Glacial Lake Levels and Eastern Great Lakes Palaeo-Indians

Lawrence J. Jackson,[1] Christopher Ellis,[2,3] Alan V. Morgan,[3,4] and John H. McAndrews[5,6]

[1]*P.O. Box 493, Port Hope, Ontario, Canada L1A 3Z4*
[2]*Department of Anthropology, University of Western Ontario, London, Ontario, Canada N6A 5C2*
[3]*Quaternary Sciences Institute University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada*
[4]*Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, N2L 3G1 Canada*
[5]*Department of Botany, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, M5S 2C6, Canada*
[6]*Departments of Botany and Geology, University of Toronto, Toronto, Ontario, M5S 1A1, Canada*

This article investigates changing lake levels in the late Pleistocene eastern Great Lakes in order to gain insights into the Early Palaeo-Indian occupations. Significant new information bearing on lake level history is provided, notably the first well-documented deposits of a high water level above modern in the ca. 11,000–10,300 B.P. period in the southern Lake Huron basin. The lake level information, along with paleoenvironmental and site data, reinforces site age estimates to the 11th millennium B.P.; suggests significant numbers of sites have been inundated by rising water levels; provides specific information on the setting of archaeological sites such as placing the Parkhill site adjacent to a large lake estuary; indicates reasons for the attractiveness of shorelines to Palaeo-Indians including persistence of more open areas conducive to higher game productivity; and points to ideal areas for future archaeological site survey, particularly in the Lake Erie drainage. © 2000 John Wiley & Sons, Inc.

INTRODUCTION

Changes in the water levels of the eastern Great Lakes and the relationship between these changes and the earliest human occupants have been recognized as important for many years (cf. Ritchie, 1957; Mason, 1958, 1960, 1962; Quimby, 1958; Roosa, 1965, 1968; Fitting et al., 1966; Deller, 1976, 1979; Storck, 1979, 1982, 1984; Jackson, 1983; Julig and McAndrews, 1993). Indeed, studies have focused so much on the apparent association between abandoned shorelines of the early glacial lakes and Palaeo-Indian settlement that the myth seems to have arisen that archaeologists have looked for such sites only along those strandlines—a perspective some of us have attempted to dispel (e.g., Ellis and Deller, 1990:50). There have

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even been claims that some researchers have invented shoreline features at their sites since it is either unthinkable that sites would occur without the associated strandline or, alternatively, because the strandlines have figured so importantly in dating sites in the absence of direct radiometric determinations (Griffin, 1977:10).

The sequence and change of lake levels in the Great Lakes basins is one of the most complex problems in North American geology and is continually being interpreted and reinterpreted. Therefore, we see a real need to produce periodic overviews of the proposed relationship between these lake levels and the Palaeo-Indian occupations as is provided here. Our main geographic area of concern is southern Ontario, specifically the drainage basins of the modern Great Lakes Huron, Erie, and Ontario, as well as the smaller but related drainage basins of Lakes Simcoe and Rice (Figure 1). Temporally, we focus on the time period beginning around 11,500–11,000 B.P. because we assume that the Great Lakes area Palaeo-Indian occupation can be no earlier than the earliest dated western occurrences of fluted points (e.g., western Clovis; see Haynes, 1992; Fiedel, 1999). Our specific goals are (1) to review and summarize the most recent geological evidence for lake level fluctuations in the Late Pleistocene/Early Holocene; (2) to examine the implications of those fluctuations for the locating (i.e., as guides to future site survey), sampling (i.e., delimiting biases in the available and accessible Palaeo-Indian site samples because of fluctuating water levels), and dating (i.e., geochronology) of early archaeological sites in the area; and (3) to review some potential reasons for the apparent attractiveness of certain of these strandlines for human occupation, and particularly those strandlines traditionally assigned to the main stage of glacial Lake Algonquin in the modern Huron basin (see Karrow et al., 1975). In the following, we examine the evidence from each of the lake basins of concern here, moving from west to east.

HURON BASIN GLACIAL AND POST-GLACIAL LAKE LEVELS

In the eastern to central Great Lakes area, the main focus of research has been on the relationship between the Palaeo-Indian occupation and ancient water levels in the Lake Huron basin. In particular, archaeologists in southern Ontario have focused much attention on site survey of the strandline usually assigned to the Main stage of glacial Lake Algonquin. A large number of Early Palaeo-Indian sites have been reported in southern Ontario lining the landward side of its shoreline, but none have been found at lower elevations (e.g., Deller, 1976, 1979; Storck, 1979, 1982; Deller and Ellis, 1992a, 1992b). This lake, which also extended into the modern Lake Michigan basin and southeastern Lake Superior basin, was at an elevation above that of modern Lake Huron and may have flooded a relatively narrow strip of what is today dry land in the southern Huron basin, as well as more extensive areas of southcentral Ontario extending inland from modern Georgian Bay to the area surrounding the current Lake Simcoe basin (Karrow et al., 1975; Figure 2).

Although earlier investigators tended to date Main Lake Algonquin before ca. 11,000 B.P. (e.g., Hough, 1958; Prest, 1970), the current traditional view of that

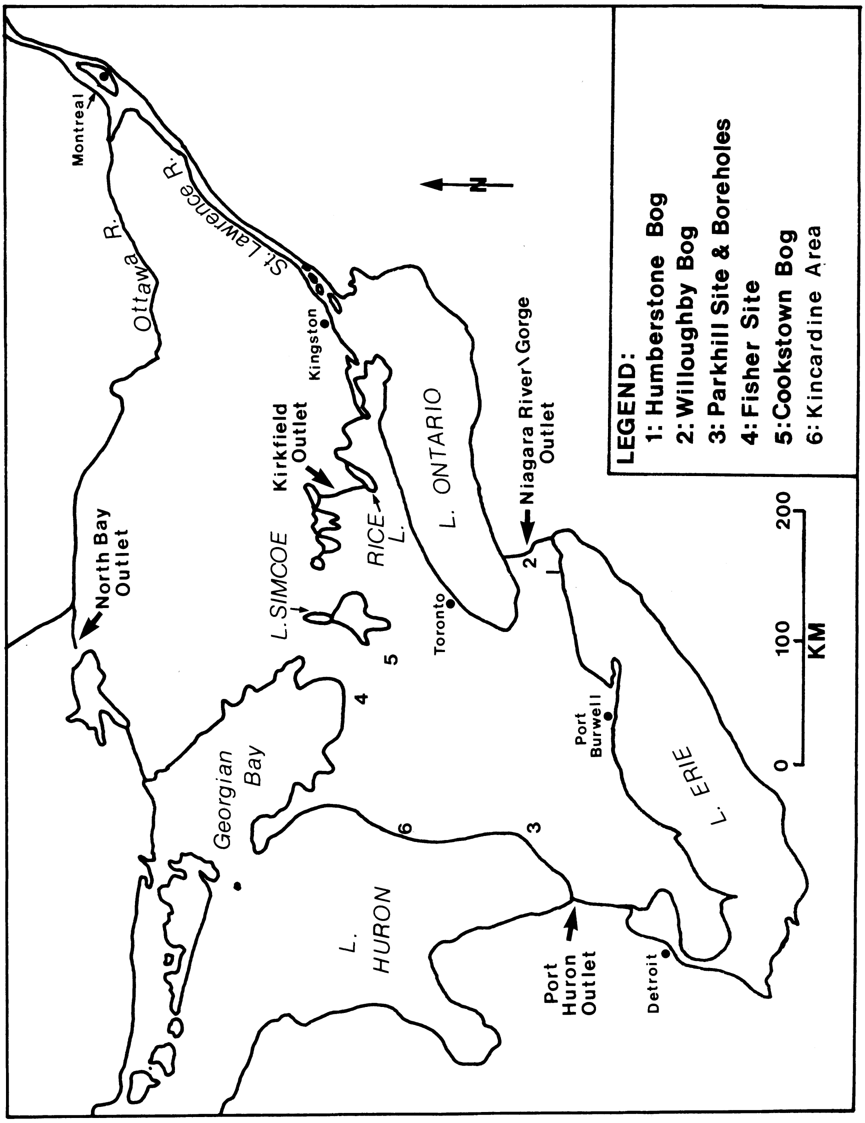

Figure 1. Map of southern Ontario showing modern lake levels and important locations, sites and outlets.

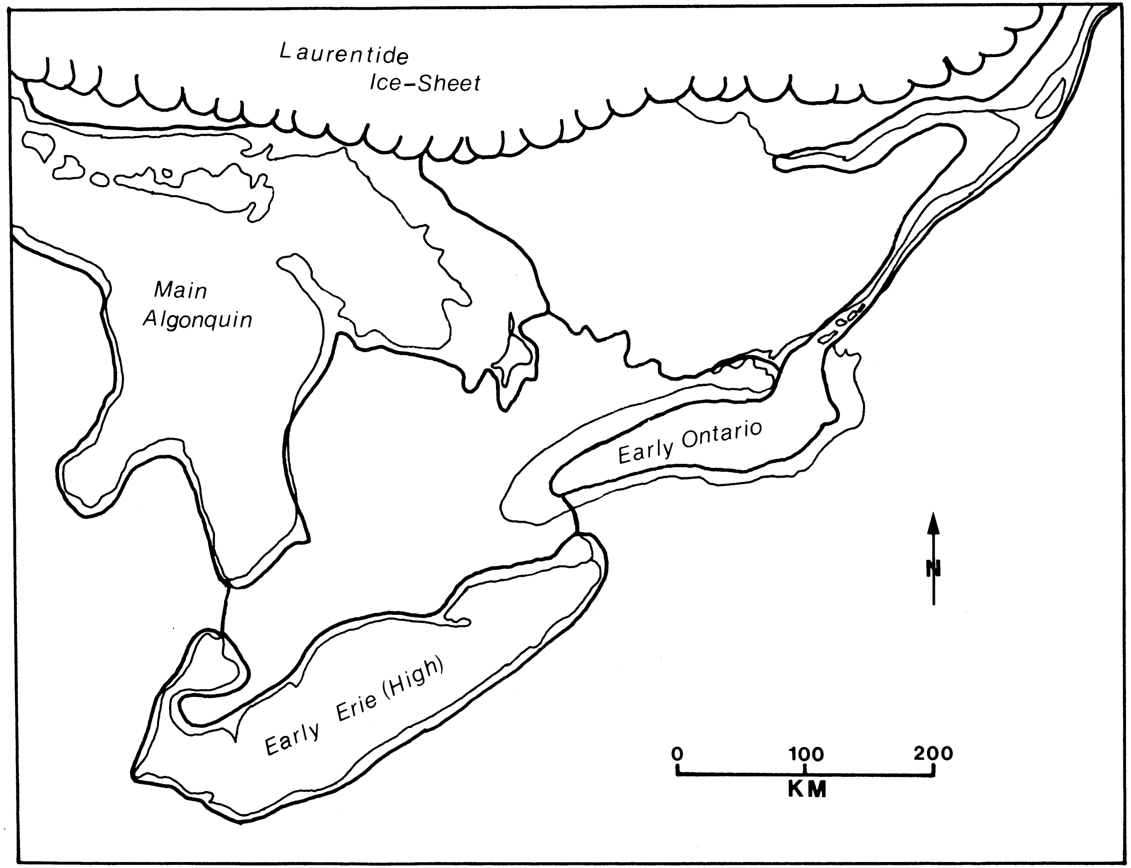

Figure 2. Map of Late Glacial lake levels, ca. 11,000–10,500 B.P. (according to Karrow et al. [1975], Tinkler et al. [1992], and Coakley and Karrow [1994]).

lake's age span is from ca. 11,200 to 10,4000 B.P. based on Karrow et al. (1975). In this model, the immediately pre-Main Algonquin lake drained through a Fenelon Falls (or Kirkfield) outlet (Figure 1) into the modern Lake Ontario basin. However, with ice retreat, isostatic uplift at the outlet raised water levels in the Huron Basin at that outlet and formed Main Lake Algonquin.

The outlet to Lake Ontario was then closed off, and Algonquin drainage shifted solely southward through the Port Huron outlet into the Lake Erie basin. Subsequently, retreat of the main Laurentide ice sheet to the north exposed lower outlets near North Bay, Ontario (Figure 1). As a result, water levels dropped from the Main Algonquin level stepwise through several Post-Algonquin lake levels as successive lower outlets were exposed. By ca. 10,000 B.P., water levels had dropped dramatically to much below those of modern times forming Lakes Stanley and Hough in the modern Huron and Georgian Bay basins, respectively (Figure 3). In this model, lake deposits and valley terraces graded to the Main Algonquin level are known in the Kincardine area (see Figure 1) of the more northern Huron basin, indicating the lake was in existence until some time after 10,500 B.P. (Karrow et al., 1975:78–79; Karrow, 1986: Table 1). This age estimate is based on direct dates on lake deposits attributed to Main Algonquin and also, evidence at some pollen sites that the lake persisted beyond the transition from spruce to pine dominance (Anderson, 1971; Karrow et al., 1975:78–79). This transition averages 10,600 B.P. at eleven sites in the eastern Great Lakes area (Karrow et al., 1975:53). The accuracy of the dating of this transition is questionable. For example, there may be some contamination by "old carbon" of dated lake sediments, and some of the averaged ages used actually precede the exact transition where spruce pollen frequency equals pine pollen. In addition, several of the sites are from Ohio to the south, and the transition may be earlier in that area than in Ontario. In fact, Muller (1999) has recently mapped the spread of various kinds of vegetation into Ontario based on ^{14}C dated pollen cores. These date indicate that the spread of pine in significant percentages into more northern areas such as the Lake Huron area did not occur until between 10,500 and 10,000 B.P. Regardless, the end of Main Algonquin is estimated at ca. 10,400 B.P. from a basal age of 10,200 $\pm$ 150 B.P. at the base of a peat bog near Cookstown (see Figure 1) in southcentral Ontario formed on, and thus overlying, the presumed drained bed of the lake (Karrow et al., 1975:53, 58–59).

Lakes Stanley and Hough drained to the east down the Ottawa River area into the St. Lawrence River as the southern Port Huron outlet of Main Algonquin was abandoned. However, by ca. 5000 B.P., isostatic rebound in the North Bay outlet closed it off. This closure caused water levels to rise and once again a lake level higher than modern levels was formed in parts of the Huron basin that drained at Port Huron; this high level is referred to as the Nipissing Phase (Lewis, 1970; Larsen, 1985a). This immense lake was at an elevation such that it also extended into the modern Lake Michigan and Lake Superior basins. In essence, the three modern upper Great Lakes were one contiguous lake in Nipissing times. In the southern Huron basin, it was generally believed that Nipissing achieved the same elevation as that of the earlier Main Algonquin (184.4 m) and shared the same strandline.

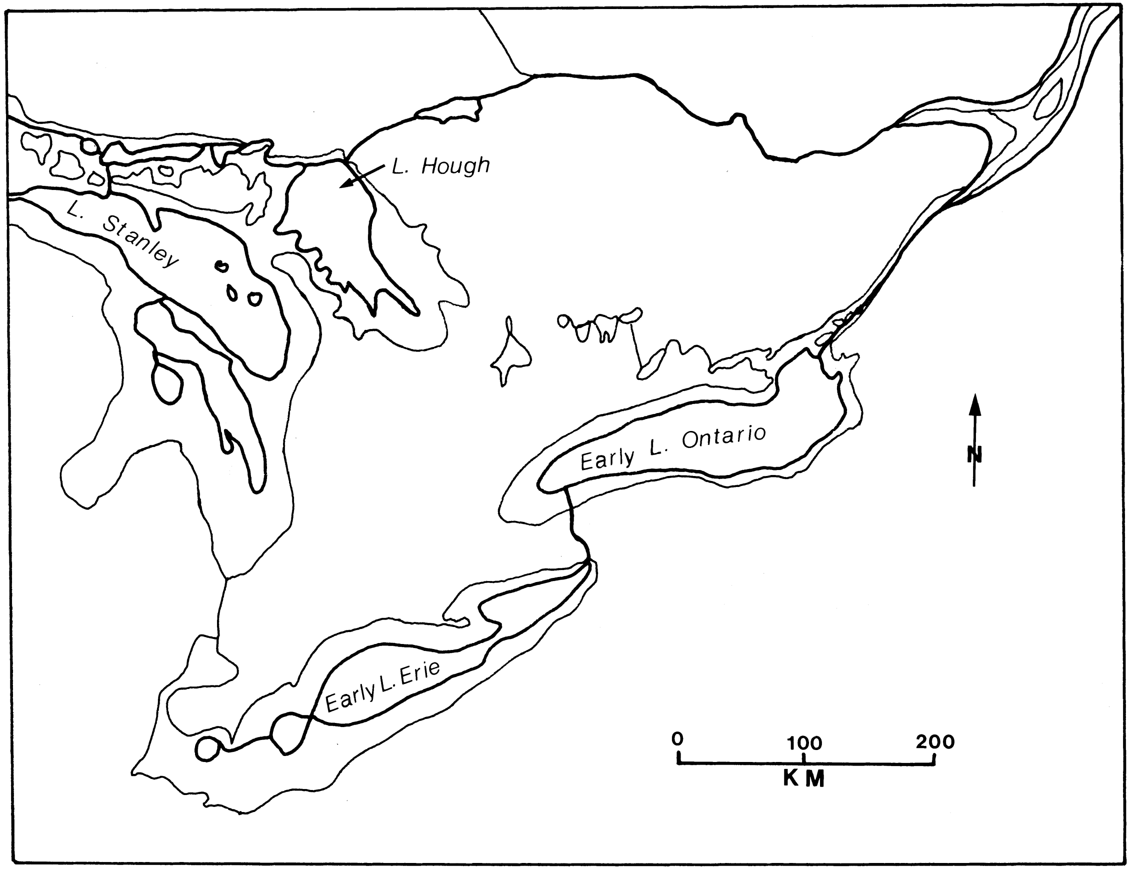

Figure 3. Map of lake levels at time of lakes Stanley and Hough (ca. 10,000 B.P.).

Hence, this abandoned strandline was referred to by some as the Nipissing–Algonquin in the literature (e.g., Cooper, 1979). More isostatic uplift farther north, however, meant that most of the Lake Simcoe area of southcentral Ontario flooded by Algonquin was not reoccupied by Nipissing waters (see, e.g., Fitzgerald, 1985).

Since early Palaeo-Indian (fluted point) sites are not known on the inferred bed of Algonquin but line its shore, it is usually inferred that these occupations were contemporary with that lake (cf. Roosa, 1977a, 1977b; Storck, 1982; Ellis and Deller, 1986; Deller and Ellis, 1988, 1992b)—an age estimate perfectly compatible with the available radiocarbon dates for Early Palaeo-Indian sites elsewhere in North America (e.g., Levine, 1990; Haynes et al., 1992). While this geochronological estimate may provide an age compatible with radiocarbon estimates from archaeological sites, in more recent years, there have been some questions raised as to not only the age but also the extent of Main Algonquin.

The first question concerns the extent of this lake in the southernmost part of the Huron basin. As noted above, one view is that Algonquin and Nipissing shared the same strandline. By 1980, however, and although he continued to believe the Algonquin and Nipissing strandlines were one and the same, Karrow (1980) was able to show that all of the dates in the southern Huron Basin area were of Nipissing age. Although there were some deposits of possible Algonquin affinity in the area (Karrow, 1980:1274), none of these had been dated to confirm such an inference. Karrow (1980) argued that the Nipissing transgression had removed and destroyed most of the older Algonquin deposits. Moreover, the idea that Algonquin and Nipissing reached the same elevation in the area was based on the concept of a "hinge-line" across the southern Huron basin. In essence, south of the hinge-line, isostatic rebound has not occurred or the beaches have not tilted (i.e., the Algonquin beach stayed level), whereas to the north in the Huron basin there was considerable deformation or tilting due to isostatic uplift (see., e.g., Sly and Lewis, 1972:58). However, some argue this viewpoint is contradicted by evidence of continued isostatic uplift in the area south of the hinge-line even today (Kaszycki, 1985:111; Larsen, 1985a:65, 1987:8).

Building upon these and other inconsistencies, as well as more recently collected data and different models of the projected elevations of lake planes, some researchers have provided new interpretations of Main Lake Algonquin's age and extent (Hansel et al., 1985; Larsen, 1985a, 1987). As an example, Kaszycki (1985) has studied deposits in the area north of the Kirkfield outlet in southcentral Ontario. These studies have led to three conclusions that contradict the traditional (i.e., 1970s) view of Main Lake Algonquin. First, Main Lake Algonquin may have drained through the Kirkfield outlet throughout its history, not through Port Huron. Second, using as a guide different models of uplift due to isostatic rebound and projecting the elevation of Lake Algonquin from the Kirkfield area throughout the Huron basin, Kaszycki (1985) concluded that the water plane of Algonquin only reached an elevation of 131 m asl or 46 m below the modern level of Lake Huron (Figure 4; see also Larsen, 1987: Figure 16). In sum, certain researchers believe Main Algonquin never reached anywhere near the Port Huron outlet or the modern location of the

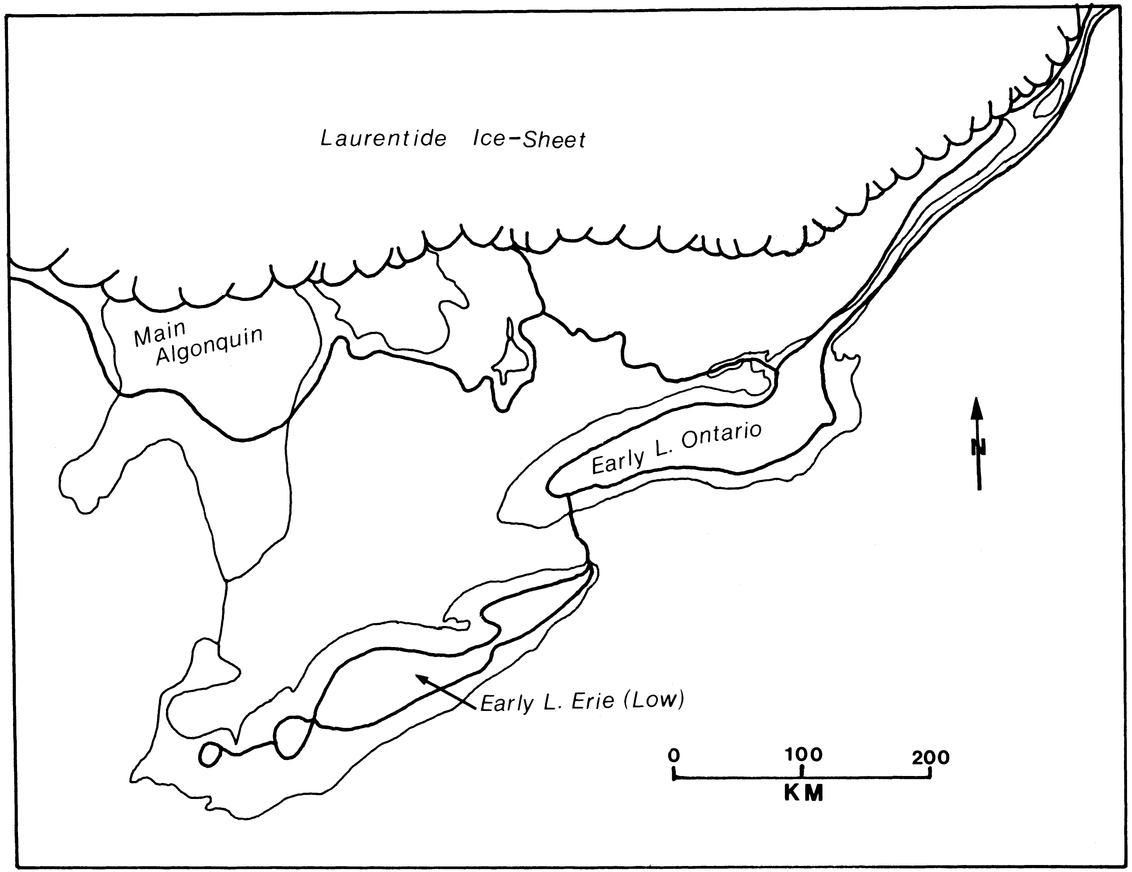

Figure 4. Map of Main Lake Algonquin extent (according to Kascycki [1985] and Larsen [1987]). Laurentide ice-sheet position assumes Main Algonquin dates to pre-11,200 B.P.

abandoned Nipissing strandline in the southernmost Huron basin area. Hence, the absence of dated Algonquin deposits in the “Nipissing-Algonquin” strandline in that area is explained not as a product of their being destroyed by the Nipissing transgression. Rather, the lake never reached anywhere near the area because its actual margin was located some 100 km to the north. Finally, Main Lake Algonquin, for the most part, drained down the Kirkfield outlet/Trent River into the modern Lake Ontario basin and that it was gone by ca. 11,500 B.P. or 300–400 B.P., before the time when the traditional view argues Main Algonquin actually began (Kaszycki, 1985:119–121). In this view, Kaszycki (1985:120) clearly implies, although this is not explicitly stated, that the sample (i.e., peat formed as presumed Main Algonquin water drained from the Cookstown bog site) used by Karrow et al. (1975:78–79) to date the end of Main Algonquin actually dates the drainage of a Post-Algonquin “Upper Group” lake, namely Ardtrea, at ca. 10,500 B.P. that also covered the Cookstown area. Needless to say, such a reinterpretation calls into question the use of Main Lake Algonquin strandlines to date the Palaeo-Indian occupation because the lake realistically cannot be contemporary with those occupations. However, it also raises new puzzles.

First, and from an archaeological perspective, why is it that numerous Early Palaeo-Indian finds in the southern Huron basin, including large and complex sites occupied on several occasions (Deller and Ellis, 1992b; Ellis and Deller, 2000), do line the “Nipissing” strandline but do not occur below it? Early Palaeo-Indian sites and findspots in the interior, more removed from Lake Huron, occur below as well as on and above the strandlines of the much older Lakes Warren and Arkona (ca. 12,000–14,000 B.P.), indicating they postdate such lakes. However, the fact that none occur below the “Nipissing” strandline suggests that the area must also have been flooded in Palaeo-Indian times. As has been noted elsewhere (Ellis and Deller, 1986), one could argue that no real survey of areas below the strandline of Nipissing has been done as opposed to areas above it. Also, the Nipissing transgression could have removed and destroyed Early Palaeo-Indian sites below its level, just as some geologists argued that the transgression had in fact destroyed the earlier Main Algonquin lake deposits. Alternatively, Nipissing could have buried, and made difficult to locate, many early sites, as has been demonstrated by studies of Middle Archaic sites in the Saginaw Bay area of Michigan (Larsen, 1985b; Lovis, 1989). Nonetheless, some attention has been devoted to looking below the Nipissing strandline and specifically in the Parkhill site vicinity of the southeastern Huron basin (cf. Deller, 1976, 1979). In addition to numerous Early and Middle Archaic components (ca. 10,000–5,000 B.P.), these surveys have located below that strandline several Late Palaeo-Indian sites with Plano and Holcombe points which, on typological grounds, date between ca. 10,500 and 9500 B.P. All these artifacts have been water-rolled and smoothed from being submerged in the transgressing Nipissing waters (Ellis and Deller, 1986). This information discredits the idea that earlier sites have been destroyed or have been deeply buried by the transgression in that vicinity. Early Palaeo-Indian sites should have been found by now if they existed below the Nipissing Phase beach in that area of the Huron basin.

A second puzzle results from the work carried out in conjunction with the excavations at the Parkhill Early Palaeo-Indian archaeological site (Roosa, 1977a, 1977b) in the southern Huron basin. This site is located adjacent to a small creek on the south and to the immediate west overlooks the old lake plain of the Nipissing Phase. In 1975 and 1977, three 5-cm diameter cores were extracted from boreholes by A. V. Morgan along the creek adjacent to the Parkhill site ca. 1 km south of the Nipissing beach and lake plain and the site itself (Figure 1; Morgan et al., 2000). A comparable sequence was found in each core, a stylized version of which is presented here (Figure 5). The lowest unit (1) represents St. Joseph Till, which is associated in the area with the Port Huron ice advance of ca. 13,000 B.P. This unit was overlain by a fluvial deposit (Unit 2) associated with the formation of Parkhill Creek. Overlying this layer was 30 cm of calcareous pond clay (Unit 3) including plant macro-fossils as well as fossil coleoptera which is ^{14}C dated to 10,870 $\pm$ 90 B.P. (WAT-376). The next unit (4) is a 3–4.2-m-thick grey lake-deposited clay with small amounts of organic detritus and a few molluscs. This unit clearly demonstrates a large elongated estuary of a glacial lake extended for a considerable distance inland up the creek and its tributaries adjacent to the Parkhill site. The plant macrofossils from Unit 3 include spruce needles and fossil Coleoptera that suggest an open, spruce woodland (Morgan et al., 1983:358, 2000). Moreover, pollen analysis of the Unit 3 and 4 sediments from one of the boreholes by McAndrews (Figure 6) indicate they represent Zone I, which is the spruce-dominated pollen zone mainly dated elsewhere as prior to ca. 10,500 B.P. (Karrow et al.,. 1975). There is a suggestion near the top of the Unit 4 deposit of a decline in spruce and a rise in pine pollen which argues the preserved deposit dates to up until the transition to pine pollen in the area (i.e., the transition from Pollen Zone 1b to 2). As noted earlier, Muller's (1999) mapping of the spread of critical percentages of pine pollen into the Parkhill vicinity indicates this transition occurred between 10,500 and 10,000 B.P. The top of Unit 4 is disconformable and is overlain by Unit 5: a 30 cm thick, noncalcareous, peaty sand and clay. The base of Unit 5 is dated to 5410 $\pm$ 100 B.P. (WAT-392) and is, in turn, overlain by more recent pond and stream deposits (Figure 5).

The stratigraphy, sedimentology, macro-fossils, coleoptera, pollen, and the ^{14}C age associated with Unit 3, clearly indicate water levels rose in the southern Lake Huron area around 11,000 years ago. This rise led to a slower creek flow which deposited the unit and its organic inclusions. Unit 4 represents the *actual influx of late waters* associated with this rise which lasted until sometime beyond ca. 10,500 B.P. Unfortunately, the subsequent fall to the Stanley low stage at ca. 10,000 B.P. led to an increased stream gradient and erosion of the top of these deposits, so we do not know very precisely how long this lake level lasted. We do know, however, that the top of the lake deposits in the core are at 180 m asl and, therefore, that lake was most certainly above the modern Huron level of 177 m asl. Given that these are preserved *lake bottom* deposits, and that the top of the deposits themselves has actually been eroded, this late Pleistocene lake had to be higher than 180m, although it could not have been above 184.4 m, which is the elevation

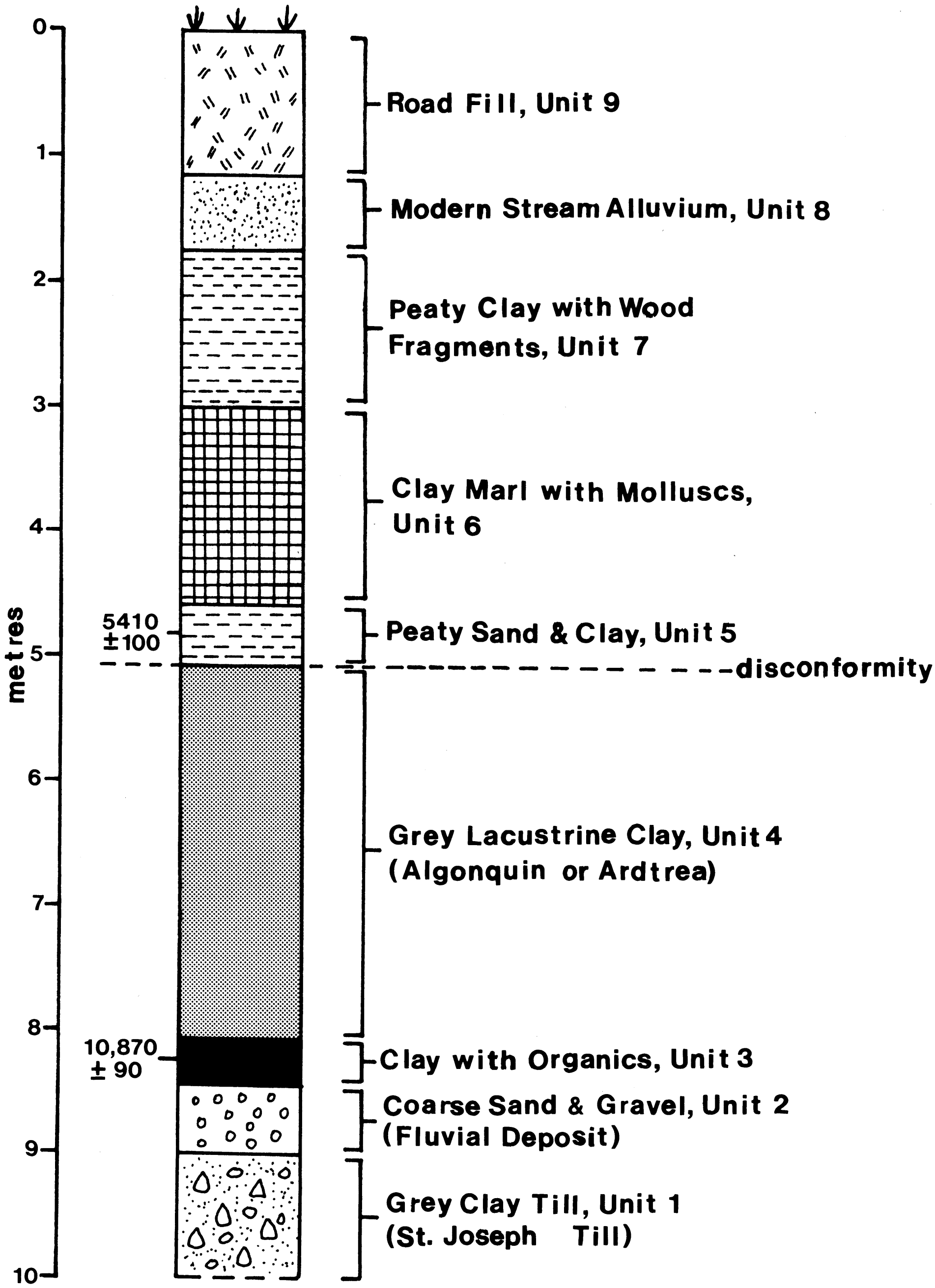

Figure 5. Stylized stratigraphy of Parkhill Creek boreholes.

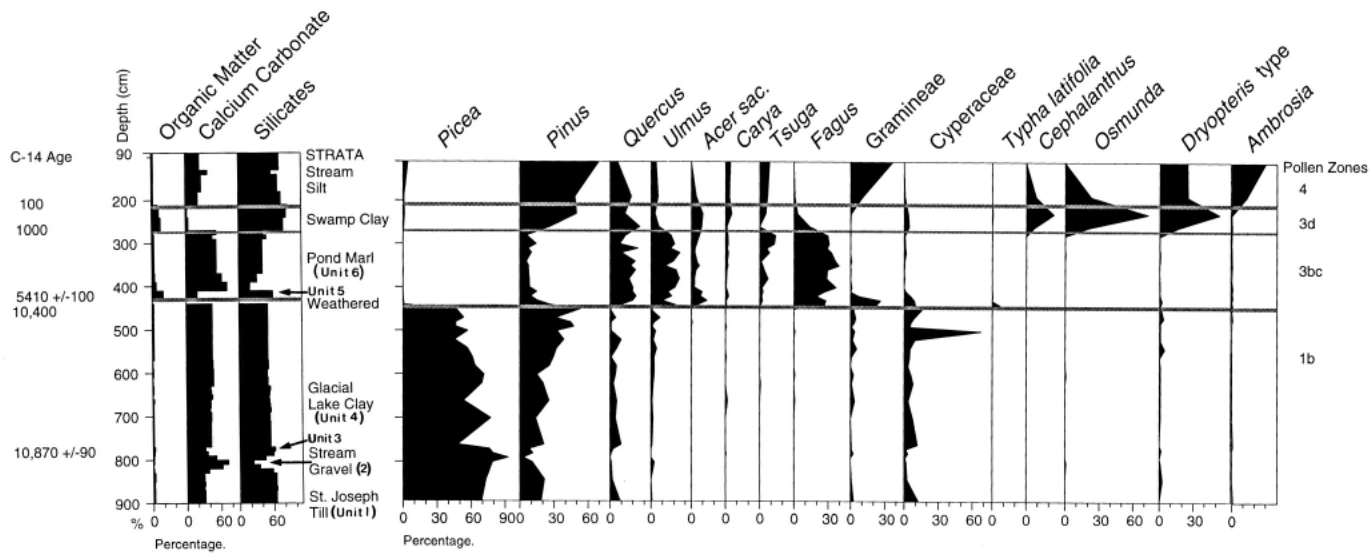

Figure 6. Parkhill Creek Core 234-75: Loss-on-ignition and fossil pollen diagrams. Loss-on-ignition follows Dean (1974). Only selected pollen and spore types are shown, but all pollen counts are deposited in the North American Pollen Database. The percentage sum is over 100 tree pollen; pollen preservation was good except above 190 cm. Pollen zonation follows McAndrews (1994): zone 4 Gramineae and *Ambrosia* are from weeds linked to Euro-Canadian farming. In subzone 3d there was upland mixed conifer–hardwood forest but *Cephalanthus*, *Osmunda*, and *Dryopteris* type indicate local shrub swamp. Zone 3bc reflects predominantly deciduous forest, but in the earliest levels Gramineae, Cyperaceae, and *Typha* indicate local fen and marsh. In Zone 1 Gramineae and Cyperaceae derive from plants growing in the openings of the boreal woodland. The C-14 ages of 100, 1000, and 10,400 were correlated from locally dated pollen zone boundaries.

of the unflooded Parkhill site itself in the area. Contrary to the views of Storck (1997:250), a large estuary of a lake was present in Palaeo-Indian times flooding the modern creek valley beside, and extending inland from, the Parkhill site location, although its precise elevation, and thus placement, can be debated. This lake may be Main Lake Algonquin because its age is exactly the same as lake deposits dated by ^{14}C and attributed to Algonquin to the north at Kincardine and in the southwestern Georgian Bay basin area (Figure 1; see Karrow et al., 1975:78–79, 1995). If so, this lake was certainly not 46 m below the current level of southern Lake Huron nor 100 km to the north of the area as is predicted for that lake stage by the more recent models of its history (see Figure 4). Finally, with the rise of lake levels by Nipissing at ca. 5500 B.P., deposition of sediments recommended with Unit 5.

As noted, one could interpret Unit 4 as Main Lake Algonquin and suggest an age of ca. 11,000 to some time after 10,500 B.P., totally consistent with the Karrow et al. (1975) interpretation of the age and position of that lake. This interpretation would also explain why Early Palaeo-Indian sites do not occur on the Nipissing bed because, of course, it was also the Algonquin bed. However, it is possible to interpret the lake deposits in another way which is also equally compatible with the suggested revisions of Main Lake Algonquin provided by Kaszycki (1985) and others. In essence, because of isostatic uplift and the position of lake outlets, the Post-Algonquin beaches such as Ardtrea in the more northerly part of the Huron basin (e.g., Lake Simcoe lowlands) are below the earlier Algonquin level. However, in the southern Huron basin, rather than regressing as in the north, these beaches would have been at progressively higher elevations (Kaszycki, 1985: Figure 9; Larsen, 1987:24, see also Finamore, 1985:130–131). Even according to Kaszycki (1985: Figure 10), rising water may have actually reached levels near or above that the southern margin of modern Lake Huron. Indeed, the suggestions of higher water levels in this period in the Lake Erie basin (see below and Pengelly et al., 1997; Tinkler et al., 1992) indicate water levels rose high enough in the southern Huron basin to drain at Port Huron south into Lake Erie. Hence, we can suggest that the lake deposits in the Parkhill Creek cores indicate the level of an Upper Post-Algonquin lake, specifically or probably Ardtrea (see also Storck, 1997:250–251), actually rose up to an elevation and location close to that of, if not the same as, the level attained again by the later Nipissing phase. As noted earlier, Kaszycki (1985) implied this lake drained by around 10,500 B.P. or the same general time as Main Algonquin (Karrow et al., 1975).

This interpretation also suggests that the sites in southcentral Ontario investigated by Storck (1982) might be associated with Lake Ardtrea instead of Main Algonquin. In fact, Storck (1994:36–37, 1997:250–251) notes that the Fisher Early Palaeo-Indian site in that area has at least two local strandlines in close proximity to one another. One of these strandlines runs across the center of the site at a higher elevation (234–235 m), and Palaeo-Indian materials are found both above and below the elevation of the beach at that site. The second strandline, called the "intermediate" strandline (Storck, 1997:249–250) is at a lower elevation (230–231

m) and is adjacent to the site on its eastern margin; that is, Palaeo-Indian materials do not occur below the elevation of this second strandline. This intermediate strandline may have existed until about 10,500 B.P. or until the end of the spruce pollen zone, based on dating of adjacent correlative deposits on its lake bed (Storck, 1994:36, 1997:246). In fact, Muller's (1999) recent research indicates the spruce zone certainly persisted after 10,500 B.P. in the Fisher site vicinity. We should expect Algonquin and Ardtrea to be in close proximity to one another and around 230–235 m in the Fisher site area if the revisionist model is correct (see Kaszycki, 1985: Figure 9). We should also expect the strandlines in this area of Algonquin and Ardtrea to be reversed when compared to the southern Huron basin (i.e., Algonquin should be higher rather than lower than Ardtrea in this part of the basin). Therefore, it is plausible that the upper beach at Fisher is Algonquin and the lower beach with which the site is apparently contemporary is Ardtrea (Storck, 1997:250). Indeed, in Kaszycki's (1985) scheme, one must interpret the basal date of ca. 10,200 B.P. from the Cookstown bog, which is in the same general area of Ontario as Fisher (Figure 1), as dating the draining of Lake Ardtrea. Therefore, the comparable dating estimate from the nearby Fisher site for the lake of ca. 10,500 B.P. presumably would date Ardtrea's existence rather than the time of Main Algonquin.

As a final comment on the Parkhill borehole information, these data indicate waters rose in the southern Huron basin to a level above modern levels around 11,000 B.P. This dating would mean that the lake bed was available for human occupation before then. However, the fact that no fluted point sites occur on that lakebed might suggest that these sites are not only contemporary with that higher level and do not postdate it, but also they are no older than 11,000 years when water levels were low enough that the lake bed could also have been occupied. Yet it is also possible that the rise to the Algonquin/Ardtrea level destroyed earlier sites.

In summary, although there have been major suggested revisions of the age of Main Lake Algonquin by some geologists, from an archaeological perspective in terms of dating and finding sites, these changes may mean nothing for our interpretations. At worst, they may only mean that the Early Palaeo-Indian sites were on the shore of Lake Ardtrea, not Main Algonquin but are still around 11,000–10,500 years old and still show a marked preference for setting up campsites in littoral areas, a preference which is still in need of explanation.

LAKE ERIE BASIN

Although some attention has been paid to site survey along very early strandlines (> 12,000 B.P.) located much inland from, but still associated with, the Erie drainage basin (e.g., Deller, 1976, 1979), little attention has been paid to searching for Palaeo-Indian sites nearer Lake Erie. There are differences of opinion on the water levels in Lake Erie during the period ca. 11,200–10,000 B.P. In one model, which is the more traditionally held one, water levels were below those of modern Lake

Erie throughout this period. In direct contrast is the second model which suggests water levels were above modern Lake Erie throughout at least part of Palaeo-Indian times. We will discuss the low level model first.

The low water level model is quite complex. In contrast to lakes in the Huron basin of this age, in this model, the Erie basin apparently held several lakes rather than a single water body during much of this period (Lewis, 1969; Coakley and Lewis, 1985; Coakley, 1992). These multiple lakes were produced by a combination of low water levels and the fact that end moraines cross the area from northwest to southeast dividing the lake basin into western, central, and eastern sections. Until such time as drainage could cut through and down into these moraines, they acted as sills which controlled the levels in each area of the basin. As a result, the lake levels could be at different elevations in different parts of the basin.

This model argues water levels in the Erie basin were below the modern level throughout Early Palaeo-Indian times. After ice had retreated completely from the lake basin, Early Lake Erie formed about 12,500 B.P. This lake had levels as much as 30–45 m below those of modern Lake Erie (173.3 m asl). However, because of isostatic rebound at the main eastern outlets of the basin, but also perhaps due to the influx of water from Main Algonquin or a Post-Algonquin lake at Port Huron into the western Lake Erie basin, water levels rose relatively rapidly over time. Current estimates based on this model suggest the western, central, and eastern basins of Lake Erie sill contained separate lakes after 10,000 B.P. (Coakley and Lewis, 1985:206–208; Coakley, 1992: Figure 10). Estimates for the period ca. 11,000–10,000 B.P. place the water in the shallow western basin at around 15 m below modern level, in the central basin at around 20 m below modern level, and in the eastern basin at around 25 m below modern level (i.e., comparable to the levels shown in Figures 3 and 4). Given current basin topography, this means that roughly one third to one half the land surface today under Lake Erie waters, encompassing some 8000–12,000 km^2, would have been available for human occupation. This area included not only the submerged shoreline area but also, of course, many locations we would now regard as interior areas somewhat removed from those strandlines (up to as much as 65 km away in the western Lake Erie basin). Under this scenario, there seems little doubt that there are Palaeo-Indian sites under water; just how many will be discussed in more detail later.

More recently, and in direct contrast to the low water level model, investigators have put forward a model that argues for high water levels coexistent with high water levels in the Huron basin of Main Algonquin or Ardtrea during the period of ca. 11,000 to $<$ 10,500 B.P. These rises are seen by some investigators to be at least partly a product of large catastrophic outflows of water into the lower Great Lakes from the drainage of Lake Agassiz. Some of the waters of this immense lake, which existed adjacent to the ice sheet in northwestern Ontario and adjacent Manitoba, were released into the upper Great Lakes as the retreat of the Laurentide ice sheet exposed various outlets (see Teller, 1985, 1990). It is argued that these discharges led to the outflow of water from the Lake Huron basin via the Port Huron outlet into the Erie basin (Lewis and Anderson, 1992; Tinkler et al., 1992; Tinkler, 1993;

Pengelly et al., 1997). Modeling of these discharges, combined with field data documenting evidence for them, has strongly suggested water levels rose to inundate large areas of the Niagara Peninsula at the northeast end of the Erie basin (Tinkler et al., 1992; Pengelly et al., 1997). The implication is that water levels were also higher (i.e., above modern as in Figure 2) in other parts of the Erie basin (James Pengelly, personal communication), although it is possible, given isostatic rebound and the position of outlets, that the water levels could be above modern Erie at the eastern end of the basin and below it at the western end (i.e., similar to the situation of several early levels in the Lake Ontario basin to be discussed below).

In any case, data that support this interpretation of higher Erie levels include lake deposits dated by ^{14}C or pollen zone attribution to ca. 11,000–10,500 B.P. in cores taken from the Humberstone Bog and other locations in the Niagara Peninsula (Pengelly, 1990:68, Tinkler et al., 1992; Pengelly et al., 1997; see Figure 1). Also of importance is a hanging fluvial terrace near Port Burwell (Figure 1) investigated by Barnett (1985) that is dated to 11,070 $\pm$ 140 B.P. and is at an elevation which Pengelly (1990:68; Pengelly et al., 1997:394) argues indicates water levels some 19 m above the modern Lake Erie level. In addition, studies in the Niagara River/Gorge area, which drains from Lake Erie, indicate water discharges in the ca. 11,000–10,500 B.P. period were of a magnitude much beyond that which can be accounted for by discharges from the Lake Erie basin alone (Tinkler et al., 1994). In sum, water from the upper Great Lakes also had to be flowing out through the Erie basin in this period. The high water level in the Erie basin is argued to have formed a small lake covering the southern part of the Niagara Peninsula (Lake Wainfleet) as well as spillways linking Lake Erie with the Ontario basin (Early Lake Ontario). The high water level may have persisted until the uncovering of the outlets at North Bay and the fall of Lake Huron basin waters to low levels by ca. 10,200 B.P. These low levels would mean Lake Huron basin waters were no longer high enough at Port Huron to flow south into the Erie basin.

One potential implication of this high water level model is that it may assist in dating material in the Niagara Peninsula. In essence, the water level rise may have disturbed Early Palaeo-Indian sites in the area. As in the case for Late Palaeo-Indian materials in the Huron basin, these inundated sites could be recognized by evidence such as waterworn artifacts and, therefore, could be dated to this period. However, no such waterworn artifacts have been found in the area, suggesting that the high water level model is wrong, or that our sampling of Palaeo-Indian materials from the basin is incomplete, or that the Early Palaeo-Indian occupation began after waters achieved the higher level. Also, even if waterworn material was found in the area, a complicating factor with regard to using such data is the fact there were comparable areas flooded in later times such as during the rise to the Nipissing level in Huron and discharge of additional water into the Erie basin around 5500 B.P. Detailed mapping of the extent of these early water levels is needed.

A second implication is that mapping of these early shorelines could serve to pinpoint locations which could then be examined for Palaeo-Indian sites. Indeed, if the Huron basin data are any guide, we should expect large concentrations of

Palaeo-Indian sites along the shorelines. Clearly, if this model continues to be supported by additional work, it has major implications for the nature and extent of the easily accessible Palaeo-Indian archaeological record and indicates an untapped source of geological data useful for providing age estimates for the Early Palaeo-Indian occupation.

LAKE ONTARIO BASIN

Archaeological survey for early sites carried out along the Ontario basin has been limited to a few studies (e.g., Jackson, 1976; Roberts 1984, 1985). Glacial Lake Iroquois (Coleman, 1899, 1937) shoreline and sand deposits with abundant Late Pleistocene fauna have been viewed as the most significant strand feature. In many areas it is also the only such feature above the modern Lake Ontario level. During Lake Iroquois times, the St. Lawrence River outlet area was blocked by glacial ice. Uplift caused water to spread southwest in the Ontario basin, rising 30 m and creating strong shore bluffs. Lake Iroquois continued to spread northeast with ice retreat and southwest because of uplift. The outlet of Lake Iroquois was through the Hudson Valley. When the St. Lawrence outlet opened south of Montreal because of the continued retreat of the Laurentide ice sheet, successively lower ice-dammed lakes resulted: Frontenac, Sydney, Belleville, Trenton, and Admiralty (Miryenich, 1962; Muller and Prest, 1985). A partial record of the falling Ontario levels *can only be seen* in eastern Ontario because uplift has caused flooding of these strandlines in the western basin.

While earlier investigators tended to date Lake Iroquois, and by extension, several subsequent lake levels, to after 10,000–11,000 B.P. (e.g., Hough, 1958), these dates have been pushed back by more recent researchers. Sly and Lewis (1972), for example, argued for inception of ice-marginal Lake Iroquois about 13,000 B.P., that falling post-Iroquois lakes Frontenac, Sydney, Belleville, and Trenton dated after 12,000, and that a final low Early Lake Ontario (Admiralty) was formed below modern Lake Ontario levels by about 11,000 B.P. Although Roberts (1984:249–250, 1985:64–69) argued that a post-Iroquois "Sydney–Belleville" level existed until ca. 10,750 B.P. at levels above that of modern Lake Ontario, including even the western end of the basin, there is little evidence to support such a position. All recent investigators indicate that the post-Iroquois lakes Sydney and Belleville levels were below the plane of modern Lake Ontario in the western end of the basin (Sly and Prior, 1984; Muller and Prest, 1985; Karrow and Warner, 1988; Coakley and Karrow, 1994). Moreover, even the subsequent level called Early Lake Ontario (Admiralty), dated to 11,700 B.P., was well below modern Ontario levels (Sly and Prior, 1984; Karrow and Warner, 1988; Coakley and Karrow, 1994). A minimum lake level (up to 100 m below the present Ontario level) was reached throughout the basin as early as 11,400 B.P. (Anderson and Lewis, 1985; Karrow and Warner, 1990; Coakley and Karrow, 1994). This extreme low exposed roughly 10,000 km^2 of former lake plain in the basin of Lake Ontario. Half the area of the modern lake was exposed land, mainly along its north shore. Immediately after Lake Ontario reached its lowest stage, isostatic rebound, in particular uplift of the St. Lawrence outlet at Kingston, led to higher water levels. We provide an approximate level of Early Lake Ontario from about 11,000 to 10,000 B.P. in Figures 2 and 4, but rising levels must have been continuous since no distinct shoreline stands are evident. Anderson and Lewis (1985) extrapolate a postglacial lake level curve, but submerged stands are difficult to identify in many areas due to the generally continuous rising water levels.

Assuming an age of ca. 11,500–11,000 B.P. for the earliest Palaeo-Indian occupation, *none* of the post-Iroquois falling levels, Frontenac, Sydney, Belleville, and Trenton, were contemporaneous. Even Early Lake Ontario (Admiralty), close to sea level, was a few centuries too early. Therefore, all post-Iroquois falling levels predate Early Palaeo-Indians, and although some strands of the earliest of these lake levels are above modern Lake Ontario and thus, accessible on dry land in eastern Ontario, they are not relevant to the question of occupation near *active* lakes. Nonetheless, because many sites are known on what were abandoned shorelines of the very early glacial lakes such as Warren and Arkona in areas to the west (e.g., in the Huron and Erie basins; Deller, 1976, 1979), it is quite clear that these strandlines deserve attention for site survey. However, and as noted earlier, except for some limited attention to these strandlines by Jackson (1976) and Roberts (1984, 1985), such surveys have not been undertaken.

The significant features of Ontario basin events for Early Palaeo-Indian occupation are twofold. First, a lake plain land mass of 10,000 km^2 was initially available and gradually disappeared as lake levels rose. Second, the western shore of Early Ontario and its immediate successors was up to 20 km *east* of its present position. Isostatic rebound has flooded not only the shoreline but also even the interior lands along the western (Mississauga) part of the basin. Records from the small Rice Lake basin just to the north of modern Lake Ontario (Figure 1) suggest a major site sample is now submerged.

NUMBERS OF SUBMERGED SITES

As just noted, during Early Palaeo-Indian times, a significant amount of land was exposed which today is under Lake Ontario and, perhaps, Lake Erie. Recent work in the small Rice Lake region, 20 km north of Lake Ontario, offers insight into late glacial events and regional land use and estimates as to the exact nature of the now submerged Palaeo-Indian site record, particularly in areas just inland from the submerged strands.

Rice Lake is a northeast–southwest trending lake in an preglacial river valley 26 km long and 3 km wide. The western basin has been flooded by isostatic rebound. This lake was part of the outlet system opened at Kirkfield during Lake Algonquin. It shows fast-water ingress and strong erosional channels along rivers entering its north shore. These probably relate to Algonquin discharge. A single high water terrace in the Rice Lake basin may relate to earlier flooding at the time of Lake Iroquois in the Ontario basin.

The inferred Main Algonquin-related *low and fast-water phase* of Rice Lake coincides with the period of Early Palaeo-Indian use (Jackson, 1994). Survey of a 200 km area around the Rice Lake basin identified six Early Palaeo-Indian sites clustered near the western basin (Figure 7; Jackson, 1976, 1991, 1994, 1998; Jackson and McKillop, 1991). In essence, even though the actual late glacial strandline(s) of Rice lake is now inundated (Yu, 1992; Yu and McAndrews, 1994), the area surveyed is close to, and very similar to, the now inundated areas that once surrounded Early Lake Ontario and, perhaps, Early Lake Erie. Excavations of located sites revealed logistical and residential sites, possibly associated with local lake-edge resources such as caribou. Site organization suggests small task groups, perhaps only a few families, yet with wider mobility and social networks evident from use of cherts originating 160 km to the east and crystal quartzes from 30–60 km to the north. Importantly, these sites suggest *interior* exploitation networks. Assuming that there was also active use of the now-submerged strands and surrounding areas of the early lakes formed in the Ontario and perhaps Erie basins, we appear to be missing an enormous segment of the Palaeo-Indian record. The Rice Lake data suggest, from total sampling of 25% of a 200 km^2 area, that as many as 1000 small sites may be present in the areas now under Lake Ontario. Moreover, if water levels were lower in Erie as well, an additional 1000+ sites would be under that lake. The obvious dense concentration of large and small sites on the strandline *per se* of Main Algonquin or Ardtrea in the Huron basin and the fact that lake edge areas with their abundant resources (see below) were intensively used throughout Great Lakes prehistory (Ellis and Ferris, 1990; Larsen, 1985b:91) make these clearly minimal estimates.

ATTRACTIVENESS OF STRANDLINES

Local lacustrine environments as well as the strandlines *per se* were a strong focus of settlement and subsistence, as suggested by the Rice Lake data. Specialized habitats may have been widespread on abandoned lake plains and strandlines. The available biomass on newly exposed lake plain areas may have been considerable, given the predilection of caribou (cf. Kelsall, 1968) and apparently mastodon (cf. McAndrews and Jackson, 1988) for low and wet habitats. Donald Simons (personal communication, 1995) has recently suggested that shoreline willow thickets were an important source of calcium for browsing mammals such as caribou. Caribou populations also may have been attracted by cool shore breezes to keep off insects as is the case in the north today (Ahti and Hepburn, 1967), and, in fact, Coleman (1941) suggested a similar reason for mastodon locations in such areas. The presence of edible ground lichens and the absence of closed forest would have also been attractive features. Game such as caribou are more plentiful in such areas (cf. Pilon, 1987:17–19). There is good evidence more open areas persisted longer over time in areas lining glacial lake shores such as those in the Huron basin where climates apparently remained cooler than in the interior (cf. Morgan et al., 1983: 358; Morgan, 1988:204–205) perhaps due to the winds blowing off the lake. It is

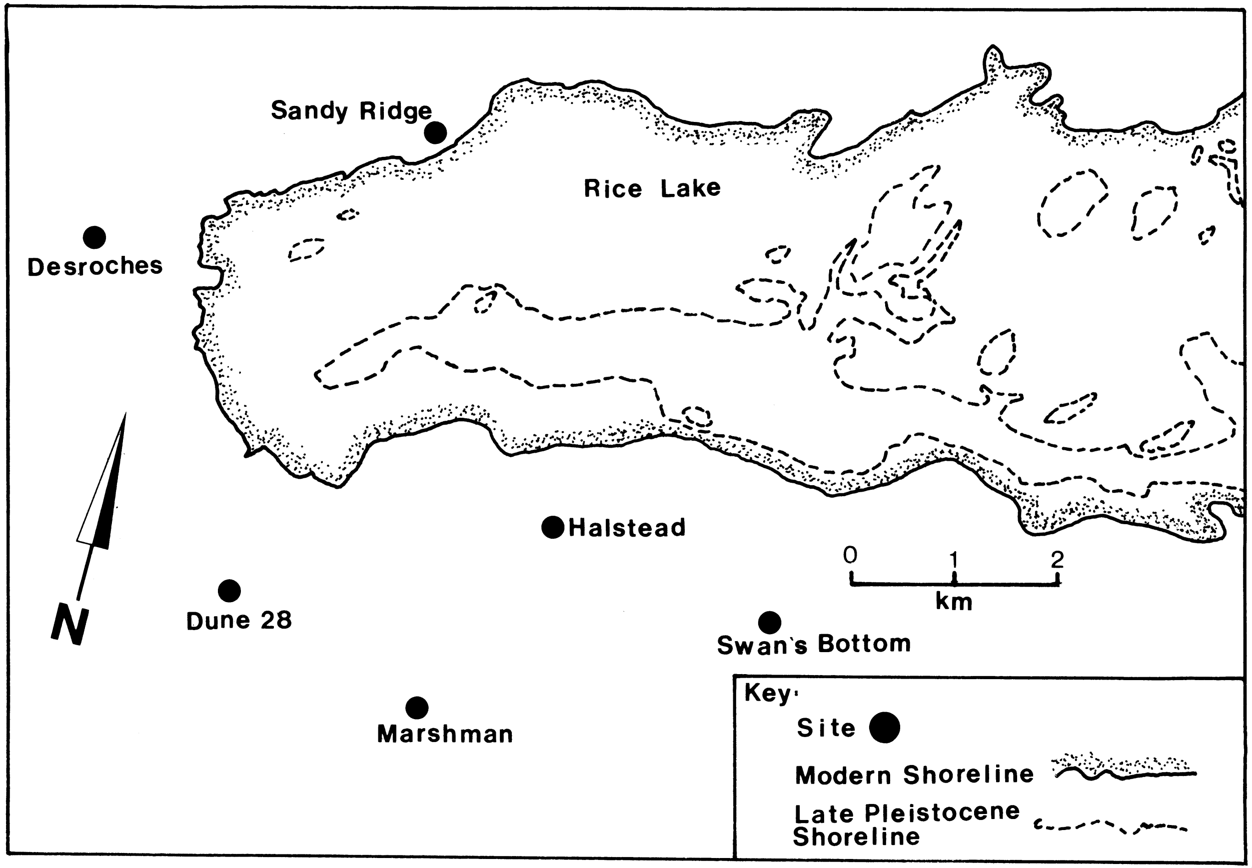

Figure 7. Map of eastern Rice Lake area showing Early Palaeo-Indian archaeological sites and late Pleistocene shoreline locations.

also possible, as is the case in areas lining modern Hudson's Bay to the north, that where the colder air masses above the waters met the warmer land areas, there would be coastal fog which would cut down on sunlight and favor a more open vegetation. Moreover, open meadows, dry gravel scree slopes, and sandy beaches may have allowed persistence of arctic plants (Karrow et al., 1975). Of course, active strandlines also would be attractive because of abundant aquatic resources such as fish and waterfowl and because open vegetation would facilitate foot travel.

Sometime between 10,800 and 10,300 B.P., pollen records document a closing vegetation cover and significant regional change from spruce to pine dominance. Newly exposed lake plains may have offered a temporary reprieve from the general closing of forests over the landscape (Dibb, 1985; Jackson, 1995). Similar reasons may be invoked for long-abandoned interior strands which Palaeo-Indians used: presence of more open areas, specific types of vegetation, and low and wet areas offering diverse habitats to grazing herbivores. Indeed, it has long been suggested that these old strandlines were selected for occupation because they represented an edge or ecotone between diverse upland and lowland environments above and below respectively, the abandoned beaches (Deller, 1976, 1979; Roosa, 1977a:351).

CONCLUSIONS

What has this review of current geological data on the eastern Great Lakes told us? The age estimates of Early Palaeo-Indian sites of ca. 11,000–10,000 B.P. based on the distribution of sites in relation to the Huron basin lake levels still seem to be viable. Clearly, however, our review of the history of changes in the models of the position of lake levels and their age leads us to expect further revisions of these models and, in turn, of models of Early Palaeo-Indian settlement and chronology in the area. It has also suggested new geographic areas that should be examined in detail, such as the early strandlines in the eastern Lake Ontario region and areas covered by potential high water levels in the Niagara Peninsula.

However, perhaps one of the most striking conclusions to come from this review is the clear evidence of extreme fluctuation in lake levels in the three lake basins, Huron, Erie, and Ontario, during the Palaeo-Indian period. Newly exposed lake plains may have been a major resource area, subject to constant change as land surfaces rebounded and lake levels rose and fell. Further, huge areas of up to 20,000 km^2 of lake plain may have been available at various times. This area is the same size as the dry land area on which we base our current knowledge of Ontario Palaeo-Indian behavior. So far, we can use only inferential data on site densities in interior lacustrine regions such as Rice Lake and along *active* strands such as Main Algonquin/Ardtrea in the Huron basin to estimate the nature of the Palaeo-Indian record in the other basins. The lake-edge record is silent for the Erie and Ontario areas, but, if the high water levels in Erie existed in this period, as suggested by some researchers, there is great potential for new sites near those higher strandlines. We might infer in those basins a diversity of micro-habitats along exposed strands, favoring persistence of arctic plants as well as herbivores, and perhaps offering respite from general closing of forest cover over Ontario ca. 10,500 B.P. We may also infer the presence of large numbers of sites under current Ontario and perhaps Erie waters. However, we are encouraged by evidence of preserved inundated sites in other areas suggesting such sites may not be inaccessible (e.g., Faught, 1988).

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