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The Fernbank interglacial site near Ithaca, New York, USA

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A R T I C L E   I N F O

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A B S T R A C T

The Fernbank interglacial site, on the west side of Cayuga Lake, New York, has been recently subjected to more detailed study. To a lengthened mollusc list are added ostracodes, insects, fish, pollen, and plant macrofossils. Of these, plants are well preserved and diverse, whereas other groups are poorly preserved and incomplete. Nevertheless, all support the interglacial assignment (Sangamon), which is further supported by minimum age radiocarbon dates (>50,000 ^{14}C yr BP) and a TL date of 81 ± 11 ka. In the plant record near the top of the sequence, abundant tree charcoal indicates forest fires. Like the Toronto interglacial record, the plants show a declining July mean temperature from 24 to 18°C (according to transfer functions) through the sequence, from mixed deciduous forest to boreal forest.

Introduction

Interglacial fossil sites below Wisconsin till are rare in glaciated areas. They can yield paleoenvironmental information about former climates and can display evidence of environmental change (e.g. Dredge et al., 1990). These sites provide baseline data for understanding the present interglacial and how environments may change in the future. Interglacial deposits also provide data for correlation with the unglaciated areas (e.g. Morrison, 1991), which prevail over most of the world's land surface.

Maury (1908) briefly described a fossiliferous section on the west side of Cayuga Lake, in west-central New York State. Based on unionid molluscs, she correlated the sediments with interglacial beds previously described from Toronto (Don beds). Rediscovered in the mid-20th century, a new study of the fossil assemblages was undertaken.

Aside from fossiliferous marine deposits and a glaciotectonic peat clast on Long Island (Stone and Borns, 1986), the Fernbank site (Fig. 1) is one of only two fossil sites in New York State (see Muller et al., 1993, for the other site in the Adirondack area) and only a handful in the Great Lakes region generally (e.g., Terasmae, 1960, Kapp and Gooding, 1964) believed to represent the last (Sangamon) interglacial. Until now, it has received little attention and study. Its nearby location in the same (Lake Ontario) basin, invites comparison with the Toronto deposits, which have received extensive study (Karrow, 1990; Karrow et al., 2001).

Previous work

The Fernbank site was discovered by R.S. Tarr of Cornell University late in the 19th century. Maury (1908) published a short description with a list of 18 fossil molluscan species from the beds, which she compared with the interglacial beds at Toronto (Coleman, 1894, 1901, 1906) and suggested they were of similar age. Her fossil collection was deposited at Cornell University and is now housed at the Paleontological Research Institution near Ithaca, New York.

The location of the site became lost over the years, but in 1966 Bloom found what he believed was the "Fernbank" section (Bloom, 1967), and in 1967 he invited McAndrews to examine the plant record. From ten sample levels they identified a lower part of the sequence with a warm-climate assemblage and an upper part with a cool-climate assemblage, together reminiscent of the Toronto sequence (Don and Scarborough formations); they also obtained three radiocarbon dates >50,000 ^{14}C yr BP (Bloom and McAndrews, 1972). Regional reviews of Quaternary history routinely refer to the site; the most recent were Muller and Calkin (1993) and Karrow (2004). Other than the brief

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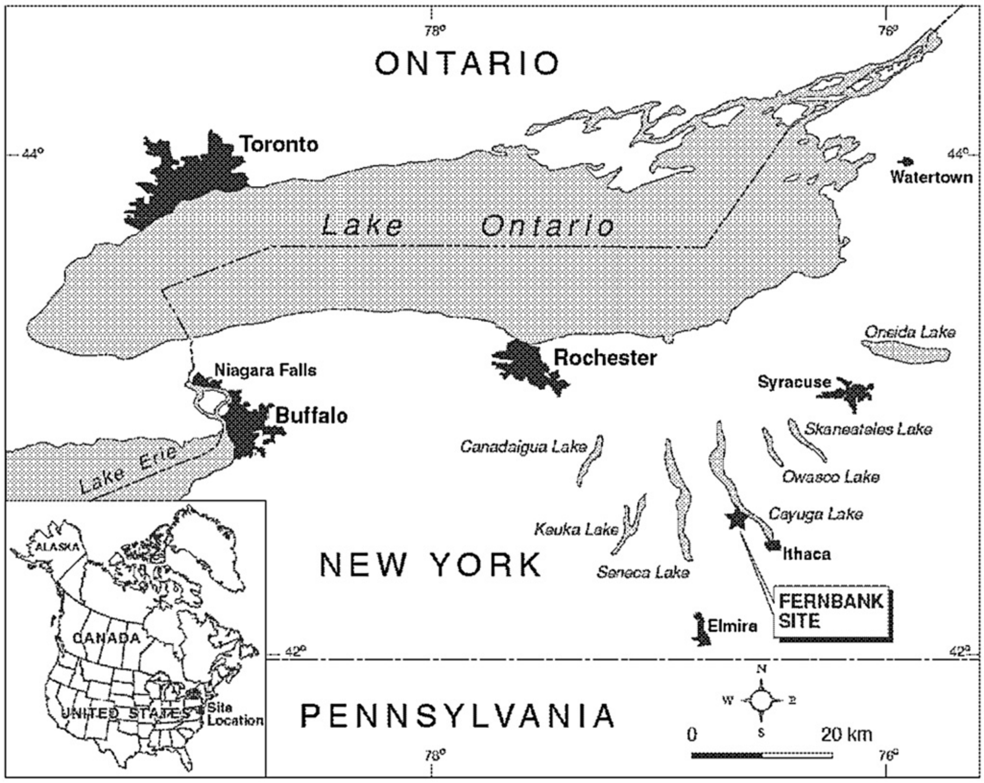

Figure 1. Map showing the location of the Fernbank interglacial site.

report of Bloom and McAndrews (1972), this is the first detailed study of the site since Maury (1908) first reported the fossiliferous beds.

Location

The Fernbank site was located by Maury (1908), in a small ravine on the west side of Cayuga Lake between Taughannock Falls and Frontenac Beach. The site found by Bloom (1967) was a shallow gully where a small landslide exposed the beds. That exposure had deteriorated, but in 1988, a fresher exposure appeared in another landslide gully about 100 m farther south, which is where our sampling was carried out. By 2006, new housing construction resulted in heavy debris accumulation across the upper part of the site and nearly total downslope cover of the interglacial beds. Any future study will be very difficult.

The site (Fig. 1) is located about 170 m north of the Seneca-Tompkins County boundary (42° 33′ N, 76° 36.9′ W), about 15 km northwest of Ithaca. The site is reached off Route 89 on a local cottage road to the west shore of Cayuga Lake. The lake (average elevation of 116.4 m, about 41.5 m above Lake Ontario) is the reference level for stratigraphic section measurements.

A small additional fossiliferous exposure was found in 2000 at Camp Barton Boy Scout Camp, just south of Frontenac Point about 1.4 km WNW of the 1988 site. The exposure, only about 50 cm high, is in the south bank of a small stream tens of meters above Cayuga Lake and thus corresponds to the upper part of the fossiliferous zone of the 1988 exposure.

The present-day upland vegetation is a mixed forest of evergreen *Pinus strobus* and *Tsuga canadensis*, together with *Acer saccharum*, *Fagus grandifolia*, *Tilia americana*, and various species of *Fraxinus*, *Quercus*, *Betula*, *Nyssa*, and other deciduous tree genera. The modern cool-temperate climate at nearby Ithaca at 135 masl is like that of Toronto at 90 m; the more southerly location of Ithaca balances its greater elevation. Ithaca mean temperature for July is 20.3°C, for January is −5.8°C, and annually is 7.7°C; the mean annual precipitation is 899 mm.

Field and laboratory work

In September 1968, Karrow, guided by Bloom, measured the Fernbank exposure and sampled for molluscs. In the summer of 1988, Karrow, Miller, and B.G. Warner made a new systematic sampling for molluscs, plants, and other fossils. Bulk samples at 0.5-m intervals at 19 levels yielded the plant and animal fossils; a separate set of five bulk samples (A to E) from the lower part of the fossil zone yielded the molluscs. Sampling proceeded from top down, with samples 1 to 5 from the silt below the gravel, 6 to 8 from the underlying sand, 9 to 16 from the clayey sand, and 17 to 19 from the clayey silt above the lower boulder gravel. The samples for mollusc study correspond approximately to the numbered samples as follows: A to 19, B to 15, C to 14, D to 13, and E to 10. Molluscs recovered from the numbered samples were studied as well as those from the lettered samples. The sampling arrangement is shown in Figure 2. A block sample was taken low in the sequence for a thermoluminescence date, and wood was collected for amino acid dating. A preliminary summary of some of the findings is in Karrow et al. (1990). Grab samples were taken from the Scout Camp site in 2000. Haas et al. (2003) presented a preliminary report on the Fernbank plant macrofossil assemblages.

Bulk samples were wet-sieved through a series of 10- (2000-μm), 35- (500-μm) and 60- (250-μm) mesh sieves. Dry residues were picked for plant macrofossils, molluscs, ostracodes, insects, and microvertebrates. Subsamples of sediment were examined for diatoms and Cladocera. Samples proved to be barren of diatoms, Chrysophyta, and sponges (H.C. Duthie, oral communication, 1992), and of Cladocera and chironomids (B.J. Hann letter, 1998). The vertebrates were identified by Seymour using recent comparative fish skeletons stored in the vertebrate paleontology collection at the Royal Ontario Museum.

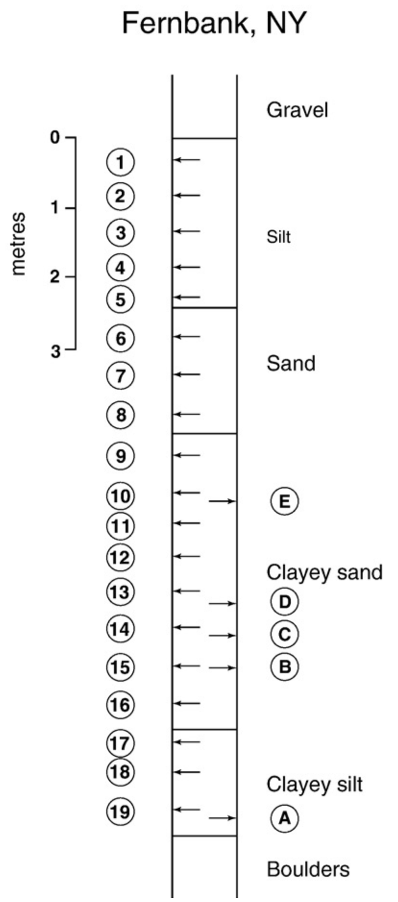

Figure 2. Sampling arrangements for the fossiliferous zone at Fernbank, 1988. Circled numbers are the general samples and circled letters are the mollusc samples.

Loss-on-ignition analysis determined sediment composition (Dean, 1974). Plant macrofossils were analyzed from the 1967 collection by McAndrews and from the 1988 collection by Haas and Heiss. Identifications were based on comparison with modern reference collections at the Royal Ontario Museum and the University of Innsbruck and by using literature, such as Montgomery (1977). The abundant fossil charcoal fragments of samples 1 and 2 in the silt below the gravel were identified (pieces ≥1 mm) using standard literature (Core et al., 1979; Hoadley, 1990; Schweingruber, 1990) as well as an interactive identification key (Heiss, 2000–2006). Plant macrofossils and charcoal particles, stored at the University of Innsbruck paleoecological archive, are available for further study.

Fossil pollen was concentrated by dispersing sediment samples with 10% KOH, decanting to remove sand, and sieving to isolate the 10–150 μm fractions; the concentrate was then digested with HF and acetolysis solution. The residue was stained with safranin and mounted in silicon oil. Pollen and spore percentages have a sum of at least 200 tree pollen; shrub and herb pollen and spore counts outside the sum were individually added to the sum before their percentages were calculated. Identifications follow McAndrews et al. (1973). Transfer functions for region G of Bartlein and Webb (1985) estimate mean July temperature and mean annual precipitation (Bartlein and Whitlock, 1993).

Stratigraphy

Figure 3 compares the stratigraphy described by Maury (1908) with 1968 and 1988 measurements. Since each exposure was probably at a different location, it is not surprising that they differ, but the sequences are generally similar.

At the base of the sequence is Devonian black shale (Geneseo Fm., Bloom and McAndrews, 1972), extending 3 to 6 m above Cayuga Lake. Maury (1908) reported 3 to 4.5 m of boulder clay resting on the bedrock, which, if the overlying fossiliferous beds are of last interglacial age (see below), would most likely be of Illinois age (comparable to the York Till at Toronto). In the 1988 exposure 2 m of boulder gravel, very resistant to hand excavation, overlay the bedrock and may be an equivalent deposit. In the 1968 exposure, no such unit was found, but it could have been concealed by slump in the lower part of the section.

Maury (1908, p. 565) recorded only 1.5 to 2.4 m of fossiliferous clay, the source of the mollusc fossils, and "several inches" of overlying gravel and sand. The more complete descriptions of 1968 and 1988 record sediment coarsening upward from clayey silt to sand with a reversal to sandy silt in the upper part with a thickness of 10 m in 1988 and 12 m in 1968. Maury (1908) noted plants concentrated at the base

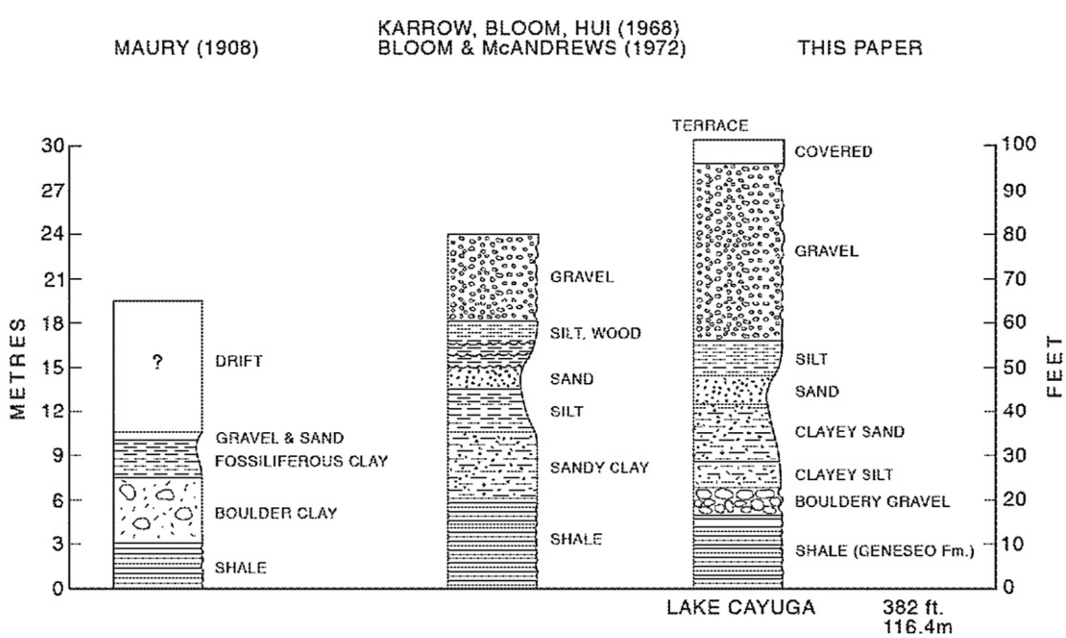

Figure 3. Stratigraphy of the Fernbank interglacial site.

of this sequence, but these were not seen in the recent exposures. Plant material occurred throughout but was most obvious as pieces of wood and woody layers in the upper sandy silt. Molluscs were evident in the underlying sand and commonly seen in the underlying beds. Maury (1908, p. 565) commented about the molluscs that “few are well preserved.” We concur, as recovery of identifiable molluscs was difficult and their state of preservation, particularly large unionid clams, was poor. Concerning plant remains, Maury (1908, p. 567) mentioned “twigs, fragments of leaves, and reeds” but considered them “too decayed and fragmentary for identification”. Bloom and McAndrews (1972, p.7), however, found plant macrofossils to be “relatively well preserved”; our most recent further work also recovered well preserved plant remains.

The uppermost unit of Maury's (1908, p. 565) section was 6 to 9 m of “drift”, inferred to be till because of her reference to “the return of the ice and the deposition of the great mass of overlying drift”. In the 1968 and 1988 exposures the uppermost material was weakly cemented gravel, mostly of medium size but with scattered small flaggy boulders. Clasts were mostly well rounded, but some were angular, and consisted predominantly of shale and siltstone. This gravel was poorly sorted and clast-supported with a clayey to sandy matrix. Its color varied from dark gray to brown and orange. Maury (1908, p. 565) described her section as “in a small ravine which has cut through one of the delta terraces so common in Cayuga valley”. von Engeln (1929, p.470), after visiting the site, referred to this comment of Maury's as suggesting “that the undescribed ‘upper drift’ may be ill-assorted or slumped deltaic material”. Certainly, the upper gravel is more like deltaic gravel than glacial sediment. The nearest source of fluvial gravel would likely be from recession of Taughannock Falls in postglacial time, suggesting a major unconformity at the base of the gravel.

There is little stratigraphic information in the district around the Fernbank site. The only map of Quaternary geology of the surrounding area is the small-scale (1:250,000) map of Muller and Cadwell (1986), which shows mainly till-covered bedrock and a pattern of end moraines indicating a digitate ice front related to small ice lobes in each Finger Lake basin. Although glacial deposits are not now recognized as capping the fossiliferous sediments, the latter's interglacial affinity is clearly indicated by their fossil content and radiocarbon minimum ages of >50,000 ^{14}C yr BP.

Chronology

There are three minimum ^{14}C dates on wood: >50,000 ^{14}C yr BP (Y-2431) 19 m above Cayuga Lake, >52,000 ^{14}C yr BP (Y-1404) 14.3 m above the lake, and >54,000 ^{14}C yr BP (Y-1403) 8.5 m above the lake (Bloom and McAndrews, 1972). Wood from the upper sandy silt was submitted for an isotope-enrichment AMS date to the Groningen laboratory in 1997, with no result reported.

Molluscs from the 1968 collection were submitted to the late E.P. Hare, Geophysical Laboratory, Washington, for an early attempt at amino acid dating (Hare and Mitterer, 1967); preliminary results indicated a similar age for molluscs from Fernbank and the Don Formation at Toronto (E.P. Hare, oral communication about 1973) as did later additional amino acid analyses (Karrow et al., 1990). Amino acid dating of wood (Karrow and Rutter, 1988) gave inconsistent results and was abandoned.

A sample of clay 30 cm above the boulder gravel and 9.8 m above the lake was submitted to Cambridge University for thermoluminescence dating. R. Grun (letter, July 10, 1989) reported a date of 81 ± 11 ka by the total bleach method; the partial bleach method suggested the sample was completely bleached during deposition. This result may be compared with TL dates of 68 to 80 ka reported by Berger and Eyles (1994) for the interglacial Don Formation at the Toronto Don Valley Brickyard type section and is similar to various other last interglacial TL dates around the world. Last interglacial luminescence dates are commonly in the range of 80 ka because of a well-known problem of “anomalous fading” (Lamothe et al., 1998). Research of the last decade has provided corrections, such as Huntley and Lamothe (2001) and others, and ages like that at Fernbank of Grun are believed to be severely underestimated. With the corrections, such dates can be brought into concordance with expected ages in the range of MIS5e (130 ka) (adapted from a letter by M. Lamothe, 2008).

Paleontology

Molluscs

It was mainly the molluscs that caught Maury's (1908) attention. Comparison with molluscs described from Toronto by Coleman (1894) led her to conclude that the Fernbank locality was interglacial, with over half of her list of species also found at Toronto. Plant remains at Fernbank were given little attention by Maury (1908, p. 565), who described the fossiliferous clay as “very peaty at the base where it is composed almost wholly of the remains of plants”, but in contrast that “the fossils are all fresh-water shells”.

It was therefore disappointing to find that many of the molluscs recovered in the present study were so poorly preserved that several taxa could only be identified to genus. Most of the mollusc shells were fragmentary. Sample E, however, included some articulated *Pisidium* with the periostracum. Many shells were broken and distorted, but were relatively complete, suggesting that they remained *in situ* after crushing, perhaps due to glacial overriding.

The large unionid clams found in this study could not be recovered adequately for identification. The shells had a soft “cottage cheese” consistency when wet and when dry they delaminated into flaky fragments. Many were buried with the umbo down and the plane of symmetry between the valves vertical, but are now compressed into a horizontal plane with the appearance of a large white butterfly. Their deformation testifies to the extreme subsequent dewatering and vertical compaction of the enclosing sediment. The unionids collected by Maury and deposited at Cornell University were not identifiable because of their poor preservation.

Maury (1908, p. 566) provides a composite list apparently derived from random sampling of the whole exposure; her assemblage does not appear characteristic of any particular part of the sequence. Our collections included six of the ten aquatic gastropod species listed by Maury (1908). In addition, we report four species of gastropod, *Valvata sincera*, *Probythinella lacustris*, *Amnicola* cf. *walkeri*, *Fossaria parva*, and four species of sphaeriid clams, *Sphaerium rhomboideum*, *Pisidium ferrugineum*, *Pisidium nitidum*, and *Pisidium punctatum* not previously reported by Maury (1908). No terrestrial taxa were reported by Maury (1908) but our collections include *Strobilops* sp. (samples 11 and 9) and *Catinella* sp. (samples 15, 11, and 9). These ten newly reported taxa significantly extend Maury's (1908) faunal list from 18 to 26 taxa. The total mollusc list from Fernbank (Table 1, plus unidentified unionids), however, is still much shorter than the over 80 taxa now known from the Toronto interglacial (*sensu stricto*, Kerr-Lawson, 1985; Karrow, 1990; Kerr-Lawson et al., 1992; Karrow et al., 2001).

The list of species is given in taxonomic order in Table 1 following Clarke (1981), with nomenclature mainly according to Turgeon (1998). Taxa for each sample are given in Table 1 according to sample level from lowest and oldest at the left and with the two series of samples (Fig. 2) interdigitated according to stratigraphic position. Numbers of taxa decline upward, with the highest diversity in A, 17, and 15 with 11, 10, and 10 taxa, respectively. This corresponds to the clayey silt and lower clayey sand units; no identifiable shells were found in the sand and silt units, and the highest visible shells extended only to the lowest part of the sand.

The two terrestrial taxa were mostly found in the highest sample levels, where the lacustrine *Valvata* spp. are not present, possibly

Table 1
Molluscs from Fernbank, New York.

	Samples														
	A	19	18	17	16	B	15	C	14	D	13	12	11	E	9
Strobilops sp.													X		X
Catinella sp.							X						X		X
Campeloma decisum						X	X			X	X			X	
Valvata sincera									X						
Valvata tricarinata	X	X	X	X	X		X	X	X	X					
Probythinella lacustris	X		X	X											
Amnicola limosus	X	X		X	X	X	X	X		X	X	X			
Amnicola cf. *walkeri*			X	X											
Fossaria parva				X											
Fossaria sp.							X							X	
Lymnaea sp.													X		X
Stagnicola sp.												X			
Physella sp.	X	X		X			X	X	X	X			X	X	
Gyraulus deflectus		X	X												
Gyraulus parvus	X			X		X	X								
Helisoma anceps	X		X	X	X	X	X	X	X	X	X	X	X	X	
Unionid fragments								X			X				
Sphaerium rhomboideum												X		X	
Sphaerium simile												X			
Sphaerium sp.						X		X							
Musculium sp.	X														
Pisidium casertanum		X													
Pisidium compressum	X			X		X	X	X	X		X	X	X	X	
Pisidium ferrugineum	X											X			
Pisidium nitidum	X	X	X					X							
Pisidium punctatum	X														
Pisidium sp.				X	X		X			X					X

X — present as juveniles only, not counted.

suggesting shallowing water and greater terrestrial influence; both terrestrial taxa are commonly found in marginal land areas such as marshes or in plant debris near water bodies.

Many Fernbank taxa prefer mud substrates and slow currents or quiet conditions (Clarke, 1981; La Rocque, 1966–1970), which is consistent with the fine sediment in which they occur in the exposure. The most abundant species present are common and widely distributed through much of North America in streams, rivers, and lakes. Also, many of the taxa are usually found in well-vegetated bottoms (e.g., *Amnicola*, *Gyraulus*, *Sphaerium*, *Pisidium*) with some such as *Amnicola* and *Probythinella* feeding on algae (Jokinen, 1992). Most Fernbank taxa can now be found living in the central New York region and are consistent with a warm interglacial interpretation.

Ostracodes

Ostracodes, few in number and species (Table 2), occur only in the lower part of the sequence, peaking in abundance in sample 17 and generally paralleling the abundance of molluscs. *Candona caudata* was the most abundant species. The assemblage indicates a permanent water body about 2–3 m deep, high in bicarbonate with a pH of 8–8.2 Annual precipitation exceeded evaporation by 40–180 mm and there was a relatively warm, wet climate supporting mixed forest vegetation of an interglacial (L.D. Delorme letter, September, 1998).

Insects

At Fernbank, three of the five sub-phyla of Arthropoda are represented by Chelicerata (Archnida: Acarini: Oribatidae), Hexapoda (Insecta), and Crustacea (Ostracoda). Oribatids live in the top layer of soil in leaf litter or debris, and can be found on mosses and lichens and other low plants (Krivolutsky and Druk, 1986); no further ecological inferences can be made.

Coleoptera (beetles) from the Fernbank site are extremely poorly preserved. Out of the several hundred fragments selected by dry-sorting only about 10% (about 25 individual fragments) are well enough preserved to allow some comments. Most of these come from samples 18, 17 and 15. Arthropod remains were not recovered from samples 6 and 7 and many of the other samples had no identifiable fragments. Poor preservation likely results from primary deposition at the site since warmer climate sites are more prone to bacterial and fungal attack, especially if the insect fragments are not immediately buried. Unfortunately, the problem of thin and corroded chitinous fragments was complicated by the dry-picking technique that was used following screening. This caused many fragments to curl and crack even further.

Most of the fragments were derived from two sources representing a transition from a forested environment to a water body. The terrestrial environment contributed a number of individuals from different Coleoptera families. These include ground beetles (Carabidae), weevils (Curculionidae), rove beetles (Staphylinidae), and bark beetles (Scolytidae). Moist lacustrine-marginal habitats also contributed individuals from the Chrysomelidae (leaf beetles) and Heteroceridae (variegated mud-loving beetles). Aquatic environments are represented by members of the Hydrophilidae (water-scavenging beetles) and Dytiscidae (predaceous water-diving beetles). Elements of both environments persist from the lowest identifiable fragments in sample 18 to the highest sample 2. The basal level (sample 19) and the uppermost level (sample 1) had only unidentifiable insect cuticle. Only general environmental comments can be made based on generic identifications of beetles and the few specimens where a specific identification has been provided.

The terrestrial environment is represented by carabid, staphylinid, and curculionid beetles from at least eight different genera, all of which, with the exception of a weevil head (likely an *Apion* species), are unidentifiable beyond the family level. Certainly there were trees in the vicinity since scolytids (bark beetles) appear at several levels (samples 18 to 14). One of these from sample 14 is a left elytron, identified as *Hylesinus* and probably *H. aculeatus*. This species lives exclusively on *Fraxinus* (ash) and has only been recovered from interglacial sites at the Don Valley, Toronto (Morgan et al., in preparation) and at Innerkip, near Woodstock, Ontario (Pilny and Morgan, 1987). The same genus *Hylesinus* (*Lepersinus*) sp. was recovered from sample 17.

Other scolytids (mostly indet.) were also recovered from samples 14 and 17. One of the beetles from sample 17 is likely a *Pityophthorus* sp., a large and diversified genus with 218 recorded species in Central and North America. Of these, the majority are confined to western and southwestern North America, Mexico, and Central American countries. The approximate 15% that occupy parts of Canada and the eastern United States are characteristically found in "…unthrifty seedlings, shaded out branches, injured tops, slash or broken branches, or the pith of green twigs." (Bright, 1976; Wood, 1982). Although the genus has been recorded from various tree species it is commonly found in *Pinus* (especially *P. strobus*), *Picea* (especially *P. glauca*), and *Abies*.

Water-marginal environments are represented by beetles that either inhabit muddy substrates such as the staphylinid *Bledius*, the

Table 2
Ostracodes at Fernbank, New York.

Samples	19	18	17	15	14	11	10
Candona sp.		X			X	X	X
Candona caudata	4	2	31	9			
Candona ohioensis		2					
Candona cf. *C. ohioensis*			2				
Cyclocypris sp.		X					
Cyclocypris ampla	1			2			
Cyclocypris sharpei			2				
Cypria cf. *C. opthalmica*			1				
Limnocythere cf. *L. paraornata*	1		6	2			
Limnocythere verrucosa			2				

X — present as juveniles only, not counted.

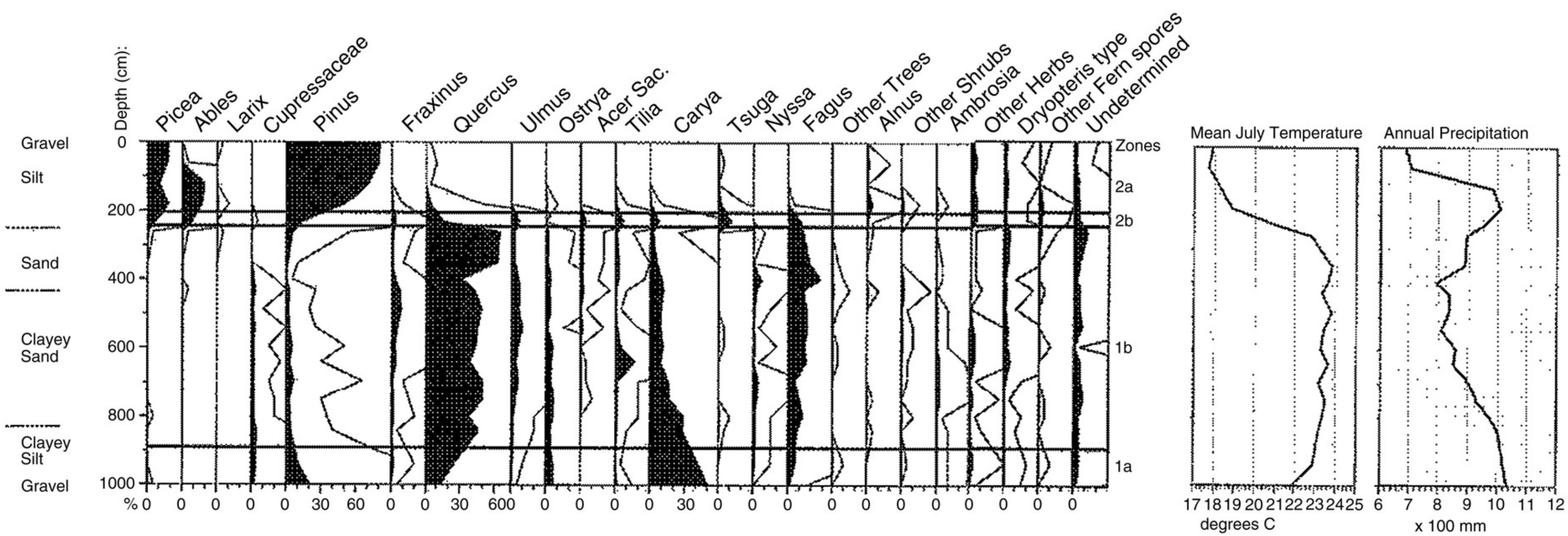

Figure 4. Fossil pollen and reconstructed climate values from the 1988 section. Modern climate values for nearby Ithaca are for mean July temperature, 20.3°C, and for mean annual precipitation, 899 mm. Other tree pollen includes rare grains of *Juglans cinerea*, *Carya*, *Platanus*, *Celtis*, *Morus* and *Liquidambar*. Other shrub pollen includes rare grains of *Shepherdia argentea*, *S. canadensis*, *Corylus*, *Sarcobatus*, and *Vitis*. Other herbs include rare pollen grains of *Thalictrum*, Poaceae, *Artemisia*, *Iva annua*, Tubuliflorae *pp*, Chenopodiineae, *Humulus*, *Arceuthobium*, Brassicaceae, Cyperaceae, and *Nuphar*. Other ferns include rare spores of *Osmunda*, *Adiantum*, *Botrychium*, *Pteridium*, *Lycopodium*, *Sphagnum*, and *Selaginella selaginoides*. There were a few pre-Quaternary spores. Pollen and spore counts are deposited in the North American Pollen Database (J.H. McAndrews).

heterocerid *Heterocerus*, and the sedge-eating beetles that belong to the genera *Donacia* and/or *Plateumaris*. Shallow, open-water environments can be concluded from the hydrophilid and dytiscid diving beetles that are represented by several individuals.

Ant (Formicidae, Hymenoptera) mandibles were found at several levels in the Fernbank site (samples 4, 9, 11, 12). Mandibles of the aquatic insect *Sialis* (Sialidae, Megaloptera) were found in samples 15, 17 and 18.

Bryozoans

A statoblast of *Cristatella mucedo* was found in Sample 18. *C. mucedo* is often present as sub-aquatic colonies in unpolluted freshwater ponds, and in shallow areas of lakes and slow streams where they coat the stems of plants and form masses on the underside of rocks in deeper water. The statoblast is distinctive as a rounded and frequently flattened disk with arms terminating in small hooks around the margin (Økland and Økland, 2000).

Vertebrates

As with the molluscs and insects, most vertebrate specimens were fragmentary, making identifications difficult, but all remains found are fish. The upper units (silt and sand, samples 1 to 8) yielded no identifiable vertebrate remains. In the clayey sand (samples 9 to 16) there were two isolated unidentified conical fish teeth (ROM 49257-8) and three fragmentary pharyngeal teeth of Catostomidae, or suckers (ROM 49255-6, 49259).

The lowest fossiliferous unit, clayey silt (samples 17 to 19), yielded ten vertebrate specimens. Two conical fish teeth (ROM 49264) remain unidentified only because many fish have similar-looking teeth. Two others are fragmentary enough to preclude secure identification, but the likely possibilities are few. An incomplete fish scale (ROM 49266) most likely represents a member of the Centrarchidae (sunfishes), but Percichthyidae (temperate basses), Sciaenidae (drums), and Percidae (perches) cannot be ruled out. Similarly, an incomplete anteriormost fish vertebra (ROM 49265) appears most similar to the percomorph families Centrarchidae (sunfishes), Percichthyidae (temperate basses) and Percidae (perches), but its incompleteness prevents identification. This vertebra superficially resembles Percopsidae (trout-perches), but this appears likely due to the angle of breakage only. Of the remaining six specimens, two small (ROM 49261) and one large (ROM 49262) pike teeth (*Esox* sp.) are the only specimens that can be identified to genus. Two others are catfish spines (Ictaluridae), the larger of these (ROM 49260) is incomplete and unidentifiable beyond catfish and the smaller (ROM 49267) is a remarkably tiny, almost complete right pectoral spine, only 2.5 mm long. This represents a tiny fish, as the smallest recent comparative material available, a 6.9-cm *Ameiurus nebulosus* (ROM R2595), has a pectoral spine 10 mm long. This fossil most likely represents a juvenile bullhead (*Ameiurus* sp.) and not a madtom (*Noturus* sp.), because the pectoral spines of madtoms have a smoother shaft without a ropy appearance, unlike *Ameiurus* and the fossil. Also, there is one tooth on the posterior face of this spine that resembles bullhead more than madtoms. The final specimen represents a minnow (Cyprinidae) pharyngeal arch (ROM 49263). Although two pharyngeal teeth have fallen out of the arch since collection, the arch appears to have a "1, 4" tooth pattern (i.e., 1 tooth on the outer row and 4 on the inner row). This is the pattern of the common *Notropis* and *Nocomis* minnows, but due to the similarity of the arches of these genera, the fossil should remain identified as Cyprinidae only.

The lowest layer (samples 17 to 19) preserves the most vertebrate remains, with a decreasing number of fossils upwards in the sequence — only a few occur in the second layer (samples 9 to 16) and the upper two layers are barren of identifiable vertebrate fossils. All remains are of freshwater fish characteristic of vegetated, quiet, soft-bottomed lakes and rivers in the Ithaca area today (Page and Burr, 1991), consistent with the sedimentological evidence.

Plants

In 1966, pollen analysis by A.A. Berti on a sample collected by Bloom yielded pollen of deciduous trees, further supporting an interglacial environment. Similar deposits have been analyzed for fossil pollen in New York (Muller et al., 1993), Indiana (Kapp and Gooding, 1964, 1974), and southern Ontario (Terasmae, 1960; Westgate et al., 1999; Richard et al., 1999).

The pollen diagram from the 1967 collection with fewer samples contains less detail but is generally similar to the 1988 collection (Fig. 4). There are two litho-biostratigraphic zones, a lower Zone 1 in calcareous sand and silt with molluscs and deciduous tree pollen,

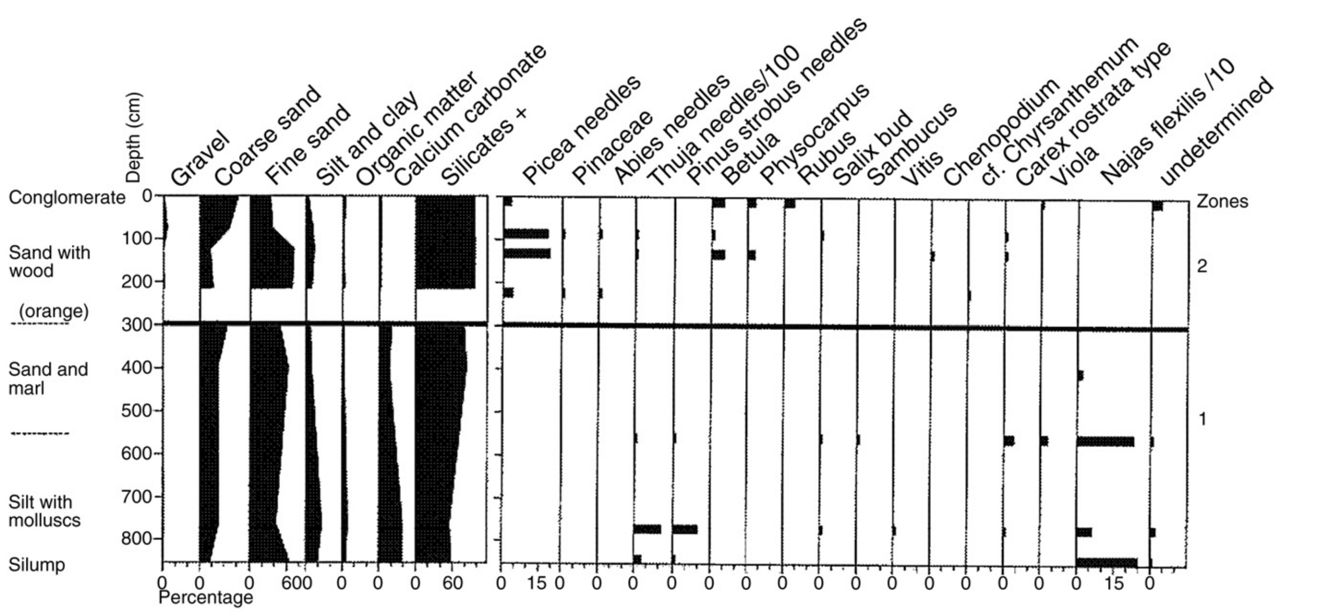

Figure 5. Fernbank Site, 1967 collection of sediment texture and composition from LOI analysis. For plant macrofossils 200 ml were examined for each of eight levels (J.H. McAndrews).

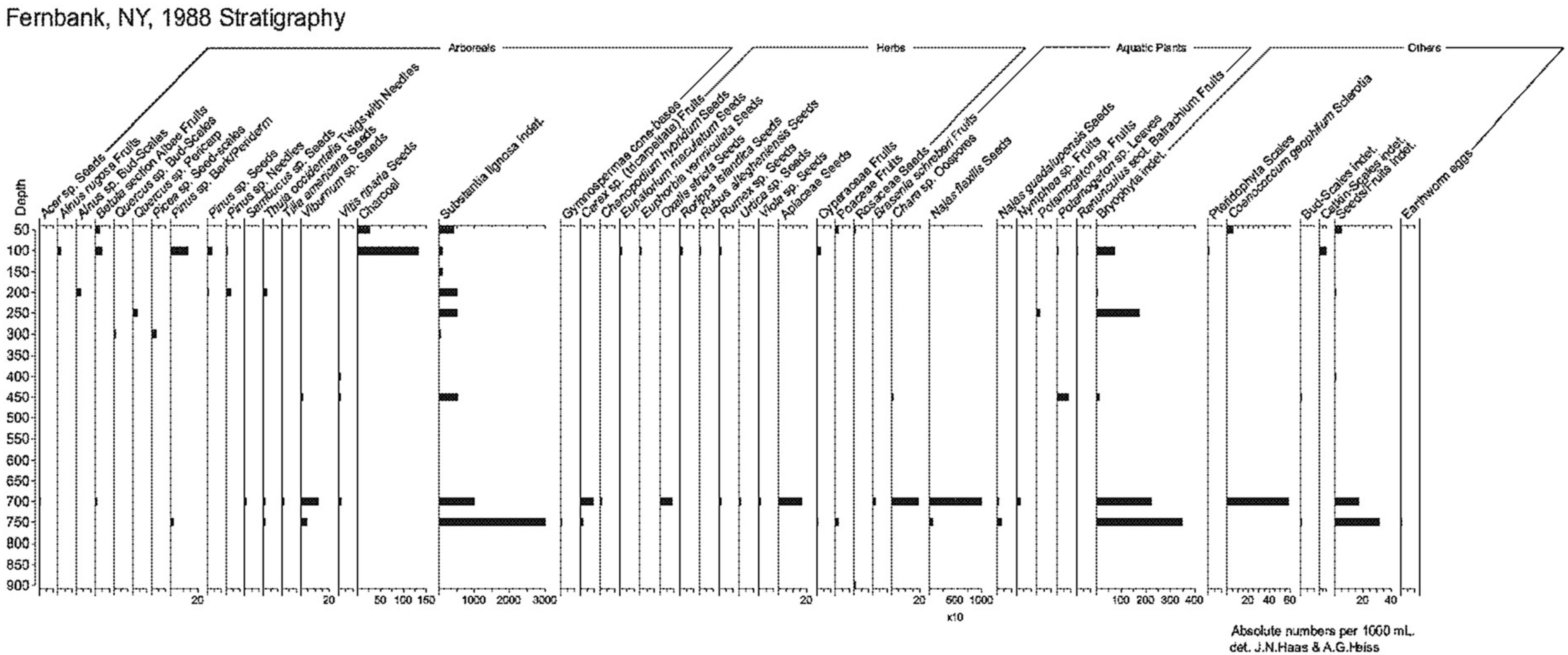

Figure 6. Selected macrofossils from the Fernbank 1988 stratigraphy found per 1000 ml sediment each (complete macrofossil data available on request from J.N. Haas).

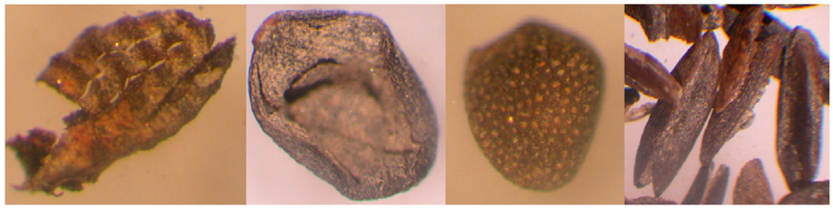

Figure 7. Examples of subfossil seeds and fruits found at Fernbank. From left to right: *Euphorbia vermiculata* seed, *Alnus rugosa* fruit, *Rorippa islandica* seed and *Najas flexilis* seeds. Determination and photos J.N. Haas.

and an upper Zone 2 in sand with conifer tree pollen. The contact is sharp, suggesting a hiatus, and in the 1967 section at the contact there was leached and non-fossiliferous coarse orange sand, suggesting subaerial exposure or lateral movement of oxidizing groundwater along a permeability boundary.

Zone 1 is dominated by deciduous tree pollen, especially *Quercus*, *Fagus*, and unusually high *Carya*; shrubs and herbs are insignificant. Peaks of *Carya* and *Pinus* distinguish Subzone 1a (Fig. 4) whereas 1b has a mixed assemblage that also includes *Fraxinus*, *Ulmus*, *Ostrya*, *A. saccharum*, and *Nyssa*, pollen types not identified from the 1967 section. In contrast, Zone 2 is dominated by evergreen tree pollen — *Pinus*, *Picea*, and *Abies*. A *Tsuga* peak defines Subzone 2a, which is transitional from 1b with modest amounts of deciduous tree pollen. *Alnus* reaches a low peak in 2b. Three samples from the small Scout Camp exposure north of the main site had consistent pollen content comprising 50% *Pinus*, 40% *Picea*, some *Betula* and other minor taxa and correlates with Subzone 2b of the Fernbank section; this is consistent with its elevated position above Cayuga Lake.

From transfer functions, July temperatures (Fig. 4) are ca. 23–24°C in Zone 1 and abruptly drop to 18°C in Zone 2b. This is comparable to a latitudinal shift of six degrees (e.g., from Columbus, Ohio, to North Bay, Ontario). Mean annual precipitation does not parallel temperature but peaks above modern levels in zones 1a and 2b.

Plant macrofossils were sparse but well preserved in the 1967 section (Fig. 5). Zone 1 has abundant needles of *Thuja* and *P. strobus* (needle tips), together with *Najas flexilis*, an aquatic annual of warm, shallow water. In contrast, Zone 2 has abundant remains of boreal species including *Picea*, *Abies*, and *Betula* cf. *glandulosa*. *Physocarpus* is a shrub of cool lakeshores.

During collecting trips in 1966 and 1967, several flattened tree trunks or large branches were collected, mostly from the sand and silt beds about 15 to 18 m above lake level (Fig. 3). Many logs were up to 0.5 m in length, 15 cm in width, and 3 cm in thickness. All were strongly compressed into the horizontal plane. Cell structure is crushed and sheared although annual growth layers are still visible. The resinous conifer wood, probably *Picea* sp., burns with a smoky flame but has the lustre and brittle fracture similar to anthracite coal. Samples for handicraft work can be highly polished. Some were stacked and deformed across each other as in a log jam. No signs of beaver gnawing were detected.

Well-preserved plant remains were collected in 1988. More than 17,000 plant macrofossils were found in the twelve samples analyzed (samples 10–13, 16–17, and 19 were not available) and were identified to species. The lower clayey silt (sample 18) as well as the sand (samples 6–8) were relatively poor in plant remains, whereas the clayey sand (samples 9, 14–15) and silt (samples 1–5) were rich in plant remains (Fig. 6). Twelve arboreal taxa, 17 herb taxa, as well as 8 aquatic and peatland taxa were identified by means of their diaspores, bud-scales, seed scales and leaves. In addition, several hundred vegetative remains were identified to plant groups. Twenty-seven larger charcoal pieces (from a total of 159 charcoal pieces found in the two uppermost sediment samples) were also identified (see below).

The macrofossils found within the clayey sands clearly indicate sedimentation in an aquatic, temperate habitat. Abundant seeds of submergent and emergent plants such as *N. flexilis* (Fig. 7), *Najas guadalupensis*, *Brasenia schreberi*, *Potamogeton*, bryophytes (mainly *Drepanocladus*), and *Chara* (Fig. 6) point to the importance of aquatic plants at that time and to sedimentation within still, shallow waters. Various terrestrial upland plants occur in the same samples. Macrofossil evidence (seeds and fruits) from woody species of *Acer*, *Betula*, *Pinus*, *Sambucus*, *Thuja occidentalis*, *T. americana*, *Viburnum*, and *Vitis riparia*, shows that the surroundings of the former aquatic habitat were dominated by trees and shrubs. These uplands, however, must have been relatively rich in herbs as shown by sedges (*Carex*), *Chenopodium simplex*, *Oxalis stricta*, *Rubus allegheniensis*, *Urtica*, and *Viola* (Fig. 6). Abundant fungal sclerotia (from *Cenococcum geophilum*) indicates soil disturbance in the littoral zone.

The few macrofossils in sand samples 6 to 8 (Fig. 6), however, are of taxa not found elsewhere in the section. *Quercus*, *Picea*, and cf. *Ostrya* show mixed forest stands. Samples 1 to 5, on the other hand, were again rich in plant macrofossils and recorded diversity (Fig. 6). Gymnosperm trees (*Pinus*, *T. occidentalis*) as well as some rare finds of *Alnus rugosa* (Fig. 7) and *Betula*, corroborate the pollen data and consequently the reconstruction of boreal forest and climate. The macroscopic charcoal of samples 1 and 2 (Fig. 6) documents possible local fire events within this forest dominated by evergreen conifers. The identification of 27 charcoal pieces larger than 1 mm (Table 3) confirms the presence and fire sensitivity of taxa such as *Picea mariana*/*glauca*, *P. strobus*, and Cupressaceae. However, charcoal from deciduous trees (e.g., *A. saccharum*) was also found, showing that such trees did, at least rarely, exist within these boreal forests.

In addition, abundant and diverse herb taxa were also recorded (Figs. 6, 7) by seeds and fruits of *Eupatorium maculatum*, *Euphorbia vermiculata*, *Rorippa islandica* and *R. allegheniensis*, among others, which show that the boreal-type forests described above also supported a rich, cold–temperate herb layer and that wet areas must have existed (e.g., presence of *R. islandica*). A few seeds from aquatic plants (e.g., *N. flexilis* in samples 4 and 5) occur during the still temperate, transitional phase from deciduous to boreal forests. *Potamogeton* and *Ranunculus* sect. Batrachium show that the silt layers were also deposited in a shallow aquatic habitat, which by this time

Table 3
Charcoal (>1 mm) determination at Fernbank, New York 1988 samples (A.G. Heiss).

	FNY — 1 50 cm	FNY — 2 100 cm
Picea sp.	1	
Pinus strobus		3
Pinus sp.		1
cf. *Pinus*		1
cf. *Picea mariana*/*glauca*	1	
Cupressaceae s.l. (incl. Taxodiaceae)	1	
Gymnosperms	2	10
Acer saccharum	1	
Deciduous tree/shrub indet.	1	1
Bark indet.	1	1
Wood indet.		2
Total	8	19

shifted toward a boreal climate. *Chara* oogonia (green algae-stonewort) were noted in samples 5, 9, and 14. These are aquatic algae of hard-water lakes (Cole, 1983).

Discussion

The fossil record from the Fernbank site, as it is now known, is best represented by plants, which are the best preserved group. Even though the original recognition of the interglacial nature of the site was based on molluscs, further study yielded disappointing results because of generally poor preservation. Nonetheless, a diversity of unidentified unionids suggests interglacial conditions. All fossils (molluscs, ostracodes, insects, vertebrates, plants) are most abundant and diverse in the lower part of the sequence and are compatible with or suggest interglacial climate, generally like assemblages living in the area today. Non-plant fossils are dominantly aquatic, with a few terrestrial fossils. The most detailed comments on paleoecology necessarily focus on the plants.

There is no indication of plants growing in place and therefore the plants are transported detritus rather than peat. The sediment coarsens upward as if a delta carrying the detritus was advancing into a lake. The pollen succession resembles that at the Smith Farm of Indiana (Kapp and Gooding, 1974) and the Don Brickyard in Toronto (Westgate et al., 1999). One difference is that the pollen of the southern *Liquidambar*, a genus that does not grow naturally in Ontario, is nearly absent at Fernbank but is more common in the Toronto site. On the other hand, *Nyssa* pollen, which is absent from the Toronto site, reaches several percent at Fernbank. Although *Nyssa* today ranges northward into southern Ontario, pollen in surface samples has been recorded over 1% only south of New York and most of these cluster at 26°C July mean temperature (Williams et al., 2006). Thus, the abundance of *Nyssa*, like the transfer-function results, supports a warmer than present interglacial at Fernbank.

Macrofossils from submergent and emergent aquatic plants that grow in warm and shallow freshwater lake conditions (0.5–3 m) indicate a warm interglacial climate for the Fernbank section, at least for the time of the deposition of samples 15 to 4. Given the extraordinary abundance of annual aquatics such as *N. flexilis*, a plant needing water temperature of at least 19°C for its seed germination in late spring and early summer as well as for success in autumnal seed production (Haas, 1996; Haas and McAndrews, 2000), the climate of the Fernbank interglacial site was at least as warm or warmer (1–2°C) than the present interglacial. This is also corroborated by the abundant *Carya* values (Fig. 4), a thermophilic tree species, associated with July means of 18 to 30°C and January means of −10 to 13°C (Williams et al., 2006). The warm–humid climatic phase during the first three-quarters of the section was characterized by upland forests rich in deciduous trees and with surprising herb diversity. No fire was recorded during this period of warm temperate climate, which may reflect few highly combustible conifer trees, as well as moist deciduous forest around Fernbank, making lightning-caused fires and their expansion difficult (Zoller and Haas, 1995). However, during the final phase of the Fernbank sediment deposition, one or more fires left a concentration of macroscopic charcoal. The species determination of the 27 charcoal particles >1 mm (Table 3) provides the first insights into the fire history of a North American interglacial older than the Holocene. Besides abundant conifers, deciduous trees such as *Acer* were burned by these fires (but only a single find). The contemporary rich herb layer may point to the fact that fire had an effect on local to regional species distribution and diversity during this phase of colder, boreal climate.

Comparison of pollen and macrofossil records resulted in general and good agreement between the two data sets. However, differences exist, such as the presence of macroscopic charcoal from *Acer* during the final Fernbank phase of boreal-type forests, where *Acer* pollen was not recorded, and presence of macroscopic *Picea* remains and absence of *Picea* pollen during the late domination of deciduous forests (sample 6) at Fernbank; redeposition may also explain these differences. On the other hand, the macroscopic determination of local herbs to species level adds to our knowledge on species diversity during interglacials. Once again, as already shown for the Toronto interglacial beds (Westgate et al., 1999) this shows the invaluable importance of analyzing pollen and plant macrofossils from the same sediment section (see also Birks, 2000, and Birks and Birks, 2003, for additional examples).

While Maury's original interpretation of the Fernbank site as interglacial is confirmed by further work, and its correlation with the Toronto interglacial is supported, the fossil record at Fernbank is much more limited. Whereas the Toronto record exceeds 500 taxa, the total for Fernbank is only about a fifth of that. The major factor causing the difference is chance preservation. The Toronto interglacial sediments occur as sheet-like deposits, whereas Fernbank sediments are known only from a small area, which limits the possibility of sampling material that was deposited under varied paleoenvironments.

A remaining issue of regional significance is the cause of the putative Sangamon higher-than-present lake levels at both the Fernbank and Toronto Brickyard interglacial sites. Moraine dams left by pre-Sangamon ice at the outlets of both Lake Ontario and Cayuga Lake can be hypothesized without any direct supporting evidence. A more interesting hypothesis is that the two sites were on the shores of a single water body, analogous to the late Wisconsin glacial Lake Iroquois, although the extent of such an earlier lake is unknown and complicated by isostatic recovery. Nevertheless, the similarities of the flora and fauna of the Don Formation and the interglacial beds at Fernbank are compatible with deposition in a common water body at altitudes comparable to those of the later Lake Iroquois levels. Cayuga Lake is by far the lowest of the Finger Lakes (116.4 m above sea level) and the only one likely to have been affected by an interglacial lake comparable to the one in which the Don Formation was deposited.

Conclusions

This study expands the known record at Fernbank in particular and for New York more generally. In addition to the early record of Maury (1908), which listed molluscs and mentioned plants, the mollusc list has been expanded, a rich plant record (from both pollen and plant macrofossils) has been detailed, and new animal groups (ostracodes, insects, vertebrates) have been added. Documentation of animal and plant assemblages has allowed more detailed interpretation of paleoenvironments in the last (Sangamon) interglacial.

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