
STRAND LINES AND CHRONOLOGY OF THE GLACIAL GREAT LAKES IN NORTHWESTERN NEW YORK¹

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ABSTRACT

Recent restudy of Glacial Great Lake history in northwestern New York tends to confirm a general sequence of nine to ten major lake stands, predicted from others' work in adjacent areas in the Erie and Huron basins. However, some doubt is raised as to the dating and position of the ice margin at the initiation of this sequence. The evidence suggests that glacial lake waters rose to form Lake Whittlesey between 12,700 and 13,800 years B.P., with advance to either the Lake Escarpment, Gowanda, or Hamburg End Moraines. Lake Whittlesey lowered to the Warren I level about 12,700 B.P., after the ice margin had retreated less than one mile from the main portion of the Hamburg Moraine. A second but brief lake stand (Warren II) is weakly suggested by a lower set of beach ridges. However, such a stand must have been very brief, for it gave way to a much lower lake soon after the ice margin had retreated from the next more northerly (Alden) moraine. This much lower lake stage, probably correlating with Lake Wayne, occurred

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during construction of the gravelly Buffalo Moraine and before waters rose again to form Lake Warren III. Lake Warren III, evidenced by the strongest beaches in this area, ended following ice-margin retreat from the Batavia Moraine, when lake level dropped 40 feet to the Lake Grassmere level.

Evidence for lower and later glacial lake stands is sparse, but includes features which may correlate with the short-lived Lakes Lundy and Early Algonquin, and a much smaller local glacial lake, Dana. Lake Dana, the last glacial lake in this portion of the Erie basin, was extinguished as the terminus of the ice sheet retreated north of the Niagara escarpment and into the present area of Lake Ontario and thus opened the Rome outlet to the Mohawk-Hudson River drainage system. The average of several C¹⁴ dates from the Lake Ontario basin suggests that this event occurred prior to 12,100 years ago. At least 170 feet of isostatic uplift has taken place on the Buffalo isobase since Lake Whittlesey time.

INTRODUCTION

The quantity and quality of published works dealing with the surficial geology of northwestern New York is impressive (Muller, 1965b) and includes such comprehensive accounts of the glaciolacustrine deposits and chronology as those by

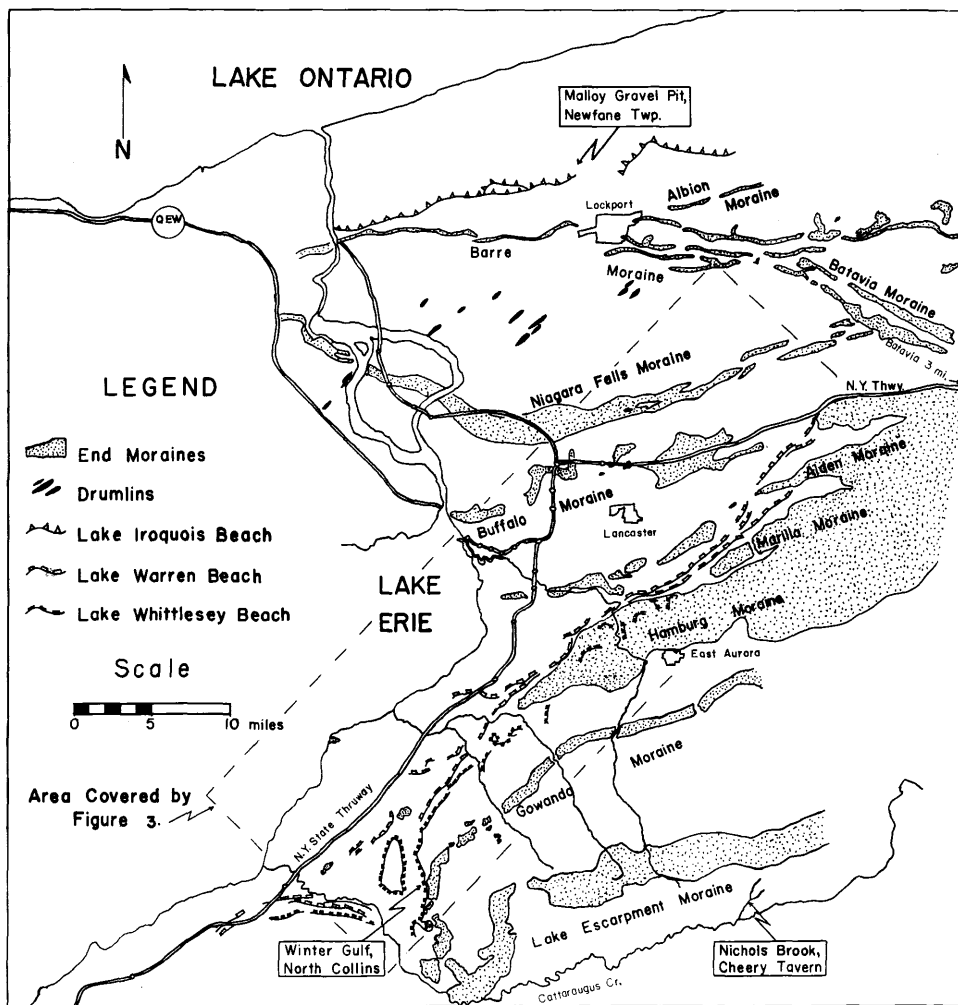


FIGURE 1. Location map of study area showing end moraines and major strand lines of northwestern New York.

Leverett (1902), Fairchild (1907), Kindle and Taylor (1913), and Leverett and Taylor (1915). Fairchild's work includes large-scale maps and systematic descriptions of the strand lines studied to that date within the Lake Erie and Ontario Lowlands of New York. Although further discussions relative to the Buffalo area were published more recently (including, among others, Fairchild, 1932c; Taylor, 1939; and Leverett, 1939), most field work was accomplished prior to the early 1900's, before aerial photographs, good topographic maps, soil logs, and radiocarbon dates were available. Therefore, as part of recent comprehensive surficial geologic studies in this area (fig. 1), the author began in 1965 to remap in detail the Late Pleistocene raised beaches and other strand features.

This paper is a progress report on these recent studies. The strand lines studied are those in the Lake Erie Lowland between Cattaraugus Creek and Batavia, including the Buffalo area (fig. 1). A brief review of both some old and some recent literature relevant to this area is also included, in order to make this report more meaningful.

CHRONOLOGICAL FRAMEWORK

The results of this survey in northwestern New York tend to support the modern Late Pleistocene glaciolacustrine history suggested by the research of numerous recent workers, including Terasmae (1959), MacClintock and Terasmae (1960), Karrow and others (1961), Dreimanis (1964), and Hough (1963, 1966), work undertaken outside of New York in nearby portions of the basins of Lakes Erie, Ontario, and Huron. It shows that the Port Huron ice was the last to cross the Lake Ontario basin and to move into western New York, while the last possible ice dam for Lake Wayne and Lake Warren existed in pre-Valders and probably in pre-Two Creeks time. Table 1 reflects some of this work and in addition suggests a correlation of glaciolacustrine features with the end moraines to be discussed in this paper. More complete chronologies are given by Hough (1966) and by Wayne and Zumberg (1965).

Eight and possibly as many as ten major lake levels prior to the earliest stage of present Lake Erie are evidenced by uplifted beaches, deltas, and wave-cut features within the study area. The oldest, best developed, and also the highest and most steeply tilted of these strand lines is believed to be that of glacial Lake Whittlesey. Lake Whittlesey was initiated by rising waters approximately 13,000 years before the present, following the Cary-Point Huron Interstade, as a result of the glacial readvance which formed the Port Huron Moraine of Michigan (Hough, 1963). The Port Huron advance has in turn been tentatively correlated with the readvance that formed the Lake Escarpment Moraine of western New York (Muller, 1963, 1965a) (The Lake Escarpment Moraine is defined in this paper as the massive morainic complex south of the Gowanda Moraine in western New York, as shown in Plate XXV of Leverett (1902) and as generally defined by Muller (1965a). It is equivalent to at least part of the Valley Heads Moraine of central New York (Muller, 1963; David Fullerton, personal communication 1969).). However, this correlation, which will be discussed briefly later in this paper, is not well substantiated. Remnants of Lake Arkona, which preceded Lake Whittlesey, are not positively recognized in the area studied in New York, and are generally believed to have been either destroyed, or reorganized by the Port Huron advance, or buried by sediments of the higher Lake Whittlesey.

Within the next 1000 years or less (approximately 13,000 to 12,000 years ago), Lake Whittlesey gave way to Lakes Warren I, Warren II, Wayne, and Warren III, and then to stands tentatively correlated with glacial Lakes Grassmere, Lundy, Early Algonquin, and probably Dana. This sequence immediately preceded the separation of waters by the Niagara Escarpment and the formation of Early Lake Erie (Lewis and others, 1966) concurrent with glacial Lake Iroquois in the Ontario basin. Within this period, the ice margin probably retreated from either the Lake

Escarpment, Gowanda, or Hamburg Moraines (depending on which one proves to be the terminal moraine of the Port Huron advance) to form, successively, the Alden, Buffalo, Niagara Falls, Batavia, Barre, and Albion Moraines (fig. 1).

TABLE 1
Correlation of Late Wisconsin lakes† and moraines, western New York

Years B.P.	Glacial Event	Lakes of Erie Basin (* evidenced in N.Y.)	Moraines in N.Y.
-11,000	St. Lawrence ice-free		
	Valders Advance		
-12,000	Two Creeks Interstade	Iroquois (Ontario basin)	
		*Early Erie (473?)	
	Rome, N.Y. ice-free	*Dana (570)	Albion M.
		*Early Algonquin (605)	Barre M.
		*Lundy (620)	
		*Grassmere (640)	Batavia M.
		*Warren III (675)	Niagara Falls M.
		*Wayne (660)	Buffalo M.
		*Warren II (680)	Alden M.
		*Warren I (690)	Marilla M.
-13,000	Port Huron Advance	*Whittlesey (738)—?	{ Hamburg M. Gowanda M. Lake Escarpment M.
	Cary/Port Huron	Ypsilanti? (543-373)	
		III (695)	
		II (700)	
-14,000	Cary Advances	Arkona I (710)	Moraines of SW New York (see Muller, 1963)

†Elevations of glacial lakes south of respective zero isobases, (after Wayne and Zumberge, 1965).

NORTHEASTERN-MOST LIMIT OF LAKE WHITTLESEY

The Lake Whittlesey strand is generally straight, continuous, and clearly evident through New York as far north as the town of Hamburg, (fig. 2). Its elevation ranges from 850 near Cattaraugus Creek to 910 feet at its northern terminus 12 miles north of Hamburg. In the area south of Hamburg, the Whittlesey strand line is expressed by wave-cut terraces and scarps, by deltas (see Fairchild, 1907, p. 80-83), by smooth, sloping shingle beaches, and most prominently by shingle beach ridges constructed on resistant shale bedrock. These latter are frequently steep-fronted ridges 15 to 20 feet high and 150 feet broad.

The Whittlesey beach ridge is strong and well formed, as compared to the more sandy and somewhat more discontinuous Lake Warren strand lines below it. This has been generally noted throughout the Erie basin and has been attributed in part to its formation by rising waters (Hough, 1958). However, its steepness and strength here must also be a consequence of its position along the steep shale bedrock slopes of the Allegheny Plateau margin and its resulting shingle composition. The beaches are composed of imbricate shale cobble, small boulders, and, frequently farther lakeward, a more varied lithologic assemblage of pebbles of discoid shape derived from the glacial drift (fig. 2). Such a composition must

certainly be a result of the lower settling velocities of the available shale which was favored for transport over the more spherical stones of equivalent diameter (see Bluck, 1967).

Very gently sloping terraces 100 to 300 feet wide have also been cut into these slopes of horizontally bedded shale bedrock. Most of these terraces occur at an elevation of 870 feet and are located only 11 to 15 miles southwest of the north-

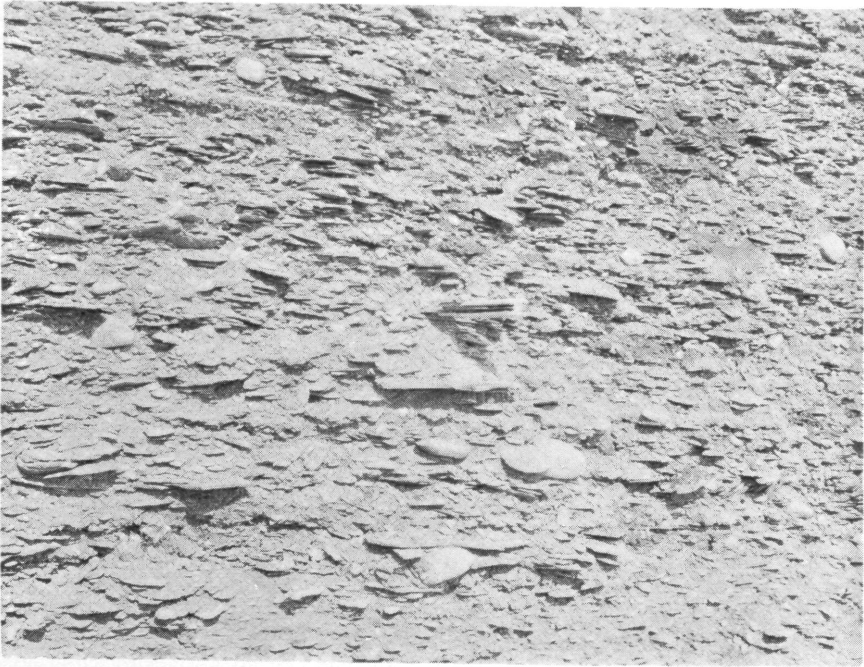


FIGURE 2. Vertical exposure in shale cobble beach of Lake Whittlesey at North Collins. The shale composition as shown in this close-up is typical of most of the Whittlesey and Warren beaches in the vicinity of Eden and North Collins.

eastern limit of the Lake Whittlesey strand (figs. 3 and 4). Because some of these features face northwest and the fetch from that direction must have been slight, they may have been initiated by earlier lake stages, such as Lake Arkona. This appears to be particularly true of a short segment of terrace and accompanying cut cliff exposed by gravel operations into the Whittlesey beach one mile south of Eden along Route U.S. 62. Here, the surface of the terrace was buried 25 to 30 feet below the crest of the overlying Whittlesey beach ridge (see section on "Beaches Intermediate between Whittlesey and Warren Levels").

North of the town of Hamburg, the Whittlesey beach becomes discontinuous, and it disappears completely 12 miles farther north near Marilla. However, perhaps because of its construction here on the north side of the Hamburg Moraine where beach materials were plentiful, its deposits, where present at all north of Hamburg, are greater than 10 feet thick and are clearly visible. Leverett and Taylor (1915, p. 381) traced the Whittlesey strand for a mile or two north of Marilla; however, the last unmistakable occurrence appears to be a weak, wave-steepened sand bar at an elevation of between 900 and 910 feet (Blackmon, 1956, p. 38) 2.5 miles southwest of Marilla. Both Leverett and Taylor concurred that

the last ice barrier of Whittlesey must have been in this area, because of the disappearance of the strand line. The criteria listed below (see Blackmon, 1956) demonstrate that glacial waters dropped from the Whittlesey level to the succeeding Warren I level as the ice margin backed off from the Hamburg Moraine to form the "Marilla Moraine" (a northern extension of the Hamburg Moraine).

1) A delta built into Warren I waters at 850 feet just northwest of Marilla and along the south edge of the "Marilla Moraine" by inwash from Cayuga Creek required the presence of the ice margin immediately to the north as a dam during formation.

2) The "Marilla Moraine" contains more clay and silt, and less evidence of stratified, washed drift between 850 and 910 feet than do adjoining sections of the main part of the Hamburg Moraine to the south.

3) All of the glacial outwash channels to the south and west of Marilla were cut down only to the level of Lake Whittlesey. To the north and east, the main channels were cut below this elevation to the level of Lake Warren I.

4) As previously noted by Leverett (1902, p. 754) and substantiated by recent work, there is no rounding, nor wave alteration, nor lacustrine mantling of the hummocks of the "Marilla Moraine" between 850 and 910 feet. Such alteration might have been expected above 850 feet if the water level had remained at 910 feet as the ice front retreated from the "Marilla Moraine."

Lakes Warren and Wayne

The relatively strong but discontinuous multiple sand and gravel beach ridges occurring as close as 40 feet and as much as 100 feet below the Whittlesey strand line in western New York (between 750 feet and 865 feet) are correlated with Glacial Lake Warren. Most of these beach ridges occur at the immediate foot of the Allegheny Plateau, where they are frequently associated with deltas. However, the ridges are also well developed in a few areas well beyond the Plateau in the Lakes Erie and Ontario Lowlands, where broad deltas provide source material. In many cases, the ridges and/or associated deltas are underlain by bottom silts of Lake Whittlesey.

Origin and Significance of Multiple Warren Beach Ridges

The beach ridges have formerly been referred to an "upper" and a "lower" Warren strand line by Fairchild (1907). A threefold division of Lake Warren strand lines undertaken in Michigan (Hough, 1958, 1963; Wayne and Zumberg, 1965) has not previously been attempted in western New York, because in many areas it is common for an average of from six to ten gravel beach ridges of similar development to be displayed within a vertical interval of 20 to 40 feet (figs. 3 and 4). Fairchild (1907) devotes several interesting pages to the origin of the beach ridges. He concludes (p. 71) that:

The multiple Warren bars probably represent only a single lake or lacustrine unit with some change in level due to land warping and lowering of outlet, the lower bars having been formed as offshore ridges, in waters of long life, supplied with abundant detritus.

He also notes as evidence (p. 70) that:

The lower Warren bars are sufficiently strong to have great continuity and uniformity of level if their formative conditions had favored it, but no separate or distinct water plane can be selected among the lower Warren bars.

Recent field work however, has suggested that, throughout the 50-mile area remapped by the author, the Warren III (lowest Warren) beach ridge is overall markedly stronger than the others, commonly with 10 to 12 feet of relief, while the highest Warren beach (Warren I) is the next strongest. The horizontal discontinuity of the lower Warren beach ridges (perhaps the crux of Fairchild's objection to a prolonged lower lake level) may be a consequence of the low overall gradients of the foreshore over which the waves must have acted, compared to the

steeper gradients of the upper Warren and Lake Whittlesey beaches above. The general absence of bars below but apparently related to the Whittlesey ridge was attributed by Fairchild to a rising water level, and to the brevity of Lake Whittlesey, as compared to Lake Warren.

The multiple occurrence of Warren ridges in the study area, compared to the single or simple dual ridges of the southern and northern parts of the Erie basin (MacLachlan, 1938), may best be explained by the greater fetch in this area and perhaps to the frequent seiche or set-up effect under prevailing westerly winds. The orientation of most spits and bars clearly displays the effects of strong south-westerly winds. These winds apparently blew toward and along the ice margin, which in turn had locally a southwest-northeast orientation during part of the period discussed.

The position and form of the Warren beaches in this area suggest that their formation may be partly the result of processes similar to those forming modern ridge and runnel beaches of tidal seas (King, 1959). Many ridges were also probably barrier islands, as suggested by Fairchild (1907). Both ridge and runnel beaches, and barrier islands are probably products of constructive wave action in front of the breaking point and hence were not destroyed as the lake gradually lowered, as subaqueous bars might have been.

None of the ridges intervening between uppermost and lowermost Warren (where there are four to ten ridges) is consistently stronger than the other; nevertheless, a three-part division of the Warren episode may be weakly indicated at several points along the strand exposure. Such areas are near Elma, Springbrook, Websters Corners, Smoke Creek south of Orchard Park, and in the Armor-Hamburg area, where beach ridges at only three elevations are well expressed.

In addition, approximately 14 miles east of Buffalo (fig. 3), the strong and easily identified single Warren I beach and an upper beach ridge of Fairchild's "lower" Warren (Warren II ?) trend off eastward from the regional northeastern trend. As they turn, the ridges divide into six northeast-trending spits. These can be traced through Alden and terminate abruptly at a point two miles beyond the village and an equal distance south of the Alden Moraine, where they lie above lake silts. These relations were discussed by Leverett (1902, p. 766-767), Leverett and Taylor (1915, p. 398), and Fairchild (1907, p. 59-63); however, detailed topographic maps of Alden Township with new mapping (by the author) on aerial photographs and accurate elevation determinations allow probable resolution into three major lake levels (fig. 3). Near their termini at Alden, four of these six spits attain an elevation of 866 feet above sea level (Warren I); the other two only reach elevations of 859 feet (Warren II). Such a series of spits may be a more representative indication of pauses in lake lowering than are the multiple beaches built on the steeper slopes nearby to the south. However, one must conclude that the paucity of evidence for a clear intermediate stand in northwestern New York is more impressive than is the evidence *for* this level, and the Warren II stand reported (Hough, 1963) to have occurred following down-cutting of the Grand river outlet must have been very brief.

Where the upper two beaches (Warren I and II ?) split off toward the east (fig. 3), the lower portion of the "lower" Warren beach (Warren III) swings to a more northerly course, cutting obliquely across the Alden Moraine at West Alden. Here, the beach ridges of this lower series include hundreds of boulders between two and six feet in diameter derived from the moraine. The elevation of this lower series of beaches, along the isobase at the termination of the afore-mentioned Warren I and Warren II ridges, is 850 feet A.T. The Alden Moraine here shows little clear lacustrine alteration above this level and it is probable that the Warren I and hypothesized Warren II lake levels were extinguished soon after the glacial front retreated north from the Alden Moraine (see Leverett, 1939, p. 12). The short distance (2 miles) traversed by the ice front (Marilla to Alden Moraine)

and the relative weakness of the two correlating moraines may further attest to the short existence of Lakes Warren I and Warren II.

Lake Wayne

Remains of what may be the next younger (but not the next lowest) glacial lake include a series of short, subdued gravel and sand deposits which can be traced with some difficulty across the study area, particularly between Orchard Park and the town of Indian Falls (fig. 3). These features fall approximately 10 to 25 feet below the later Warren III beaches and may represent one or more strand lines of glacial Lake Wayne. These strand features are not strong or continuous enough to be traced south of New York into the type Lake Wayne area, so vertical position is the only means of correlation that can be used, which is also true for the post-Warren III strand features.

A line on Figure 4 representing these generally subdued shore features also encompasses a small number of elevation points from well-formed gravel ridges. Some of these latter may belong to post-Wayne (Warren III) lake activity (See Leverett and Taylor, 1915, p. 389).

As indicated by Hough (1963, p. 95), "Most writers, following Leverett and Taylor [1915, p. 386], have placed the Wayne stage as pre-highest Warren in age," but Hough described the Wayne stage as "a brief lowering of lake level to 660 feet above sea level" and noted that it "probably was immediately pre-lowest Warren in age and that it could have discharged down the Grand River Valley" (rather than to the east). If all the beaches and buried gravel deposits in question are correlative with the Wayne level, then they must be post-Warren II in age, as noted by Hough (1963), because they can be traced north as well as south of the Alden Moraine, the probable position of the northern-most ice barrier of the Warren II stage.

Although Leverett and Taylor (1915, p. 389) made mention of bars that run westward from 790 feet at Hamburg to 750 feet A. T. at Eden (fig. 3) as possible correlatives of Lake Wayne, there have been no other published references to Wayne beaches northeast of Cattaraugus Valley in western New York. The following possible Wayne strand features have recently been mapped. 1) Sparse, thin, narrow ridges of sand cross lake-bottom silts, bedrock, or shaly till two miles northwest to northeast of Orchard Park and between Elma and Crittendon (fig. 3). They have only a few feet of relief, are broad, and are more sparsely pebbly than the Warren ridges above. These ridges are believed to be subaerial deposits. Although offshore submarine bars are common below the beaches of the modern Great Lakes, they are ephemeral features on tidal areas, and experimental work (King, 1959) suggests that they would be removed by any lake lowering. 2) Washed till and occasional ice-rafted boulders occur 20 feet below Warren III ridges off of Two Rod Road two miles southwest of Alden. These deposits are partly covered by fine, offshore sands (perhaps of the Warren III stand). 3) Gravel bars buried by clay and peat lenses and subsequently by what is probably Warren III sand were displayed in a pipeline trench two miles north of Marilla (Blackmon, 1956). 4) Broad but subdued chert-pebble ridges are found at 850 feet A.T. along the cherty Onondaga Limestone escarpment immediately north of the Buffalo Moraine near Akron (fig. 3).

According to the older chronology of Leverett and Taylor (1915), Hough (1958), and Bretz (1966), Lake Wayne was correlated with the Two Creeks Interstade and with eastward drainage to the Hudson River. Field relations in western New York do not clearly either corroborate or deny eastward drainage at this time.

The Wayne stage may be tentatively correlated with construction of, and retreat from, the Buffalo Moraine. This correlation is based, rather insecurely, on the assumption that the ice margin, both in Michigan and in the Erie basin, reacted similarly to some widespread climatic event. The sequence of events of

this correlation may be outlined as follows. In Michigan, Hough (1965, p. 67) has provisionally characterized the Wayne event as having occurred following ice-front retreat from the Tawas Moraine but prior to the next major readvance. He suggested that the sequence involved an increased delivery of meltwater during retreat, cessation of retreat and delivery of less volume of meltwater, fall of lake level to the Wayne stage, and subsequent readvance. In western New York, a similar sequence may be recorded in the Buffalo Moraine (fig. 1). This moraine, unlike the adjacent, more continuous till moraines at Alden to the south and the Niagara Falls (till) Moraine to the north, is composed largely of ice-contact stratified drift, capped in places by lodgement till. From the events outlined above, one could reasonably envision a local sequence of rapid glacial thinning and increased meltwater production, with sand and gravel deposition, followed by a short readvance without appreciable increase in melting. Because subdued pebble beach ridges possibly correlative with the Wayne level occur on the north margin of this moraine, the Wayne lake even may have persisted until the ice margin had backed off to a position at or near the Niagara Falls Moraine. At this point in the history, waters must have risen to form the Warren III lake.

Lake Warren III

The multiple Warren III (lowest Warren) beach ridges are strong as they pass north through West Alden and Sand Ridge, with the main ridge being up to 28 feet thick and 150 wide. Through and beyond the town of Crittenden, there is only a single strong 30-foot gravel bar, which at the Alden Township boundary, becomes a northeast-trending complex of nine gravel spits (fig. 3). The orientation of this series of spits appears to indicate a migration of the locus of beach deposition toward the southwesterly (prevailing) winds. The spits consist almost entirely of gravel, grading from cobbles at their base upward into fine material, this vertical change perhaps reflecting the transgressive nature of Warren III formation. The spits are formed on the gravelly outwash delta of Murder Creek, a delta which may have been constructed into Lake Wayne as the ice margin stood at the Buffalo Moraine immediately adjacent to the north.

Eastward from Crittenden and Pembroke, the beaches are weak and discontinuous. Although Fairchild (1897) traced the Warren III strand through Indian Falls and east through the Genesee Valley to near Canandaigua, the shoreline is extremely weak and, as noted by Fairchild (1907, p. 63),

The Warren shore west of Crittenden must have felt the wave work several times longer than the shoreline to the east of Indian Falls. The conclusion is that the glacier front rested for a long time on the high ground north and west of Batavia, and the Warren waters were then dammed off from the land to the east.

The Warren III stage apparently ended when the glacial margin retreated eastward from the Batavia Moraine (see Leverett, 1902, pl. III). Fairchild (1932a, 1932b) correlates the drop from the lowest Warren lake with glacial retreat from the Waterloo-Auburn Moraine. Fairchild noted (1932a, p. 612) that retreat from this moraine allowed eastward escape of Ontario-basin waters, as revealed by marginal channels in the Syracuse area. The Waterloo-Auburn Moraine is in part an equivalent of the Barre Moraine shown in Figure 1.

UPLIFT OF WHITTLESEY AND WARREN STRAND LINES

The points of measured elevation shown by Figure 4 define the tilted levels of Lake Whittlesey, as well as the 24-to-45-foot vertical range of the Lake Warren strands, 70 to 45 feet below. The water planes suggested below the Warren level are less well defined and the lines of Figure 4 are positioned with some prejudice gained in the examination of individual beach segments. There is no control for the slopes of the suggested tilted water planes other than the elevations of the individual beach segments at various places, as shown in Figure 4.

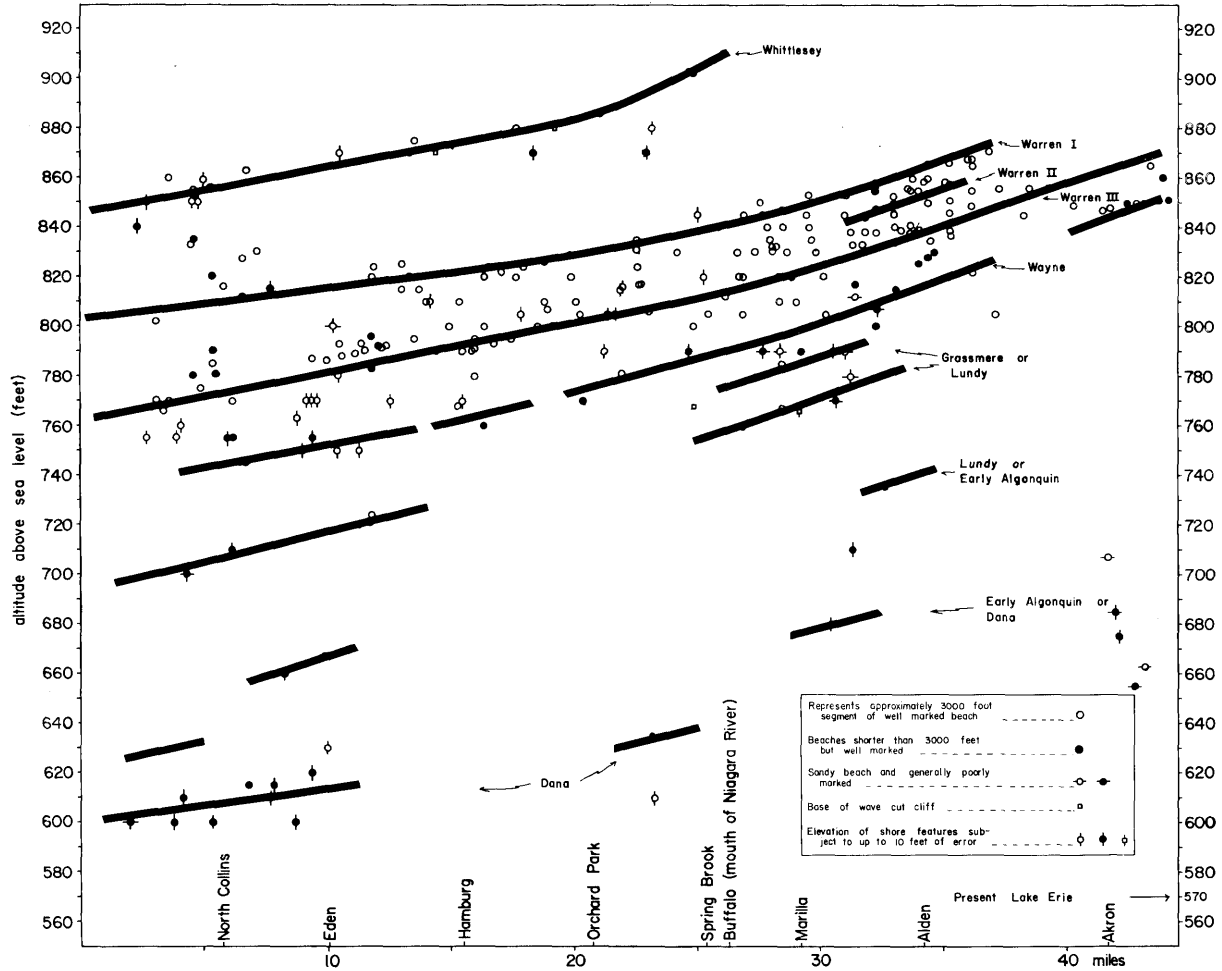


FIGURE 4. Graph of position versus altitude (distance diagram) of sites on shorelines of tilted glacial lakes of the Erie basin. Elevations have been projected to a line running N 24 E between Cattaraugus Creek at Versailles and the town of Indian Falls. Slopes and positions of water planes below Warren III have little control.

Elevation of points shown (fig. 4) were taken on beach ridge crests or, where indicated, at the foot of wave-cut cliffs (or on erosional benches) with surveying altimeter, by transit, or by ground-controlled photogrammetric means. In order to help avoid atypical beach ridge elevations due to storms or local physiographic control, elevations were taken at points where the ridge crests were reasonably horizontal for several hundred feet. In addition many points of elevation were measured to help average out any gross irregularities in storm-beach construction which could cause errors in the interpretation of the former water-plane configuration. Neglecting a maximum 10-foot error in elevation measurement, the crests of beach ridges may be as much as 12 to 18 feet above the associated water plane. This assumes a maximum fetch (southwest-northeast, or west-east length) of 200 to 300 miles (respectively) and optimum conditions of wind velocity, water depth, wave height, and generation time, as suggested by Elson (1967, table 7).

The orientation of the section shown in Figure 4 is N24°E, which is probably within 5 degrees of the line of maximum tilt of the land during post-Warren time in the eastern Lake Erie basin. Figures cited in the literature vary between N20°E for Lake Iroquois beaches (Goldthwait, 1910) to N29°E for direction of the post-Warren average regional tilting of Ontario (MacLachlan, 1939, p. 80). Isolated Warren and Whittlesey elevations of Chapman and Putnam (1967) and of Karrow (1963), in conjunction with those in the Buffalo area, give values of between N20°E and N30°E for the direction of maximum tilt.

Correlation of strand lines of Lake Whittlesey and Warren (multiple) throughout northwestern New York suggests that considerable uplift of this area may have occurred during the late stages of Lake Whittlesey and prior to major development of the Warren I strand line. The beaches diverge northward between Hamburg and the town line of Eden. As shown in Figure 4, the maximum uplift affecting the Whittlesey strand near Marilla is about 170 feet (that is, 910 minus 738). Total recorded uplift of Warren I and Warren III strand lines at this same point (which also corresponds to the isobase passing through the outlet of Lake Erie at the mouth of Niagara River) are 150 feet and 140 feet, respectively. The divergence of the Whittlesey and Warren beaches here may reflect the rapid retreat of the ice margin from the Hamburg-Eden area during Lake Whittlesey time. For additional discussion of the ancient and recent uplifts of the northeastern part of the Erie basin, the reader is referred to Taylor (1927, 1928), MacLachlan (1939), Moore (1948), and MacLean (1963).

BEACHES INTERMEDIATE BETWEEN WHITTLESEY AND WARREN LEVELS

Detailed mapping of western New York beach ridges has revealed gravelly ridges intermediate in elevation between Lake Whittlesey and Warren I strand lines at two main locations: just south of Springbrook, and on the north and south borders of the village of North Collins (fig. 3). They are marked by question marks (" ? ") in Figure 3. The ridge near Springbrook is only a few hundred feet long and may be explained either as an offshore bar of Lake Whittlesey (Symecko, 1966) or as an early beach of that lake preserved after uplift of the land in late Whittlesey time. Near North Collins, however, the Warren and Whittlesey ridges are nearly parallel and the beach ridges in question occur at about 825 feet A.T. (fig. 3), 25 to 30 feet below the Whittlesey ridge and 10 to 15 feet above the subjacent Warren I beach ridges. These intermediate-level ridges extend for only one-half mile. Each consists of an imbricate shale cobble ridge 125 feet wide, and with at least 10 feet of relief. The ridge is slightly less strong than the Whittlesey ridge above, but is as prominent as most of the Warren ridges below. None shows mantling of crests by finer material.

Because of their thickness and coarse-cobble composition, these do not appear to be off-shore submerged bars of Lake Whittlesey. They may represent: 1) a brief lake stand during lowering of Whittlesey (perhaps near the level of Lake

Saginaw of the Huron Basin) during or before downcutting of the Grand River outlet channel to Lake Chicago in the Michigan basin (Hough, 1963, fig. 4), though evidence for such a strong beach as this might be expected elsewhere in the Erie and Huron basins; or 2) beaches of glacial Lake Arkona formed during fall from Lake Maumee (Hough, 1963, fig. 3E) or formed during rise of lake waters to the Whittlesey level from low water stage which followed Lake Maumee time.

The second of the above explanations was initially rejected on the basis of the following observations. 1) The beaches do not show specific evidence of submergence or alteration by Whittlesey waters. 2) Beaches of corresponding vertical position have not been reported elsewhere to the south in New York (except possibly near the towns of Ripley and Forsyth, where Fairchild (1907, p. 65) assigned beaches 35 to 32 feet below the Whittlesey strand to the "upper" Warren strand line), nor do published maps show them in Pennsylvania. 3) It has been suggested by most workers in western New York, though unproven, that the Port Huron ice, which initially blocked Lake Whittlesey on the north, formed either the Gowanda Moraine (Leverett, 1902, p. 673-684; Taylor, 1939, p. 386-387) or the Lake Escarpment-Valley Heads Moraine (Muller, 1965, p. 48; David Fullerton, personal communication, 1969). Because both the Gowanda and Lake Escarpment Moraines occur south and east of this area, Arkona beaches here should have been destroyed by this advance. However, investigations now underway by Calkin and McAndrews (1969) suggest that retreat from the outer or distal side of the Lake Escarpment Moraine of western New York may have occurred earlier than that from the Port Huron maximum and the initiation of Lake Whittlesey (see following section on dating). In addition, work now being undertaken north of Erie, Pennsylvania, by Beth Evans (personal communication, 1969), of Bowling Green University (Ohio), indicates that there may be Arkona beaches in north-western Pennsylvania.

Considering the hypothesis that the above-considered beaches of western New York are indeed a product of Lake Arkona, we must assume that the terminus of the last ice advance into western New York is represented by the Hamburg Moraine (fig. 1). Should this be the case, the fetch would have been very slight at North Collins and, because beaches submerged to a depth of 30 feet or more are essentially below any effective wave action (King, 1966, p. 149), alteration and mantling of an Arkona beach might have been immeasurably small. In support of this point, Leverett (1939, p. 463-464) notes,

In the paper just noted [Taylor, 1905], Taylor presented the interesting evidence that the Arkona beaches suffered little or no modification by the waters of Lake Whittlesey where they are close to the Port Huron Moraine in St. Clair and Sanilac Counties [Michigan], but are washed down and made obscure as they pass away from the border of the moraine, wave action there having been more effective. The same condition of preservation is exhibited near Arkona, Ontario.

Final correlation of these intermediate beaches with Glacial Lake Arkona or with another glacial lake stage must await further detailed mapping to the south of the study area. In addition this correlation may be dependent upon the position that is proved to be the terminal one for the Port Huron advance in western New York.

EVIDENCE OF POST-WARREN GLACIAL LAKES

Lakes Grassmere and Lundy

In reference to Lakes Grassmere and Lundy, Leverett and Taylor (1915, p. 404) note that:

From this valley [Cattaraugus Creek] northward to the Niagara quadrangle, only a few faint and unconnected fragments of shorelines have been observed in the interval usually occupied by these [Grassmere and Lundy] beaches.

A similar paucity of "Lundy" beaches is sited by Chapman and Putnam (1966) in southern Ontario. Although the recent remapping of the lake plain below the Warren III and Wayne levels shows the beach ridges to be slightly more numerous

than formerly believed, in most cases these ridges are so poorly developed and so discontinuous (fig. 3) as to make definite correlation difficult. Correlations with possible contemporary strands in Michigan, Ohio, and Ontario, suggested in Figure 4 can only be very crude at this time, as no continuous tracing is possible. Correlation of these titled beach remnants below the Warren III level with their untilted counterparts in Ohio may be possible following more detailed mapping in southern New York and Pennsylvania.

Beach-making materials in the forms of kame moraine, deltas, and inwash gravels, so common on the margin of the Allegheny Plateau where Whittlesey and Warren strand lines occur, are almost absent below the lowest Warren strands. In addition, the very gentle slope must have allowed extensive spreading of beach materials with slight lake-level changes, some of these changes perhaps being induced by glacial rebound during this time. The steepest slopes between the Warren beaches and the Lake Erie shore are approximately 75 feet per mile, and in most places, the slope is much more gentle. Finally, perhaps most important of all, the sum total of time occupied by the lake stages following Warren III time, as well as the individual periods, must have been very brief, because absolute radiocarbon dates (discussed in more detail farther on in this paper) suggest that the post-Whittlesey, pre-Early Lake Erie period occupied less than 600 years.

Discontinuous gravel ridges in the Marilla-Springbrook area and a continuous ridge leading through North Evans (fig. 3) fall near or slightly below 780 feet (on the Buffalo isobase), the expected maximum elevation for the Grassmere beach (fig. 4). This expected maximum elevation is determined by adding the untilted Grassmere elevation in Michigan (640 feet A.T.) to the maximum post-Warren uplift (140 feet). These probable Grassmere ridges vary in length, reaching a maximum of two miles at North Evans, but most are much shorter. In most places they are about 150 feet wide and show less than 10 feet of relief. Leverett (1939, p. 472) suggested the correlation of the lower of the two lines of ridges above the Marilla isobase (at 767 feet) in this same area with a lower Lundy stage (Elkton stage), which is now generally referred to simply as the Lundy stage. Beaches correlative with the Lundy might be expected at an elevation more than 20 to 30 feet below the Grassmere, if there was uplift during this time (see table 1), and therefore Leverett's correlation seems an unlikely one. However Figure 4 shows few elevation points at the afore-mentioned levels, therefore documenting the uncertainties in post-Grassmere correlations. Taylor (Kindle and Taylor, 1914) suggested that Lake Lundy endured for some time after withdrawal of the ice margin from the Albion Moraine (fig. 1), but there is no field evidence for this interpretation in western New York.

Lake Early Algonquin

Hough (1963) and Chapman and Putnam (1966) have made good cases for an Early Algonquin stage (605 A.T. untilted) in the Erie basin, and Chapman and Putnam (1966) have mapped Early Algonquin beach ridges in southern Ontario. These beaches should be above the Lake Dana beaches in the study area, since the latter appear to dip below present lake level in southern New York. In addition, Glacial Lake Early Algonquin had to precede retreat of the ice margin, opening of the Rome outlet to the Mohawk River, and formation of Lake Iroquois in the Ontario basin, a sequence not realized in the glacial Great Lakes correlation chart of Wayne and Zumberg (1965, fig. 7). These relations are discussed in detail by Hough (1963, p. 96-100, and 1966).

Correlation of such lower shore features is aided by a curve drawn by Lewis (Lewis and others, 1966, p. 182), showing uplift of Lake Erie's outlet at Buffalo. This curve, based on the warped glacial Lake Iroquois shorelines mapped by Coleman (1936) and on dates determined from materials gathered from deposits of Lakes Whittlesey, Warren, Iroquois, and Early Lake Erie, suggests that Early

Lake Erie began with the outlet at 475 feet A.T., thus giving a minimum uplift, since the time of opening of the Rome outlet, of 95 feet, in order to reach the present 570-foot level of Lake Erie. Hough (1963, p. 200) has previously estimated this amount as a minimum for uplift accomplished since initiation of Lake Iroquois.

Remnants of the Early Algonquin beaches should appear at a minimum elevation of 605 plus 95 feet or at about 700 feet, according to the data discussed above, and at a maximum elevation of about 745 feet on the Buffalo isobase, based on maximum post-Warren III rebound. As shown by Figure 4, beaches at this elevation are more rare than those 50 to 100 feet below, perhaps suggesting that the Early Algonquin lake was short-lived, compared to the succeeding Lake Dana in this area. Chapman and Putnam (1966, p. 97) have made tentative correlations of beaches at 618 feet A.T. (projected to Orchard Park isobase) between Sherkston and Crystal Beach of Ontario with Early Lake Algonquin. This elevation seems much too low, considering the uplifts interpreted above, and so these latter beaches in Ontario may be assigned to Lake Dana.

Lake Dana

All of the post-Warren glacial lake beaches of northwestern New York were considered to be the work of slowly subsiding waters by Fairchild (1907), because of the supposed opening of eastward drainage to the Mohawk-Hudson River system at this time. Although the beaches resulting from this slow subsidence were to be assigned to a Lake Dana, his discussions under the Dana heading mainly considered a spectrum of very faint but numerous short ridges approximately 180 feet below the Warren I plane (fig. 4), or from about 600 feet A.T. at Cattaraugus Creek to 700 feet in the Ontario basin. As shown by Figures 3 and 4 in this report, there do seem to be several faint ridges near this elevation range, which in turn would appear to represent more than one water plane. However, a single line has been passed through these points on Figure 4 simply to bring them to the attention of the reader. There is no clear tilt for the Dana surface(s). Nearly all of them lack appreciable gravel content and show less than five feet of relief. Many of them originally mapped by Fairchild (1907), or by Gilbert and Taylor (Kindle and Taylor, 1913), are now difficult or impossible to distinguish (in many cases because of recent construction by man) and are so marked in Figure 3. The remnants probably represent a very slowly lowering water surface (relative to more rapid lowering after the Early Algonquin or Lundy stages) before formation of the nonglacial Early Lake Erie. The ridges at 680 feet in East Buffalo, originally assigned by Fairchild (1907) to his Lake Dana, may be Early Algonquin in origin.

Fairchild (1907, p. 76) suggested that the upper limit of the Dana water plane was between 660 and 680 at Buffalo; based on this, the upper limit of the untilted Lake Dana would be 585 feet (680 feet minus 95 feet of uplift). Because there was probable more than 95 feet of uplift (95 was a minimum figure), it is probable that the Dana beaches have been submerged south of Westfield, New York, near the zero isobase designated by Fairchild (1907). In addition, as pointed out by Leverett (1939, p. 473) and later by Hough (1958, p. 200), the Lake Dana beaches cannot be correlated with the Lundy beaches of Michigan, as was indicated by Leverett and Taylor (1915) and more recently suggested by Forsyth (1959). The Lundy strand occurs at about 620 feet where untilted, or at least 30 feet higher than the Dana beaches.

DATING OF THE GLACIOLACUSTRINE EVENTS

Examination of Table 2 part "A" reveals that the interval between formation of glacial Lake Whittlesey and the time of removal of the ice barrier and formation of Glacial Lake Iroquois may be bracketed between the average dates of 12,900

to about 12,000 B.P. Such a conclusion has also been reached by others, including Dreimanis (1966), Goldthwait and others (1965), and Muller (1965a).

A recent date for Glacial Lake Warren or Lake Wayne by R. P. Goldthwait and T. Lewis (personal communication, 1968) of 11,200 ± 170 years B.P. (I-2918) does not fit well with the other dates. If Early Lake Erie and glacial Lake Iroquois were in existence by 12,100 B.P., as other dates suggest, this younger date for Lake Warren require a glacial readvance following Iroquois time, a history overwhelmingly denied by previously cited evidence.

Two previously unpublished dates in Table 2 give minimum dates for ice recess-

TABLE 2

Summary of radiocarbon dates† defining late glacial history of the Lake Erie basin

Event	Date Number	Age-Years B.P.	Remarks	Reference
<i>A) Specifically Dating Pleistocene Great Lake Stages</i>				
Lake Arkona III	*W-33	13,600 ±500	Tree fragments from lagoon deposits (689 ft. A.T.) overlain by Whittlesey sand and silt.	Hough, 1958 (D)‡
Lake Whittlesey	*W-430	12,920 ±400	Wood from a peaty zone below Whittlesey gravels at Parkerstown, Ohio.	Alexander and Rubin, 1958 (D)
	I-3175	12,900 ±200	Wood in Whittlesey beach, Elyria, Ohio.	T. Lewis and R. Goldthwait, 1963 personal communication Hough, 1958 (D)
	*Y-240	12,800 ±250	Wood fragments in Whittlesey sediments 4.5 miles southeast of Bellevue, Ohio.	
	*S-31	12,660 ±440	Driftwood from Lake Whittlesey gravel near Ridgetown, Ontario (minimum date).	McCallum, 1955 (D) A. Dreimanis, 1966 personal communication
Lake Warren or Lake Wayne	I-2918	11,200 ±170	Wood from Lake Warren—Wayne beach, Cleveland, Ohio.	T. Lewis and R. P. Goldthwait, 1969, personal communication
Early Lake Erie	S-172	12,000 ±200	Plant remains at 581 ft. near Tupperville, Ontario below beach deposits of Early Lake St. Clair 590-600 A.T.	Dreimanis, 1964 (D)
	GSC-211	11,860 ±170	Same as above.	Goldthwait <i>et al.</i> 1965 (D)
	GSC-382	11,300 ±160	Buried plant detritus western Lake Erie	Lewis <i>et al.</i> 1966
	GSC-330	10,200 ±180	Buried driftwood central Lake Erie	Lewis <i>et al.</i> 1966
Lake Iroquois	W-861	12,660 ±400	Organic material from Lake Iroquois sediments, Lewiston, N. Y.	Rubin and Alexander 1960 (D)
	I-838	12,100 ±400	Wood in the Iroquois sediment 4.5 mi. north of Lockport, N. Y.	Buckley <i>et al.</i> , 1968
	W-883	12,080 ±300	Organic material from Lake Iroquois sediments, Lewiston, N. Y. (previously run as W-861).	E. H. Muller, 1956a
	Y-391	11,570 ±260	Wood from Lake Iroquois bar, Hamilton, Ontario	Dreimanis, 1966

TABLE 2—Continued

Event	Date Number	Age-Years B.P.	Remarks	Reference
<i>B) Defining Glacial Recession on Northwestern N. Y.</i>				
Minimum for recession from:				
Gowanda and Lake Escarpment M. (may also date late Whittlesey early Warren I)	I-3665	12,730 ±220	Organic detritus in lake silts, at 810 ft. A.T., 2.4 miles south of North Collins, Erie Co., N. Y.	Calkin and McAndrews, 1969
Lake Escarpment M. (distal side)	W-507	12,020 ±300	Wood over outwash, southeastern-most Erie Co., N. Y. (Nichols Brook at Cherry Tavern).	Muller, 1960, 63, 65a
"	I-4043	13,800 ±250	Same as above except specimen of organic detritus taken 25 cm above outwash. Stratigraphically below spec. W-507.	This report
"	I-4216	14,900 ±450	Same location as above (I-4043) except dated material from 2 cm above outwash (23 cm below I-4043).	This report

†Dates reported are based on the standard half-life value for C-14 of 5568 years. Dates above must be increased by 350 to 400 years based on the more accurate half-life of 5730 years.

*According to Dreimanis (1966, this journal) these date the transition from Lake Arkona to Lake Whittlesey.

‡(D) in reference column notes that date is also referenced in summary of Dreimanis (1966, this journal).

sion from the outer part of the Lake Escarpment Moraine of 14,900 ± 450 (I-4216) and 13,800 ± 250 (I-4043) years B.P. Two other little publicized dates give minimum dates, one for recession from the Gowanda Moraine of 12,730 ± 220 (I-3665) (Calkin and McAndrews, 1969) and the other for initiation of Lake Iroquois at Lockport, New York, of 12,100 ± 400 (I-838) (Buckley and others, 1968). Complete analysis of these four dates and their stratigraphic and paleontologic significance is currently being studied (Calkin and McAndrews, 1969) and will be treated in detail in subsequent publications. However, a brief resume is given below.

Initial dating of Lake Wisconsin ice retreat in western New York as 12,020 ± 300 (W-507) was provided by Muller (Merritt and Mueller, 1959). The dated material was spruce wood, collected from marly silt overlying outwash just south of the Lake Escarpment Moraine at Nichols Brook, Cheery Tavern, southeastern-most Erie County, New York. This date was reasonably interpreted as a minimum date for recession from the Lake Escarpment Moraine because of the position of the lacustrine marl on the coarse gravelly outwash in front of the Lake Escarpment Moraine. Woody detritus collected more recently from a few centimeters above the outwash (probably stratigraphically below the site of the original collection by Muller) gives a new minimum date of retreat from the distal side of the Lake Escarpment Moraine of 14,900 ± 450 years B.P. (I-4216). This date appears to be corroborated by another date on the peat 25 cm above I-4216 of 13,800 ± 250 years B.P. (I-4043). This date of 14,900 is considerably older than the average dates for transition from Lake Arkona to Whittlesey (table 2) and in turn for the Port Huron maximum. Hence, there is some suggestion that the inception of

Lake Whittlesey and the time of the Port Huron maximum may correlate with a local readvance to the Gowanda Moraine or to the Hamburg Moraine (fig. 1).

A minimum date of recession from the Gowanda Moraine of $12,730 \pm 220$ years B.P. (I-3665) was recently obtained from a horizon of silty peat overlain by stream deposits exposed in a stream cut 4.5 miles south of North Collins (fig. 1). Deposition of the peat occurred at the mouth of a long gully (referred to here as Winter Gulf) incised through the shale bedrock margin of the Allegheny Plateau. Because of the possible importance of this date in the glacial lake history, the stratigraphic section from which the dated material was taken is given below.

<i>Depth</i>	<i>Description</i>
	Top of bank
0-30 cm.	Soil horizon, silt
30-138 cm.	Shale pebbles and cobbles, imbricated (probably by current moving lakeward from Winter Gulf stream), mottled gray-brown matrix of silt.
138-193 cm.	Organic detritus embedded in gray clay and silty clay; dated peat (12,730 B.P.) from 178 cm; this horizon appears to grade "landward" into a 1- to 2-m-thick laminated clay and silt sequence.
193 cm.	Stream bottom, elev. 807 ft. A.T. \pm 10 ft.
193-265 cm.	Sand and gravel, bedded
265-343 cm.	Silt, bedded, with numerous scattered shale pebbles
343-443 cm.	Sand, fine; bedded; few silt laminae and scattered shale pebbles.

The organic material noted in the section above includes spruce cones and wood, as well as a pollen spectrum illustrative of periglacial, open-forest conditions (Calkin and McAndrews, 1969). Although rooted material was not found, pollen of shallow-water plants was so plentiful as to imply an origin from the immediate area.

The nature and position of the dated peat and the comparison of this 12,730 date with others of the Erie Basin suggest that the peat was deposited during the late stage of Lake Whittlesey or during the highest Lake Warren (Warren I) stage. The Whittlesey water plane would have been 45 feet above the peat, while the Warren I plane would have been at the level of the top of the peat or up to five feet above the dated material. The occurrence of shallow-water floral remains in the peat, and the position of the peat beneath alluvial gravel and over a sequence including fine lake deposits, may slightly favor correlation with the Warren I stage. The protected environment suggested by the presence of great quantities of organic material would have been provided in late Whittlesey time by the construction of the spit built eastward across this arm of the lake at North Collins (see fig. 3).

One alternative hypothesis is that the organic materials are of Lake Arkona age and were drowned during water rise to the Lake Whittlesey stage. If the standard deviation error of 220 years were added to the 12,730 date, the resulting figure of 12,950 years would agree with dates for initiation of Lake Whittlesey in the Erie basin, which average 12,900 years. However, the stratigraphy tabulated above suggests a sequence of lowering lake levels rather than the rising sequence required by this last hypothesis. Therefore, correlation with Lake Whittlesey or Lake Warren I is favored in this report.

The fourth date of $12,100 \pm 400$ B.P. years (I-838) was taken on spruce wood from Lake Iroquois silts on the Thomas E. Malloy property 4.5 miles north of Lockport, New York (fig. 1). The wood, collected and dated by Richard McCarthy of Lockport, occurs in lake silts which are overlain by gravel related to a low stage of Lake Iroquois. This date is in good agreement with the three previous dates of

Lake Iroquois deposits in this area, which together average 12,103 years. Although the new 12,100-year date is only a minimum one for ice recession, it is probably reasonably close to the time of opening of the Rome outlet and the end of the glacial lake sequence in the Erie basin.

CONCLUSION

The sequence of events and the correlations discussed in this paper are summarized in a general way in Table 1. At least nine and possible ten lake stands may be distinguished by tilted shore features in the northeastern corner of the Lake Erie basin. However, of these, only Lake Whittlesey, Warren I (highest Warren), and Warren III (lowest Warren) have left shore features which are strong enough and continuous enough to be traced with certainty to type areas outside New York. More in the way of correlation may be accomplished when detailed mapping has been carried through southern New York and Pennsylvania into Ohio, where the strand lines are horizontal.

The multiplicity of the Warren beach ridges in this area, perhaps due to its favorable geographic location for wave attack (exposed to maximum fetch for prevailing southwesterly winds), prohibits clear differentiation of a middle Warren level. A few well-developed beach ridges near North Collins intermediate in elevation between Whittlesey and Warren I levels may suggest the existence of an Arkona or other lake stand not recorded previously in this area.

There is no evidence to delineate definitely the direction of drainage of these lakes. No evidence has been found for eastward drainage of post-Warren lakes, as suggested by Wayne and Zumberge (1965) and others.

An equidistant plot of the shore features suggests that the amount of isostatic uplift of northwestern New York decreased rapidly from Whittlesey through Dana time. The maximum uplift recorded on the Buffalo isobase is approximately 170 feet since Lake Whittlesey time.

Recently published radiocarbon dates cast some doubt on the correlation of the Lake Escarpment Moraine of western New York with the Port Huron maximum and the initiation of Lake Whittlesey recorded in Michigan. Alternatively, if the Lake Escarpment Moraine does correlate with the rise to Lake Whittlesey, this rise may have occurred several hundreds of years earlier than previously published dates suggest. The transition from Lake Whittlesey to Lake Warren I may have occurred about 12,700 years B.P. The cessation of the glacial lake sequence in the Erie basin and the inception of Early Lake Erie and Glacial Lake Iroquois occurred prior to 12,100 years B.P.

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**STRAND LINES of the
GLACIAL GREAT LAKES,
NORTHWESTERN NEW YORK**

by Parker E. Calkin
1969

1/62,500

1 1/2 0 1 2 3 4 miles
contour interval 20 feet

EXPLANATION

beaches
scarp or
bench
Lake Whittlesey

? Prominent beaches
between Whittlesey
and Warren in
elevation

beaches
scarp or
bench
Lakes Warren

Bedrock outlines
(from Buehler and
Tesmer, 1963)

beaches
scarp or
bench
Lakes Below Warren

Beaches mapped
by Fairchild (F) or
Gilbert and Taylor
(GT) now barely
distinguishable

beaches
scarp or
bench
Lakes Below Warren

(Includes all separate features
below general level of Warren
III. Some may be subaqueous
bars of Lake Warren)

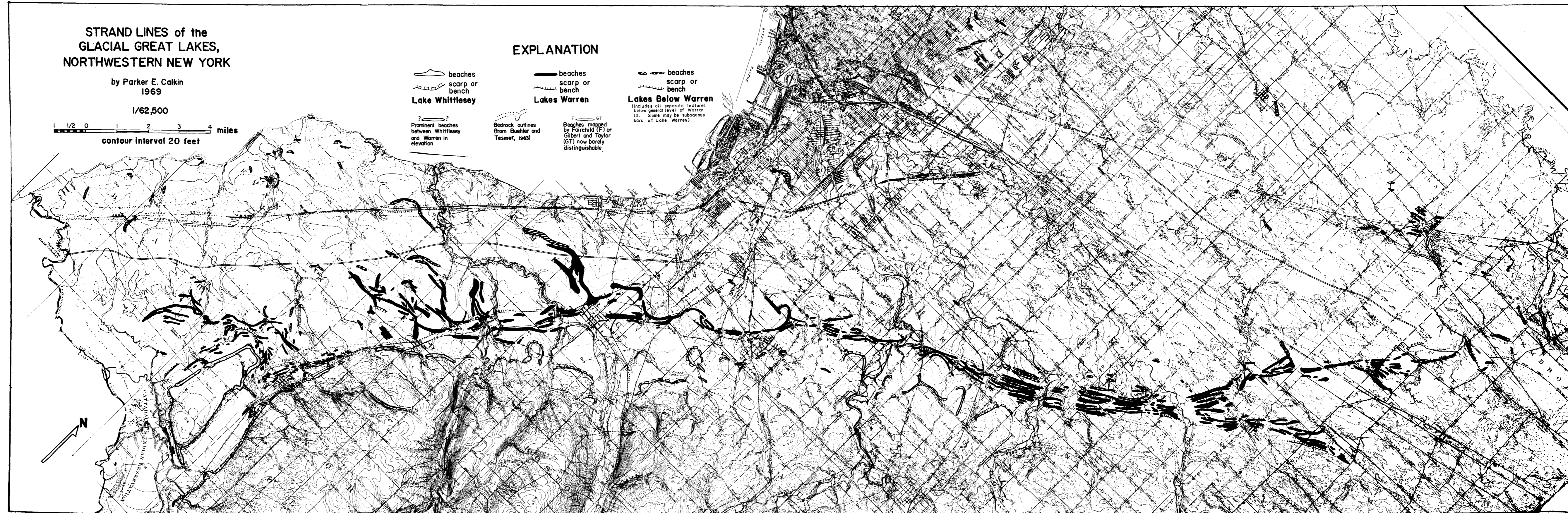


FIGURE 3. Strand lines of the Glacial Great Lakes, Northwestern New York.