained and a much smaller, lower lake formed. The evolution of Lake Erie over the next nine millennia, from this Holocene low stage to its present level, involved glacio-isostatic rebound, changes in discharge water to and from the lake, and climatic fluctuations (Table 1). These processes eventually brought Lake Erie to its present level about 3,500 years ago (Holcombe and others 2003; Lewis and others 2012) and the present landforms, including islands, embayments, beaches, and spits began to form. Lake processes and erosion continue to modify these landforms, often resulting in dramatic changes during violent storms.

Early Lake Erie (glacial retreat)

The glacial lake stages in the Lake Erie Basin ended ~12,000 years ago when the Wisconsinan ice margin retreated sufficiently to the east to allow lake level to be controlled by the sill at the Niagara Escarpment. At about the same time, ice had also retreated between the Lake Huron and Lake Ontario Basins opening a northern drainage (Kirkfield Outlet) so that the Upper Lakes (Lake Algonquin) no longer drained into the Lake Erie Basin as they had done during the latter glacial lake stages (Fig. 3). This removed direct glacial influence in the Lake Erie Basin and initiated the Holocene history of Lake Erie. Forsyth (1973) described a catastrophic flood of water over the escarpment that incised a channel in the moraines and bedrock, resulting in a low water stage (Fig. 4). The Niagara River Outlet, still depressed by glacial loading was over 50 m (164 ft) below the present level of Lake Erie (Holcomb and others 2003; Lewis and others 2012). Known as Early Lake Erie, this low stage had an elevation of ~120 m (~394 ft) above sea level and consisted of a small lake in the eastern basin

TABLE 1
Timeline of lake stages in the Lake Erie Basin[1]

Lake Stage	Radiocarbon Years (bp)	Elevation (asl) m (ft)	Elevation (lel) m (ft)	Outlet
GLACIAL LAKE STAGES				
Lake Maumee I	~14,400	244 (800)	+70 (+229)	Wabash River, IN
Lake Maumee II	~14,200	232 (760)	+58 (+189)	Grand River, MI
Lake Maumee III	~14,000	238 (780)	+64 (+209)	Grand River, MI
Lake Arkona I	~13,800	216 (710)	+42 (+139)	Grand River, MI
Lake Arkona II	~13,700	213 (700)	+39 (+129)	Grand River, MI
Lake Arkona III	~13,600	212 (696)	+38 (+125)	Grand River, MI
Lake Ypsilanti (low stage)	~13,400	~85 (279) ?	-89 (-292) ?	closed basin ?
Lake Whittlesey	~13,200	226 (740)	+52 (+169)	Grand River, MI
Lake Warren I	~13,000	210 (690)	+36 (+119)	Grand River, MI
Lake Warren II	~12,900	208 (682)	+34 (+111)	Grand River, MI
Lake Wayne	~12,800	200 (655)	+26 (+84)	Mohawk River, NY
Lake Warren III	~12,700	207 (680)	+33 (+109)	Grand River, MI
Lake Grassmere	~12,600	195 (640)	+21 (+69)	Mohawk River, NY
Lake Lundy	~12,400	189 (620)	+15 (+49)	Mohawk River, NY
POST GLACIAL LAKE STAGES				
Early Lake Erie (Figs. 3 & 4)	~12,000	~120 (394)	-54 (-177)	closed basin
Lake Algonquin discharge (Figs. 5 & 6)	~10,400	~140 (459) ?	-34 (-122) ?	Niagara River ?
Early Lake Erie (Figs. 7 & 8)	~10,300	~130 (426)	-44 (-145)	closed basin
Middle Lake Erie (Figs. 9 & 10)	~7,500	~145 (476)	-29 (-95)	closed basin

TABLE 1 (cont.).
Timeline of lake stages in the Lake Erie Basin[1]

Lake Stage	Radiocarbon Years (bp)	Elevation (asl) m (ft)	Elevation (lel) m (ft)	Outlet
Middle Lake Erie (Fig. 11)	~5,400	~160 (525)	-14 (-46)	closed basin
Lake Nipissing Discharge (Fig. 12)	~5,300	~165 (541)	-9 (-30)	Niagara River
Lake Erie (high stage, Figs. 13 & 14)	~4,700	177 (581)	+3 (+10)	Niagara River
Modern Lake Erie (Fig. 1)	~3,500	174 (571)	—	Niagara River

bp—before present asl—above modern sea level lel—relation to modern Lake Erie level

[1]Modified from Bolsenga and Herdendorf 1993; Holcombe and others 2003; Lewis and others 2012.

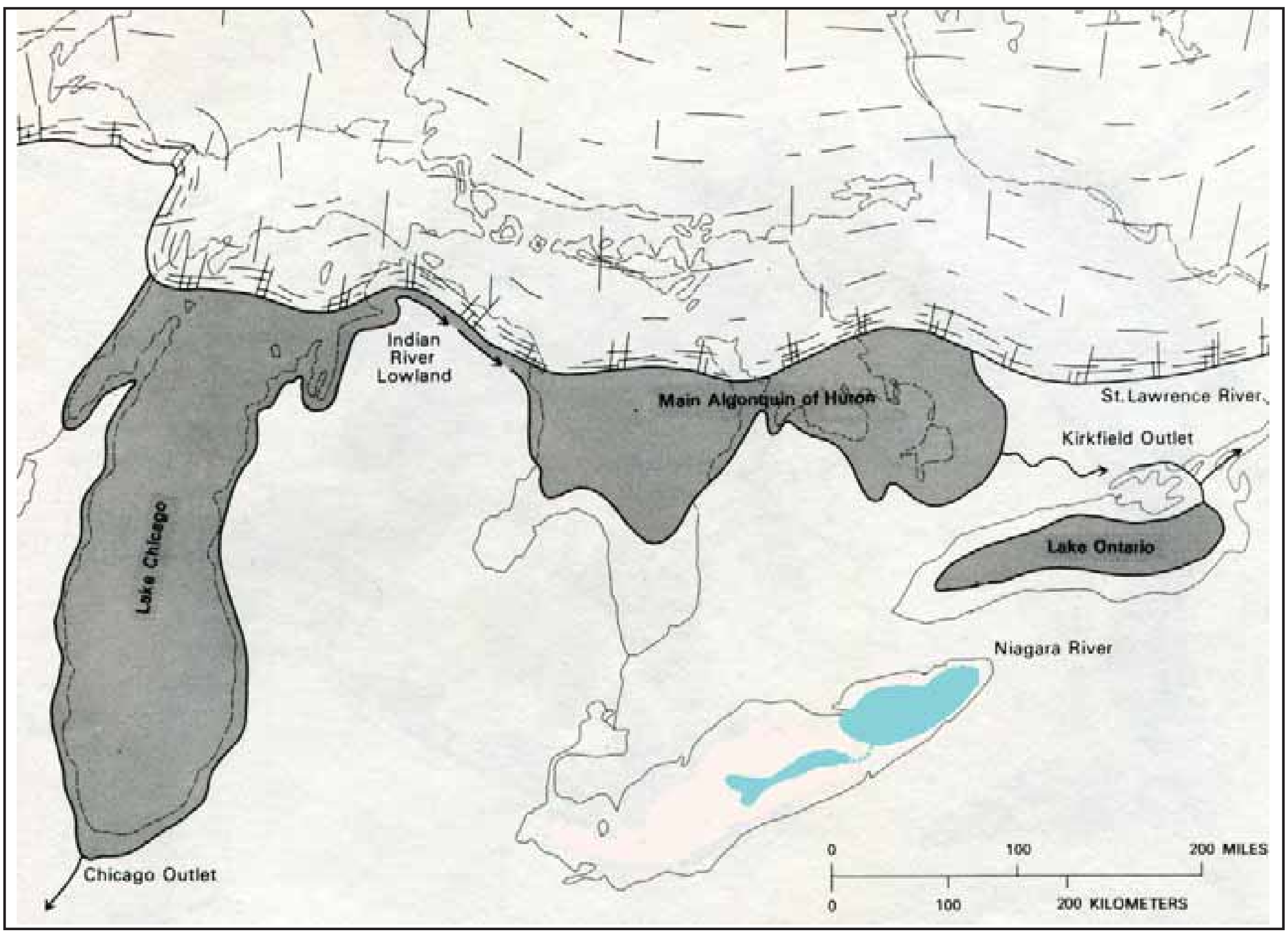

FIGURE 3. Southern portion of the Great Lakes Region, showing the water bodies in the Lake Erie Basin at the outset of the Holocene Epoch, ~12,000 years ago, following the opening of the Niagara River Outlet once the Wisconsinan ice sheet had retreated from the Lake Erie Basin. As the ice retreated from the land north of Lake Ontario, as shown above, Lake Algonquin in the Lake Huron Basin drained eastward via the Kirkfield Outlet, bypassing Lake Erie. Shortly thereafter the water level in Lake Erie dropped below the Niagara River Outlet.

and a much smaller, and perhaps unconnected, lake in the central basin (Fig 4).

Early Lake Erie (discharge from Lake Algonquin)

A re-advancement of the glacial margin north of Lake Erie blocked the Kirkfield Outlet ~10,400 years ago (Fig. 5). With this outlet blocked, Early Lake Erie began to receive discharge from Lake Algonquin (Lake Huron and Lake Michigan Basins) via the Port Huron Outlet through the newly formed St. Clair River-Lake

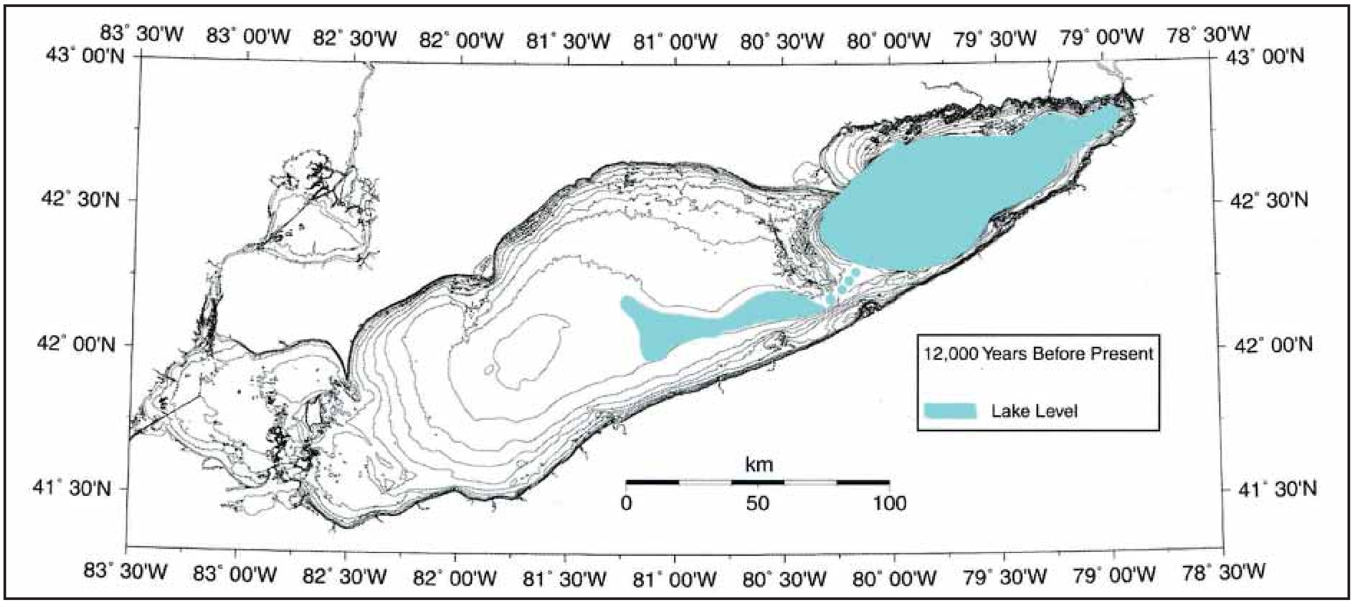

FIGURE 4. Early Lake Erie was bypassed by Upper Lakes drainage ~12,000 years ago, establishing isolated (endorheic) lakes in the eastern and central basins. A connection of these lakes via the Pennsylvania Channel is uncertain.

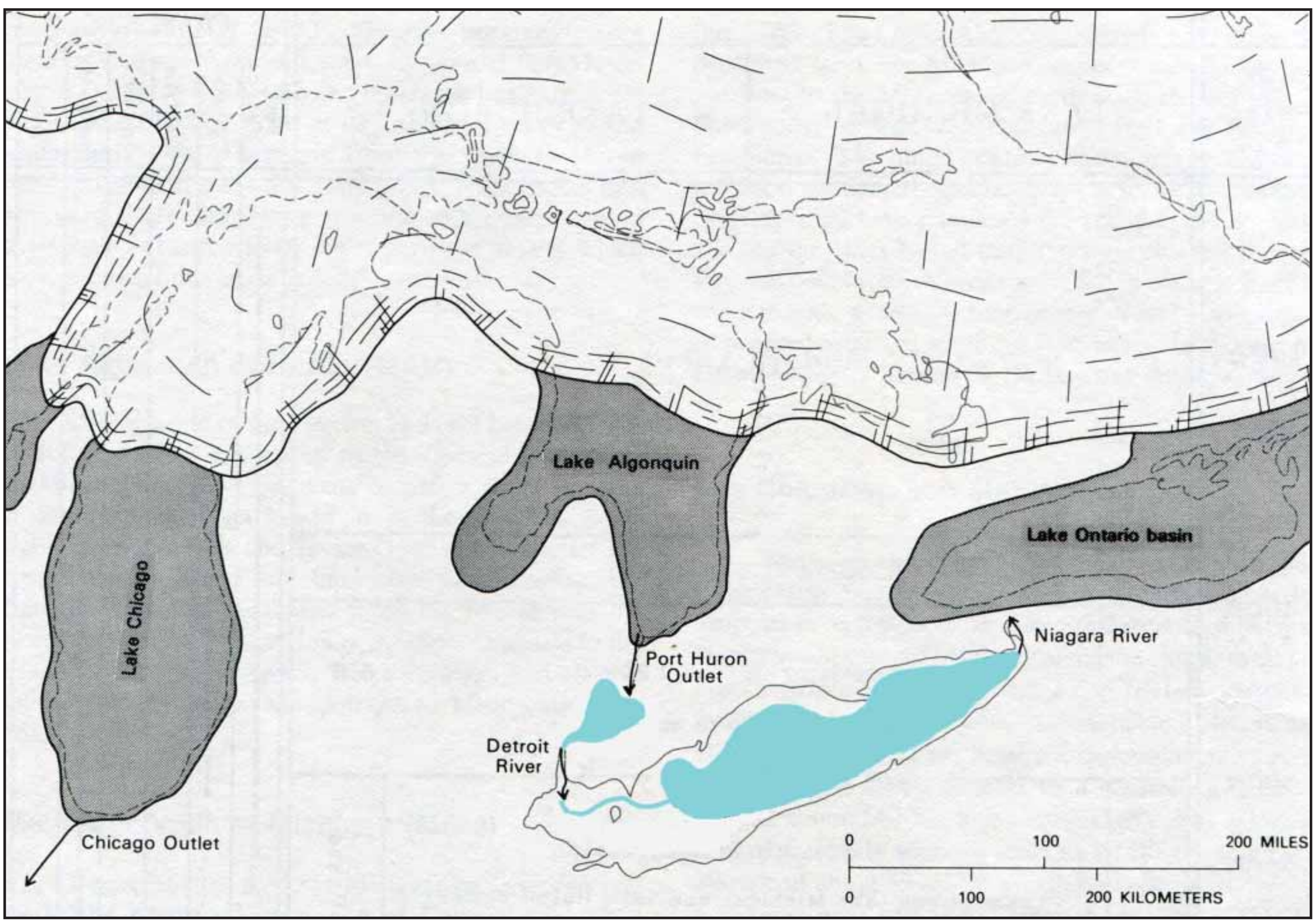

FIGURE 5. Glacial re-advance ~10,400 years ago closed the Kirkfield Outlet, redirecting Upper Lakes discharge to the Lake Erie Basin.

St. Clair-Detroit River system (Calkin and Feenstra 1985; Larsen 1987). By ~10,400 years ago this additional inflow formed a lake that consisted of (1) a marshy western basin through which an extension of the river system flowed via Pelee Passage, (Hobson and others 1969; Herdendorf and Braidech 1972), (2) a shallow central basin lake that flowed to the east via a channel (Pennsylvania Channel) cut through the Norfolk Moraine, and (3) a deeper eastern basin, which may have drained to the east over the Niagara Escarpment via the Niagara River (Fig. 6). Holcomb and others (2003) determined that for a brief period of time, ~10,400 years ago, Early Lake Erie rose above the Niagara River sill by virtue of Upper Lakes drainage (Fig. 6), while Lewis and others (2012) contend that Early Lake Erie remained an isolated lake at this time.

Early Lake Erie (second low stage)

Flow into western Lake Erie was interrupted ~10,300 years ago when the North Bay Outlet was opened from Lake Algonquin to the St. Lawrence River by deglaciation (Fig. 7). This lowered the level in the Lake Huron Basin for several thousand years and halted drainage to Early Lake Erie (Kaszycki 1985; Larsen 1987). For the next ~5,000 years drainage from the Upper Lakes bypassed Lake Erie. The cessation of over 90 percent of Lake Erie's former inflow created stagnant and perhaps eutrophic conditions (Fig. 8). Climatic changes, particularly lower precipitation rates and increased evaporation, likely exacerbated these conditions. The likelihood that Early Lake Erie resided within a closed (endorheic) lake basin was proposed by Lewis and others (1999, 2012) and was shown by new bathymetric data compiled by National Geographic Data Center (1998) that reveal former shoreline features now submerged below Lake Erie (Holcombe and others 2003). Shoreline features, such as the Buffalo Ridge at the eastern end of the lake, are 10 to 12 m (33 to 39 ft) below the current Niagara River Outlet.

At first, the central basin may have been the site of an isolated lake separated from the eastern basin by the Norfolk Moraine. Later as isostatic rebound at the eastern end of the lake progressed, rising water flooded the moraine at a low spot known as the Pennsylvania Channel (Fig. 8), forming a single lake in the two basins. An alternative mechanism for forming a single lake involves filling the central basin lake by major south shore tributaries to the point that it flooded and deepened the Pennsylvania Channel connecting the basins. This influx of tributary water to the central basin, coupled with isostatic rebound, permitted Early Lake Erie to expand (Fig. 9).

Middle Lake Erie

About 10,000 years ago the rising water in the Lake Erie Basin slowed, leveled off ~7,500 years ago at an elevation of ~145 m (476 ft), and was followed by a very slow rise for the next 2,000 years. Hartley (1958) called this intermediate stage "Middle Lake Erie" (Figs. 9 and 10) and presented a compelling argument for a low stage at 25 m (82 ft) below present Lake Erie based on field evidence from test borings; whereas

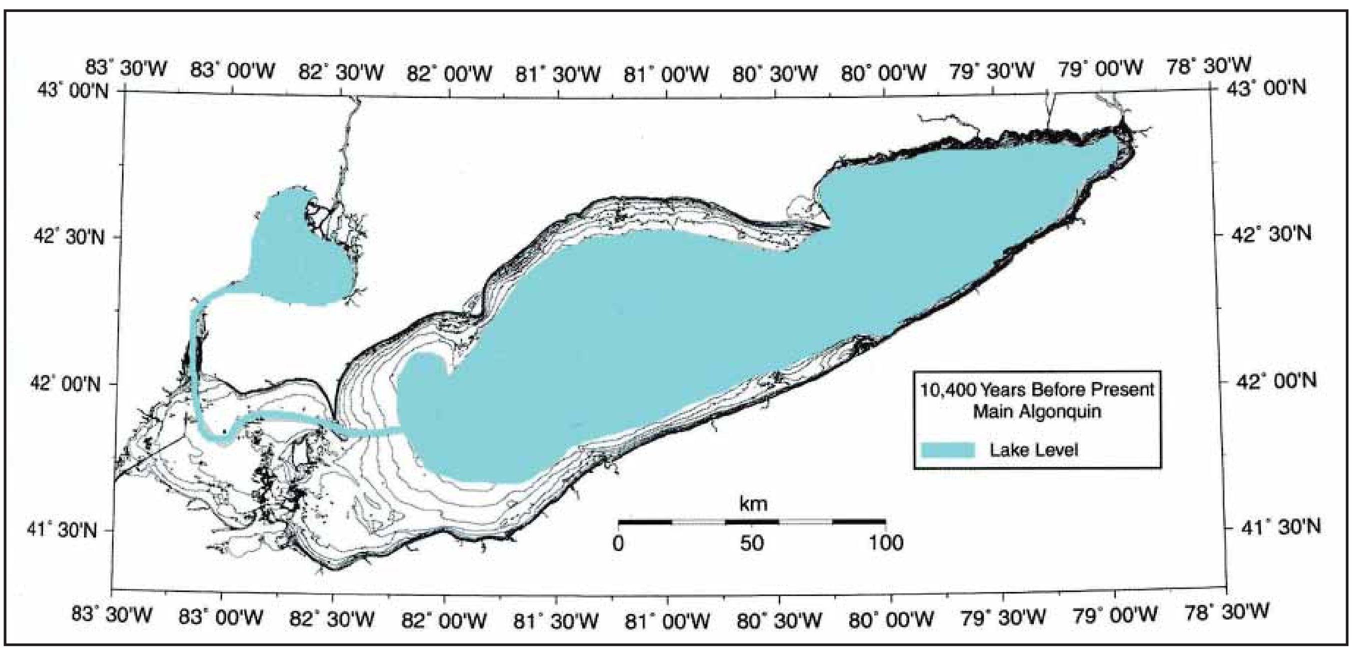

FIGURE 6. Early Lake Erie expanded with discharge from Lake Algonquin. Note that Lake St. Clair-Detroit River flow is directed through Pelee Passage. For a brief period Lake Erie may have drained eastward via a Niagara River Outlet.

Coakley and Lewis (1985) used radiocarbon dates and contours on the glacial till to arrive at a level at least 30 m (100 ft) below the present level of the lake. Forsyth (1973) explained this stable-level period as a response to decreased precipitation and increased evaporation during the Xerothermic or Hypsithermal Interval (Sears

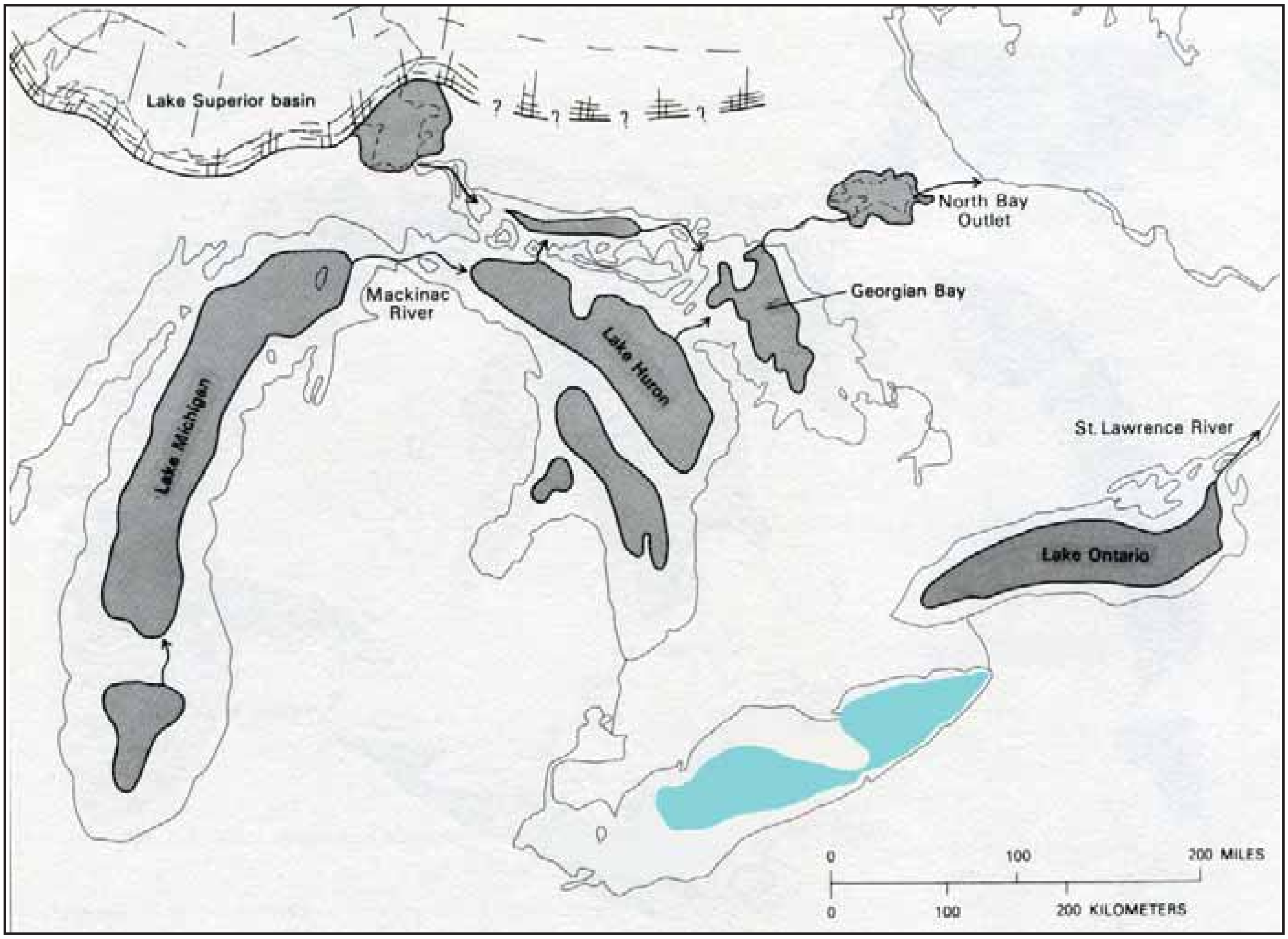

FIGURE 7. Glacial retreat opened the North Bay Outlet, lowering the Upper Lakes ~10,300 years ago and halted drainage to the Lake Erie Basin.

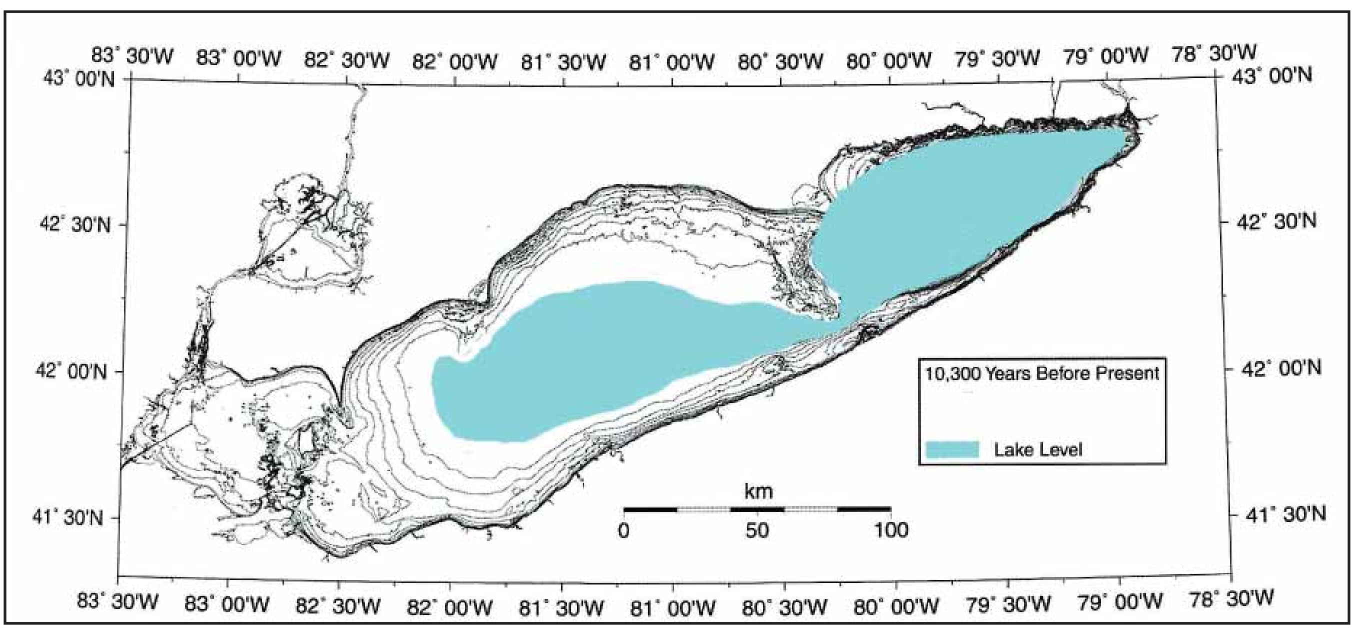

FIGURE 8. Glacial retreat to the north isolated Early Lake Erie, recreating an endorheic basin. A connection of the eastern and central basins is shown via the Pennsylvania Channel.

1942; Phillips 1989; Shane and others 2001), which counterbalanced the isostatic uplift. As a result, for a period of approximately 5,000 years (10,300 to 5,300 years ago) Lake Erie was a closed basin (Table 1).

Uplift of the North Bay Outlet began to raise the levels of the Upper Lakes, a stage known as Lake Nipissing, ~5,400 years ago. Lake Erie continued to slowly rise, but still remained an isolated lake (Fig. 11).

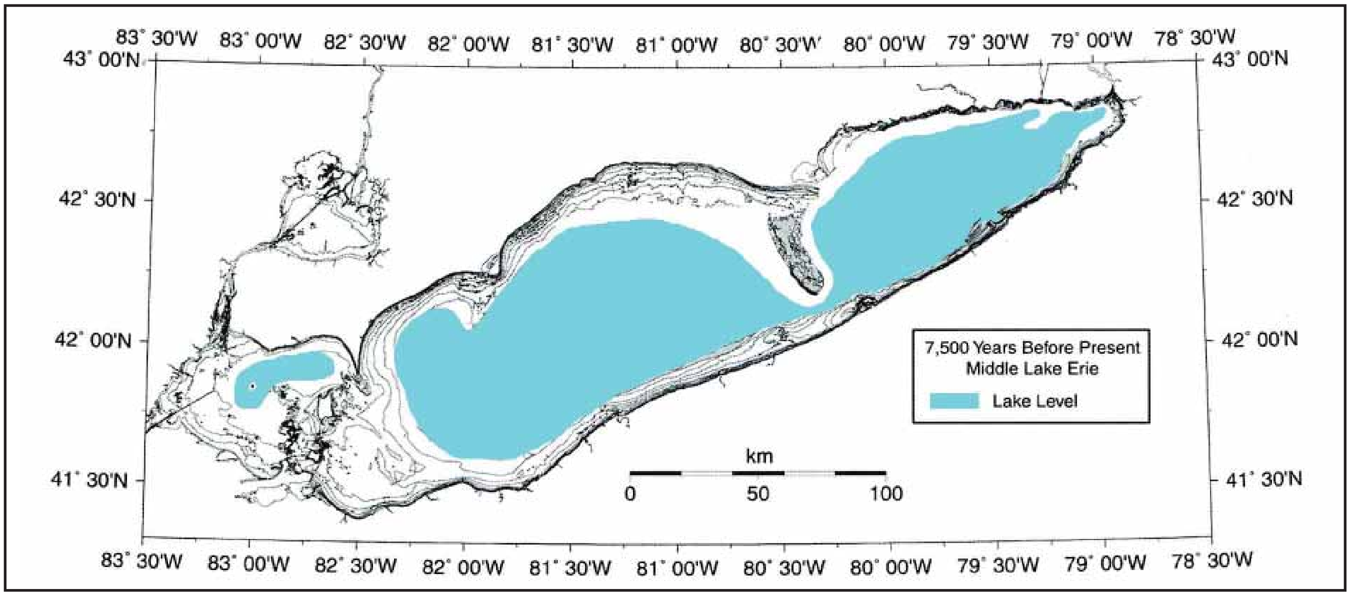

FIGURE 9. Isostatic rebound of the eastern basin, coupled with tributary input to the central basin, was counterbalanced by high rates of evaporation that resulted in a slow rise in the level of Middle Lake Erie for several thousand years from ~10,300 to 5,300 years ago.

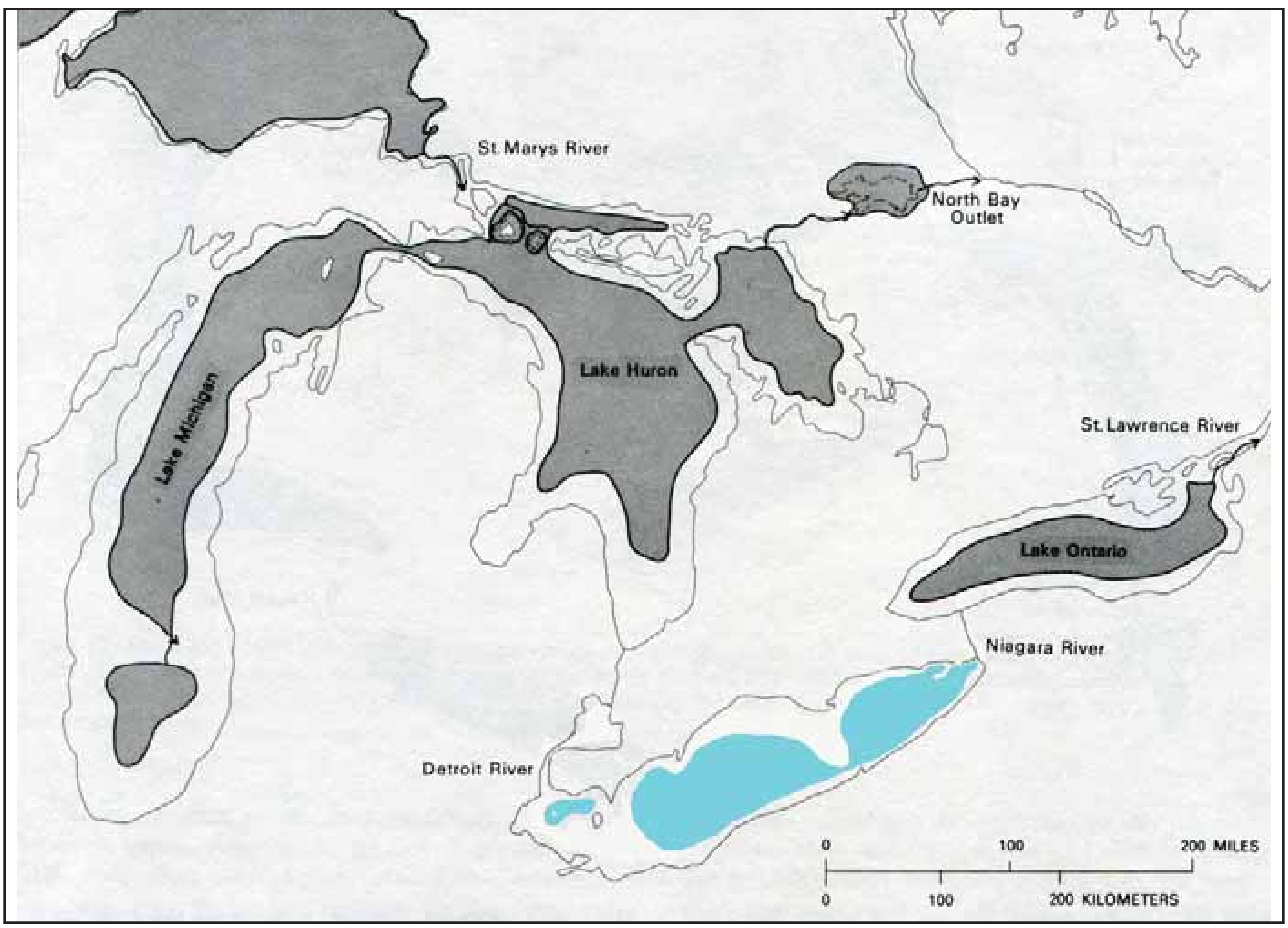

FIGURE 10. Isostatic rebound to the north raised the elevation of the North Bay Outlet, expanding the Upper Lakes ~7,500 years ago. However, Lake Erie remained a closed basin with no direct drainage to Lake Ontario.

Middle Lake Erie was brought to a close ~5,300 years ago when drainage from the Upper Lakes returned to the Lake Erie Basin as a result of continued postglacial uplift around North Bay, Ontario (Fig. 12). This uplift ended Upper Lakes drainage directly to the St. Lawrence River and created the Lake Nipissing stage in the Lakes Huron-Michigan-Superior Basin (Lewis 1969; Calkin and Feenstra 1985; Holcombe and others 2003). This major influx of water from the Upper Lakes, plus more humid climatic conditions, sharply increased water levels in Lake Erie (Fig. 12) and gave impetus to the formation of a large, now submerged, delta in western Lake Erie at the mouth of the ancestral Detroit River (Herdendorf and Bailey 1989). Low water depositional features previously formed in Lake Erie (such as on the Buffalo Ridge, Norfolk Moraine, Conneaut Bank, and Presque Isle Bank) were flooded at this time (Figs. 13 and 14), changing the water circulation patterns (Holcombe and others 2003). Altered littoral drift patterns initiated the formation of large spits, including Long Point on the Ontario shore and Presque Isle on the Pennsylvania coast.

Deposition of the massive delta in Lake St. Clair is also believed to have taken place at this time (5,000-3,600 years ago); radiocarbon dates for lacustrine clays (7,300 years ago) underlying the pre-modern St. Clair River delta show that formation of the delta began during Lake Nipissing time (Raphael and Jaworski 1982; Kaszycki 1985), and not during Lake Algonquin time (~12,000-

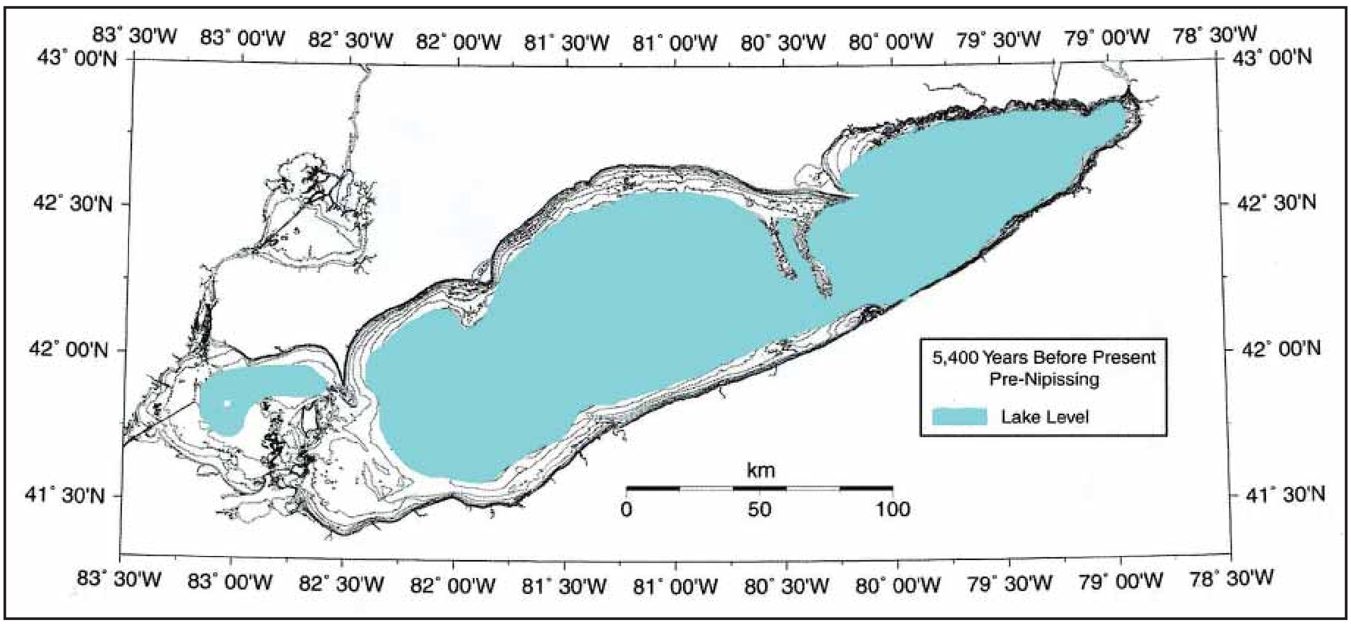

FIGURE 11. Middle Lake Erie continued to rise by isostatic rebound at the eastern end of the lake prior to the return of Upper Lakes drainage.

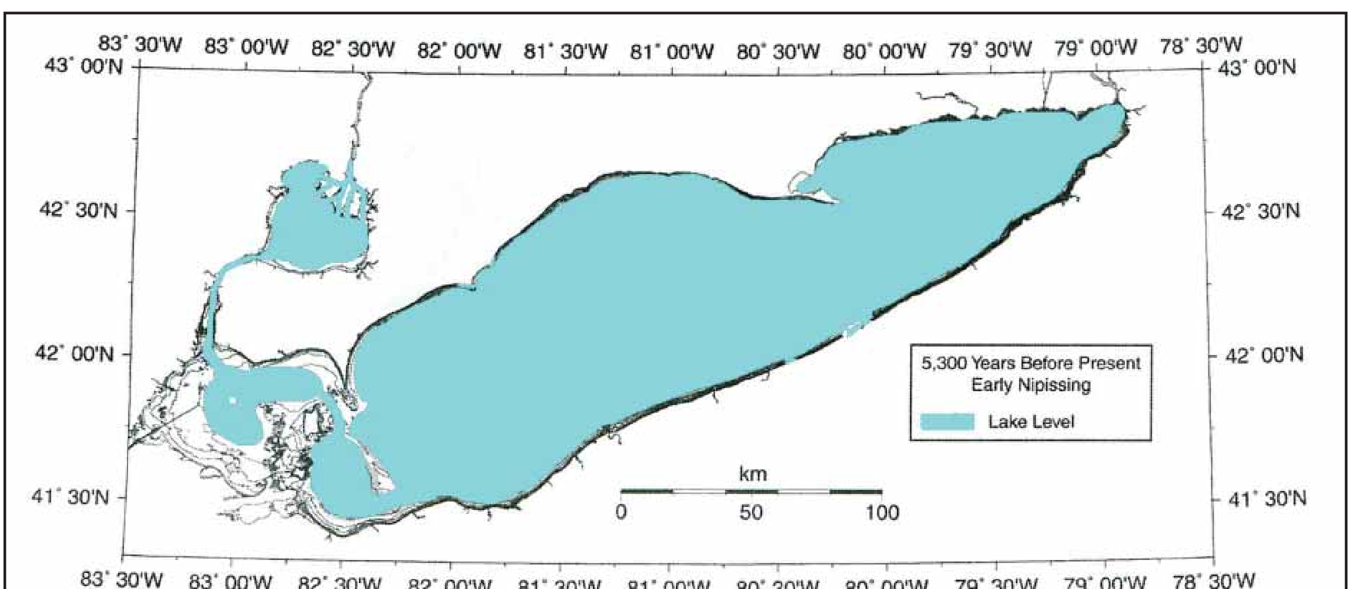

FIGURE 12. As the North Bay Outlet was raised by isostatic rebound, Lake Nipissing drainage began to flow to Lake Erie as well as continue to flow directly to the St. Lawrence River.

10,400 years ago) as ascribed by earlier investigators (Flint 1957). Coakley and others (1999) also found evidence of a "Nipissing flood" in test borings at Point Pelee on the Ontario shore of western Lake Erie. Lewis and others (2012) and Pengelly and others (1997) have documented shoreline features that indicate Lake Erie rose to a highstand about 3-4 m (10-13 ft) above its present level ~4,700 years ago (Figs. 13 and 14). Erosion

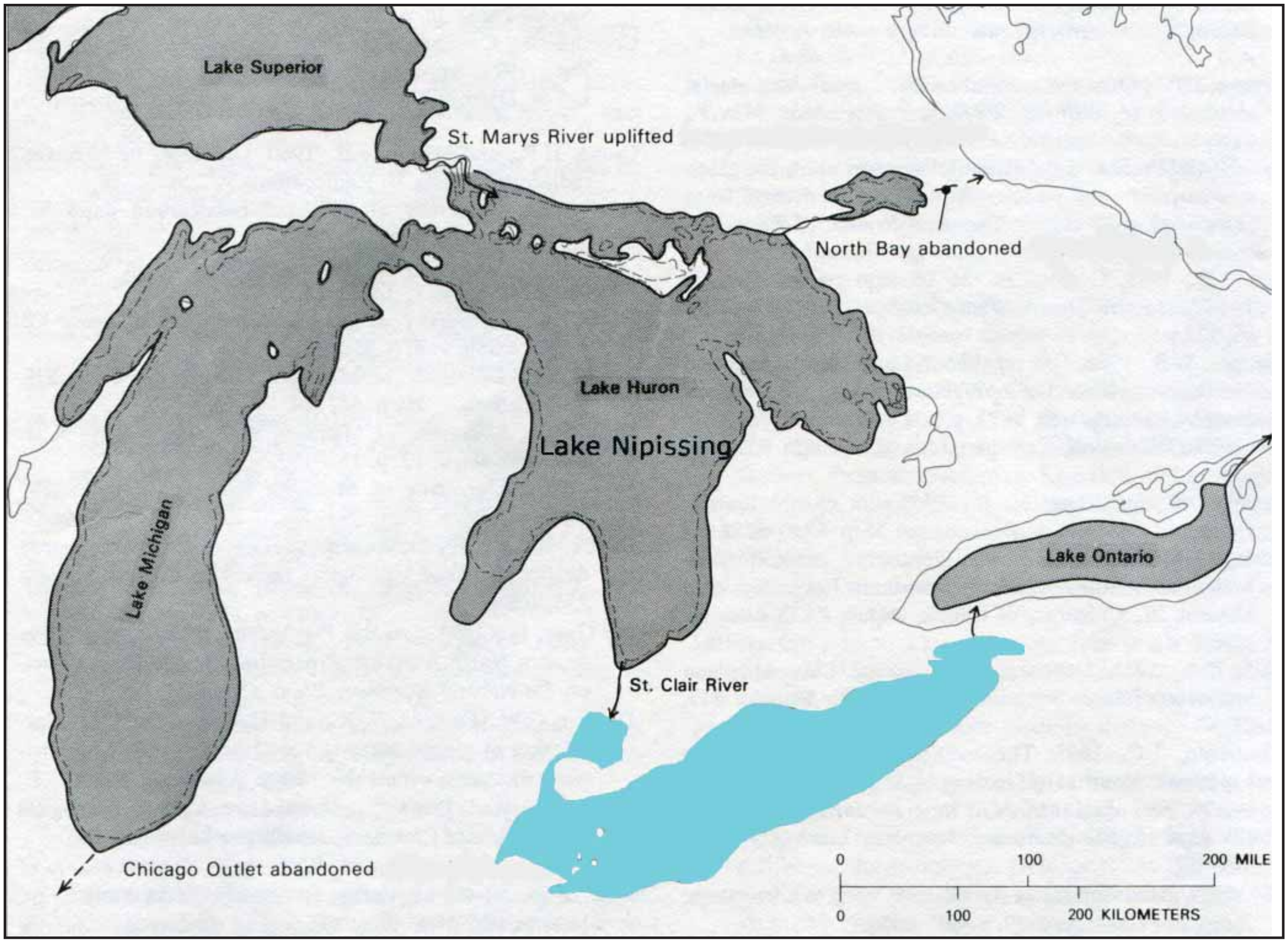

FIGURE 13. Isostatic rebound closed the North Bay Outlet ~4,700 years ago, returning all Upper Lakes drainage to Lake Erie. Deltas formed in Lake St. Clair and western Lake Erie during this time and the water level in the Lake Erie Basin rose to a highstand.

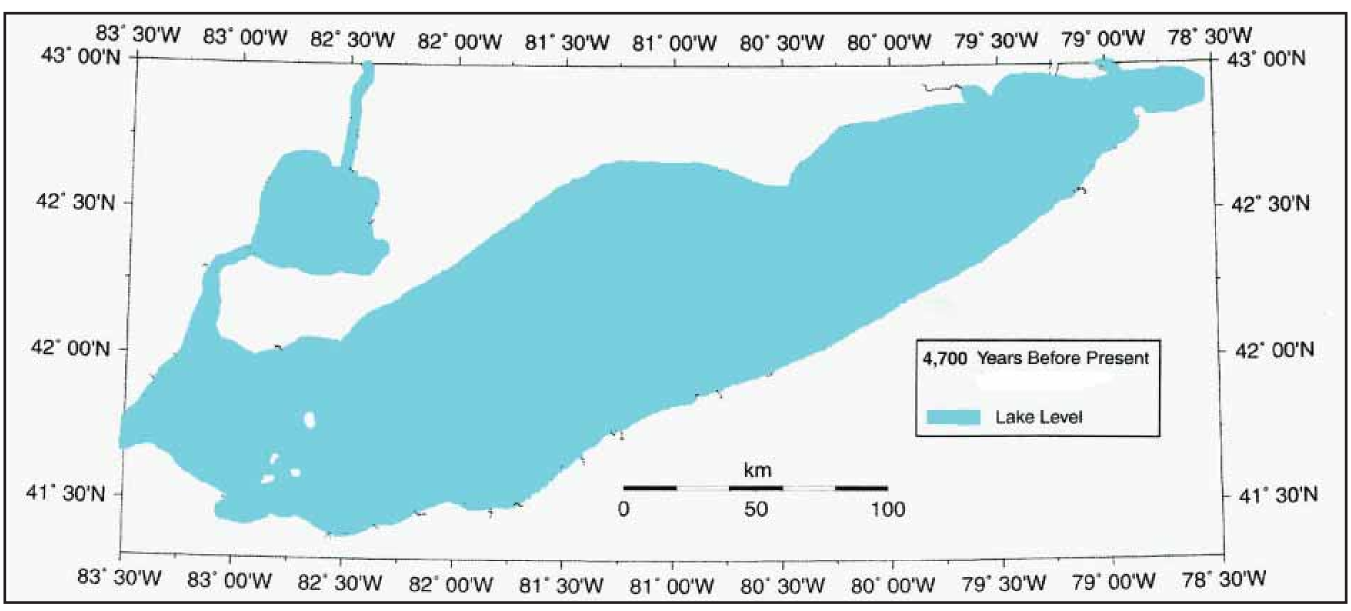

FIGURE 14. A high water level stage formed ~4,700 years ago as drainage from the Upper Lakes returned to the Lake Erie Basin. Erosion of the Niagara River Outlet channel eventually established the current lake level.

of the bedrock sill in the Niagara River Outlet caused the lake to fall to its current level about 3,500 years ago.

Modern Lake Erie

As Lake Erie reached its current level~3,500 years ago), the south shore tributary channels that were deeply incised into lacustrine sediment and glacial till during the low water stages, were flooded by lake encroachment (Fig. 1), creating estuarine-type drowned mouths (Brant and Herdendorf 1972; Herdendorf 1990b). As coastal erosion proceeded, delivering beach-building sand to the littoral zone, the massive sand spits at Long Point and Presque Isle were further nourished, as well as creating new spits at Point Pelee, Ontario and Cedar Point, Ohio. At the same time barrier beaches were formed across the mouths of most of the estuarine tributaries. However, human construction projects along the coast have greatly modified these natural landforms creating commercial harbors, energy works, recreational facilities, and shore protection structures, but often resulting in accelerated erosion rates to adjacent reaches of the shoreline.

Lake Erie appears to have now reached a near-stable water level (Fig. 1), with only minor crustal warping. A study by the US Army Corps of Engineers (1977) showed the maximum deformation rate for all sites measured in the Lake Erie Basin to be less than 6.35 cm/century (2.5 in) and concluded that the present crustal movement rates for Lake Erie are minimal between the inlet (Detroit River) and outlet (Niagara River) of the lake; thus there is currently very little tectonic effect on mean lake level.

CONCLUSIONS

In essence, water levels and lake stages in the Lake Erie Basin can be divided into three primary phases (Table 1). The oldest group of lakes, from ~14,400 to 12,000 years ago, were ice contact lakes that ranged higher than present Lake Erie. The middle group of lake stages, from 12,000 to 4,700 years ago, were isolated from Upper Lakes drainage during dry climatic conditions and fell well below the present level of Lake Erie. The last group of lake stages, from 4,700 to present, experienced renewed Upper Lakes drainage and ranged slightly higher to near the present level of Lake Erie.

With progressive ice retreat at the end of the Pleistocene Epoch, new and lower outlets were uncovered and new lake stages were formed at successively lower elevations in the Lake Erie Basin, except where minor re-advances of the ice temporarily reversed this trend. Massive sand ridges and dunes were deposited along each of these shores and thick glacio-lacustrine deposits were laid down (Pavey and others 1999). Sandy beach ridges and wave-cut cliffs, inland from the present lakeshore, mark the position of these former lakes. When the last glacier retreated from the Niagara Escarpment, the Niagara River Outlet was finally available, but greatly depressed by the weight of the 1,500 m-high (5,000 ft) ice mass that had covered the region (Forsyth 1973). As a consequence, the last glacial lake quickly drained through this new opening and much of the present bed of Lake Erie was dry for an extended period (12,000 to 5,400 years ago).

Early Lake Erie, a low-water stage, was the first of a series of Holocene lakes to form in the basin once the Niagara River Outlet was uncovered. Shortly thereafter the opening of the Kirkfield Outlet, north of Lake Ontario, permitted drainage from the Upper Lakes to bypass Early Lake Erie. This kept the water level in the Lake Erie Basin low until a minor re-advance of the ice ~10,400 years ago blocked the Kirkfield Outlet. According to Holcombe and others (2003) this brought some Upper Lakes water to the Lake Erie Basin, briefly re-establishing the Niagara River Outlet. Lewis and others (2012) however, concluded that Lake Erie remained endorheic during this period.

Soon after, a major retreat of the ice sheet opened the North Bay Outlet, again halting drainage to Early Lake Erie for the next 5,000 years. Influenced by dry climatic conditions, the water level in the basin dropped below the Niagara River Outlet again, creating a closed basin with stagnant and perhaps eutrophic conditions. Isostatic rebound raised the water level to a higher stage known as Middle Lake Erie about 7,500 years ago, but the basin was still endorheic. About 5,300 years ago uplift of the North Bay Outlet returned flow to the Lake Erie Basin, leading to near-modern or slightly higher levels some 4,700 years ago. Eventually isostatic rebound and channel erosion of the Niagara River Outlet brought water in the Lake Erie Basin to near-modern levels about 3,500 years ago.

ACKNOWLEDGMENTS

Diagrams used in this paper have been modified from works by Bolsenga and Herdendorf (1993), Holcombe and others (2003), Larsen (1987), and Lewis and others (2012).

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