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Paleohydrological Implications of Holocene Peatland Development in Northern Michigan

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Sediment, pollen, and plant macrofossil stratigraphies from two small oligotrophic *Chamaedaphne–Sphagnum* peatlands provide data about local hydrologic changes in northern Michigan during the Holocene. Gleason Bog started about 8000 yr B.P. as a shallow pond that supported rich fen vegetation. After it was partly filled with peat and sand (about 4000 yr B.P.), the vegetation changed to oligotrophic bog. At Gates Bog paludification starting about 3800 yr B.P. caused peat accumulation over sand without an initial pond phase. The onset of peat accumulation at both sites is attributed to a rise in the water table resulting from the onset of cool and moist late Holocene climates. The water table of Gleason Bog is linked to the water level of adjacent Douglas Lake, which may have undergone a simultaneous rise. The results emphasize the individuality of hydrological conditions and hydroseral development in northern Michigan peatlands.

INTRODUCTION

The formation of peatlands is controlled by complex interactions among hydrology, climate, nutrient supply, and vegetation. The hydrological characteristics of a site are influenced in turn by climate, topography, near-surface geology, and soils. In regions where peatlands are abundant the histories of individual peatlands differ according to local hydrology, which may vary over time. In this paper we present evidence that climatically mediated changes in hydrology have been important in the genesis of peatlands in northern Michigan.

Holocene moisture and temperature changes in the Upper Midwest are indicated by numerous paleoecological studies (e.g., Bartlein *et al.*, 1984; Wright, 1976). These climatic changes have coincided with changes in water levels in wetlands and lakes, for example, Kirchner Marsh, Minnesota (Watts and Winter, 1966), Lake Mendota, Wisconsin (Winkler *et al.*, 1986), and Lake Sixteen, Michigan (Futyma and Miller, 1986). However, the relationship between hydrological change and peatland development is poorly documented.

We chose two peatlands in which to investigate the relationship between the chronology of peat accumulation and environmental change. These studies reveal a close linkage between water table elevation and the onset of peat deposition.

STUDY AREA

Northern Lower Michigan is a region of flat to hilly topography marked by glacial landforms. Glacier ice last retreated about 11,500 yr B.P. and was replaced by the waters of Glacial Lake Algonquin. Glacier retreat and isostatic rebound led to the complete regression of proglacial lake waters by 10,000 yr B.P. (Drexler *et al.*, 1983).

The peatlands studied are on opposite sides of Douglas Lake in western Cheboygan County, an area of ice-stagnation features (Fig. 1). Douglas Lake occupies a basin with nine subbasins of ice-block origin separated by wide shallow areas (Wilson, 1945). The peatlands are at the edges of high areas that were islands in Glacial Lake Algonquin (Spurr and Zumberge, 1956).

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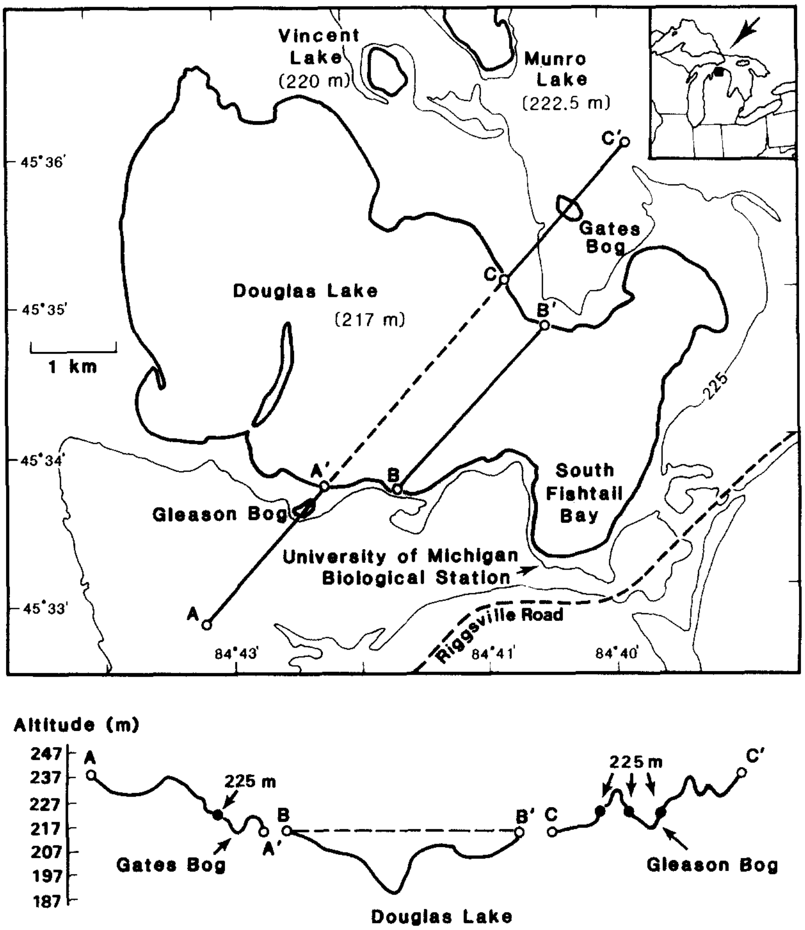

FIG. 1. Map of the Douglas Lake region showing the location of the study sites and elevational relationships along two transects. The 225-m contour marks the position of the shoreline of Glacial Lake Algonquin.

A map published by Gates (1926) shows that Gleason Bog was located between white pine/red pine forest (on the south) and beech/maple forest (on the north) and that Gates Bog was surrounded entirely by beech/maple forest.

STUDY SITES

Gleason Bog (45°33′51″N, 84°42′30″W) occupies a basin of 0.34 ha (Fig. 2). A sand and gravel ridge that formed as a spit in Glacial Lake Algonquin separates it from the southwest shore of Douglas Lake. On 16 August 1984 the surface of the peatland lay 216.6 m above sea level or 0.6 m below the surface of Douglas Lake. Maximum peat depth is ca. 2 m. The basin is bordered by a zone of shrubs (mainly *Nemopanthus mucronata*), inside of which is a low shrub zone dominated by *Chamaedaphne calyculata* and an associated ground layer of *Sphagnum capillifolium. S. magellanicum*, and *S. recurvum*.

Gates Bog (45°35′24″N, 84°40′15″W) occupies a 4.4-ha basin (Fig. 3) that lies in hummocky terrain. To the west is a broad sandy ridge situated at the elevation of the Algonquin shoreline (ca. 225 m). The surface of the peatland lies at ca. 220 m (Indianville, Michigan, 7.5′ quadrangle, USGS 1982). Maximum depth of peat is 0.95 m. The peatland is ringed by a discon-

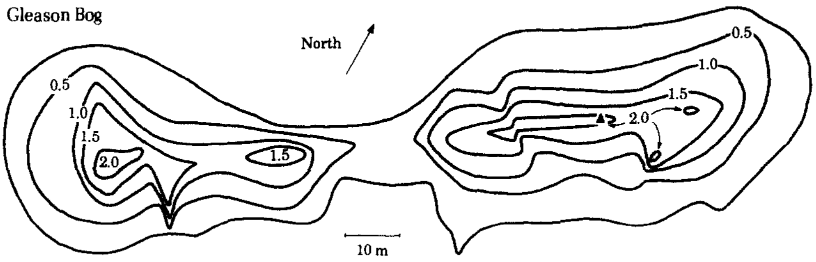

FIG. 2. Morphometry of the Gleason Bog basin. The triangle marks the location at which the core was taken. Contours are in meters.

tinuous shrub zone (*Nemopanthus mucronata* dominant). A low shrub vegetation (*Chamaedaphne calyculata* and other ericads) intermixed with tussocks of *Eriophorum spissum* occupies all of the bog except part of the northwestern quadrant. Throughout the bog *Sphagnum* and *Polytrichum* species form a nearly continuous ground layer.

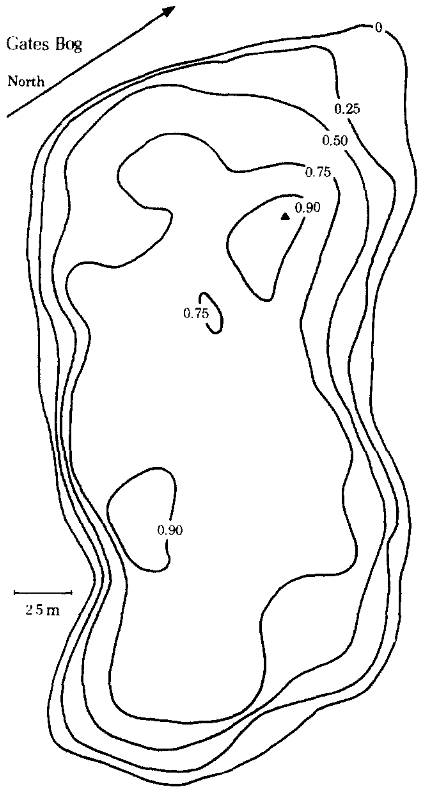

FIG. 3. Morphometry of the Gates Bog basin. The triangle marks the location at which the core was taken. Contours are in meters.

METHODS

Field methods. Sediment samples were taken at the deepest locations in the basins. At Gleason Bog, one core was taken for macrofossil analysis with a Hiller sampler and another for pollen analysis with Jowsey and Hiller samplers. Samples for ^{14}C dating were taken with a Jowsey sampler and a 7.5-cm-diameter polyvinyl chloride tube. Pollen and plant macrofossil analyses of the upper 25 cm of peat were made on samples obtained from a monolith removed with a spade. At Gates Bog, a Jowsey sampler was used to collect peats to a depth of 72 cm; a Davis-type sampler was employed to recover deeper sediments and to take multiple samples of the deepest peats for ^{14}C dating. At Gates Bog, a bucket auger was used to examine the nature of the mineral substratum beneath the peat.

To aid in the interpretation of the plant macrofossil assemblages, vegetation sampling was carried out at four nearby fens studied previously by Schwintzer (1978). Thirty randomly located 50 × 50 cm quadrats were studied at each fen, following Schwintzer's sampling design. Abundance of each bryophyte species was expressed as frequency (percent of plots where present), mean percentage cover, and importance values (sum of relative frequency and relative cover, i.e., percent frequency of a given species divided by frequency of all species plus mean percent cover of a given species divided by mean percent cover of all species).

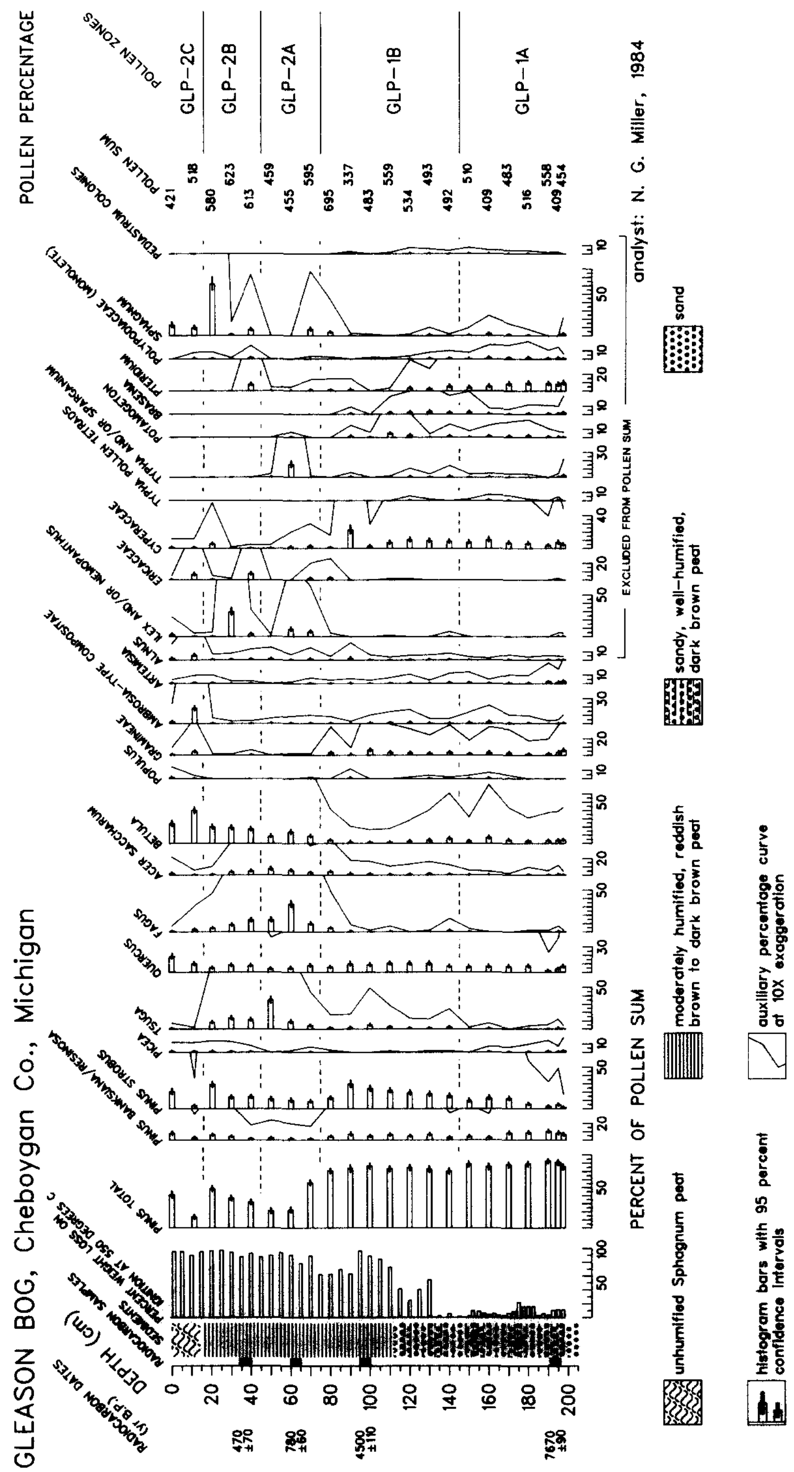

FIG. 4. Gleason Bog pollen diagram.

To establish basin morphometry, distances were measured by plane table and alidade. Peat depth to mineral substratum was determined with metal rods. The water table height in the peat was measured in Gleason Bog in August 1983 near the coring location. The well consisted of a 7.5-cm-diameter PVC pipe with diagonal slits, installed in a hole augered through the peat to the mineral substratum. The relationship between the peatland water table and the surface elevation of Douglas Lake was established by leveling from Douglas Lake to the water surface in the well. The water table elevation in the ridge between Gleason Bog and the lake was determined by augering to wet sand and leveling at four sites north of the peatland with stadia surveying methods.

Laboratory methods. Subsamples of the sediment cores and the monolith were treated with standard methods (Faegri and Iversen, 1975). Residues were mounted in silicone fluid (2000 cST). Pollen counts were made at a magnification of 400×. At least 400 tree pollen grains were counted in each sample except in those having very low pollen concentrations.

Volumetric samples of peat (1 cc above 20 cm, 47 cc below 20 cm) were dispersed in water and searched for plant macrofossils (seeds, fruits, identifiable stem and leaf fragments) under a dissecting microscope. Owing to the abundance of *Sphagnum* leaves from 0 to 35 cm, the original samples were diluted to 100 cc and from three to ten 1-cc subsamples were removed and identified. The counts of fossils were multiplied by an appropriate factor to obtain an estimate of the number of fossils in the original sample volume.

The pollen and plant macrofossil data were calculated and/or plotted using the MICHIGRANA computer program (Futyma and Meacham, 1984). Pollen percentages for all taxa were based on the sum of trees and upland shrubs and herbs. Pollen percentages are given with 95% confidence intervals based on the method of Mosimann (1965).

The pollen stratigraphies were zoned with the aid of the ZONATION computer program (Gordon and Birks, 1972) and a program that compares each sample with all others in the core, calculating the squared chord distance dissimilarity coefficient for each pair. A graphical representation of the dissimilarity matrix identified core segments with relatively uniform pollen spectra. This method was also used to compare the pollen data from the two sites and to distinguish similar stratigraphic units. Data for the following taxa were used: *Pinus, Betula, Tsuga, Quercus, Fagus, Acer saccharum, Carpinus/Ostrya, Ulmus, Fraxinus americana/pennsylvanica, Populus, Ambrosia*-type, *Artemisia,* Chenopodiineae, and Gramineae. The pollen diagrams (Figs. 4 and 7) show only indicator taxa and the most important types (i.e., those with percentages >1–2% in most spectra). Complete data in tabular form are available from the authors.

RESULTS

Gleason Bog

Sediments. The upper 14 cm of sediment consisted of unhumidified, light-reddish-brown *Sphagnum* peat. Between 14 and 20 cm the peat was moderately decomposed and darker brown. Between 20 cm and ca. 112 cm the peat was reddish brown to dark brown and moderately humified and contained wood fragments, charcoal particles, and fibrous matter. Some sand grains were found in these upper peats, but below 112 cm sand was very abundant in the dark-brown, well-decomposed peat, and some thin layers of sand were encountered. Impenetrable sand was reached 198 cm below the surface. Radiocarbon ages were as follows: 34–40 cm, 470 ± 70 yr B.P. (Beta-6456); 60–65 cm, 780 ± 60 yr B.P. (Beta-10497); 95–100 cm, 4500 ± 110 yr B.P. (Beta-6457); 191–196 cm, 7670 ± 90 yr B.P. (Beta-6458).

Pollen. In zone GLP-1 (Fig. 4) pine values are very high (71–83%), whereas pollen of trees important in the hemlock/white pine/northern hardwoods forest (*sensu* Braun, 1950), such as *Acer, Betula, Fagus*, and *Tsuga*, is poorly represented (mainly <2%). The pollen of aquatic plants, including *Brasenia, Potamogeton*, and *Typha* spp., is confined to GLP-1A and -1B. Cyperaceae have consistently high values (5–10%). Subzone GLP-1B has pine values usually at least 5% lower and *Acer saccharum* and *Tsuga* values above 1%.

In zone GLP-2 *Pinus* values are more variable and lower (15–55%), and at least twofold increases in percentages of *Tsuga* and northern hardwoods pollen types (*Acer saccharum, Betula, Fagus*) are evident. Pollen of emergent and floating aquatics is nearly absent, but peatland plants such as Ericaceae, *Ilex*/*Nemopanthus*, and *Sphagnum* are abundantly represented. Subzone GLP-2A is marked by a decline of *Pinus* (to 22%) and peaks in *Fagus* (34%) and *Tsuga* (35%). In subzone GLP-2B *Fagus* and *Tsuga* return to their previous levels (5–15%) and are surpassed by *Betula* (17–20%), while *Pinus* rises to ca. 50%. Above the subzone GLP-2B/2C boundary *Pinus* reaches its lowest value (15%) in the diagram, and parallel declines are evident in *Acer saccharum, Fagus*, and *Tsuga*. *Ambrosia*-type percentages reach a peak (20%) in GLP-2C.

Macrofossils. Fruits, seeds, leaves, and plant fragments of *Sphagnum* and brown mosses were recovered from all peat samples except those between 20 and 50 cm, where only *Sphagnum* was abundant (Figs. 5 and 6). GLM-1 is defined by fruits and seeds of wetland plants, needle fragments and fruits of some upland trees, and brown and *Sphagnum* mosses. In GLM-2 only *Chamaedaphne* and species of *Sphagnum* were present. *Chamaedaphne* and *Sphagnum recurvum* are mainly confined to the upper part of the zone. *Sphagnum* leaves were so numerous that it was necessary to use logarithmic values (Fig. 6).

Gates Bog

Sediments. The upper 6 cm of sediment at the sampling point (Fig. 3) consisted of raw unhumified fibrous *Sphagnum* peat. Below that and to a depth of 86 cm was a dark-reddish-brown peat with some fibers in a highly humified matrix. A 2-cm-thick layer rich in fine charcoal was present at the base of the peat, directly on the underlying sand, which was sampled to a depth of 95 cm. The interval 84–89 cm was radiocarbon-dated at 3840 ± 80 yr B.P. (Beta-10498).

Sediments were also examined at a point 85 m southeast of the sampling site. The following stratigraphic sequence was found: 0–20 cm, raw fibrous *Sphagnum* peat; 20–85 cm, dark-reddish-brown highly humified peat with the bottom 0.5 cm darkened by fine charcoal; 85–105 cm, dark-grayish-brown sand; 105–120 cm, dark-reddish-brown sand with friable nodules of iron-oxide-cemented sand (ortstein); 120–150 cm, orange-brown sand grading to light-yellowish-brown with depth; 150–330 cm, light-grayish-brown sand, somewhat coarser below 300 cm.

Pollen. Zone GA-1 (Fig. 7) includes the three deepest samples, which are marked by *Pinus* values of 58–72%, *Betula* and *Tsuga* below 10%, and *Acer saccharum* and *Fagus* below 4%. Pollen of floating-leaved aquatics was not encountered, and emergent aquatic plants are possibly indicated only by the pollen of Cyperaceae and *Typha*/*Sparganium* type. *Ilex*/*Nemopanthus, Pteridium*, and Polypodiaceae (monolete spores) have their highest values in this zone.

Zone GA-2 has *Pinus* values between 15 and 68% and increased values of *Acer saccharum, Betula, Fagus*, and *Tsuga*, all of which attain peak percentages in the upper 40 cm of sediment (subzone GA-2B). The high values of *Tsuga* (13–28%), compared with earlier values of 1–12%, separate subzone GA-2B from GA-2A. Peatland and

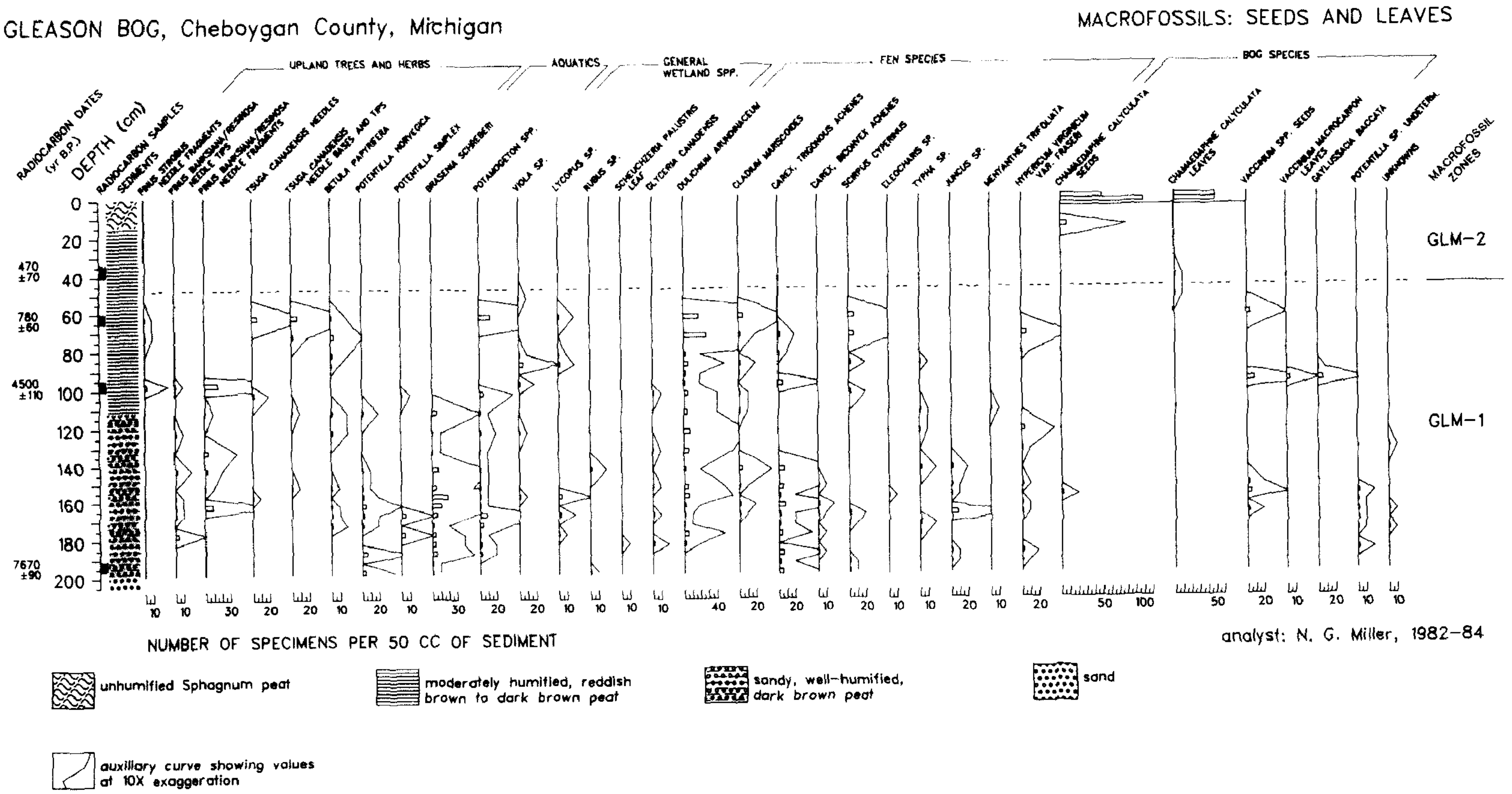

FIG. 5. Gleason Bog plant macrofossil diagram—seeds and leaves.

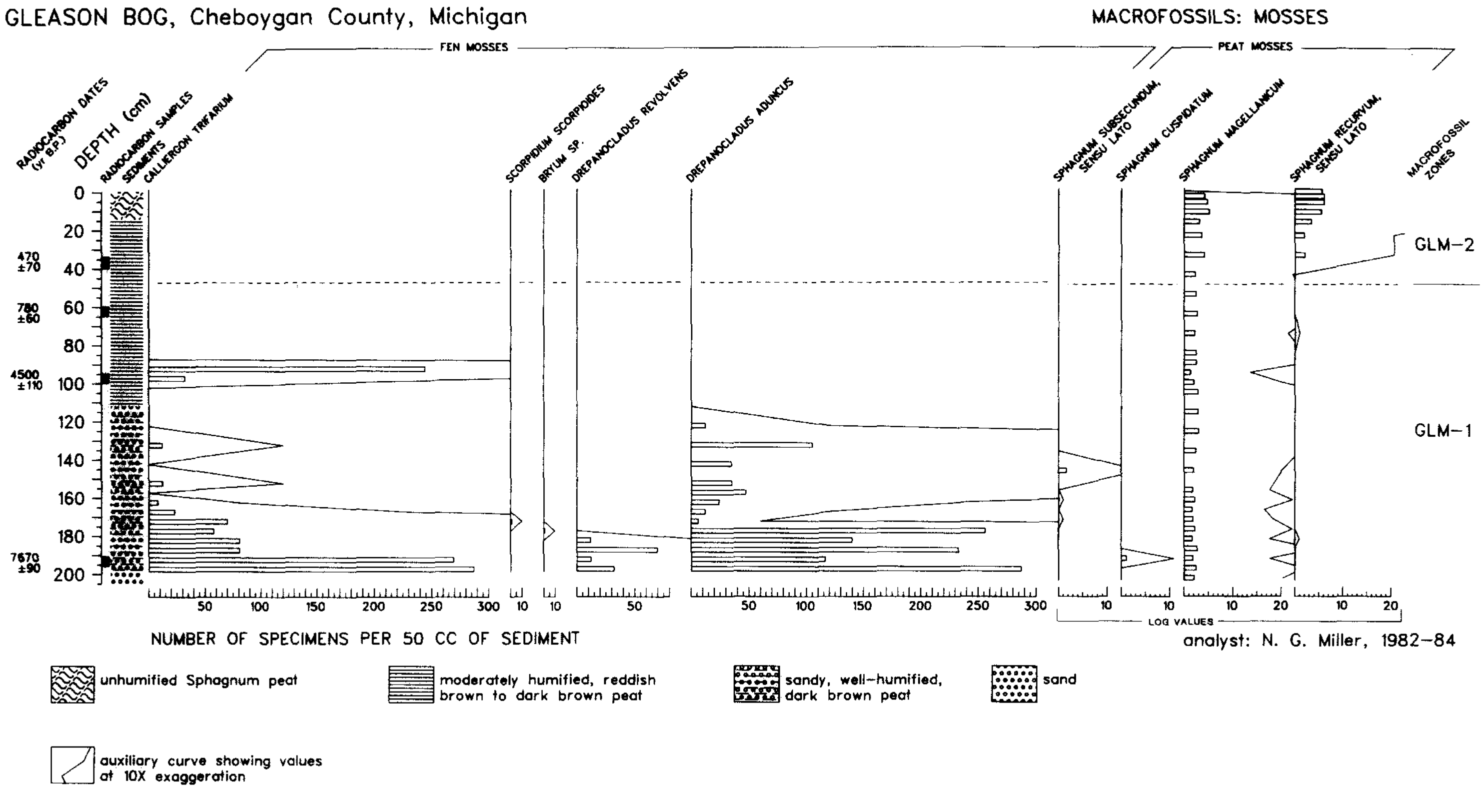

FIG. 6. Gleason Bog plant macrofossil diagram—mosses.

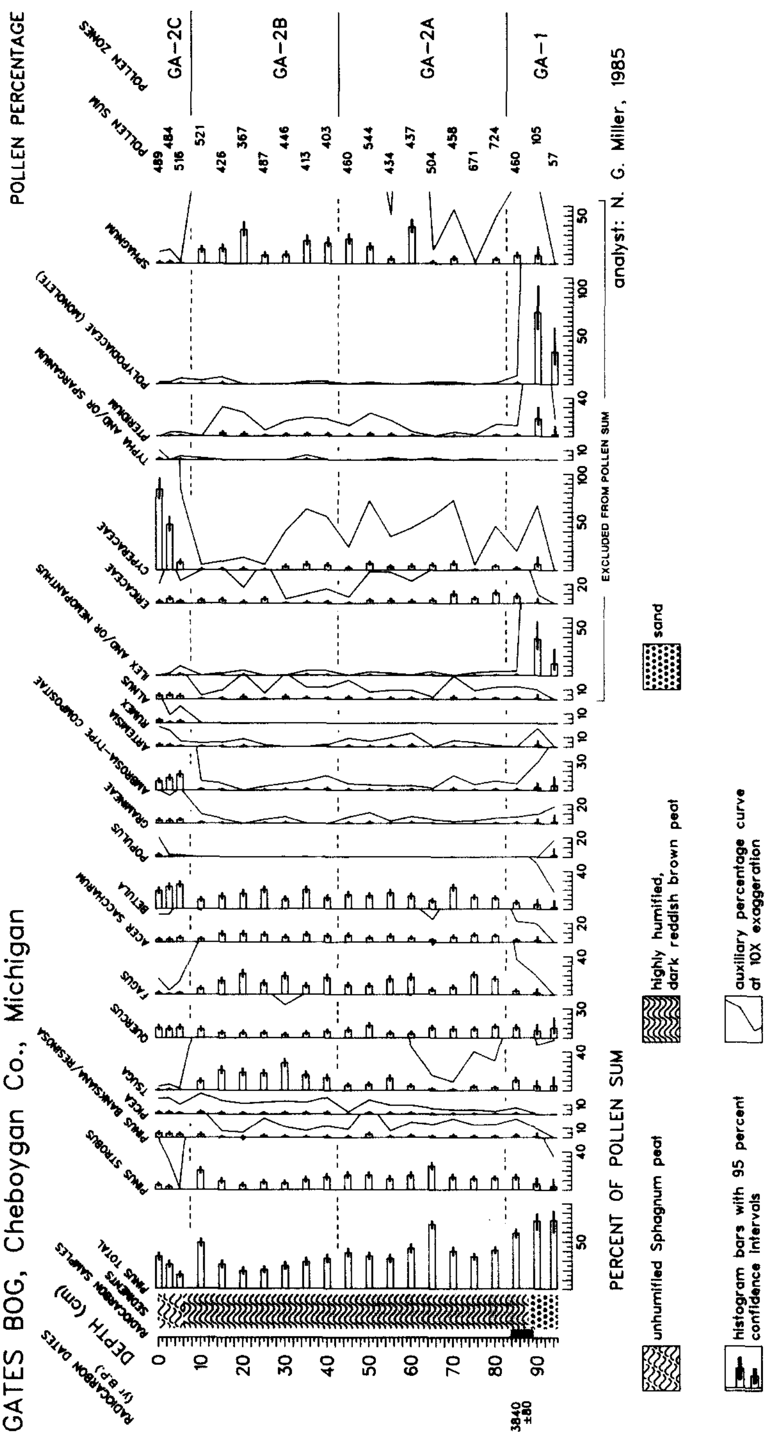

FIG. 7. Gates Bog pollen diagram.

wetland plants are poorly represented in zone GA-2, with the exception of *Sphagnum* (percentages several times higher than those of GA-1), Ericaceae, *Alnus*, and Cyperaceae (possibly in part from upland plants). Subzone GA-2C (the topmost 5 cm of peat) is distinguished from the remainder of the zone by the lowest value for *Pinus* and by decreases in *Acer saccharum*, *Fagus*, and *Tsuga*. Also, peak values for *Betula*, *Populus*, *Alnus*, Cyperaceae, *Ambrosia*-type, Gramineae, and *Rumex* are reached in subzone GA-2C.

DISCUSSION

The Gleason Bog and Gates Bog stratigraphies record only a part of the Holocene. In complete Holocene diagrams from the Upper Great Lakes region (Brubaker, 1975; Futyma and Miller, 1986; Webb, 1974) the oldest sediments contain *Picea–Pinus* assemblages, which are followed by *Pinus*-dominated assemblages. The initial pollen zones at Gleason and Gates Bogs correspond compositionally and chronologically to these pine assemblages. Subsequent zones with lower *Pinus* percentages and increasing values for *Acer saccharum*, *Betula*, *Fagus*, and *Tsuga* (GLP-2, GA-2) are also characteristic of the region. Webb (1974) interpreted the transition from pine pollen dominance to a mixture of the pollen of conifers and hardwoods as indicating the origin of the modern hemlock/white pine/northern hardwoods forest of the Upper Great Lakes region. This appears to be the result of a change to a cooler and moister climate after 6000 yr B.P. (Bartlein *et al.*, 1984). Pollen stratigraphic features of the last 800 yr, particularly the *Pinus* curve as seen in GLP-2A and -2B, are similar to those found by Bernabo (1981; Fig. 5) at lake sites ca. 70 km southwest of the Douglas Lake region. These changes are correlated with a period of cooler climate (equated with the Little Ice Age) from the 13th to 19th centuries. Vegetational disturbance during the past 140 yr, including logging, wildfire, and agriculture followed by regrowth of forests, is recorded in the uppermost pollen subzones (GLP-2C, GA-2C).

The sequence of peatland development is revealed by the sediment, pollen, and plant macrofossil records. At Gleason Bog the pattern consists of two phases. The first is a pond environment supporting various mosses and floating-leaved and emergent aquatics. Although an algal component is indicated by the presence of *Pediastrum*, gyttja was not deposited because the trophic status and size of basin were such that vascular plant remains and other organic matter were the predominant components of the sediment. The abundant sand in these sediments was derived from slope wash or through erosion and redeposition within the pond. Bordering the pond or growing in shallow water were brown mosses (Fig. 6) and a group of vascular plants, including *Cladium mariscoides*, *Dulichium arundinaceum*, *Hypericum virginicum* var. *fraseri*, and *Menyanthes trifoliata*, which in northern Michigan are confined to fen communities (Schwintzer, 1978; cf. Schwintzer, 1981) but do not now grow at Gleason Bog.

The second phase in the development of Gleason Bog began with the change from fen to oligotrophic bog. Evidence for this is seen in both pollen and plant macrofossil diagrams, for example, increases in pollen of bog shrubs (*Ilex*/*Nemopanthus* and Ericaceae) and spores of *Sphagnum*, loss of fruits and seeds of minerotrophic plants (*Cladium*, *Dulichium*), appearance of the remains of *Chamaedaphne* and *Sphagnum recurvum* s. lat., and a several-fold increase in *Sphagnum magellanicum*. For at least the last 700 yr, the floristic composition of the bog vegetation has been constant. The transition from fen to bog, which took place between 4500 and 800 yr B.P., reflects increasing isolation of the peat mass from mineral-rich groundwater. The pond environment of phase 1 came to an end as peat accumulation shallowed the pond. Disappearance of pollen of *Brasenia* (an aquatic) and remains of the alga *Pediastrum* (both last found at 90 cm) and *Potamogeton* signal the end of continuous inundation. However, the temporary reappearance of standing water is indicated by the presence of pollen and fruits of *Potamogeton* at 60 cm.

Associated with the vegetational change from pond/fen to oligotrophic bog were changes in water chemistry. Estimates of the pond's pH and calcium ion concentration, two important correlates of wetland plant occurrence (Sjörs, 1950), can be derived from the qualitative similarity between the macrofossil assemblages and known fen floras. On the basis of data from northern Michigan (Table 1; Schwintzer, 1978; Schwintzer and Tomberlin, 1982), we estimate water chemistry values during phase 1 (fen) in the following ranges: pH of 6.1–6.9, conductivity of 140–380 mhos/cm at 25°C, and Ca^{++} concentration of 22–66 mg/liter. Such values are associated with rich fen vegetation (Moore and Bellamy, 1974).

Measurements of pH and conductivity at Gleason Bog in 1983 were 3.1 and 57 mhos/cm at 25°C. These values compare favorably with data from six other oligotrophic bogs studied by Schwintzer and Tomberlin (1982), who reported values (mean ± SD) for pH of 4 ± 0.2, conductivity 57 ± 9 mhos/cm at 25°C, and Ca^{++} 2.3 ± 0.8 mg/liter.

At Gates Bog a two-phase sequence is not apparent. Absent from the record are sediments and fossils indicative of a lake or pond environment. High values of *Ilex*/*Nemopanthus* pollen and monolete fern spores indicate that peat accumulation began in a moist, shrubby basin. The onset of peat deposition has been dated at 3840 yr B.P. The uniformity of pollen percentages of peatland plants from ca. 85 cm to the surface indicates that oligotrophic bog vegetation similar to that now existing in the basin has been present since shortly after the peat accumulation began. The only significant change in wetland vegetation is indicated by an increase in sedge pollen in the topmost three spectra (GA-2C). The cause of this may be human disturbance, possibly burning (Gates, 1942), which favored the growth of various Cyperaceae, such as the large populations of sedges in the northwestern sector of the bog.

HYDROLOGICAL CONTROL AND TIMING OF PEATLAND DEVELOPMENT

Our data indicate the inception of the pond phase of peatland development at Gleason Bog at about 7700 yr B.P. There are other sites in northern Michigan where the first organic deposition did not begin until after 8000 yr B.P. (Futyma and Miller, 1986). In fact, most small, shallow lake basins (under 30 ha) and peatlands in the region appear to follow this pattern. The apparent cause of the lack of earlier sediments is the drier climate of the early Holocene, which was accompanied by lower water tables than exist now.

The earliest plant communities recorded in the Gleason Bog basin comprised fen bryophytes and vascular plants that grow in shallow water or on intermittently wet minerotrophic sites. These existed early in a period of deepening water as recorded by an increase in the abundance of pollen and macrofossils of aquatic and fen plants.

The water table in Gleason Bog is closely linked to the water level of Douglas Lake. A series of holes augered to or near water-saturated sand in the ridge between Gleason Bog and Douglas Lake shows that the water table slopes gently southward from the lake to the bog (Fig. 8). Fluctuation of the water level in the Gleason Bog well is highly correlated with changes in the level of Douglas Lake. Between July 1984 and September 1986 the water levels in Gleason Bog and Douglas Lake fluctuated over ranges of 54 and 56 cm, respectively. Linear regression of seven measurements during this period shows a strong and significant correlation ($r = 0.93$, $P < 0.01$) between the two.

Since it appears that the water table in

TABLE 1. PRINCIPAL BRYOPHYTE SPECIES IN NORTHERN LOWER MICHIGAN FENS[a]

	Crooked River			Hebron Mud Lake			Minnehaha Creek			Mullet Creek		
	Frequency (%)	Mean Cover (%)	IV	Frequency (%)	Mean Cover (%)	IV	Frequency (%)	Mean Cover (%)	IV	Frequency (%)	Mean Cover (%)	IV
Bryum pseudotriquetrum	23	t	10	3	t	1	77	5	43	43	0.5	14
Calliergon trifarium	20	1	14	37	0.2	20	—	—	—	—	—	—
Calliergonella cuspidata	3	t	1	3	t	1	33	5	28	50	6	25
Campylium stellatum	77	4	38	50	0.1	25	67	12	41	80	39	87
Drepanocladus aduncus	—	—	—	—	—	—	10	1	7	—	—	—
D. revolvens	—	—	—	37	3	46	7	0.5	4	27	12	28
Fissidens adiantoides	43	0.6	21	—	—	—	7	t	2	13	0.1	4
Scorpidium scorpioides	33	11	64	73	7	102	—	—	—	—	—	—
Aneura pinguis	23	0.2	11	7	0.1	4	20	0.4	0.3	20	0.3	7
Moerckia hibernica	10	0.3	6	—	—	—	17	0.1	6	57	3	22
pH*		6.5 ± 0.2			6.7 ± 0.1			6.6 ± 0.2			7.0 ± 0.1	
Ca(mg/liter)*		75.0 ± 48.8			25.9 ± 4.6			51.0 ± 16.0			51.5 ± 2.8	

[a] Key: IV = importance value; t = trace amount; * mean ± SD (from Schwintzer, 1978).

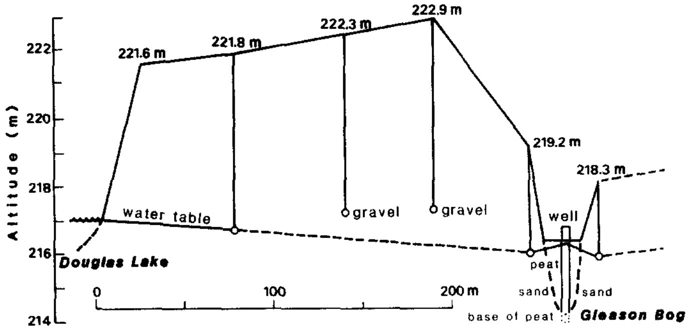

FIG. 8. Surface and water table elevations between Gleason Bog and Douglas Lake based on stadia surveying and wells dug in July and August 1984.

Gleason Bog was lower in the early Holocene than it is at present, the level of Douglas Lake must also have been lower. Support for this prediction may have been found in a sediment core from South Fishtail Bay, southeastern Douglas Lake, which was studied for fossil pollen (Wilson and Potzger, 1943) and diatoms (Stoermer, 1977). The early Holocene diatom record is dominated by an assemblage of benthic species that may represent a low stand of Douglas Lake (Stoermer, 1977). Succeeding this, in a portion of the core containing pollen stratigraphic changes corresponding to zone GLP-1, is a shift to an assemblage dominated by planktonic diatoms, which suggests that Douglas Lake stabilized at or near its modern trophic status during the time of GLP-1. We estimate this to correspond to the period from just prior to the arrival of *Tsuga* (ca. 6500 yr B.P.) until the arrival of *Fagus* (ca. 3000 yr B.P.) (Davis *et al.*, 1986). The change in trophic status may be related to the onset of anoxic conditions in the bottom waters of South Fishtail Bay, which in turn may have been caused by deepening water.

In a like manner the inception of peat accumulation at Gates Bog appears to be caused by a climatically mediated rise in the water table. However, the water table did not rise sufficiently to form a pond in the basin. Instead, the sandy soil became water-logged and decomposition of plant litter slowed. The development of a peat layer further impeded percolation from the basin. This process, paludification, led to the accumulation of nearly 100 cm of peat in much of the basin.

The environment at the initiation of peat accumulation in Gates Bog was a tall shrub carr. Although we have no pollen record of the vegetation before the tall shrub phase, the substratum beneath the peat contains a layer of iron-oxide-cemented sand 20–35 cm below the peat/sand interface. Soil profiles similar to this have been interpreted by some pedologists to indicate development of a podzolic soil prior to peat accumulation (Buurman, 1984), while others believe such profiles formed subsequent to peat accumulation (Kovalev and Generalova, 1967; Rieger, 1983). Sampling of the sand/peat interface at 50 locations throughout the bog showed the widespread occurrence of a 0.5- to 1.5-cm layer of black peat, frequently with charcoal fragments, immediately overlying the sand. This may be the remnant of the surface organic horizon of the soil developed before peat accumulation.

Although Gates and Gleason Bogs are at nearly the same elevation and lie in similar topographic settings, their local hydrological conditions are sufficiently different to have resulted in different modes and timing of peatland development. In contrast to Gleason Bog, the bottom of the peat-containing basin at Gates Bog is about 2 m above the surface of Douglas Lake.

The water levels of lakes just north of Douglas Lake indicate that water tables slope from north to south and that Gates Bog is hydrologically up-gradient from Douglas Lake. Some independence between Gates and Gleason Bogs is thus expected. Rising mid-Holocene water tables in the region did not intersect the bottom of Gates bog basin until about 4000 yr later than at Gleason Bog.

CONCLUSIONS

The mode and chronology of peatland development in small basins separated by distances as short as 4 km may differ substantially. In spite of having similar modern vegetation, Gates and Gleason Bogs differed in the time of initiation and course of their seral development and in their processes of peat accumulation. Hydrological conditions, particularly water table elevational changes over time, have been important determinants of the initiation of peat accumulation in northern Michigan. Such changes are linked to broad-scale trends in mid- and late Holocene climate, probably lower temperatures and/or increased precipitation.

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