

POLLEN DIAGRAMS FOR SOUTHERN ONTARIO APPLIED TO ARCHAEOLOGY



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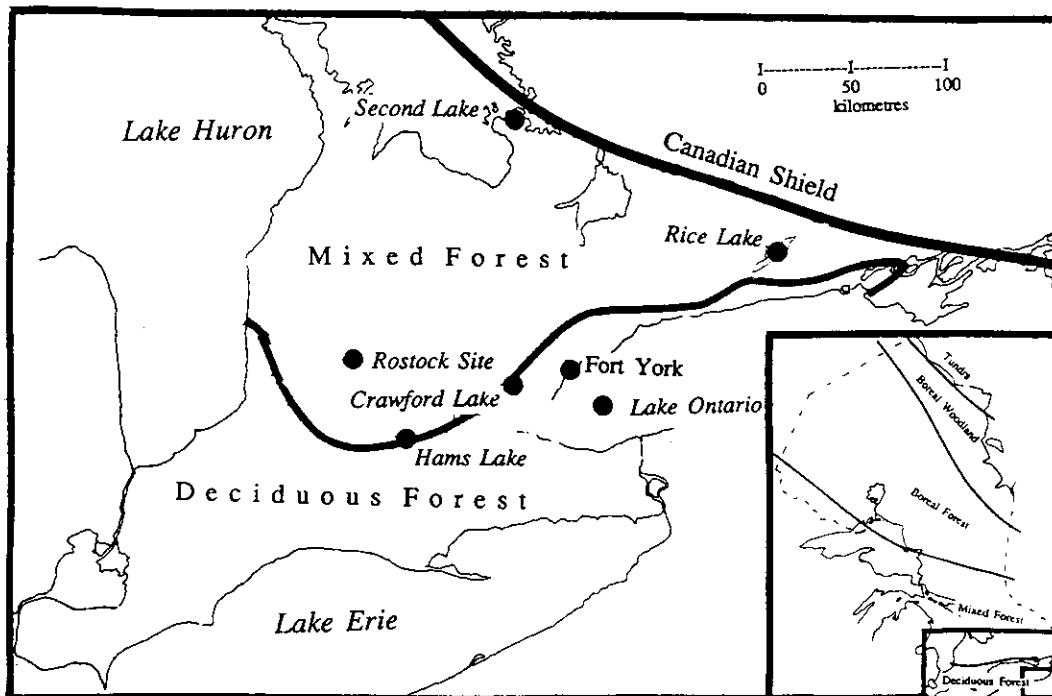
ABSTRACT

Pollen diagrams from the Late Pleistocene (Rostock Mammoth Site) and for the Holocene (Hams Lake) were selected as regional postglacial standards because they have continuous sedimentation, good pollen preservation, and abundant radiocarbon dates. Also the sites are centrally located along the boundary between the deciduous and mixed forest regions. With deglaciation a periglacial desert was formed and then succeeded by herb/shrub tundra followed by spruce woodland, boreal forest and modern forest, deciduous forest in the south or mixed forest northward. The Hams Lake diagram when converted to tree biomass shows that sugar maple was the forest dominant for the past 8,000 years. Transfer functions applied to these pollen diagrams estimate mean July temperature to be 9°C around 12,800 years B.P. with a slight hypsithermal of 21.2°C around 5,500 years B.P.; modern mean July temperature is about 20.8°C. A pollen diagram from Lake Ontario shows how poor preservation biases pollen percentages much like the pollen assemblages from archaeological soils. At Rice Lake the Late Archaic McIntyre site was occupied most intensively when adjacent to a wild rice marsh and virtually abandoned when separated from the wild rice by shallow marsh. At Crawford Lake corn pollen from A.D. 1350 to 1650 records Iroquoian farming; pollen of the introduced sheep sorrel appears in 1820 but ragweed, the main indicator of forest clearance due to Eurocanadian agriculture, does not expand until 1850. Dated soils from Forts Rouille and York, like Lake Ontario, have poorly preserved pollen except for the relatively robust grains of pine, hemlock, basswood, and the introduced dandelion.

INTRODUCTION

Southern Ontario is the area south of the Canadian Shield with generally deep calcareous soils and low relief (Figure 10.1). For this area, Karrow and Warner (1990) reviewed the glacial and postglacial geology and vegetation history of the past 20,000 years and listed 78 fossil pollen sites. However, they only provide a "generalized representative pollen diagram" and a pollen diagram from Greenbush Swamp, a peatland on Manitoulin Island where soils are atypically shallow. The following builds upon their work by presenting two specific pollen diagrams which together make a standard which spans the period from glacier retreat to the present. I then use this standard for forest and temperature reconstruction and to interpret pollen analyses at three archaeological sites.

Figure 10.1: Map of Ontario showing modern vegetation zones and sites of pollen diagrams.



Regional standard diagrams are from lake sites rather than from peatland sites. Warner *et al.* (1991) compared the pollen stratigraphy of a peatland with a nearby lake, and their data illustrates some of the following generalizations: 1) lakes are older than peatlands and thus have a longer record, 2) lake mud accumulation is steadier and more continuous than the growth of peat, 3) peatlands tend to dry out and relatively young pollen may be displaced downward into older strata through desiccation cracks, 4) pollen is usually better preserved in lake mud, and 5) pollen in lake mud reflects vegetation on

the upland whereas peat often contains abundant pollen from local wetland plants which can be confused with those from upland plants, e.g. spruce and sedge. Thus lakes provide a more generalized record of vegetation and climatic history; however, local pollen from wetlands (and soils) may help answer questions posed by archaeologists about human subsistence potential, impact on the environment, introduction of plant species, site location, and dating. The purpose of this paper is to present two regional pollen diagrams, to describe their zonation and chronology, and to interpret them together with local pollen diagrams to reconstruct climate and both regional vegetation and local vegetation at archaeological sites, ranging in time from Paleoindian through historic.

Standard pollen diagrams spanning the postglacial reflect regional upland vegetational succession largely driven by climatic change. They are zoned according to McAndrews (1981) and McAndrews and Jackson (1987) and have a time scale based on interpolation between radiocarbon dates and extrapolation of the rate of sedimentation downward where there is no basal radiocarbon date. The percent pollen diagrams, biomass diagram, and mean July temperature estimates were made with a micro-computer and laser printer using the program CANPLOT (Campbell and McAndrews 1992). Original data is available from the Royal Ontario Museum.

Ontario regional vegetation (Figure 10.1) reflects poleward decline of temperature (McAndrews and Manville 1987); mean July temperature ranges from 21°C along the shore of Lake Erie to 12°C along the coast of Hudson Bay (Bartlein and Webb 1985). The area south of the Canadian Shield is dominated by mixed forest of evergreens and deciduous hardwoods while deciduous forest prevails north of Lake Erie and along the shore of Lake Ontario (Figure 10.1). Forest inventory data (Table 10.1) show the deciduous forest is dominated by maple, elm, oak, beech, ash, and other deciduous species with evergreen species less than 2%. In contrast, the mixed forest has 23% evergreens led by white cedar, white pine, and hemlock with the deciduous maple, elm, poplar, birch, and beech each over 4%. These values give only an indication of the presettlement nineteenth century forest because white pine and oak have been intensively logged and replaced by pioneering species such as elm, white cedar, and poplar (since 1957 elm has mostly died from disease).

Postglacial Ontario was generally forested (Ritchie 1987). However, tundra prevailed both upon deglaciation (McAndrews and Jackson 1988, Liu 1990) and on land emerging from Hudson Bay (McAndrews *et al.* 1982), prairie openings appeared in northwestern Ontario during the mid-postglacial hypsithermal (McAndrews 1982), local oak savanna was present on dry soils in southern Ontario (Szceicz and MacDonald 1991), and weedy herbs locally supplanted trees on land deforested by Iroquoian and Eurocanadian farmers (McAndrews 1988).

**GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY:
EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES**

Table 10.1: Percent tree biomass (growing stock volume) for mid-20th century southern Ontario.

Derived from forest inventory for Districts of Lake Erie, Lake Huron, Lake Simcoe, and Lindsay (Ontario Department of Lands and Forests 1957). A '+' indicates 0.5% or less.

	Deciduous Forest Region	Mixed Forest Region
<i>Evergreen species</i>		
White Pine	1	5
White Cedar	+	9
Hemlock	+	4
Balsam Fir	+	3
Spruce	+	2
Tamarack	+	+
<i>Deciduous species</i>		
Soft Maple	17	5
Sugar Maple	9	22
Elm	29	12
Oak	11	4
Beech	8	5
Ash	8	4
Poplar	4	2
Basswood	4	4
Hickory	4	+
Black Cherry	2	+
Birch	1	7
Ironwood	1	1
Butternut	+	+

REGIONAL POLLEN DIAGRAMS

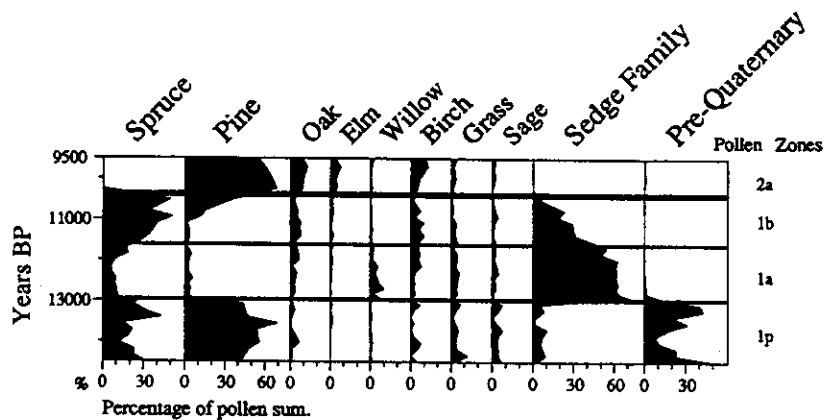
Rostock Mammoth Site

The site is a swale in ground moraine containing pond sediment overlain by 30 cm of peat; mammoth bones were found near the surface but there were no associated artifacts (McAndrews and Jackson 1988). In a 2 m deep excavation the basal glacial till was overlain by proglacial pond silt which was followed by pond marl and finally the surficial peat. Fossil pollen were well preserved in the till, silt, and marl but less so in the peat. The pollen diagram (Figure 10.2) shows the peat to contain the Holocene pine zone (zone 2) and the pond sediment to have the spruce zone (zone 1). Three subzones are distinguished: 1p is dominated by jack/red pine type pollen (small size indicates jack pine) with abundant pre-Quaternary spores, 1a by high sedge family pollen, and 1b by high spruce. Subzone 1p represents periglacial desert. Silt was deposited in the pond

from erosion of glacial till on surrounding slopes; pre-Quaternary spores and pine pollen grains were recycled with the silt. The spores were derived from local Palaeozoic bedrock, but the pine pollen grains were wind blown from trees growing south of the ice sheet and had been frozen into the glacier (McAndrews 1984a). Beginning about 13,000 years B.P. climatic warming caused tundra sedge and shrubs such as willow, birch, and poplar to invade this periglacial desert and form a tundra-woodland, a habitat for large mammals. Continued warming caused spruce to spread over the landscape to form a boreal woodland suitable for the browsing mastodon as well as the grazing mammoth and caribou. The vegetation successions are most plausibly driven by monotonic climatic warming with no evidence of a *Dryas* cold oscillation such as Shane (1987) described from Ohio.

Figure 10.2: Pollen diagram from the Rostock Mammoth Site (adapted from McAndrews and Jackson 1988).

The chronology is controlled by two radiocarbon dates. The pollen percentage sum is total upland plant pollen; the upper four levels are from wetland peat; the pollen of spruce and sedge are omitted because they are probably from local wetland plants.



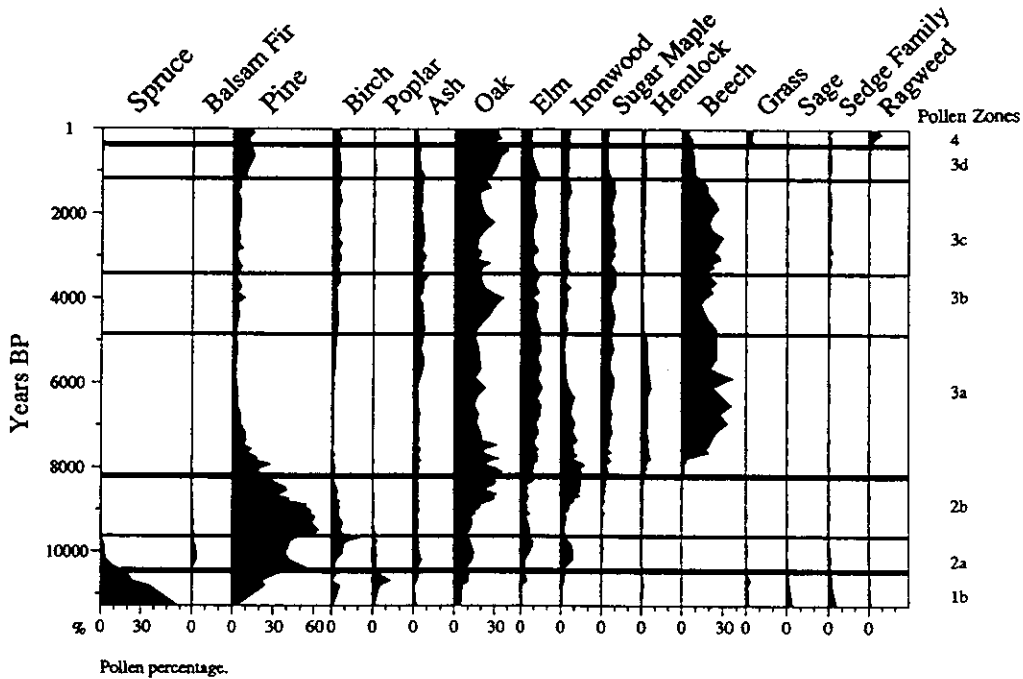
Elsewhere in southern Ontario pollen analysis of mud surrounding bones of 16 mammoth and mastodon show that they lived during zone 1, either 1a or 1b (McAndrews and Jackson 1988). My recent analysis of mud from the Highgate mastodon (Pantin 1891) shows that it belongs to subzone 1b.

**GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY:
EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES**

Hams Lake

Figure 10.3: Pollen diagram from Hams Lake (adapted from Bennett 1987 with the addition of zone 4 analyses by J. McAndrews).

The chronology is controlled by 11 radiocarbon dates. The pollen percentage sum is trees; zonation follows McAndrews (1981).



This lake is located on the boundary between the deciduous forest and mixed forest regions (Rowe 1972), and thus its pollen diagram (Figure 10.3) displays characteristics of both forest regions, *i.e.* it has both high deciduous tree pollen and relatively abundant evergreen tree pollen. It was also chosen as a standard pollen diagram because it has 11 radiocarbon dates. The diagram contains four pollen assemblage zones and several subzones. Zone 1, the spruce zone of late Pleistocene age, is represented by subzone 1b where there is high spruce with low herbs: it reflects a spruce-dominated boreal woodland. Because the lake was formed upon the melting of a long-buried ice block, the earliest postglacial sediment is absent (Florin and Wright 1969) and the subzones 1p and 1a described from the Rostock site are missing. Zones 2, 3, and 4 comprise the Holocene. Zone 2, the pine zone, is dominated by pine and contains two subzones, an early 2a jack/red pine subzone and a later 2b white pine subzone. By zone 3, the beech zone, all the modern forest dominants have immigrated northward to form the modern forest. Subzonation of zone 3 is based on highs and lows of hemlock and white pine: subzone 3b, where hemlock is low, separates subzone 3a

from 3c where hemlock is high; a white pine peak defines subzone 3d. Zone 4, the ragweed zone, is the most recent and continues to accumulate; it records deforestation and weed proliferation due to Eurocanadian agricultural disturbance (McAndrews 1988).

Except for zone 4, the diagrams represent the influence of climatic warming on forest tree migration and succession (McAndrews 1981), a conclusion supported by a temperature curve from stable isotope study (Edwards and McAndrews 1989). The zone 1 pollen assemblage is analogous to tundra and boreal woodland, the zone 2 assemblage resembles southern boreal forest, and zone 3 equates with mixed and deciduous forest (McAndrews and Manville 1987). An exception to the explanation of climate forcing succession is the 1,000-year long hemlock minimum defining subzone 3b which is best interpreted as a suppression of hemlock trees for a millennium by disease (Davis 1978). The decline of beech and rise of white pine defining subzone 3d is not an unequivocal indication of climatic cooling because it occurs during the period of Iroquoian farming when abandoned fields were available for colonization by the relatively shade-intolerant white pine. However, using prehistoric population estimates and forest stand modelling Campbell (1992) showed that the area of old fields was too small to account for the pine population and that the Little Ice Age climatic cooling of 1-2°C was sufficient to cause white pine expansion.

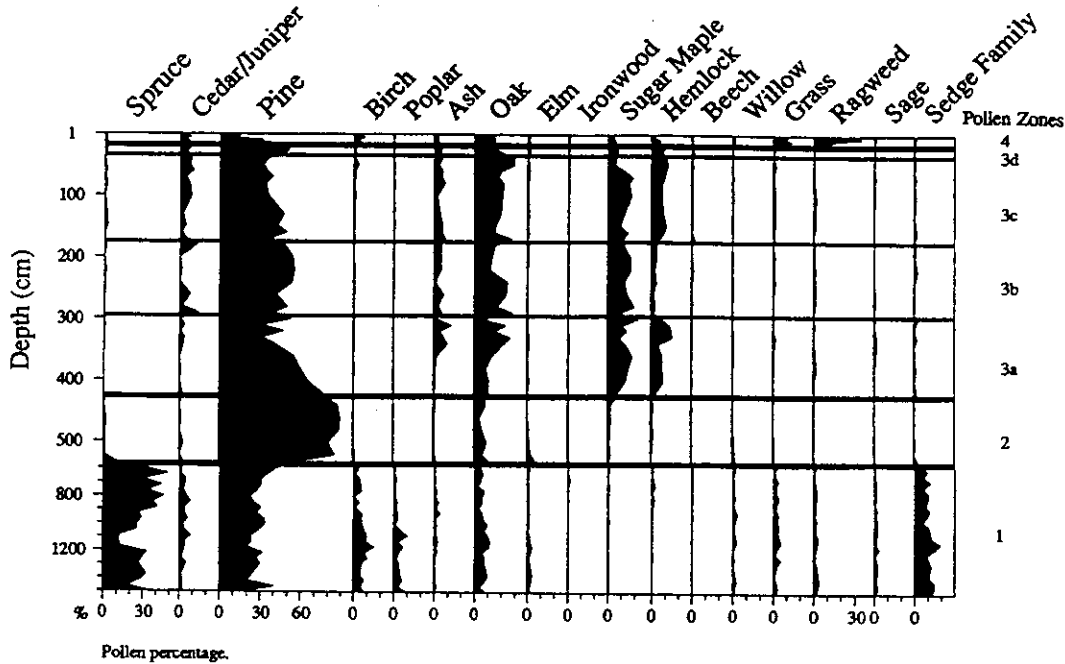
Lake Ontario

This Great Lake pollen diagram (Figure 10.4) is unsuitable as a standard because the Holocene pollen is poorly preserved, but it is included to illustrate the differential pollen preservation that is also encountered in archaeological soils. It has most of the pollen zones of Hams Lake, but the pollen types are in different proportions, e.g. higher pine and almost no beech. In contrast to the well preserved pollen of the Pleistocene zone 1, pollen in Holocene zones 2, 3, and 4 is degraded: tough thick-walled pine, sugar maple, and hemlock are relatively abundant compared with Hams Lake. Most of the pollen has been degraded because it was transported to the lake by streams rather than through the air as in small lakes (McAndrews and Power 1973). Degradation of pollen grains by oxidation occurs on the soil surface after atmospheric dispersal but before rain storms wash it into streams which flow into the lake. Pleistocene zone 1 pollen, in contrast to the Holocene pollen, is well preserved because it was largely recycled from glacier ice and had quick transport by meltwater into the proglacial lake (McAndrews 1984a).

**GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY:
EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES**

Figure 10.4: Pollen diagram from Lake Ontario (Mississauga Basin).

Note change of depth scale at 540 cm depth; there are no radiocarbon dates. Upland plant pollen forms the pollen sum. Pollen preservation is variable; excellent in the proglacial clays of zone 1 but poor in the Holocene silt of zones 2, 3, and 4.



**FOSSIL POLLEN CONVERTED TO TREE BIOMASS
AND MEAN JULY TEMPERATURE**

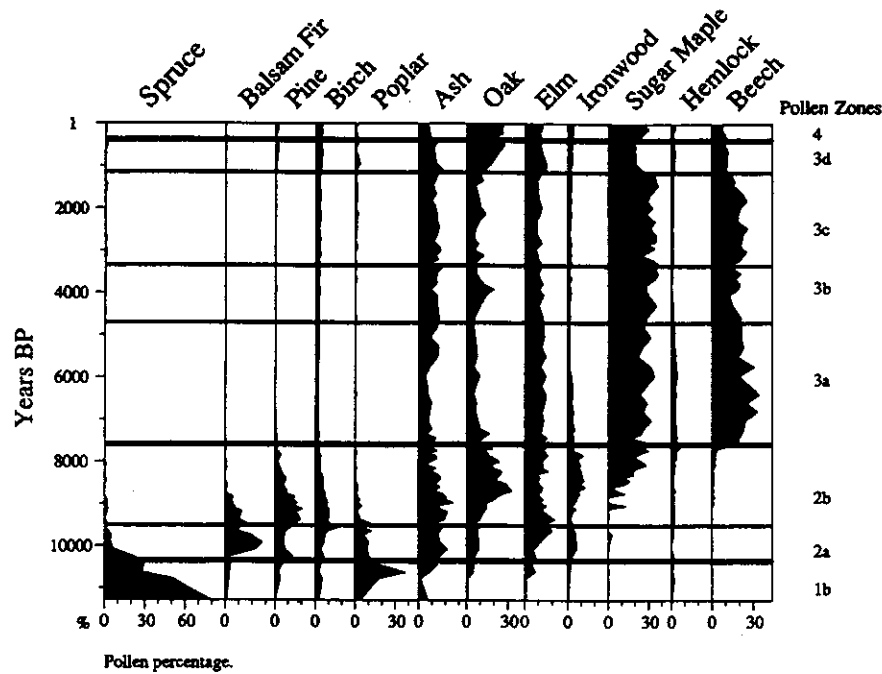
Fossil pollen percentages do not accurately represent the forest around the site of a pollen diagram because species vary in their pollen production, dispersivity, and preservability. Fortunately, in southern Ontario all important tree species are wind-pollinated, except the insect-pollinated soft maples, basswood, and black cherry, and their pollen are ordinarily well preserved; however, poplar only preserves abundantly in sediments having low biological activity such as proglacial lake clays (Figure 10.4) and mud from meromictic lakes (Figure 10.9).

Fossil tree pollen percentages can be converted to tree biomass percentages with correction factors using the r-value model of Davis (1963) to which Webb *et al.* (1981) added the y-intercept to account for unusually long-range or short-range dispersal. Webb *et al.* (1981) calculated r-values (slopes) and y-intercepts for common tree species in Wisconsin and Upper Michigan by regressing percent tree pollen in the surface sediment of lakes with the forest tree basal area within a 30 km radius of each lake. Because Wisconsin and Upper Michigan vegetation is similar to that of southern Ontario,

10: POLLEN DIAGRAMS FOR SOUTHERN ONTARIO
 APPLIED TO ARCHAEOLOGY

John McAndrews

Figure 10.5: Tree biomass percentage diagram calculated from Hams Lake pollen diagram using correction factors in Webb *et al.* (1981).



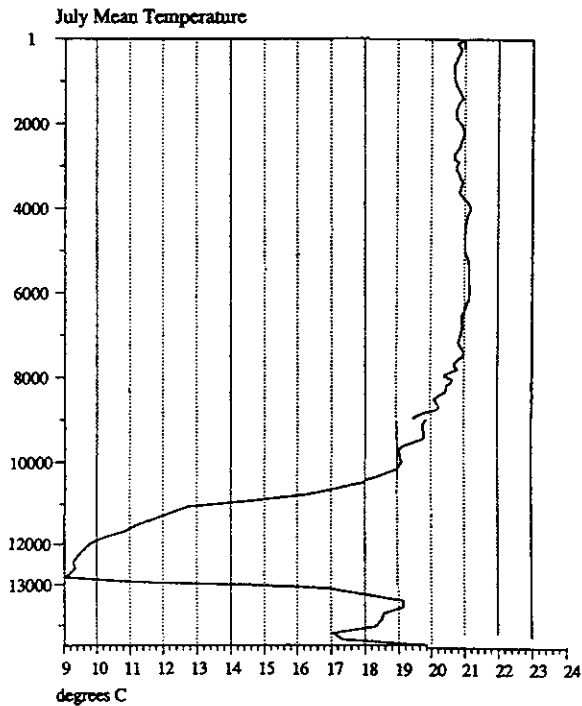
these correction factors were applied to Hams Lake (Figure 10.5). Comparison of the pollen and biomass diagrams show that pine played a smaller role in forest history than indicated by the pollen diagram and that maple and beech were leading dominants through much of the postglacial just as they are today in remnant woodlots.

By comparing a geographical array of modern pollen surface spectra from lakes with modern climatic values, regional transfer functions can be calculated (Arigo *et al.* 1986). I have chosen to calculate mean July temperature for southern Ontario (Figure 10.6) using equations in Bartlein and Webb (1985). The method, based on regression between pollen percentages in surface samples and nearby records of modern mean July temperature, assumes that the vegetation is in equilibrium with the climate. In general, the curve is ditonic from a low of 9°C at 12,800 with a rapid warming to the Pleistocene-Holocene boundary and then a more gradual warming to modern temperature at 7,500 years B.P. followed by a hypsithermal about 5,500 years B.P.; there has been a slight decline of perhaps 0.4°C since then. This July trend is paralleled by the mean annual temperature trend derived from stable isotopes (Edwards and McAndrews 1989) but the post-hypsithermal decline is a much greater 2.5°C.

GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY: EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES

Figure 10.6: Mean July temperature for southern Ontario for the postglacial.

The temperature was calculated using transfer functions in Bartlein and Webb (1985) and smoothed with three-point averaging. Three equations were used: for 0-9000 years B.P. equation G was applied to Hams Lake (268 m asl), for 9000-10,500 years B.P. equation J was applied to Hams Lake, and for 10,500-14,500 years B.P. equation A was applied to the Rostock Site (372 m asl). To match the calculated modern temperature of Hams Lake with the modern temperature for nearby Brantford of 20.8°C, the post 9000 year temperatures were each lowered 1°C. The pre-10,500 year B.P. temperatures were raised 4°C so that the trend line would be continuous and also to compensate for the higher altitude of the Rostock site. The pre-12,800 year B.P. temperatures are spurious because of recycled pollen.



LOCAL POLLEN DIAGRAMS AND ARCHAEOLOGICAL SITES

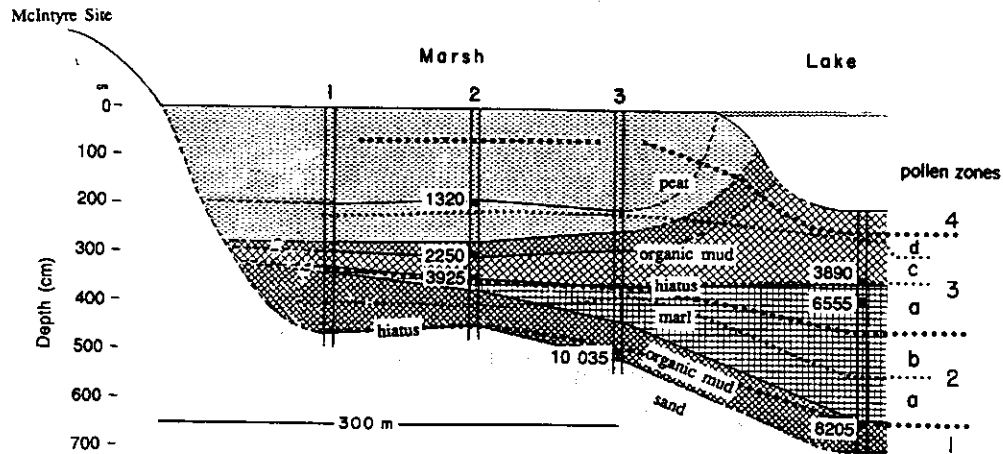
Rice Lake Marsh

This site is located adjacent to the McIntyre archaeological site which was principally occupied by Late Archaic peoples about 3700 years B.P. (Johnston 1984). The marsh today is now dominated by impassable cat-tail, shrub willow, and alder which block access to the lake and its historic Indian food, wild rice. To test the hypothesis that the marsh succeeded open water after the Archaic occupation, pollen diagrams were made from four cores, one from the lake and three in the modern marsh (McAndrews 1984b). Sediment stratigraphy, fossil pollen and seed analysis, and radiocarbon dating (Figures 10.7, 10.8) show that sedimentation was discontinuous and that wild rice was abundant only in the past 5,000 years. There were two hiatuses (gaps) in sedimentation probably caused by low water. In Marsh core 2 (Figure 10.7) subzones 1a and 1b are

**10: POLLEN DIAGRAMS FOR SOUTHERN ONTARIO
APPLIED TO ARCHAEOLOGY**
John McAndrews

Figure 10.7: Stratigraphy of Rice Lake Marsh located adjacent to the McIntyre archaeological site (adapted from McAndrews 1984b).

The radiocarbon dates are shown. Pollen grains are sparse and poorly preserved in the zone 3d peat.



missing because of low lake level; it was low because the outlet sill had not yet rebounded from isostatic depression caused by glacier loading. In zone 2 and the beginning of subzone 3a there was a marshy lake without enough grass pollen (Figure 10.7) to indicate that wild rice was present. A second low-water hiatus spans most of subzone 3a and subzone 3b, 7,600 to 4,000 years B.P. This low water interval was probably due to a dry hypsithermal climate according to transfer function analysis in Yu (1992). At 4,000 years B.P. moistening climate caused water levels to rise and the area became a deep marsh dominated by wild rice: at this time the adjacent upland was occupied by Archaic people who probably harvested the rice. At 1,500 years B.P. a shallow marsh displaced the wild rice and blocked human access to wild rice growing farther out in the lake. Consequently, the McIntyre site was essentially abandoned.

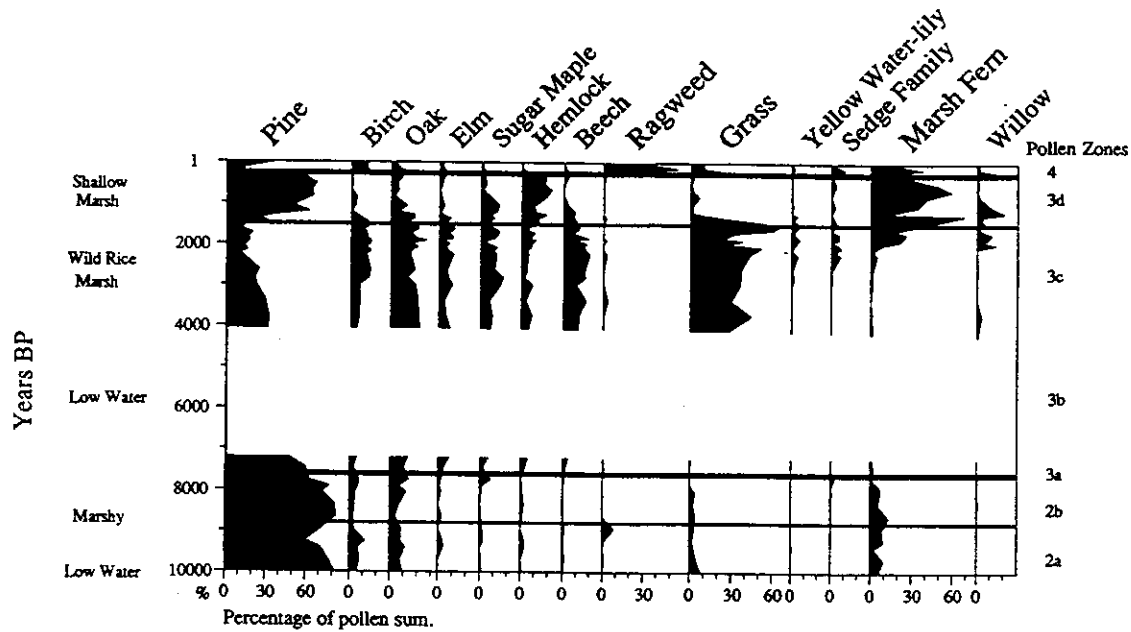
Crawford Lake

This lake, like Hams Lake and Rice Lake is on the boundary between the deciduous and mixed forest. Its small size (2 ha) and great depth (23 m) causes meromixis (stagnant bottom water) which permits two seasonal pulses of distinct sediment to be preserved as varves (annual paired mud layers). The upper 80 cm of varved sediment contains a pollen record dating back to A.D. 500, and the pollen diagram includes zone 4 and subzones 3d and 3c (Figure 10.9).

**GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY:
EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES**

Figure 10.8: Pollen diagram from Rice Lake Marsh (core 2) adjacent to the McIntyre Archaic site (adapted from McAndrews 1984b).

The chronology is controlled by three radiocarbon dates. The pollen sum is upland plants; wetland plant pollen types are individually added to the sum before their percentages are calculated.



Zone 4 begins at A.D. 1820 when pollen grains of the introduced sheep sorrel appear together with pollen of weedy grasses. Ragweed and grass pollen do not become abundant until forest clearance and crop cultivation became widespread about 1850. Maize pollen appears after 1900.

Maize pollen first appears in prehistoric subzone 3d but occurs most abundantly from 1350 to 1380 which indicates a period of local Iroquoian corn fields. An Iroquoian Middleport village which dates to the fourteenth century is 100 m from the lake: other Iroquoian villages clustered within 5 km of the lake range in age from ca. 1200 to 1650 (Finlayson *et al.* 1989). Such maize-supported villages imply local forest clearance for corn fields, perhaps with the use of fire. However, charcoal analysis of the sediment shows only slightly higher charcoal concentrations during the village occupation period (J.D. Clark, personal communication) which is more consistent with domestic fires than with the use of fire for forest clearance. Nevertheless, the abandoned fields probably served as sites for some of the white pine trees whose pollen dominates subzone 3d.

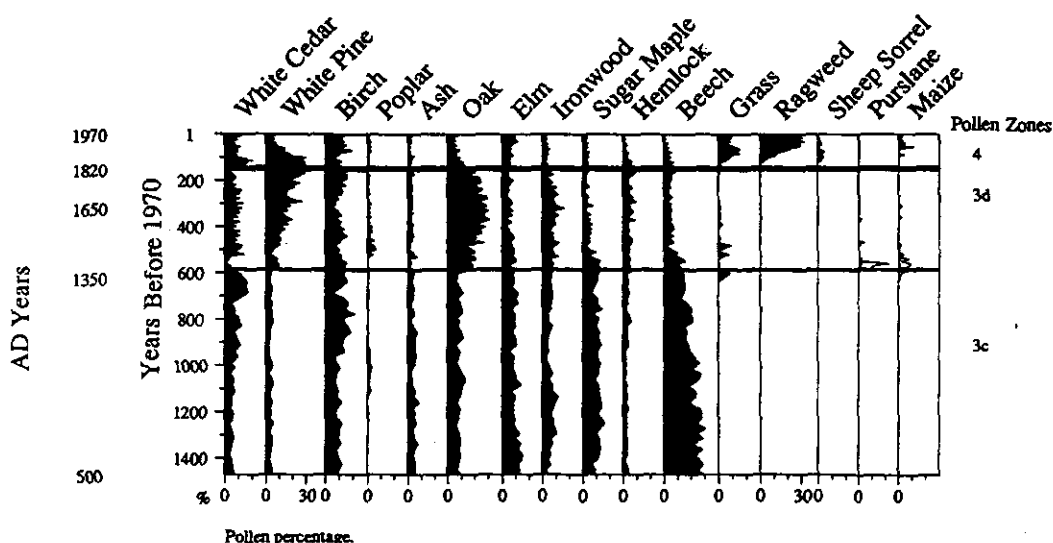
Second Lake, like Crawford Lake, is surrounded by a cluster of Iroquoian villages. Its pollen diagram (Burden *et al.* 1986), although lacking detail, is similar to Crawford Lake, especially the white pine rise of subzone 3d. However, this subzone occurs in

10: POLLEN DIAGRAMS FOR SOUTHERN ONTARIO APPLIED TO ARCHAEOLOGY

John McAndrews

Figure 10.9: Pollen diagram from Crawford Lake (adapted from McAndrews and Boyko-Diakonow 1989 with additions).

For clarity, lines of 10X exaggeration were added to Purslane and Maize. The pollen sum is tree pollen. The chronology is by varve counts.



areas of Ontario and Michigan where prehistoric horticulture is unknown. The white pine succession is in general best explained by climatic cooling of the Little Ice Age (Campbell and McAndrews 1991).

Fort York and Fort Rouille

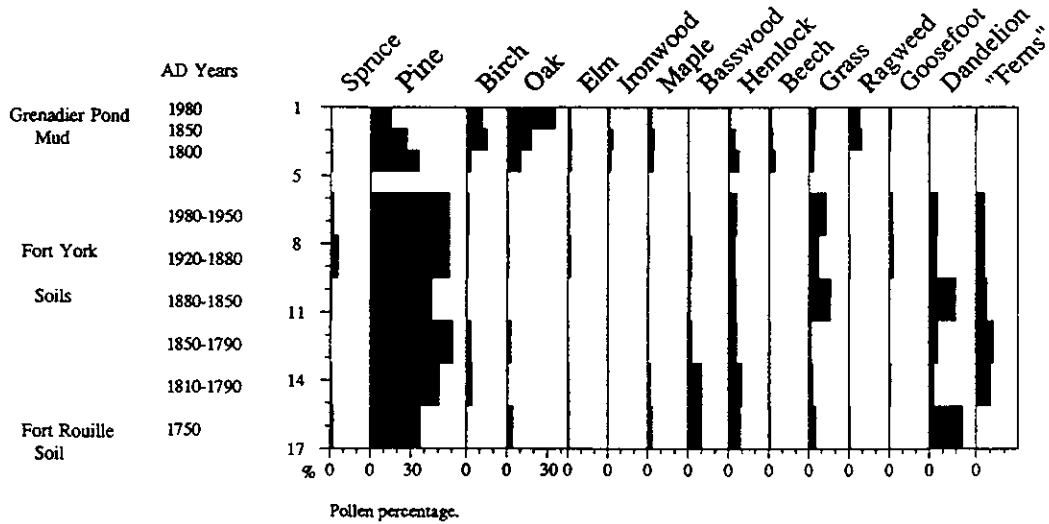
Pollen analysis of buried soils yields assemblages which differ from contemporaneous lake mud because of differential pollen preservation. Figure 10.10 shows three pollen analyses from Grenadier Pond together with analyses from five periods of Forts Rouille and York. Fort Rouille was active in the mid-eighteenth century, and Fort York was built in 1793 and rebuilt in the nineteenth century. During these activities pits were dug and filled and the ground surface was levelled with clay fill. Such events sealed soil surfaces and at least partly preserved pollen spectra derived from contemporary vegetation.

Although pollen preservation was generally poor due to oxidative degradation as in Lake Ontario, at least 100 pollen grains were identified per interval. In contrast, the Grenadier Pond mud had excellent pollen preservation. Relative to the mud samples, the soil samples are dominated by the large and thick-walled pollen grains of pine, hemlock, basswood, grass, dandelion, and "ferns." On the other hand, the more delicate, small, and thin-walled pollen of birch, oak, and ragweed dominate the well-preserved pollen grains in the modern soil surface as well as the older Grenadier Pond samples. This

**GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY:
EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES**

Figure 10.10: Pollen spectra from historic buried soils at Forts York and Rouille and Grenadier Pond in Toronto.

The Fort Rouille pollen spectrum is the pooled pollen counts reported by S. Monckton in Brown (1983). The pollen sum is total upland plant pollen. Grenadier Pond (McCarthy and McAndrews 1988) is 4 km west of the forts. Grenadier Pond chronology was by correlation with Crawford Lake; the soil chronology was by artifact association.



indicates that these less robust pollen, especially ragweed, are differentially destroyed in the soil and consequently ragweed cannot be used as a stratigraphic indicator of Eurocanadian age in buried soils. However, dandelion pollen is useful because it preserves well and because the plant is introduced. As a whole the fossil assemblage reflects the local mixed conifer-hardwood forest that had been partly cleared, allowing growth of weedy plants. There are no stratigraphic trends within the buried soils, nor are there insightful groupings.

DISCUSSION

Pollen diagrams elsewhere in southern Ontario (McAndrews, unpublished) have zone 1 assemblages similar to the Rostock diagram but diagrams from basins originating as kettle holes, where lake formation was delayed, commonly lack the older subzones. Holocene pollen diagrams are similar to Hams Lake except that deciduous tree pollen becomes more abundant southward and evergreen tree pollen more abundant northward. There is no sharp pollen boundary that corresponds with the ecotone between the forest regions, nor is there ecotone shifting after 8,000 years B.P. However, there is some regional variation; pollen diagrams in the Dundalk Highland (300-500 m asl) contrast with the surrounding lowland by having a weakly developed subzone 3d, e.g. Edward Lake (McAndrews 1981), which corresponds with the virtual absence of modern white pine trees. Pine was probably excluded from the Highland because it could not

compete with the more shade-tolerant hardwoods and hemlock due to relatively wet soils and wet climate (Chapman and Putnam 1984). Pine, a long-lived tree, commonly gets started in large canopy gaps created by lightning-ignited fire, but fire requires dry fuel. The Highland relative to the lowlands has wetter, less freely-drained soils and more rain days because of its greater altitude and position leeward of Lake Huron. Hence this dearth of dry fuel and fire would exclude pine from the Highland but not from sites on the drier soils in the warmer climate of the lowlands.

Hemlock pollen is also more prominent northward although it still displays the mid-Holocene minimum with an abrupt crash at ca. 5,000 years B.P. After a millennium it slowly rises but seldom reaches its pre-crash peak.

Pollen preservation must be considered when interpreting fossil pollen assemblages from mud, peat, and soils. Zone 1 pollen is mostly from mud and is well preserved, including the delicate poplar pollen which is mostly absent from zones 2, 3, and 4. An exception is zones 3 and 4 of Crawford Lake. In both cases the preserving sediment probably had low biological activity, zone 1 because of cold water and Crawford Lake from low oxygen. Unusually high pine values in Lake Ontario relative to the regional standard Hams Lake indicate differential preservation; pine pollen bladders remain identifiable when most other fossil pollen cannot be distinguished. In fact, poor preservation has removed the beech pollen from the beech zone of Lake Ontario and the ragweed from the ragweed zone at Fort York; similarly, the high pine and rarity of beech pollen in the subzone 3d shallow marsh peat at Rice Lake is due to poor preservation.

ACKNOWLEDGEMENTS

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GREAT LAKES ARCHAEOLOGY AND PALEOECOLOGY: EXPLORING INTERDISCIPLINARY INITIATIVES FOR THE NINETIES

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**10: POLLEN DIAGRAMS FOR SOUTHERN ONTARIO
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