TERRESTRIAL ENVIRONMENTS AND AGE OF THE CHAMPLAIN SEA BASED ON POLLEN STRATIGRAPHY OF THE OTTAWA VALLEY-LAKE ONTARIO REGION

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The earliest palynological analyses of the Ottawa Valley-Lake Ontario region (Auer, 1930; Potzger, 1953; Potzger and Courtemanche, 1956, 1957) were restricted mainly to southern Quebec and lower St. Lawrence Valley area and lacked chronological control. Later studies by Terasmae (1965, 1980), Mott and Camfield (1969), and Camfield (1969) in eastern Ontario and Richard (1977), Savoie and Richard (1979), Mott and Farley-Gill (1981), Mott et al. (1981), and Delage et al. (1985) in southernmost Quebec provide regional coverage and each contains at least one basal radiocarbon date and, at some sites, up to five dates on major pollen boundaries. On-going palynological studies of sites outside the Champlain Sea basin and in the highlands of Ottawa Valley, east-central Ontario, and adjacent New York State are aimed towards filling gaps in the regional pollen stratigraphic coverage.

The majority of the pollen-analyzed sites are Late Wisconsinan and Holocene (post-23 ka, Fulton, 1984) with the exception of the sediments at the Pointe-Fortune site which are believed to correlate with the Late Sangamonian or Early Wisconsinan St. Pierre Interval of the St. Lawrence Lowlands (Veillette and Nixon, 1984). The Late Wisconsinan-Holocene records are from Champlain Sea sediments, underlying glaciolacustrine clay, overlying lake and bog deposits, and sediments from lake basins located outside the limit of the Champlain Sea.

Several lake and bog sites were selected as being representative of the region (Fig. 16). Pollen records at these sites provide data on regional patterns of deglaciation, vegetation and climatic history, and environments of deposition. Pollen counts from Champlain Sea sediments and the underlying glaciolacustrine unit in a core from adjacent to Mer Bleue Bog on the east side of Ottawa are compared with the upland pollen stratigraphy in an attempt to estimate the time of arrival of marine water in the western basin of the Champlain Sea.

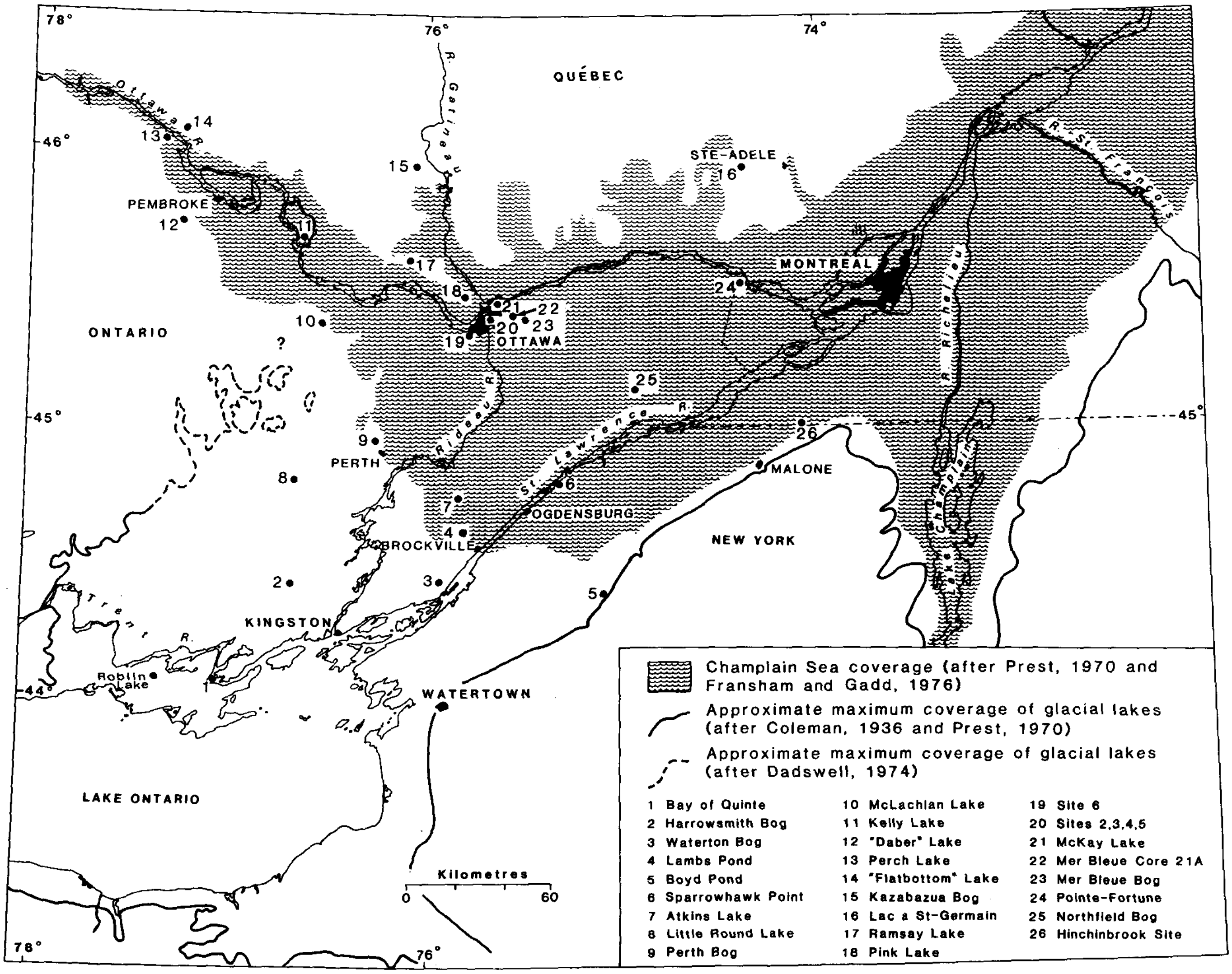

Figure 16. Lake Ontario-upper St. Lawrence-Ottawa Valley region showing approximate extent of glacial lake coverage, Champlain Sea shoreline, and locations of sites discussed in text.

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SETTING AND PRESENT-DAY VEGETATION

The geological setting and Quaternary deposits and features of the Ottawa Valley-Lake Ontario region are described by Gadd (this publication). Fulton and Richard (this publication) outline the general chronology of late Quaternary events based largely on ^{14}C dates on marine shells.

The Ottawa-St. Lawrence Lowlands stand in sharp contrast with the highlands to the north, west, and southeast providing a variety of lowland and upland habitats for plant colonization. Because this region is transitional between the Deciduous Forest Region to the south and southeast and the Boreal Forest Region to the north, it comprises a mixture of southern elements and those which are more typical of northern areas. Some plant taxa such as **Celtis occidentalis** and **Cephalanthus occidentalis** reach their northern limits in this region (I. Bayly, personal communication, 1985).

The present-day forest of the Ottawa Valley-upper St. Lawrence Valley region falls in the Great Lakes-St. Lawrence Forest Region of Rowe (1977). A mixed forest dominated by sugar maple (**Acer saccharum**), beech (**Fagus grandifolia**), yellow birch (**Betula lutea**), red maple (**Acer rubrum**), and eastern hemlock (**Tsuga canadensis**), almost always accompanied by white and red pine (**Pinus strobus** and **P. resinosa**), characterizes the upland areas to the north and west of the Champlain Sea basin. Within the basin the forest is predominantly deciduous, consisting of sugar maple and beech, with red maple, yellow birch, basswood (**Tilia americana**), white ash (**Fraxinus americana**), largetooth aspen (**Populus grandidentata**), and red and bur oak (**Quercus rubra** and **Q. macrocarpa**). Local occurrences in the Champlain Sea basin include white oak (**Quercus alba**), red ash (**Fraxinus pennsylvanica**), grey birch (**Betula populifolia**), rock elm (**Ulmus thomasii**), blue-beech (**Carpinus caroliniana**), and bitternut hickory (**Carya cordiformis**). Varying amounts of white spruce (**Picea glauca**), balsam fir (**Abies balsamea**), trembling aspen (**Populus tremuloides**), and white birch (**Betula papyrifera**) are common at higher elevations outside the basin. Black spruce (**Picea mariana**), black ash (**Fraxinus nigra**), white elm (**Ulmus**), and eastern white cedar (**Thuja occidentalis**) dominate hardwood and mixed-wood swamps; white butternut (**Juglans cinerea**), eastern cottonwood (**Populus**), and slippery elm (**Ulmus rubra**) are sporadically distributed along river valleys.

PRE-LATE WISCONSINAN RECORD

The only pre-Late Wisconsinan deposits in the area were described by Veillette and Nixon (1984) from a site near Pointe-Fortune. At this site, till is overlain by crossbedded sand and silt which is overlain by organic-rich clay. The organic-rich clay is overlain by stratified silt and fine sand which in turn is overlain by till. A date of >42 ka was obtained on wood from the upper sand-silt sequence (GSC-2932; Gadd et al., 1981).

Preliminary pollen and plant macrofossil analyses were undertaken on the organic clay interval and underlying and overlying silt and fine sand (Fig. 17). The pollen assemblage is dominated by **Picea, Pinus, Salix, Alnus**, Gramineae and Cyperaceae and minor occurrences of **Abies** and thermophilous tree pollen. Plant macrofossils consist mainly of seeds of **Carex, Eleocharis, Potentilla**, and **Hippuris vulgaris.**

The overall pollen assemblage indicates that cooler than present climatic conditions prevailed in the area during deposition of the organic bed. This supports the assignment of the interval to the St. Pierre Interstade of the St. Lawrence Lowlands by Gadd et al. (1981). The overlying till is believed to correlate with the Gentilly Till (LaSalle, 1984).

LATE WISCONSINAN-HOLOCENE RECORD

Pollen diagrams from Lambs Pond (Fig. 18), McKay Lake (Fig. 19), Ramsay Lake (Fig. 20), and Lac à St-Germain (Fig. 21) were chosen as being representative of the late glacial and Holocene pollen stratigraphy of the Ottawa Valley-St. Lawrence River valley-Lake Ontario region. These are supplemented by partial (late glacial) diagrams from Waterton Bog (Fig. 22), Boyd Pond (Fig. 23), Northfield Bog (Fig. 24), Kelly Lake (Fig. 25), and "Daber" Lake (Fig. 26). Figure 16 shows the locations of these sites.

Pollen stratigraphy

The pollen stratigraphy and radiocarbon dates for sites in the Ottawa Valley-Lake Ontario region are summarized in Figure 27. The lowermost zones (zones 9 to 6) are clearly time transgressive from south to north. Zones become synchronous for the first time everywhere in the region in the **Pinus** zone (5).

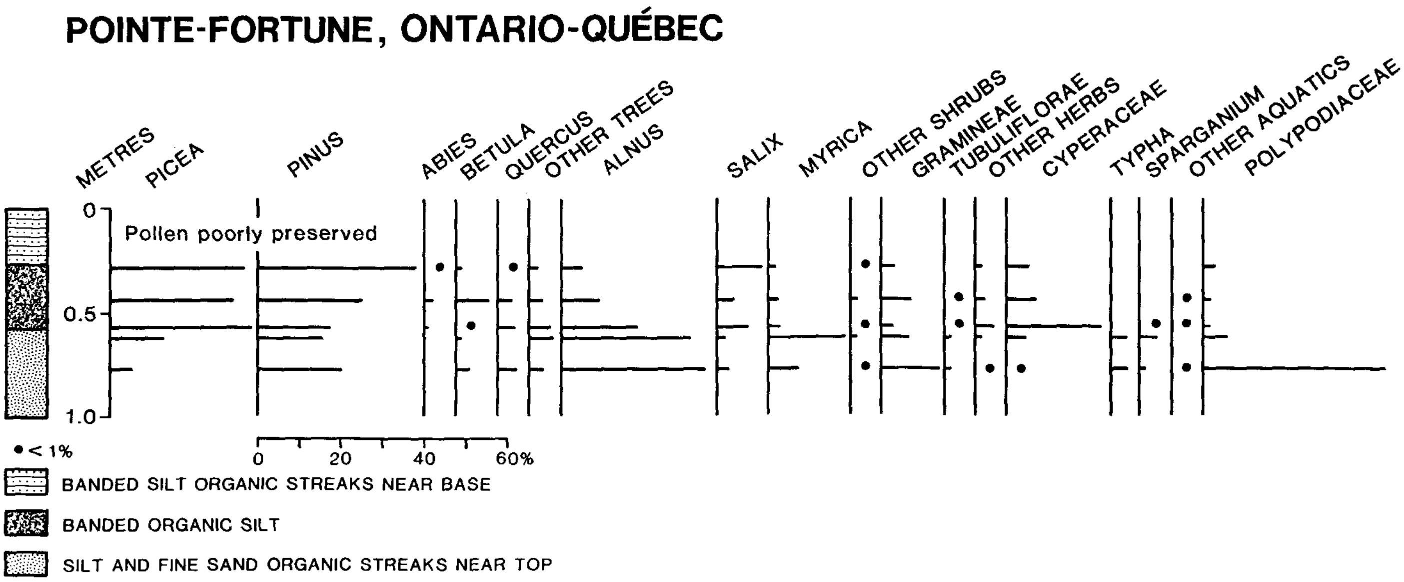


Figure 17. Pollen diagram of the Pointe-Fortune section, Ontario-Quebec border.

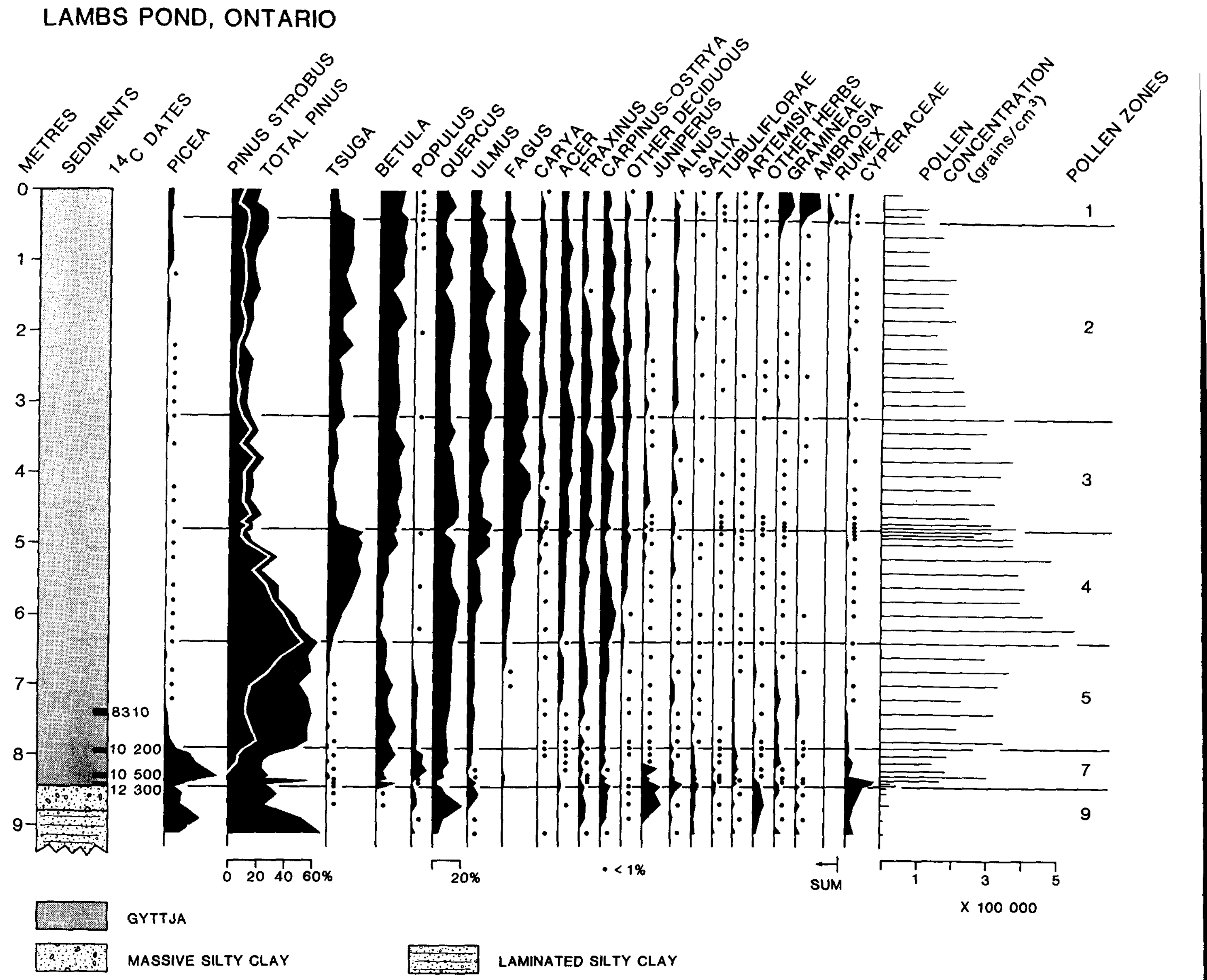


Figure 18. Abbreviated pollen diagram for Lambs Pond, Ontario.

The earliest pollen assemblage zone (9) is characterized by a shrub-herb component of **Salix, Artemisia,** Gramineae and Cyperaceae. In the southern part of the region the herb-shrub assemblages are succeeded first by a **Picea** or **Picea-Populus** zone (7) whereas in Ottawa Valley and areas to the north they give way exclusively to **Populus** (8). The progressive succession from **Picea** or **Picea-Populus** to **Pinus** in the south is replaced by one from **Populus** to **Picea** to **Betula** to **Pinus** in Ottawa Valley and sites northeast of St. Lawrence River. **Picea** becomes less prominent towards the northeast, especially at sites north of St. Lawrence River, for example at Lac à St-Germain (16, Fig. 16; Fig. 21) the **Populus** zone is succeeded by a zone dominated by **Betula** (6) which, in turn, gives way to **Pinus** (5). The **Pinus** zone is characterized initially (lower part) by **Pinus banksiana/resinosa** type pollen and higher in the zone by **Pinus strobus** type (see Lambs Pond diagram).

Zones 4, 3, and 2 are defined on the basis of two peaks in the **Tsuga** curve. The **Tsuga canadensis** zone (4) represents the first peak in **Tsuga,** the **Betula-Pinus strobus** zone (3) marks the **Tsuga** minimum, and the **Tsuga canadensis**-Mixed hardwoods zone (2) denotes the second peak in **Tsuga.** The uppermost zone, the **Ambrosia** zone (1), is represented by sharp increases in weed pollen such as **Ambrosia,** Gramineae and **Rumex,** and by decreases in tree pollen of **Pinus, strobus, Tsuga** and **Fagus.**

Vegetation History

Pollen evidence shows that the initial upland vegetation bordering the western Champlain Sea basin was herb-shrub tundra intermixed with woodlands of spruce, poplar, juniper, and shrub birch and alder. The high values of pine, oak, and other thermophilous tree pollen in zone 9 are attributed to long distance, transport from sources to the south and deposition in a forest-tundra landscape. Tundra woodland vegetation prevailed in the southern uplands around the Champlain Sea from shortly after deglaciation to as late as 11.2 ka at Boyd Pond and grew to the north of the Champlain Sea and on certain islands in the sea to as late as 10 ka (Webb et al., 1983).

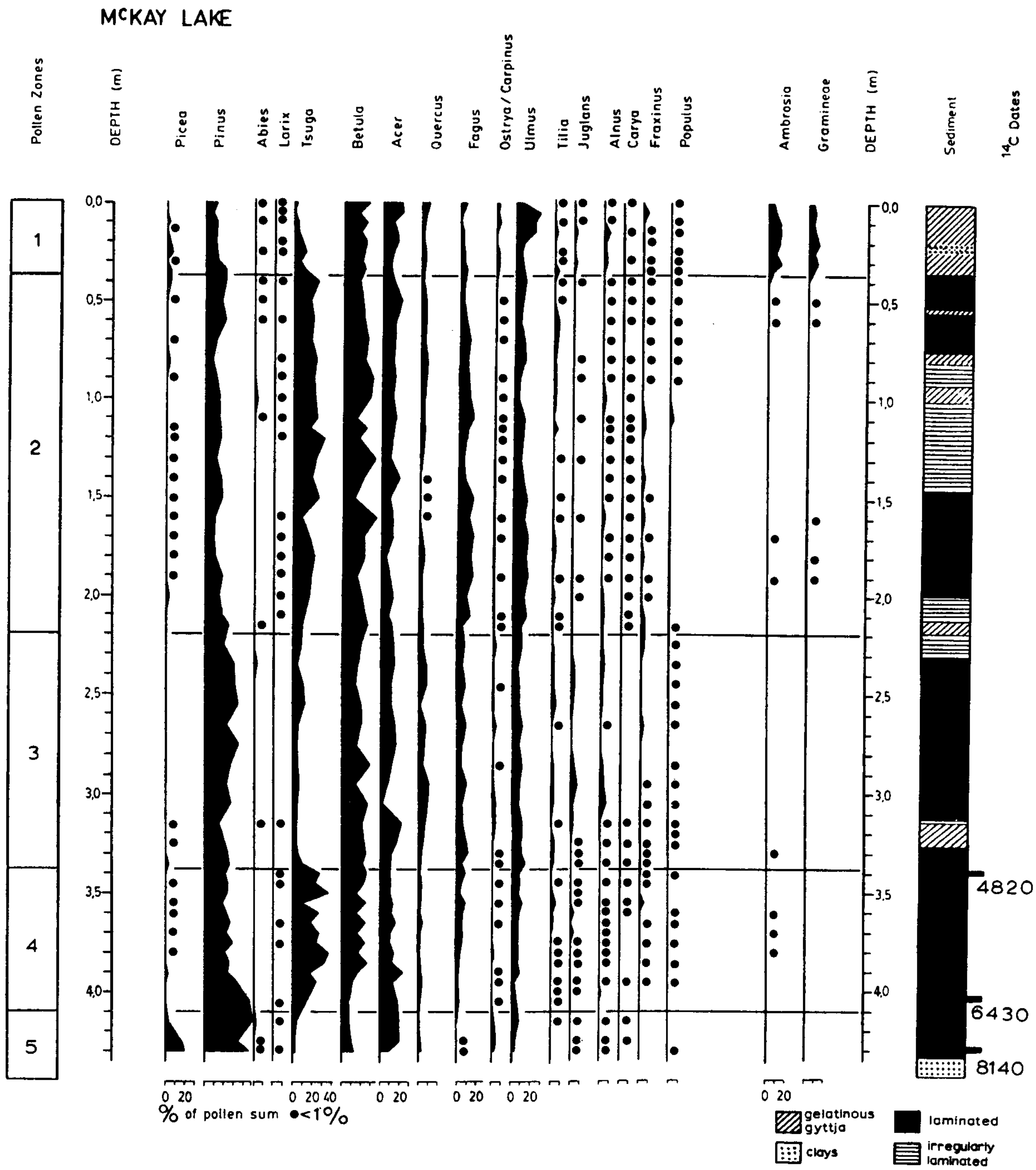


Figure 19. Abbreviated pollen diagram for McKay Lake, Ottawa, Ontario courtesy of R. McNeely, Geological Survey of Canada, and T. Oliver, Department of Biology, Queen's University.

Tundra-woodland gave way to spruce-poplar woodland in the southern uplands of the Champlain Sea and to poplar woodland on the recently deglaciated terrain bordering the Champlain Sea in Ottawa Valley and the southern Laurentians north of Montreal (Webb et al., 1983). At Ramsay Lake pollen influx increased two-fold across the shrub and herb-poplar boundary indicating a sudden increase in overall vegetation productivity associated with the movement of trees into the region.

By ca. 11 ka spruce had become abundant at localities to the south and southeast of the Champlain Sea. The spruce forest eventually moved northward and replaced poplar woodland in Ottawa Valley by ca. 10.2 ka and slightly later (ca. 10-9.5 ka) at sites in the southern Laurentians (Webb et al., 1983). Thus, by ca. 10 ka a spruce forest occupied the entire western basin of the Champlain Sea and surrounding uplands from Lake Ontario to the southern Laurentians.

Spruce forests dominated for about 1 ka until birch and pine migrated into the region from the south. Birch (mainly white birch) occupied upland sites in Ottawa Valley prior to pine. Jack Pine was widespread throughout the Ottawa Valley-Lake Ontario region apparently as early as ca. 9.4 ka but it was later replaced (after ca. 9 ka) by white pine. By ca. 8-7.5 ka the pine populations had shifted northward into the southern Laurentians (Webb et al., 1983).

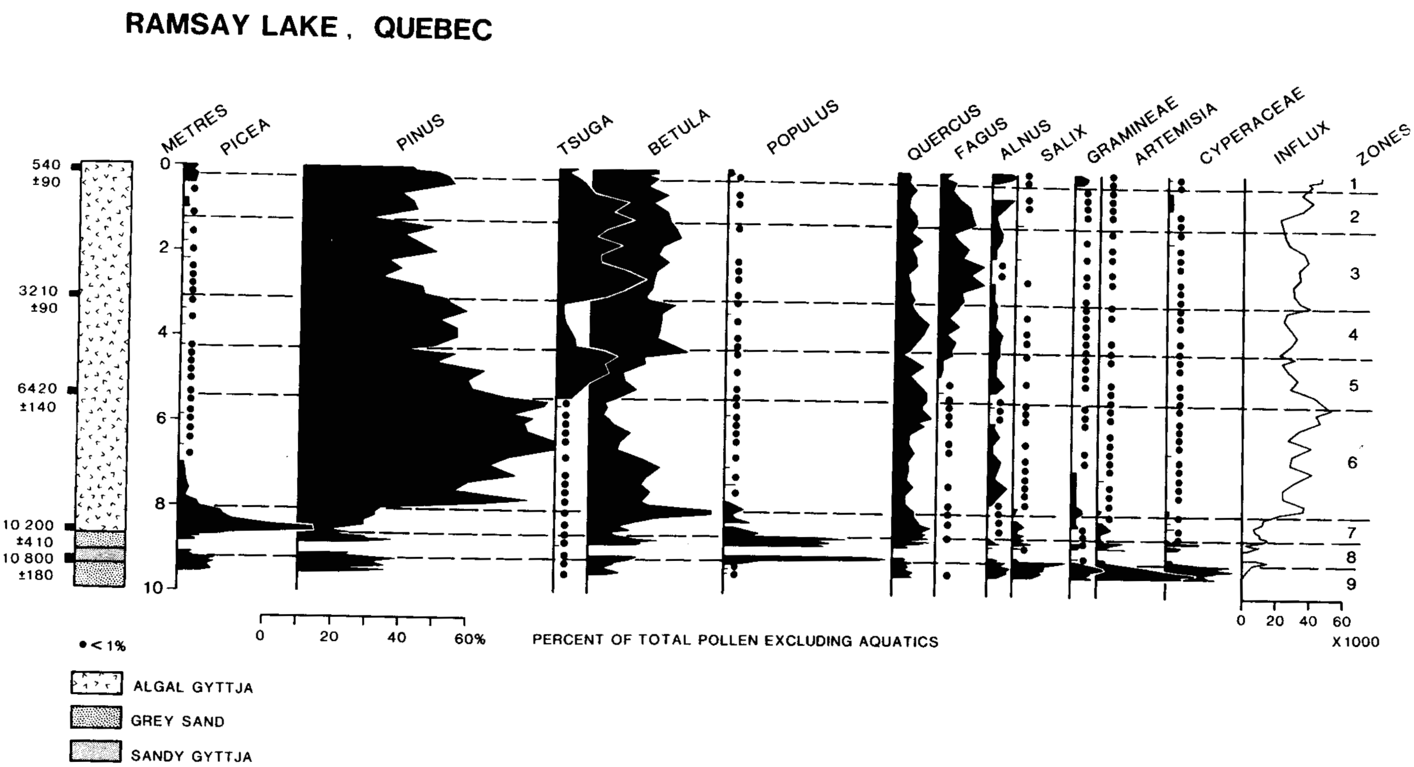


Figure 20. Abbreviated pollen diagram for Ramsay Lake, Quebec (modified from Mott and Farley-Gill, 1981).

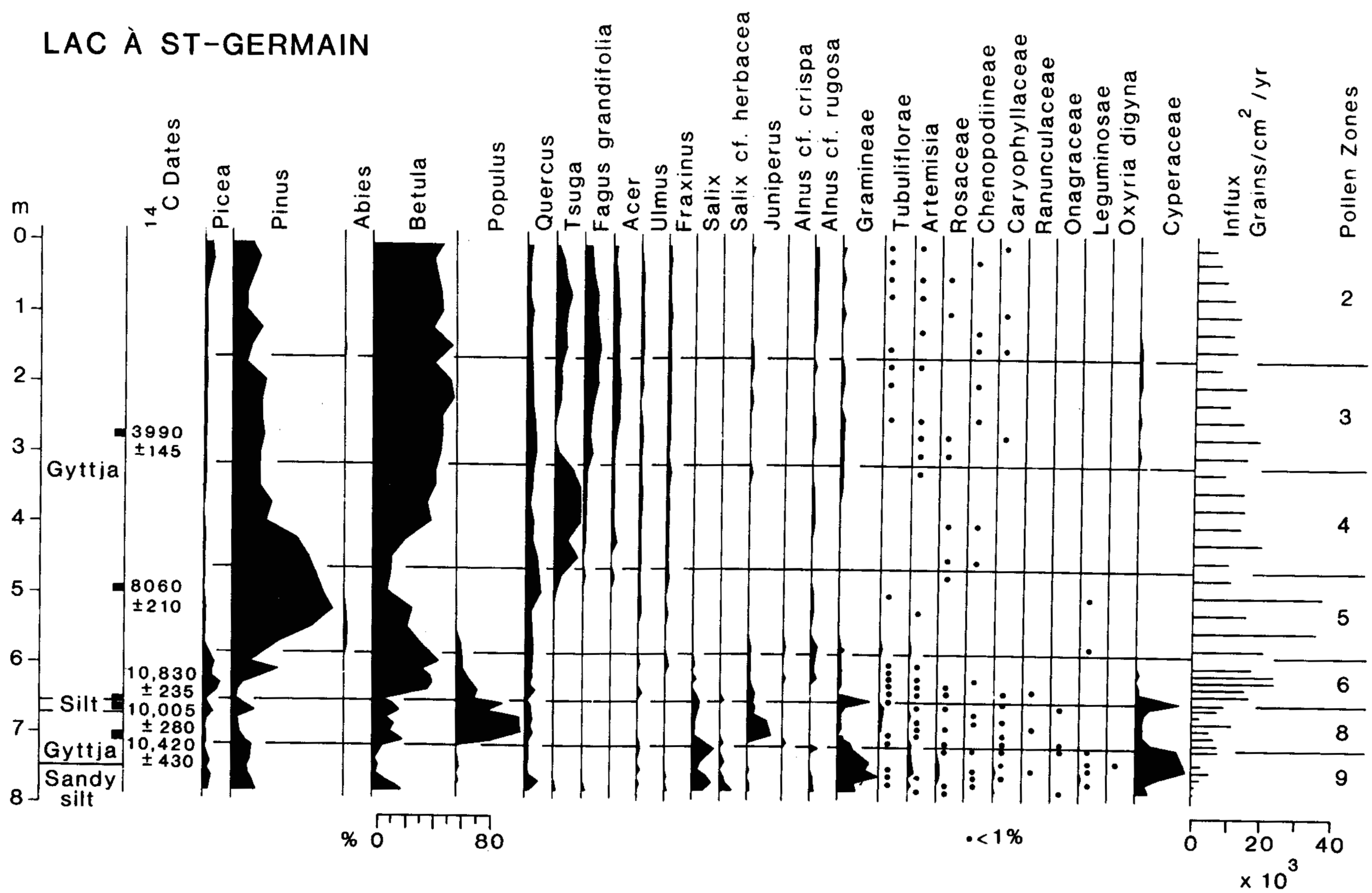


Figure 21. Abbreviated pollen diagram for Lac à St-Germain, Quebec (modified from Savoie and Richard, 1979).

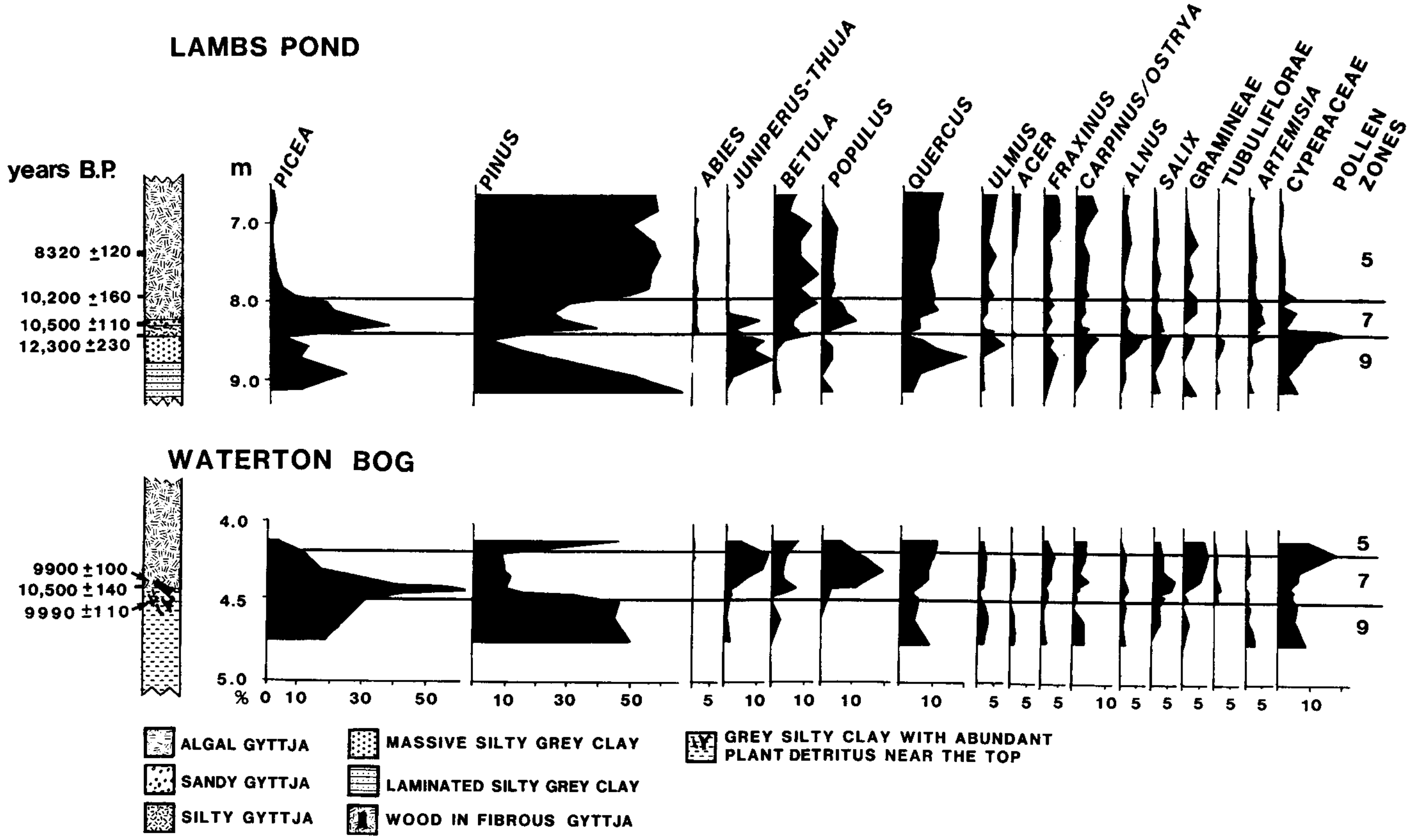


Figure 22. Abbreviated pollen diagram of basal sediments in Lambs Pond and Waterton Bog, Ontario.

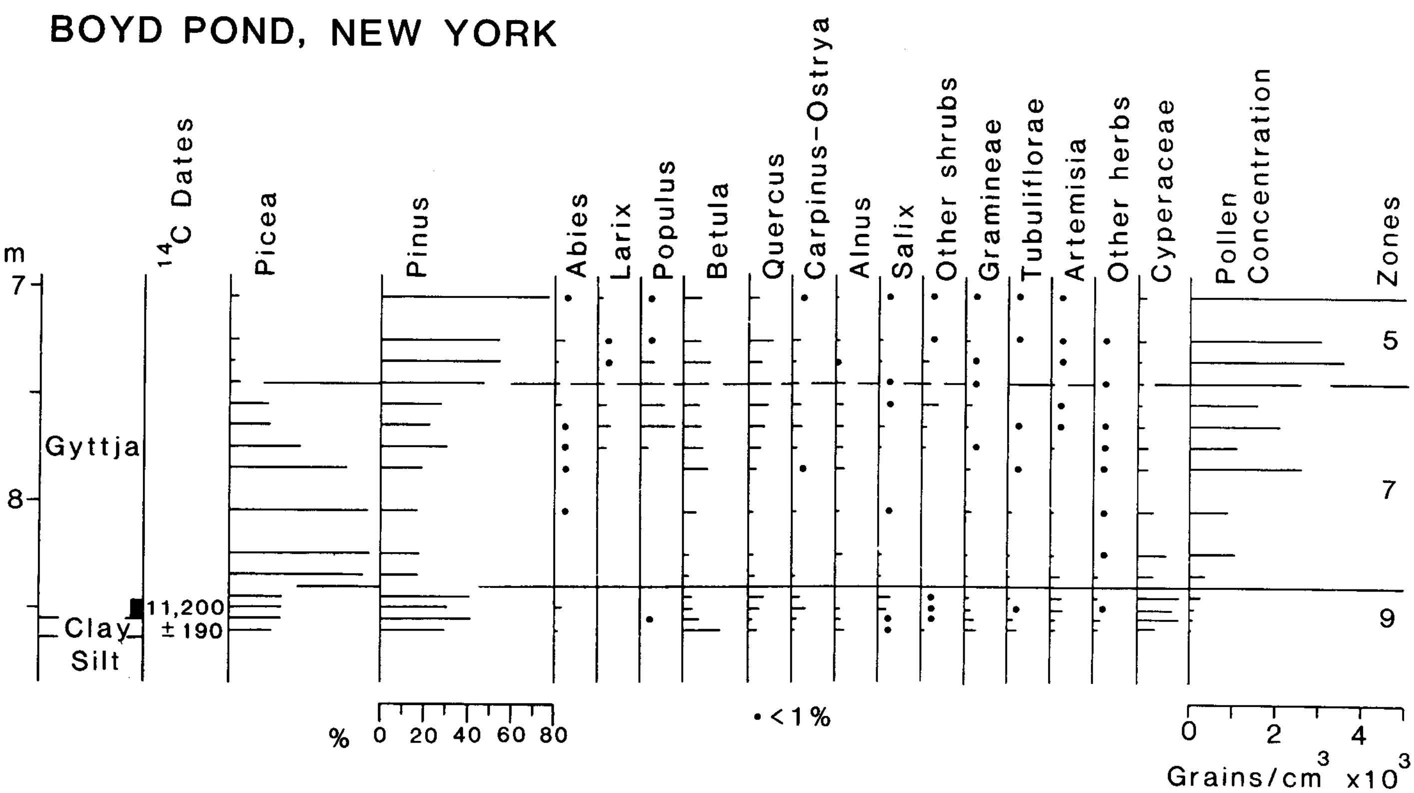


Figure 23. Abbreviated pollen diagram of basal sediments in Boyd Pond, New York State.

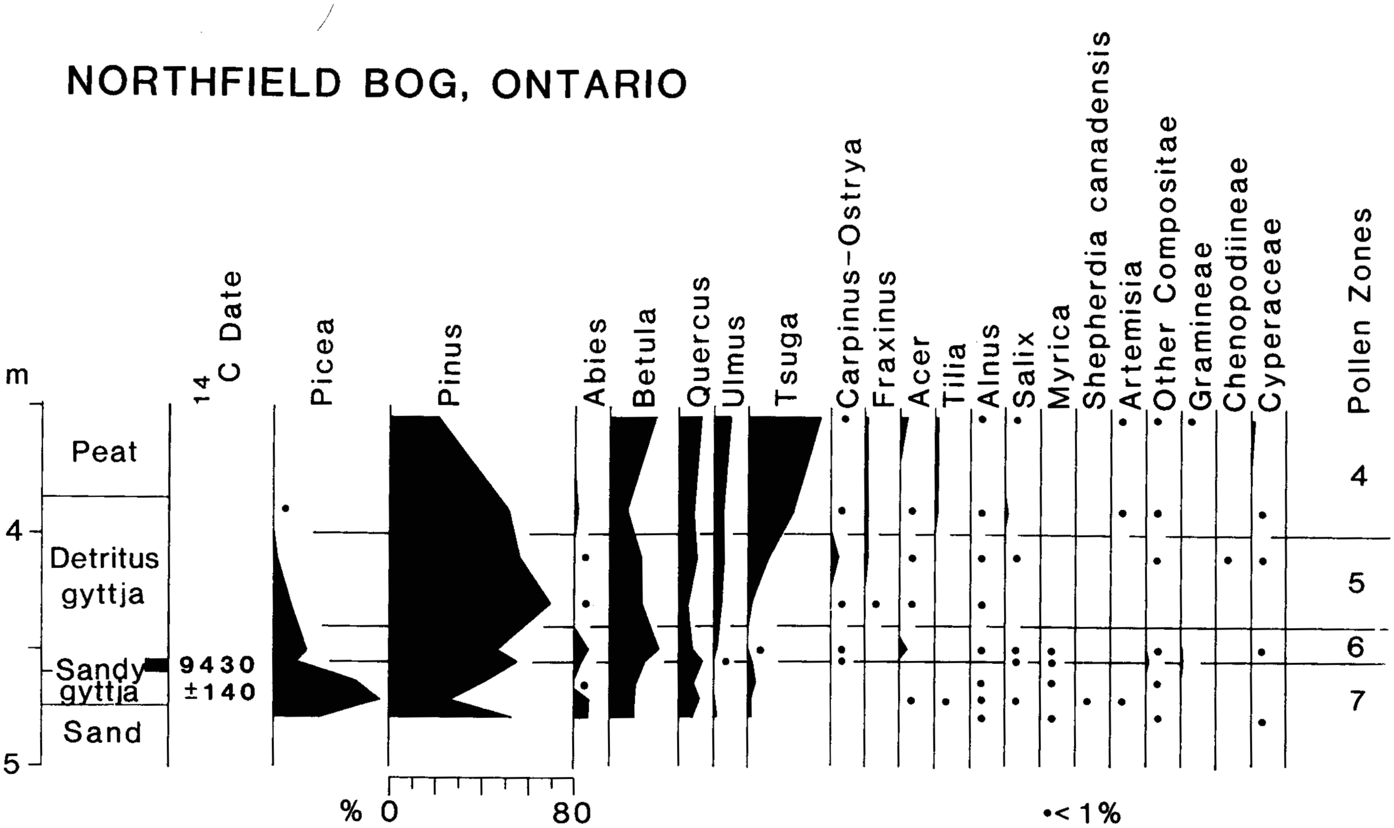


Figure 24. Abbreviated pollen diagram of basal sediments in Northfield Bog, Ontario (modified from Terasmae, 1965).

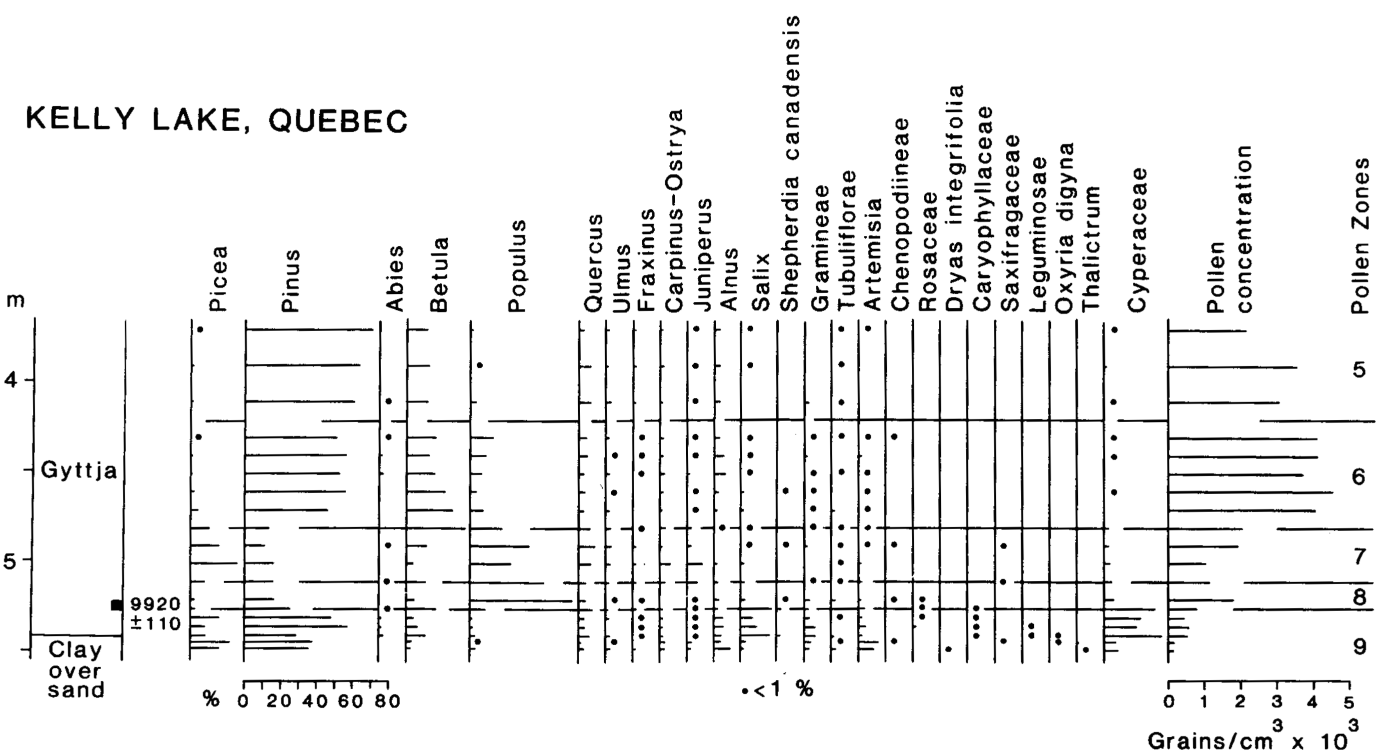


Figure 25. Abbreviated pollen diagram of basal sediments in Kelly Lake, Quebec.

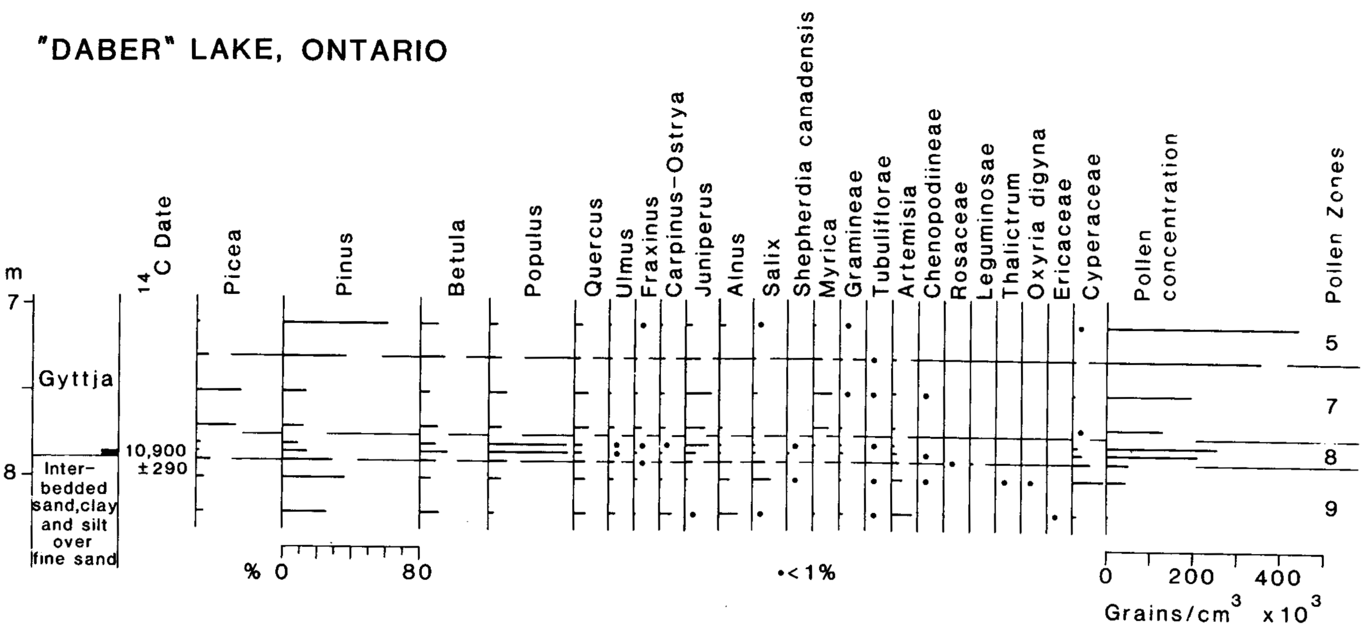
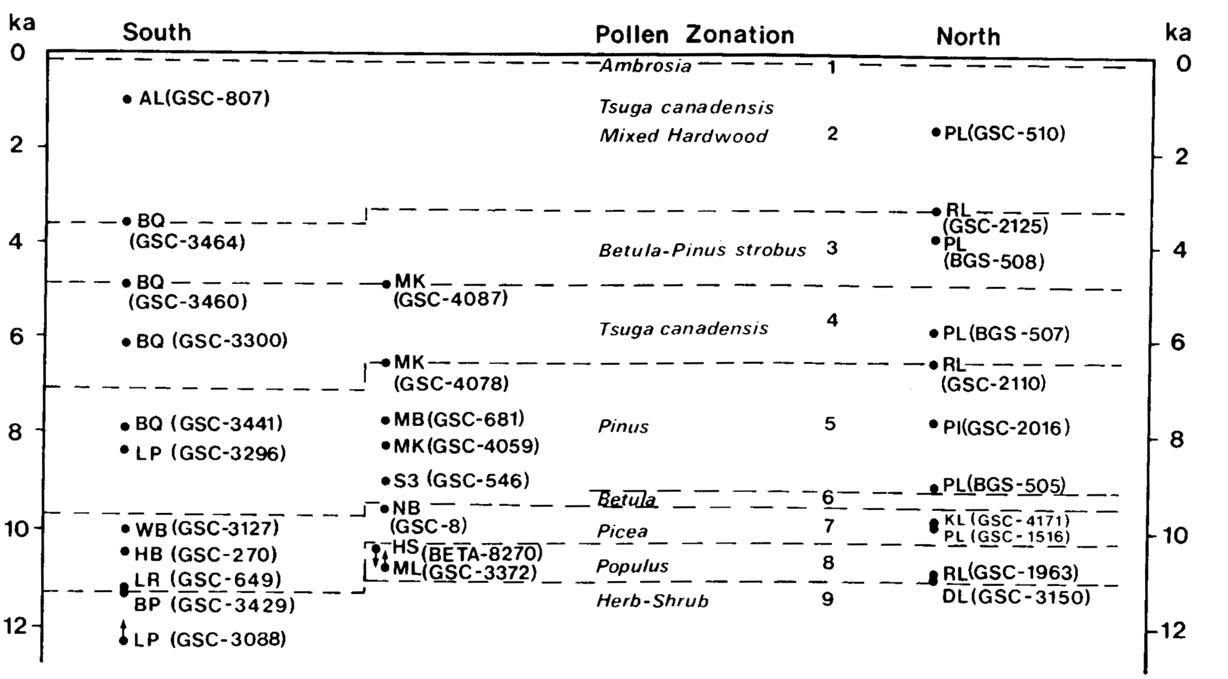


Figure 26. Abbreviated pollen diagram of basal sediments in "Daber" Lake, Ontario.



- • Control date
- Date considered too old
- Date considered too young

Sources of control dates

AL Atkins Lake (Terasmae,1980)
BP Boyd Pond (unpublished)
BQ Bay of Quinte (Anderson and Lewis,1985)
DL "Daber" Lake (unpublished)
HB Harrowsmith Bog (Terasmae,1968)
HS Hinchinbrook Site (Delage et al.,1985)
KL Kelly Lake (unpublished)
LP Lambs Pond (unpublished)
LR Little Round Lake (Terasmae,1980)
MB Mer Bleue Bog (Camfield,1969)
MK McKay Lake (R.McNeely,pers.comm.,1985)
ML McLachlan Lake (unpublished)
PI Pink Lake (Mott and Farley-Gill,1981)
PL Perch Lake (Terasmae and McAtee,1979; Terasmae,1980)
RL Ramsay Lake (Mott and Farley-Gill,1981)
S3 Ottawa Site 3 (Mott and Camfield,1969)
WB Waterton Bog (unpublished)

Figure 27. Summary diagram of pollen stratigraphy and radiocarbon dates for lake and bog sites – Ottawa Valley-Lake Ontario region. Dates indicated are listed in Table 8.

The vegetation of the region changed dramatically between about ca. 8 ka and 6 ka when other tree taxa invaded and displaced pine. Hemlock, in particular, and maple and birch (most likely yellow birch) increased perceptibly as early as ca. 7.6 ka at Roblin Lake (Terasmae, 1980) southwest of the region and not until about ca. 6.4 ka in Ottawa Valley. Even though hemlock, white pine, birch, and oak may be unequally represented in the pollen profiles between ca. 7.5 and 4.8 ka, hemlock is considered to have been the more dominant tree species at this time. Based on its modern-day silvical characteristics (Hough, 1960), the shade tolerant hemlock became established under dense stands of white pine and slowly advanced to a dominant position in the forest stand, thus behaving as a climax species. At ca. 4.8 ka, however, the hemlock population was suddenly and drastically reduced, possibly as a result of the spread of a forest pathogen (Davis, 1981). Beech and maple populations migrated northwards into the region and probably occupied the openings left by hemlock. Shade intolerant hardwoods such as elm, ash, hickory, and basswood were also more prominent at this time. The inferred vegetation during the time of the hemlock pollen minimum (ca. 4.8 to 3.5 ka) probably resembled a mixed conifer-hardwood forest with white pine, white and yellow birch, beech, and maple the dominant taxa. Hemlock populations increased again as early as ca. 3.5 ka in the southern part of the region. The lower hemlock percentages of pollen zone 2, compared with those of pollen zone 4, suggest that hemlock did not regain its earlier Holocene dominance in the mixed forest. The inferred vegetation from ca. 3.5 ka to present consisted of a hemlock-white pine-mixed hardwoods association with hemlock, white pine, beech, and maple the dominant taxa.

AGE OF THE CHAMPLAIN SEA BASED ON POLLEN STRATIGRAPHY

Pollen analyses are being undertaken on Champlain Sea sediments and underlying glaciolacustrine clay at two sites in the Ottawa Valley-St. Lawrence River area for the purpose

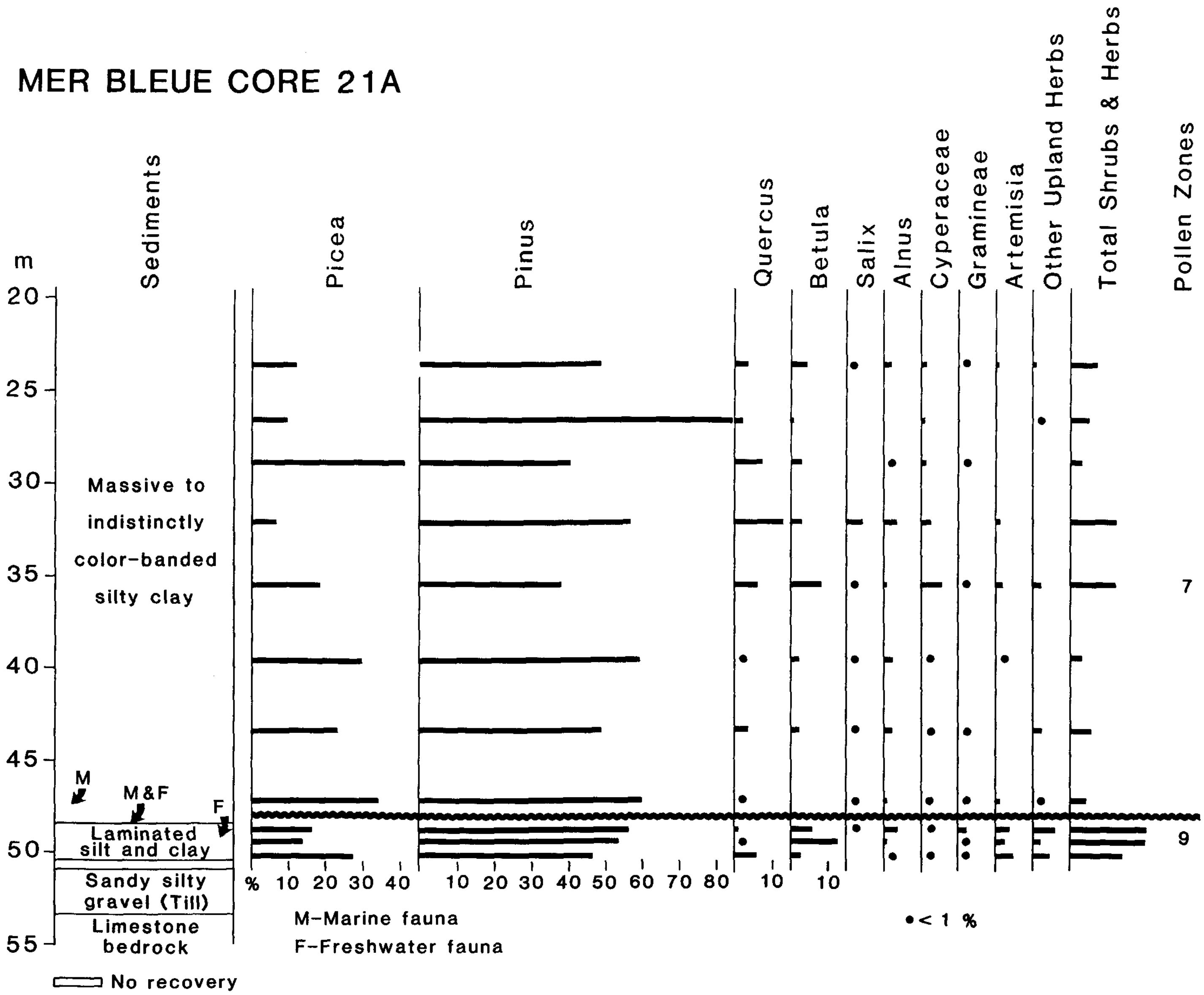


Figure 28. Abbreviated pollen diagram for Mer Bleue core (21A). Core depth is in metres below ground surface. F-freshwater ostracodes; M-marine foraminifers.

of using pollen stratigraphy as an independent method to estimate the age of the Champlain Sea as opposed to dating marine shells. The two sites are the Central Research Forest located adjacent to the west side of Mer Bleue, east of Ottawa (22, Fig. 16) and a section on St. Lawrence River near Sparrowhawk Point, located 17 km northeast of Ogdensburg, New York (6, Fig. 16).

Preliminary results from the Mer Bleue Central Research Forest core (21A) are reported here. The box containing this core had been erroneously labelled "LaRose Forest" and the core was discussed as such in Anderson et al. (1985). However, archived documents show that the core was obtained from the Central Research Forest, Mer Bleue Bog area by the Testing Laboratories, Department of Public Works in 1969 as requested by M.J.J. Bik formerly of the Geological Survey of Canada. The core was extruded and described by Gadd (1986b). Briefly, 48.26 m of massive to indistinctly colour-banded light and dark grey, blue-grey, and reddish brown to brownish grey clay of the Champlain Sea overlies 2.22 m of laminated (varved?) grey clay and silt, which overlies 2.9 m of silty, sandy gravel (till). Limestone bedrock was reached at 53.38 m below surface. The contact between the marine sediments of Champlain Sea and underlying freshwater clay is based on upward changes from freshwater ostracodes to marine ostracodes and foraminifera at 48.35 m depth in the core (Anderson et al., 1985).

Pollen spectra from the 20 to 50 m interval of Mer Bleue core (21A) fall into two assemblage zones (Fig. 28). The lowermost zone occurs between about 47 and 50 m and is differentiated on the basis of low **Picea** (10 to 20%), high **Pinus** (50 to 60%) and **Betula** (5 to 10%), and up to 20% shrubs and herbs notably **Betula**, **Artemisia**, Compositae and Gramineae. An upper zone is recognized between about 28 and 47 m on the basis of maximum values in **Picea** (30-40%), lower but fluctuating values in **Pinus** and lower percentages (up to 12%) of shrub and herb pollen than in the previous zone.

The pollen trends compare closely with those in pollen zones 9 and 7 at Lambs Pond and Boyd Pond (4 and 5, Fig. 16) which bordered the Champlain Sea in the south. The **Picea** counts from near the top of the herb-shrub zones at Lambs Pond (Fig. 18) and Boyd Pond (Fig. 23) decrease to minimum trends like those in the Mer Bleue core. **Pinus** is high at both sites but it fluctuates more in Boyd Pond in a manner similar to that at Mer Bleue. The decline in herb and shrub pollen in the basal marine sediments of the Mer Bleue core

Table 8. Radiocarbon dates of pollen stratigraphic sites in the Ottawa Valley-Lake Ontario Region

	Site and No. (cf. Fig. 16)	Latitude (to the nearest minute)	Longitude	^{14}C Age BP Uncorrected	^{14}C Age BP Corrected (based on $\delta^{13}C$)	Laboratory Dating No.	Elevation ^{14}C Sample (m a.s.l.)	Sample Interval (cm)	Reference
1	Bay of Quinte	44°02'	77°05'	3610 ± 80	3550 ± 80	GSC-3464	60.9	215-220	Anderson and Lewis, 1985
				4850 ± 80	4790 ± 80	GSC-3460	59.9	320-325	Anderson and Lewis, 1985
				6140 ± 100	6080 ± 100	GSC-3300	59.3	378-382	Anderson and Lewis, 1985
				7960 ± 120	7920 ± 120	GSC-3441	59.1	393-397	Anderson and Lewis, 1985
2	Harrowsmith Bog	44°25'	76°42'	10 390 ± 160		GSC-270	152.8	560-570	Terasmae, 1968
3	Waterton Bog	44°25'	75°58'	9930 ± 100	9900 ± 100	GSC-3127	83.8	440-443	This study
				10 600 ± 140	10 500 ± 140	GSC-3146	83.8	441-443	This study
				10 000 ± 110	9990 ± 110	GSC-3163	83.7	448-460	This study
4	Lambs Pond	44°39'	75°48'	8410 ± 120	8320 ± 120	GSC-3296	106.2	737-743	This study
				10 300 ± 160	10 200 ± 160	GSC-3259	105.6	793-796	This study
				10 600 ± 110	10 500 ± 110	GSC-3273	105.3	828-831	This study
				12 300 ± 230	12 300 ± 230	GSC-3088	105.2	841-843	This study
5	Boyd Pond	44°23'	75°05'	11 200 ± 190	11 200 ± 190	GSC-3429	250.0	847-856	This study
7	Atkins Lake	44°45'	75°51'	1020 ± 160		GSC-807	114.7	0.69-0.82	Terasmae, 1980
				11 100 ± 270		GSC-762	111.6	376-388	Terasmae, 1980
8	Little Round Lake	44°48'	76°42'	11 180 ± 180		GSC-649	186.5	322-327	Terasmae, 1980
9	Perth Bog	44°57'	76°16'	8790 ± 100	8770 ± 100	GSC-3298	138.6	467-472	This study
10	McLachlan Lake	45°22'	76°33'	10 700 ± 150	10 700 ± 150	GSC-3372	167.7	1100-1104	This study
11	Kelly Lake	45°40'	76°39'	9920 ± 110		GSC-4171	185.3	523-528	This study
12	"Daber" Lake	45°45'	77°17'	10 900 ± 290	10 900 ± 290	GSC-3150	148.2	785-788	This study
13	Perch Lake	46°02'	77°32'	1340 ± 100		BGS-510	151.5	100-110	Terasmae and McAtee, 1979
				2510 ± 130		BGS-509	150.5	200-210	Terasmae and McAtee, 1979
				3790 ± 120		BGS-508	149.5	300-310	Terasmae and McAtee, 1979
				5780 ± 160		BGS-507	148.5	400-410	Terasmae and McAtee, 1979
				7800 ± 300		BGS-506	147.5	500-510	Terasmae and McAtee, 1979
				9030 ± 220		BGS-505	147.0	550-560	Terasmae and McAtee, 1979
				9830 ± 250		GSC-1516	146.5	595-605	Terasmae, 1980
14	"Flatbottom" Lake	46°03'	77°16'	9490 ± 160	9460 ± 160	GSC-3659	315.4	501-509	This study
15	Kazabazua Bog	45°57'	76°04'	9910 ± 200		GSC-680	176.0	895-905	Terasmae, 1980
16	Lac à St. Germain	45°56'	74°22'	3990 ± 145		GX-5229	464.0	270-280	Savoie and Richard, 1979
				8060 ± 210		GX-5230	461.8	490-500	Savoie and Richard, 1979
				10 830 ± 235		GX-5231	460.3	647-657	Savoie and Richard, 1979
				10 005 ± 280		GX-5232	460.2	658-668	Savoie and Richard, 1979
				10 420 ± 430		GX-5233	459.2	700-712	Savoie and Richard, 1979
17	Ramsay Lake	45°36'	76°06'	3320 ± 90	3210 ± 90	GSC-2125	185.9	311-316	Mott and Farley-Gill, 1981
				6510 ± 140	6420 ± 140	GSC-2110	183.6	542-547	Mott and Farley-Gill, 1981
				10 300 ± 410	10 200 ± 410	GSC-2122	180.4	860-864	Mott and Farley-Gill, 1981
				10 900 ± 180	10 800 ± 180	GSC-1963	179.6	930-942	Mott and Farley-Gill, 1981
18	Pink Lake	45°28'	75°49'	3410 ± 260	3270 ± 260	GSC-2014	141.3	132-136	Mott and Farley-Gill, 1981
				7920 ± 170	7750 ± 170	GSC-2016	140.0	222-227	Mott and Farley-Gill, 1981
				10 600 ± 150	10 600 ± 150	GSC-1956	139.0	295-300	Mott and Farley-Gill, 1981
19	Site 6 - Ottawa	45°21'	75°48'	8220 ± 150		GSC-547	63.3	500-550	Mott and Camfield, 1969
20	Site 3 - Ottawa	45°24'	75°42'	8830 ± 190		GSC-546	57.2	380-390	Mott and Camfield, 1969
20	Site 4 - Ottawa	45°25'	75°42'	7870 ± 160		GSC-628	61.7	680-695	Mott and Camfield, 1969
21	McKay Lake	45°27'	75°18'	4910 ± 80	4820 ± 80	GSC-4087	32.0	343-347	R.N. McNeely, pers. comm.
				6510 ± 80	6430 ± 80	GSC-4078	31.4	401-403	R.N. McNeely, pers. comm.
				8260 ± 100	8140 ± 100	GSC-4059	31.1	429-430	R.N. McNeely, pers. comm.
23	Mer Bleue Bog	45°24'	75°30'	7650 ± 210		GSC-681	63.4	515-525	Mott and Camfield, 1969
25	Northfield Bog	45°08'	74°56'	9430 ± 140		GSC-8	94.2	475-485	Terasmae and Mott, 1959
26	Hinchinbrook Site	45°01'	74°04'	10 480 ± 140		Beta-8270	110.0	78-80	Delage et al., 1985

GSC - Geological Survey of Canada
BGS - Brock University
GX - Geochron Laboratories
Beta - Beta Analytic Inc.

is comparable to that across the shrub and herb-**Picea** boundary in Boyd and Lambs ponds. Accompanying the decrease in herb and shrub pollen is the sudden increase in **Picea** which remains relatively high in the marine sediments.

The top of the herb-shrub zones at Boyd and Lambs ponds coincides with the end of glaciolacustrine deposition dated 11 200 ± 190 BP (GSC-3429, Table 8) at Boyd Pond. Thus, on the basis of palynological zonation, the change from proglacial lake sedimentation to marine deposition in the Champlain Sea at the Mer Bleue site is placed between 11 and 11.5 ka.

The retreat of marine waters from the western basin of the Champlain Sea was followed closely by the migration of spruce-dominated vegetation into Ottawa Valley. The spruce pollen peak at the base of Northfield Bog (Fig. 24) begins in eolian sand which postdates the Champlain Sea (Terasmae and Mott, 1959). The base of the spruce peak occurs at a level dated 10 200 ± 410 BP (GSC-2122, Table 8 and Fig. 20) at Ramsay Lake. The spruce pollen rise thus provides a convenient marker horizon to date the recession phase of the Champlain Sea and subsequent dune development in eastern Ottawa Valley.

DISCUSSION

The late glacial pollen stratigraphy and hence implied vegetation is time transgressive in a north-south transect across the western Champlain Sea basin. After ca. 9.5 ka, pollen zonations are everywhere synchronous for the first time.

The late glacial variations in pollen stratigraphy may be explained partly on the basis of the regional patterns of ice retreat, regional changes in late glacial climate, and the effect of the Champlain Sea on the composition of the late glacial vegetation, and on vegetation migration. These considerations bear on the use of pollen stratigraphy as an independent means of dating the Champlain Sea and are discussed below.

Deglaciation of the Ottawa Valley-Lake Ontario region

Late Wisconsinan ice recession in upper St. Lawrence Valley allowed glacial Lake Iroquois and the post-Iroquois glacial lakes of the Ontario basin to extend northeastward into the Central St. Lawrence Lowland and to drain to lower lake levels (Prest, 1970). The Ontario basin extension existed for a time in contact with the north and west retreating ice margin. Dates on basal gyttja in small lake and bog basins, located outside the Champlain Sea and at or beyond the limits of the glacial lakes, provide minimum ages for deglaciation of the Ottawa Valley-Lake Ontario uplands. The basal date of 11 200 ± 190 BP (GSC-3429, Table 8) at Boyd Pond provides a minimum estimate for ice retreat from the Adirondack Highlands south of the Champlain Sea. Basal gyttja dates from the Madawaska Highland west of the Champlain Sea are 10 700 ± 150 BP (GSC-3372) at McLachlan Lake (10, Fig. 16) and 10 900 ± 290 BP (GSC-3150) at "Daber" Lake (12, Fig. 16). Dates from the uplands north of the Champlain Sea are 10 420 ± 430 BP (Gx-5233) at Lac à St-Germain (16, Fig. 16), 10.2 ka at Ste. Agathe, 10 ka at Tania (Webb et al., 1983), 10 800 ± 180 BP (GSC-1936) at Ramsay Lake (17, Fig. 16), 9910 ± 200 BP (GSC-680) at Kazabazua (15, Fig. 16) and 9460 ± 160 BP (GSC-3659) at "Flatbottom" Lake (14, Fig. 16). The range of dates from ca. 11.2 ka in the southeast to 9.5 ka in the north and northwest confirms a northwesterly retreat of ice from the western Champlain Sea basin and surrounding Madawaska and Laurentian highlands.

According to Terasmae (1980) the ice retreated north of Ottawa before ca. 11 ka and west of Pembroke ca. 10 ka. The basal dates of 9.9 ka at Kazabazua and 9.5 ka at "Flatbottom" Lake indicate therefore that a lapse time of about 1 ka may have occurred between deglaciation and initiation of accumulation of organic sediment deposition in these lake basins. However, 1 ka seems more than adequate for deposition of the stratified silt and clay underlying gyttja at "Flatbottom" Lake.

Influence of the Champlain Sea and climate on the late glacial vegetation

Tundra woodland existed in contact with the Champlain Sea in the southern part of the basin until ca. 11.2 ka and formed the initial vegetation of the newly deglaciated areas to the north, west, and northwest of the Champlain Sea. It was replaced by spruce-poplar woodlands in the southern part of the basin and by poplar woodlands to the west and north of the sea. Poplar grew at the northwest margin of the Champlain Sea at ca. 10.9 ka, to the north of the sea at ca. 10.7 ka, and slightly later (ca. 10.0 ka) at sites in Laurentian Highland areas farther east. Poplar was able to reach areas to the north and west of the Champlain Sea and islands within the Champlain Sea prior to other trees because its seeds were more easily transported by wind currents and in the water of the Champlain Sea than those of other tree species including spruce (Richard, 1977; Mott, 1978; Webb et al., 1983). In addition, poplar seeds, especially those of **Populus balsamifera, P. grandidentata, P. deltoides** and **P. tremuloides**, prefer wet, bare mineral soil seedbeds that have abundant sunlight (Fowells, 1965). Such conditions prevailed in the recently deglaciated sites around the sea and poplar was quick to colonize these habitats.

By ca. 11 ka spruce dominated the uplands bordering the south shore of the Champlain Sea. The earliest arrival time for spruce north of the Champlain Sea was ca. 10.2 ka at Ramsay Lake. In contrast to poplar, spruce experienced a migration lag of about 1.5 ka in reaching the north shore of the Champlain Sea. The migrational lag may be attributed to the presence of the Champlain Sea, which represented a physiographic barrier preventing spruce seeds from dispersing to the north and northwest. Once the sea barrier had decreased in areal extent, spruce advanced northward and eventually occupied the entire western basin of the Champlain Sea. The peak in **Picea** pollen above Champlain Sea sediments at Northfield Bog (Terasmae, 1965; Terasmae in Dyck and Fyles, 1963) shows that spruce formed the pioneer forest of the Champlain Sea basin.

Alternatively, the lag in spruce migration may have been climatically induced. Convincing evidence now exists at several pollen-analyzed sites in Nova Scotia and New Brunswick (Mott, 1985) and at two areas in Newfoundland (Brown Macpherson and Anderson, 1985) for a climatic oscillation which interrupted deglacial warming between about ca. 11 and 10 ka. It may be more than coincidental that the timing of the spruce lag corresponds closely with that for the climatic oscillation in eastern Canada and possibly with the climatically induced St. Narcisse event in Quebec (LaSalle and Elson, 1975) bracketed between ca. 11 and 10.3 ka (LaSalle, 1984). The spruce lag resulted from the presence of the Champlain Sea perhaps in combination with regional climatic cooling even though evidence for climatic cooling at this time is not clear in pollen diagrams from the Ottawa Valley-Lake Ontario region.

Correlation of Champlain Sea chronologies and implications

The palynological findings reported here are in agreement with a previous correlation between the Champlain Sea and the post-Iroquois-Early Lake Ontario transition in the Lake Ontario basin (Anderson and Lewis, 1985). The Champlain Sea may have been confluent with water levels in the Ontario basin after the fall of the post-Iroquois lake phases to the low water phase of Early Lake Ontario (Anderson and Lewis, 1985). The low water phase is palynologically dated at ca. 11.4 ka in shallow water deposits from western Lake Ontario (Anderson and Lewis, 1985). Since Lake Ontario may have been confluent with sea level just prior to or at its lowest level, i.e. prior to or during early isostatic uplift of the controlling Duck-Galloo sill in eastern Lake Ontario (Anderson and Lewis, 1985), the 11.4 ka estimate is therefore a minimum age for the Champlain Sea at its maximum. Ontario basin and Champlain Sea waters separated as a result of isostatic uplift of the upper St. Lawrence outlet area.

The oldest dates on the Champlain Sea range from ca. 12.1 to 12.7 ka for marine shells collected at or near marine limit in the western basin of the Champlain Sea (Fulton and Richard, this publication). The shell dates differ by as much as 1.7 ka from estimates of ca. 11.0 to 11.5 ka for the beginning of the Champlain Sea as determined from pollen stratigraphy. Younger shell dates, however, overlap with age estimates derived from pollen stratigraphy. For example, one of the youngest marine shell dates on the recession phase of the Champlain Sea (10 000 ± 320 BP, GSC-1553; Table 7; Fulton and Richard, this publication) corresponds closely with the estimated 10.2 ka age for the post-Champlain Sea spruce arrival in Ottawa Valley.

The discrepancy between the older shell dates and the pollen-dated chronologies might be attributed to the possibility that the oldest marine shells incorporated carbon from carbonate-charged glacial meltwater that flowed into the western basin of the Champlain Sea (Hillaire-Marcel, 1981). With time, the carbonate-rich glacial meltwater became diluted by the marine water of the Champlain Sea and eventually reached equilibrium with atmospheric CO_2. Younger dated shells were therefore less affected.

Basal gyttja from McLachlan Lake, located in the same general area as the oldest marine shells, also appears to have been affected by hardwater dating error. The gyttja yielded a date of 10 700 ± 150 BP (GSC-3372) which is about 1.3 ka older than the date anticipated from pollen correlation with other sites in the area. In a similar manner basal gyttja from Lambs Pond is too old by about 1000 years.

Thus a chronological framework for the western basin of the Champlain Sea based on marine shell dates greater than about 10 ka and dated pollen stratigraphy in carbonate-rich areas should be regarded with suspicion. Pollen studies on Champlain Sea sediments correlated with ^{14}C dated pollen zones from the Adirondack Highlands where Proterozoic igneous and metamorphic rocks predominate (Isachsen and Fisher, 1970) perhaps offer the most reliable means to date the Champlain Sea incursion. Additional lake sediment coring and basal sediment dating in the Adirondack Highlands are recommended in order to establish better chronological control for the late glacial interval of the Lake Ontario-Ottawa Valley region.

SUMMARY AND CONCLUSIONS

Following deglaciation, herb-shrub tundra-woodland represented the earliest colonizing vegetation of the Ottawa Valley-Lake Ontario region. In the south, spruce began arriving about ca. 11.2 ka and dominated a spruce-poplar woodland ca. 11 ka. Poplar woodlands replaced tundra woodland in areas bordering the Champlain Sea to the west and north between ca. 10.9 to 10.7 ka. Spruce did not migrate northward to replace poplar until ca. 10.2 ka.

Invasion of the Champlain Sea appears to correspond approximately with movement of spruce into the area (ca. 11.2 ka). The end of the Champlain Sea correlates closely with the replacement of poplar by spruce on the north shore of the basin (ca. 10.2 ka).

The oldest shell dates on the Champlain Sea (12.7 to 12.1 ka) are too old by up to 1.7 ka on the basis of the pollen stratigraphy presented here and correlation between Champlain Sea and the post-Iroquois water-level history of Lake Ontario basin. Younger marine shell dates overlap with those derived from pollen correlations. Pollen studies on Champlain Sea sediments and underlying glaciolacustrine deposits correlated with dated pollen profiles from the Adirondack Highlands probably represent the most reliable potential method for dating the Champlain Sea.

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