PART 1

SUMMARY OF THE QUATERNARY OF THE OTTAWA REGION

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Ottawa lies in a segment of the St. Lawrence Lowlands that is bounded by highlands on the north, south, east and west but opens to the Atlantic to the northeast and to the Great Lakes Basins to the southwest. Quaternary deposits are abundant in the area with most related to the last ice retreat and occupation of the area by postglacial waterbodies. The scope of recorded Quaternary history may be limited but it is highly significant because the area lies in the region where the late Quaternary Great Lakes interacted with the Champlain Sea.

The purpose of the first section of this volume is to describe the general setting of the Ottawa region, to characterize the nature of Quaternary deposits, to summarize the Quaternary history of the region and to introduce some of the main controversies and problems. This is provided as background information for the Day Excursion guides which follow (Part II) but serves equally well as an introduction to the Quaternary of the region for all participants of the XII INQUA Congress.

REGIONAL SETTING

The nature and distribution of Quaternary deposits, the pattern of ice flow and retreat, and the pattern of occupation and regression of Late Glacial water bodies in the Ottawa Region were strongly influenced by bedrock lithology and the regional physiographic framework (Fig. 1). The bedrock consists of two major types: Precambrian metamorphic and igneous rocks and early Paleozoic carbonates, shales and sandstones (Baer *et al.*, 1977). Precambrian rocks occupy highlands to the north, south and west whereas the Paleozoic rocks occupy a broad lowland (the St. Lawrence Lowlands) that extends southwestward into the Lake Ontario basin and eastward down the St. Lawrence River valley (Fig. 1). The present day physiographic framework is partly the result of failed Cretaceous rifting which was related to opening of the Atlantic Ocean (Kumarapeli and Saull, 1966). However, this Mesozoic development apparently follows similar activity that occurred in the region during Late Precambrian (Kumarapeli, 1985). The lower Ottawa River valley now occupies a graben-like structure whereas the Precambrian rocks of the Gatineau Hills to the north and in the Madawaska Highland to the southwest are the uplifted part of this structure (Fig. 1). The region contains no pre-Quaternary deposits younger than late Ordovician.

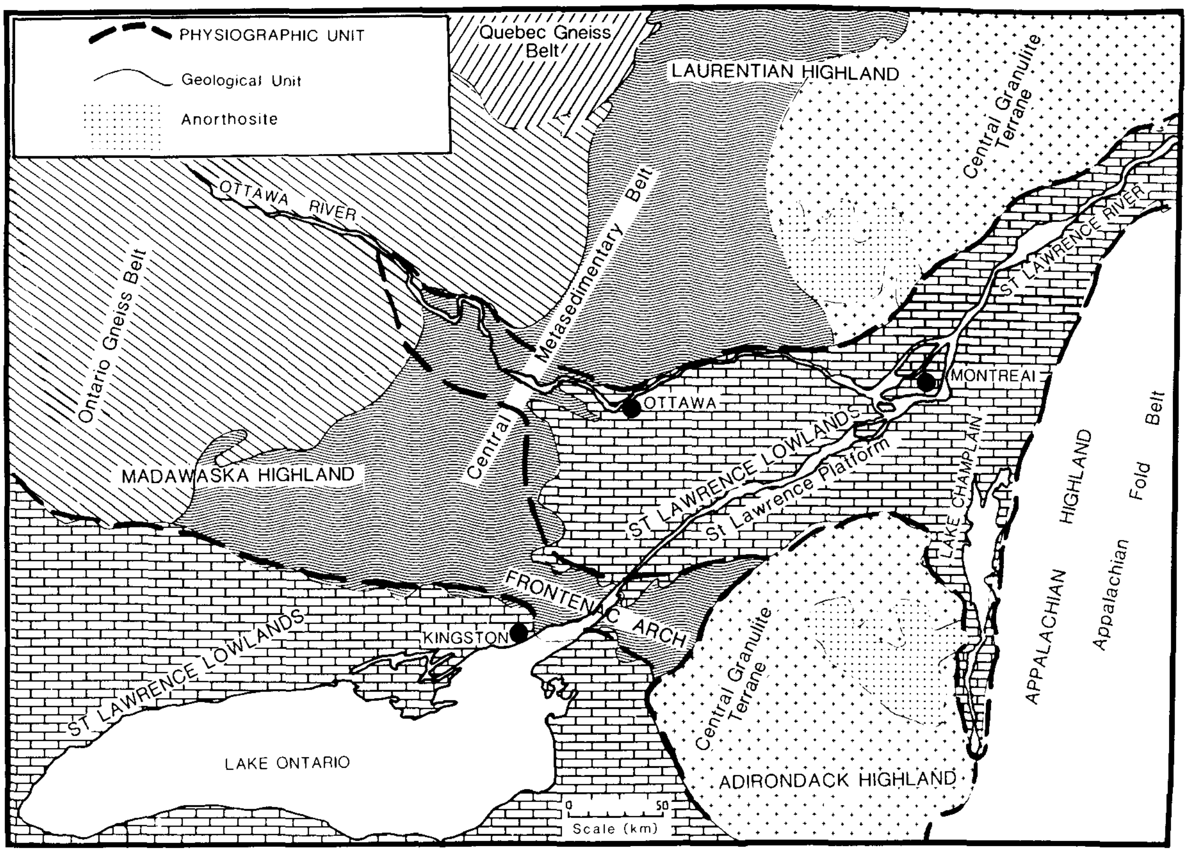


Figure 1: Physiographic and bedrock map of the Ottawa region. Physiographic subdivisions after Bostock (1970); bedrock geology after Sanford *et al.* (1979)

UATERNARY DEPOSITS AND LACIATION

The only Quaternary deposits which predate ıte Wisconsinan (in this area) are fluvial sands which ·ntain organic materials, clay, and underlying till, that e all overlain by till at Pointe Fortune on the Ontario-uébec border (Veillette and Nixon, 1984). These depos-; might relate to a Wisconsinan interstade or they might : older.

The last ice which occupied the area was of Late 'isconsinan age and supposedly was part of the same ice ass that extended to the Late Wisconsinan terminal .oraine in New Jersey. At the time of the glacial max-ıum, flow through this area apparently was mainly ɔrth to south. During waning glacial stages, to-ɔgraphical control dominated and flow became strongly bate (Gadd, 1980a; 1980b). Major lobes moved south ıd southwestward in the Lake Champlain valley and in ıe St. Lawrence Valley east of Valleyfield; south from 'ttawa; southwestward into the Lake Ontario basin; and ɔutheastward in the Ottawa Valley, upstream from Ot-.wa (Fig. 2 and Fig. 3).

Till deposited during the Late Wisconsinan is the ıost extensive Quaternary sediment in the area (Fig. 4). he till is generally sandy and the texture of the finer than mm fraction in areas underlain by carbonates and other Paleozoic rocks has a slightly higher silt and clay content than that in areas underlain by Precambrian crystalline rocks (Kettles and Shilts, in press; Fig. 5). A carbonate-rich facies of till is recognized with the till carbonate content increasing rapidly where ice moved from an area of crystalline rocks to an area underlain by Paleozoic carbonates. Where ice moved from Paleozoic carbonates to areas of crystalline rocks however, the till retains high levels of carbonate for long distances down ice from the carbonate/crystalline contact (Kettles and Shilts, in press; Fig. 6a). The distribution of trace elements in till is closely tied to local bedrock composition. The occurrence of anomalously high arsenic values for instance (Fig. 6b) is apparently related to a number of small mineralized areas in the Precambrian bedrock (Kettles and Shilts, in press). In addition, high levels of Zn, As, Fe, Pb, Mn, Cd, Mo, Hg and U are related to northeast to southwest striking belts of metasedimentary and metavolcanic rocks in the Frontenac Arch area whereas, Co, Cr and Ni are commonly associated with large basic plutons.

The till is of variable thickness but generally is thin and can be found in most parts of the area where it has not been stripped by later erosion (Fig. 4). The sandy texture of the till and inclusion of lenses of sorted sediments suggest that much of the till is of meltout origin. Flowtills are present near the top of many glaciofluvial deposits. These occurrences have led to the speculation

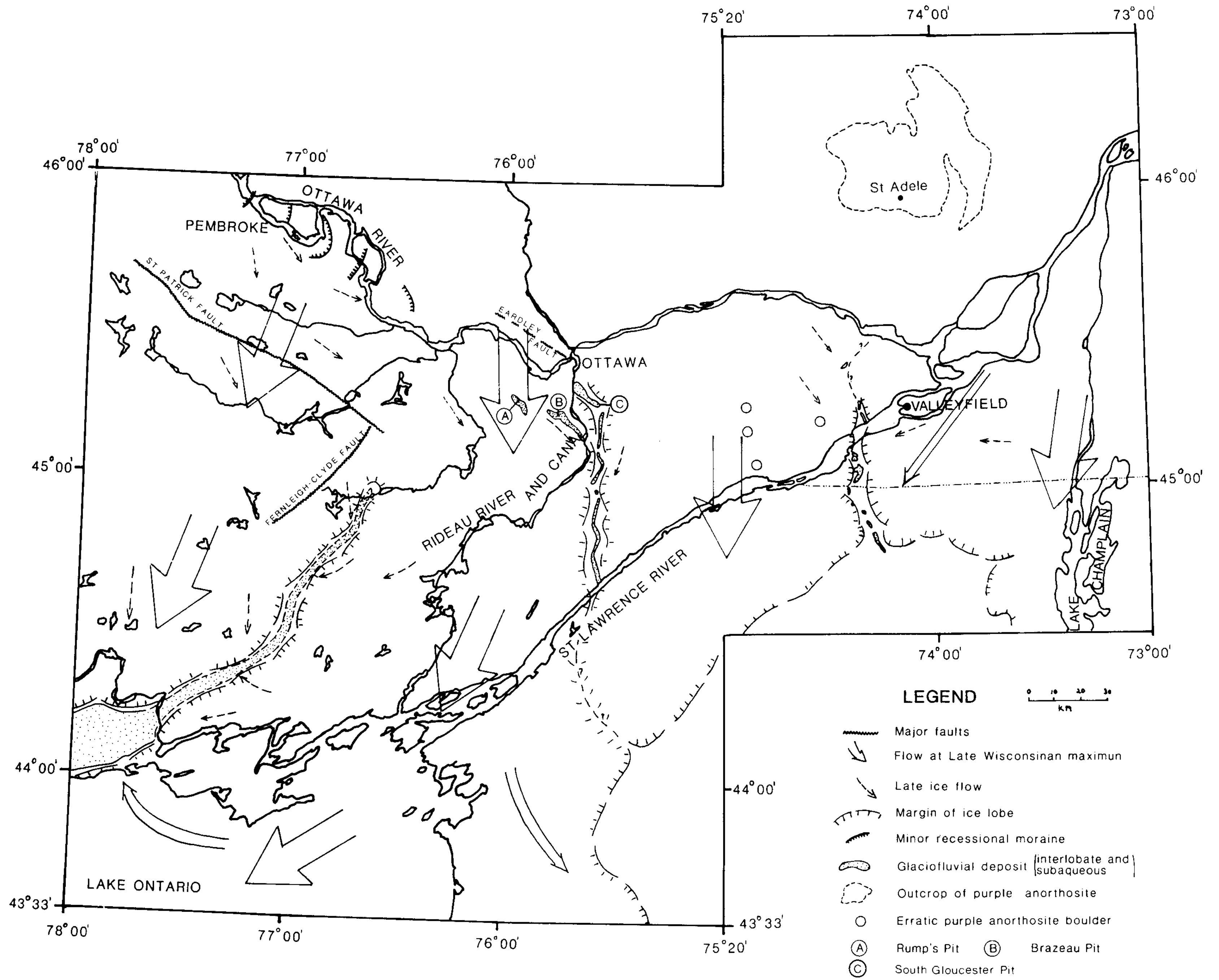
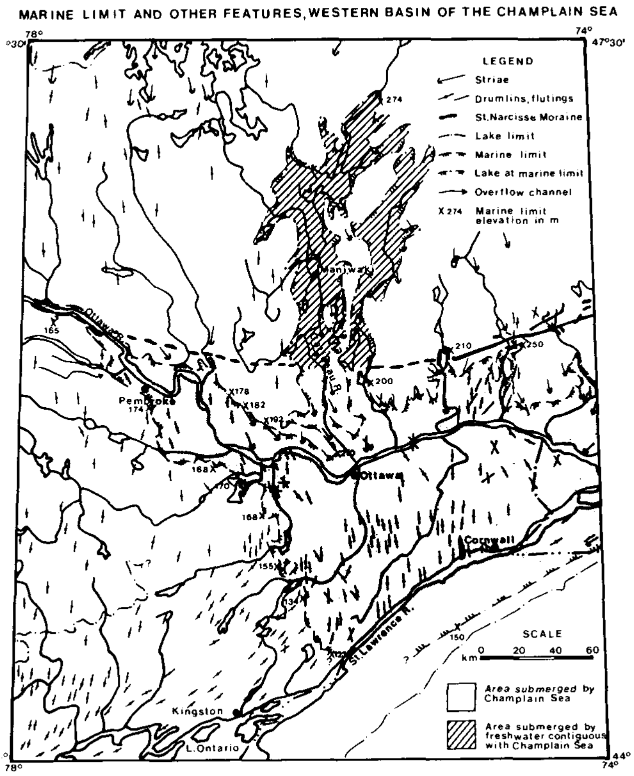


Figure 2: Main pattern of Late Wisconsinan ice lobation and flow (from Gadd, in press)



:gure 3: Map showing marine limit in western basin of Cham-
ain Sea, glacial flow features and miscellaneous late glacial
·atures of the Ottawa region. Limit of Champlain Sea is from an
ıpublished compilation by J-S. Vincent of the Geological Survey
: Canada

ıat upper parts of the till sheet in many areas may be of owtill origin (Kettles and Shilts, in press).

Glaciofluvial sediments are abundant in the re- ion. Eskers are common on the Frontenac Arch to the ›uth and in the Madawaska Highland to the west; out- 'ash fans and pitted outwash plains are common at the orthern limit of the Champlain Sea; and subaqueous utwash, possibly in the form of eskers, fans, and interlo- ate moraines, are abundant within the basin of the :hamplain Sea. Several detailed studies have been car- .ed out on deposits immediately south of Ottawa and it as been concluded that these consist of overlapping ıcies of subaqueous fans deposited within or at the ıouth of meltwater conduits (Rust and Romanelli, 1975; .ust, 1977; Cheel, 1982; and Rust, in press). Imbricate oulder gravel and horizontally stratified gravel are sedi- ıents which generally were deposited within or adjacent › the mouths of these conduits; sand facies, including ross-bedded, coarse, pebbly sand, medium grained, ıassive sand and ripple-drift units that fine upwards :om sand to silt, were deposited on the fan aprons; and ıassive sand, in many places containing ball and pillow tructures, were deposited as mass flow deposits in the hannels of the subaqueous fans (Fig. 7). Most other laciofluvial deposits have not been studied in the detail of those near Ottawa so it is not possible to say whether all were deposited under the same general conditions in the Champlain Sea basin. Most deposits do however, contain similar successions of sediments.

DEGLACIATION AND LATE GLACIAL WATER BODIES

The style of deglaciation of the area is a point of controversy. The conventional idea is that ice in the lowland retreated in a roughly south to north direction with proglacial lakes extending into the central part of the area from the Lake Ontario basin to the west and the Lake Champlain basin to the east (Prest, 1970; Clark and Karrow, 1984). Rhythmically bedded sediments containing the freshwater ostracode *Candona*, which locally occur in the Ottawa area, are related to this early phase of glaciolacustrine deposition (Anderson *et al.*, 1985). An alternate proposal suggests that a calving bay moved up the lower St. Lawrence Valley from the east and into the Ottawa area, isolating ice in the upper St. Lawrence Valley (between Cornwall and Kingston) which retained proglacial lakes in the Lake Ontario basin (Gadd, 1980a). Under this hypothesis the rhythmically bedded sediments are referred to a temporary phase of freshwater deposition which occurred at the head of the calving bay. The calving bay hypothesis best explains why marine shells dated older than 12 ka occur in the southern

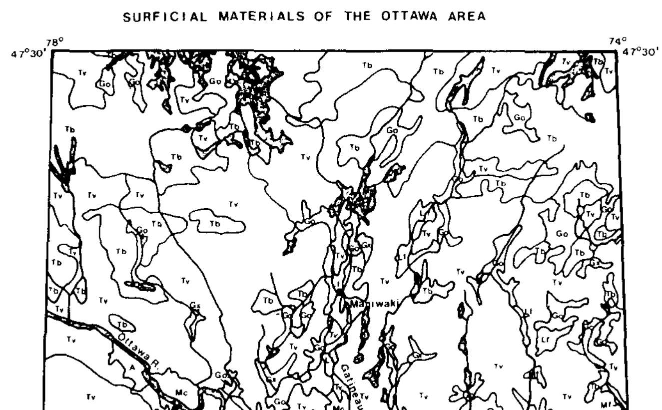


Figure 4: Surficial materials of the Ottawa area. Figure from data compiled at a scale of 1:1,000 000 by N.R. Gadd and J.J. Veillette, Geological Survey of Canada

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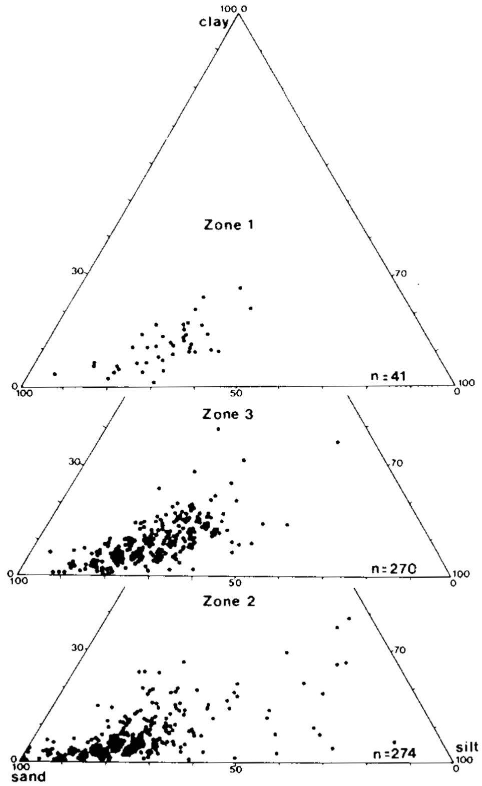


Figure 5: Triangular diagram showing the texture of the finer than 2 mm fraction of tills in the Ottawa region (from Kettles and Shilts, in press)

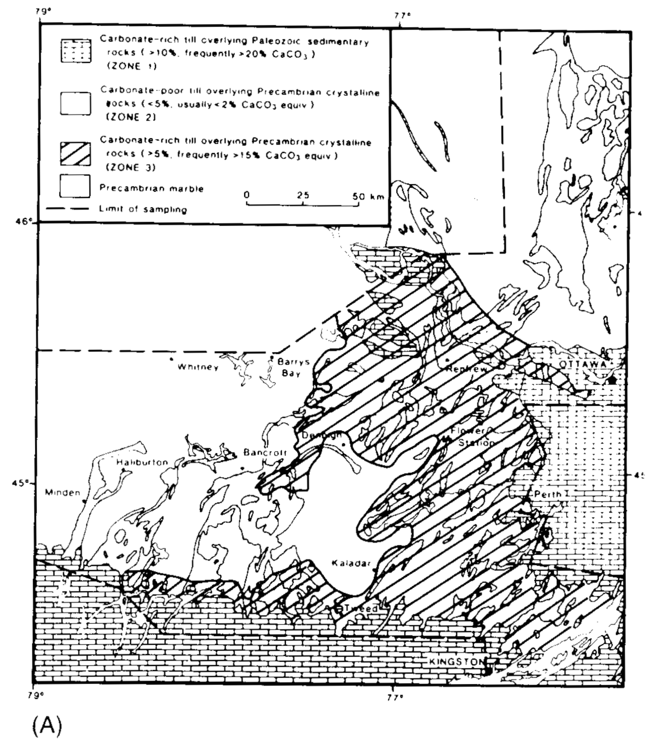


Figure 6: Distribution of geochemical components of tills of tl Ottawa Region (from Kettles and Shilts, in press) (A). Per ce carbonate in till.

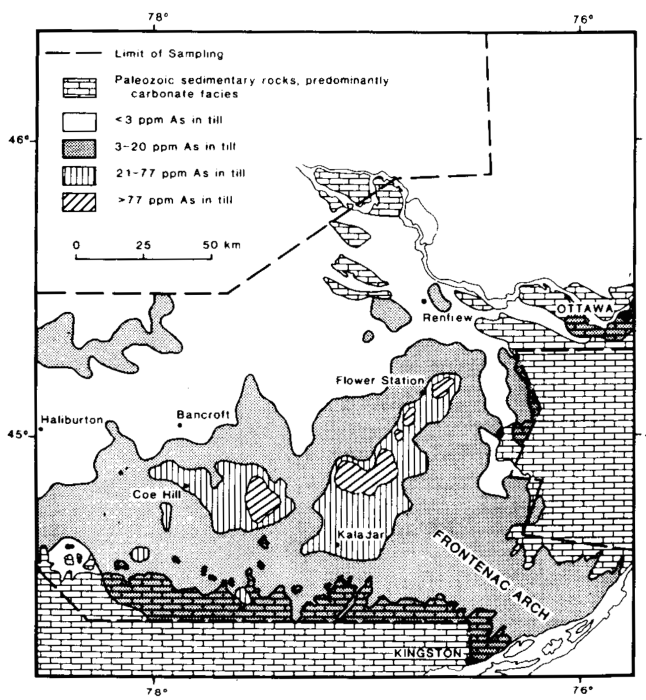


Figure 6: (B). Parts per million arsenic in till

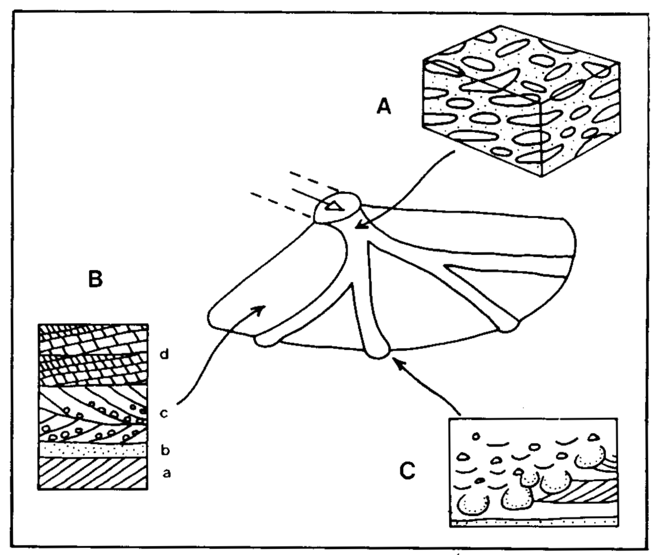


Figure 7: Depositional model for subaqueous fans south c Ottawa. Dashed line represents margins of meltwater conduit ir ice; for simplicity, ice contact features are omitted. A: Grave facies. B: Stratified sand facies. a: planar cross-stratified sand b: structureless sand; c: trough cross-stratified pebbly sand d: graded ripple-drift units. C: massive sand facies in a channe (from Rust, 1977)

:atineau Valley whereas 11.9 ka is the oldest date in the pper St. Lawrence Valley; it also provides a means of ·taining a proglacial lake in the Lake Ontario basin while ıe Champlain Sea occupied the Ottawa area. Chauvin *et* . (1985), however, argue that the calving bay in the St. awrence did not advance upstream from Québec City. he conventional or "window blind" retreat best explains ıe distribution of lacustrine deposits which underlie hamplain Sea sediments and the pattern of glaciofluvial dges.

)evelopment of the Champlain Sea

Whatever the style of ice retreat, deglaciation was ›llowed by submergence of the area by the Champlain ea, an arm of the Atlantic Ocean that extended up the St. awrence River into the isostatically depressed lower)ttawa and upper St. Lawrence valleys. The upper limit f marine submergence apparently slopes up to the north ·om about 120 m at the southwest extremity of the ma- ne basin, to 200 m near Ottawa, and to 274 m in the orth. It also slopes down to the west from Ottawa, eaching 165 m near the western extremity of the basin Fig. 3). Over at least the northern and western parts of ıe area, the ice margin retreated in marine waters and ıus marine limit in at least these areas is time transgressive. Dates on marine limit vary in other parts of the basin as well and this is one of the main bases for disagreement on the pattern of ice retreat and subsequent submergence.

The oldest dates on marine fossils, 12.7, 12.2 and 12.2 ka (Rodrigues and Richard, 1985; 1, 2a, and 3 of Table 1; Clayton, Cantley, and White Lake on Fig. 8) have been obtained from deposits near marine limit west of Ottawa and at the southern end of the Gatineau River valley. The oldest shell dates from the southern part of the basin are 11.9 ka (30 of Table 1) and 12.0 ka (from silts in downtown Massena; Kirkland and Coates, 1977, laboratory number not reported). Hence it could be argued that the Champlain Sea entered the Ottawa and Gatineau areas before or at least as soon as it reached the upper St. Lawrence Valley, a pattern of occupation that might have occurred if marine water had entered the area via a calving bay. However, the older ^{14}C dates for marine shells from the highest fossiliferous beaches along the northern and western margins of the basin may be anomalously old because of "old water" effect or local influx of dead carbon from areas of carbonate-rich bedrock (Hillaire-Marcel, 1981; Karrow, 1981).

Pollen stratigraphy of mineral sediments has been suggested as a possible technique for obtaining an

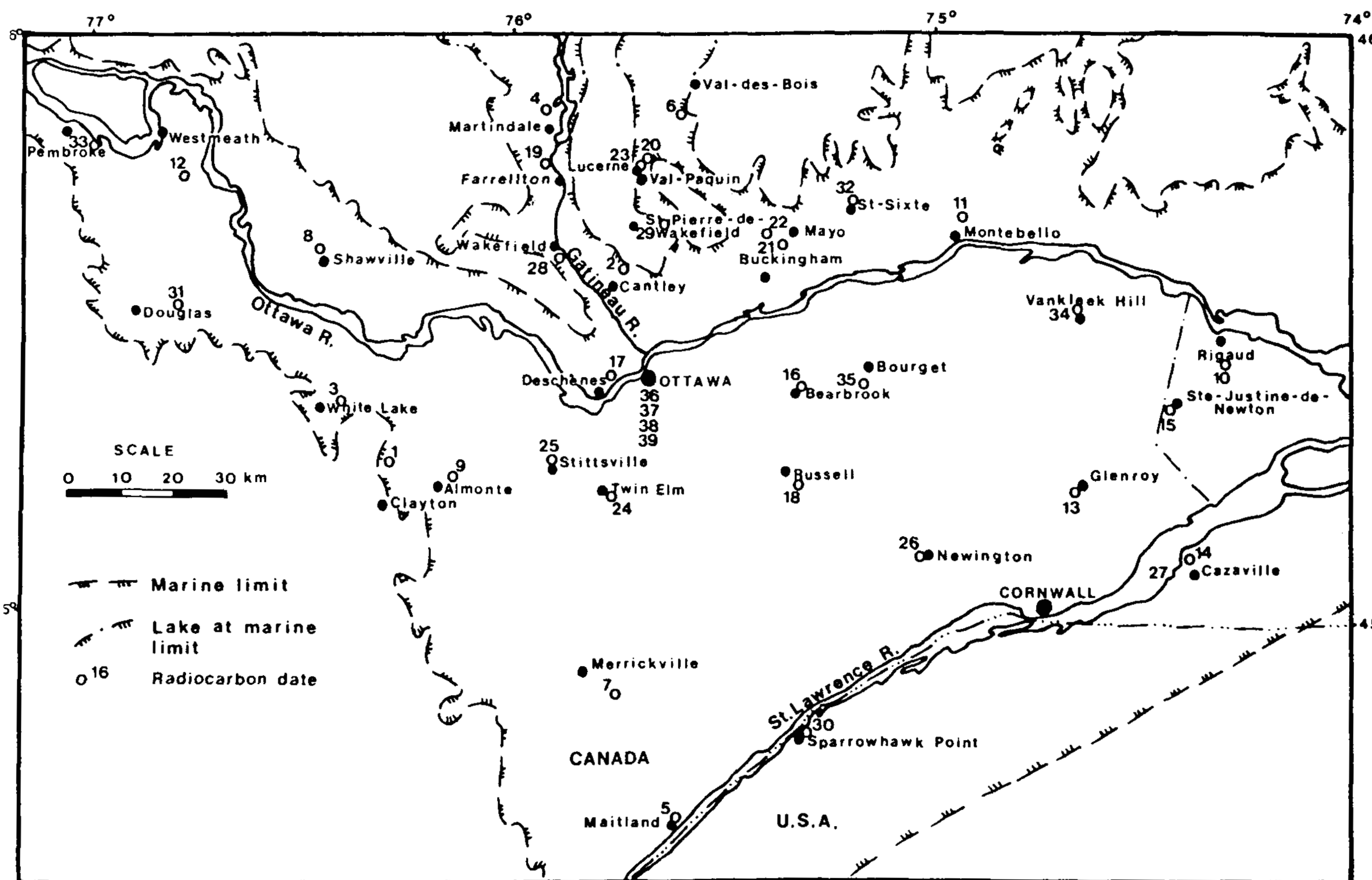


Figure 8: Location map for radiocarbon dated sites (Table 1)

Table 1 Radiocarbon dates from the Ottawa region (from Fulton and Richard, in press).

No.	Site Name	Elev. (m.a.s.l)	Lab. No.	Age (years BP)	Material Dated	$\delta^{13}C$ (‰)	Collector	Reference	Comment
A. Dates from beach and nearshore sediments									
1.	Clayton	168	GSC-2151	[1] 12 800 ± 100 [2] 12 700 ± 100	**Macoma balthica** (Linné)	-0.2 -0.2	S.H. Richard and W. Blake, Jr.	Richard 1978	Marine limit
2a.	Cantley	194	GSC-1646	12 200 ± 160	**Macoma balthica**		R. Romanelli	Romanelli, 1975	Marine limit (198 m?)
3.	White Lake	170-71	GSC-3110	[1] 12 100 ± 100 [2] 12 200 ± 100 [3] 12 100 ± 100	**Macoma balthica**	-0.6 -0.5 -0.6	S.H. Richard	Rodrigues and Richard, 1983	Marine limit
4.	Martindale	176	GSC-1772	11 900 ± 160	**Macoma balthica**		R. Romanelli	Lowdon and Blake, 1973	Marine limit
5.	Maitland	103	GSC-1013	11 800 ± 210	**Macoma balthica**		E.P. Henderson	Lowdon and Blake, 1970	Near marine limit limit (123 m?)
6.	Val-des-Bois	180	GSC-2769	11 800 ± 100	**Macoma balthica**	-1.8	S.H. Richard	Richard, 1980	High marine level
7.	Merrickville	118	GSC-3523	11 800 ± 100	**Macoma balthica**	-0.7	C.G. Rodrigues and S.H. Richard	Blake, 1984	Near marine limit
8.	Shawville	170	GSC-3670	11 400 ± 190	**Macoma balthica**	1.7	R.J. Fulton	Blake, 1983	20 m below marine limit (?)
9.	Almonte	154	GSC-1672	11 200 ± 160	**Macoma balthica**		S.H. Richard	Lowdon et Blake, 1973	Intermediate level
10.	Rigaud	160	GSC-2296	11 200 ± 90	**Hiatella arctica** (Linné)	1.7	S.H. Richard	Richard, 1978	Near marine limit
11.	Montebello	167	GSC-2590	11 100 ± 120	**Hiatella arctica**	2.3	S.H. Richard	Richard, 1980	Intermediate level
12.	Westmeath	158	GSC-1664	11 000 ± 160	**Macoma balthica**	-1.6	P.J. Howarth	Lowdon and Blake, 1979	Intermediate level
13.	Glenroy	79	GSC-3845	10 700 ± 100	**Mya arenaria** Linné	-2.7	C.G. Rodrigues and S.H. Richard	Rodrigues and Richard, 1985	Low level
14.	Cazaville	55	GSC-2423	10 600 ± 140	**Macoma balthica**		S.H. Richard	Richard, 1978	Low level
15a.	Ste-Justine-de-Newton	75	GSC-2261	10 300 ± 100	**Mya truncata** Linné	1.5	S.H. Richard and W. Blake, Jr.	Richard, 1978	Low level
16.	Bearbrook	69	GSC-3907	[1] 10 200 ± 110 [2] 10 200 ± 90	**Hiatella arctica**	-0.8 0.3	C.G. Rodrigues	Rodrigues and Richard, 1985	Low level
17.	Deschênes	94	GSC-2189	10 100 ± 130	**Hiatella arctica**	1.3	S.H. Richard	Richard, 1978	Low level
18.	Russell	70	GSC-1553	10 000 ± 320	**Macoma balthica**		S.H. Richard	Lowdon and Blake, 1973	Youngest marine date in region
B. Dates from high level fine grained marine sediments.									
2b.	Cantley	195	GSC-3844	11 800 ± 170	**Macoma balthica**		S.H. Richard	Rodrigues and Richard, 1985	Near marine limit (198 m?)
19.	Farrellton	180	GSC-3862	11 700 ± 100	**Macoma balthica**	-1.4	S.H. Richard	Rodrigues and Richard, 1985	Maximum for emergence
20.	Val-Paquin	195	GSC-3865	11 500 ± 130	**Macoma balthica**	-1.7	S.H. Richard	Rodrigues and Richard, 1985	Maximum for emergence
21.	Mayo	182	GSC-2878	11 500 ± 210	**Macoma balthica**	-0.6	S.H. Richard	Richard, 1980	Maximum for emergence
22.	Buckingham	180	GSC-2763	11 400 ± 140	**Hiatella arctica**	1.9	S.H. Richard	Richard, 1980	Maximum for emergence
23.	Lucerne	175	GSC-3997	11 200 ± 130	**Macoma balthica**	0.7	S.H. Richard	Unpublished	Maximum for emergence
C. Dates from glaciomarine(?), glaciofluvial(?) and glacial(?) sediments									
24a.	Twin Elm	105	GSC-3641	11 200 ± 200	**Portlandia arctica** (Gray)	-2.8	S.H. Richard	Blake, 1983	Marine clay interbedded with glaciofluvial(?) gravel
24b.	Twin Elm	104	GSC-587	10 620 ± 200	**Macoma balthica**		R.J. Mott	Mott, 1968	Glaciofluvial(?) sand
25.	Stittsville	130	GSC-2448	11 300 ± 120	**Hiatella arctica**		N.R. Gadd	Gadd, 1973	Sands (glaciofluvial?) with ball and pillow structure
26.	Newington	106	GSC-2108	11 200 ± 100	**Hiatella arctica**		S.H. Richard	Richard, 1975	From compact diamicton
15b.	Ste-Justine-de Newton	74	GSC-2391	10 500 ± 110	**Hiatella arctica**	1.5	S.H. Richard	Richard, 1978	From diamicton
27.	Cazaville	71	GSC-3882	[1] 10 300 ± 90 [2] 10 500 ± 90	**Hiatella arctica**	-0.1 1.2	S.H. Richard	Rodrigues and Richard, 1985	From diamicton
28.	Wakefield	140	TO-112R[4]	11 760 ± 120	**Portlandia arctica**		R.J. Fulton	Unpublished	From glaciomarine diamicton
29.	Saint-Pierre-de-Wakefield	160	GSC-3834	11 700 ± 150	**Portlandia arctica**	-1.1	S.H. Richard	Rodrigues and Richard, 1985	From glaciomarine diamicton

Table 1 Radiocarbon dates from the Ottawa region (from Fulton and Richard, in press).

No.	Site Name	Elev. (m.a.s.l)	Lab. No.	Age (years BP)	Material Dated	$\delta^{13}C$ (‰)	Collector	Reference	Comment
D. Other dates									
30.	Sparrowhawk Point	76	GSC-3767	11 900 ± 100	**Portlandia arctica**	0.2	C.G. Rodrigues and S.H. Richard	Rodrigues and Richard, 1985	Marine clay overlying rhythmically laminated sediments
31.	Douglas	120	GSC-3872	11 700 ± 120	**Macoma balthica**	-3.6	C.G. Rodrigues, S.H. Richard and R.J. Fulton	Rodrigues and Richard, 1985	From clay clasts in sand
32.	Saint-Sixte	145	GSC-2863	11 500 ± 200	**Macoma balthica**	-4.8	S.H. Richard	Richard, 1980	Maximum age of emergence
33.	Pembroke	139	GSC-90	10 870 ± 130	**Marine shells**		J. Terasmae	Dyck and Fyles, 1963	Maximum age of emergence
34.	Vankleek Hill	61	GSC-3235	10 300 ± 90	**Lampsilis radiata** (Gmelin) s.l.		S.H. Richard	Lowdon and Blake, 1981	Early Ottawa R. terrace
35.	Bourget	53	GSC-1968	10 200 ± 90	**Lampsilis sp.**		N.R. Gadd	Gadd, 1976	Alluvium in abandoned channel
36.	Ottawa	60	GSC-546	8 830 ± 190	**Marly gyttja**		R.J. Mott	Lowdon et al., 1967	Basal organic in channel
37.	Ottawa	70	GSC-547	8 220 ± 150	**Woody peat**		N.R. Gadd and J. Terasmae	Lowdon et al., 1967	Dates channel filling
38.	Ottawa	46	GSC-4059	8 140 ± 100	**Gyttja**		R. McNeely, S.R. Brown and J.P. Smol	Unpublished	Dates low terrace
39.	Ottawa	67	GSC-628	7 870 ± 160	**Marly gyttja**		J. Terasmae	Lowdon et al., 1967	Dates channel filling

[1]Outer fraction [2]Inner fraction [3]Middle fraction
GSC – Geological Survey of Canada
To – IsoTrace (University of Toronto)

[4]Originally IsoTrace normalized this date to $\delta^{13}C$ = -25 ‰ and reported an age of 12 160 ± 120. The revised date is normalized to 0 ‰ and hence is directly comparable to GSC shell dates.

estimate of the timing of the arrival of marine waters. Anderson (in press) surmized that the earliest marine deposition in the western basin of the Champlain Sea, occurred at about the contact between his herb-shrub and spruce pollen zones. The change from dominance of herb-shrub to spruce pollen is estimated to have occurred between 11.7 and 11.2 ka based on dates from lake sediment cores (Table 2). This is between several hundred and a thousand years younger than the chronology based on marine shell dates but fits with the apparent chronology of glacial Lake Iroquois which occupied the Lake Ontario basin to the west (Karrow, 1981).

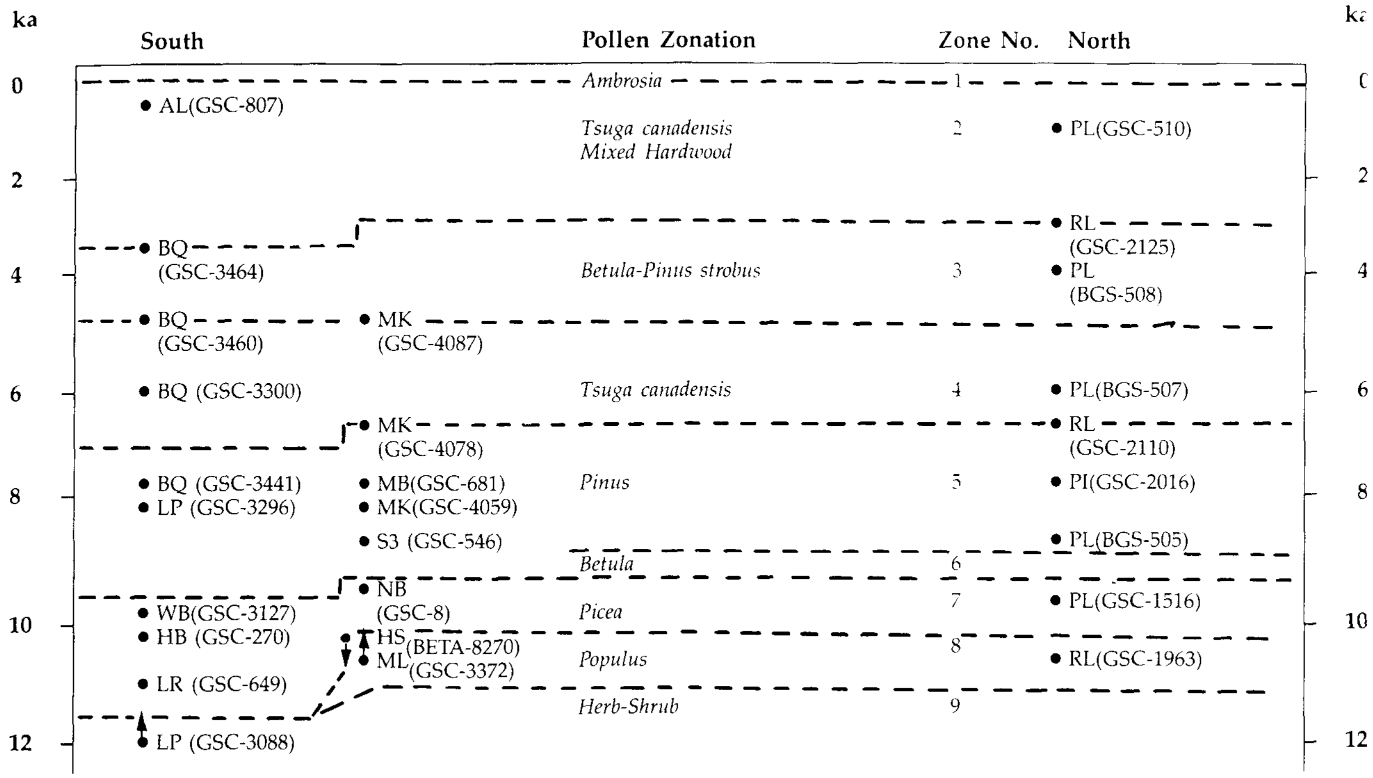
Champlain Sea Sediments

Ice contact stratified drift and subaqueous outwash; thin deposits of rhythmically bedded (varved?) silts and clays containing the freshwater ostracode *Candona*; and thick, extensive, marine sediments were deposited in the Champlain Sea basin during deglaciation (Fig. 4). The glaciofluvial deposits have already been mentioned. The glaciolacustrine sediments are not a volumetrically significant unit and are commonly less than 2 m thick, grading upward into thinly laminated and massive marine clay in the deeper parts of the basin.

Lithofacies of the marine deposits have been described from boreholes in the Ottawa Valley (Gadd, 1986). The stratigraphically lowest marine deposits consist of massive to weakly stratified blue-grey clay and silty clay which apparently was deposited at the time of deglaciation and while the Champlain Sea was a salinity stratified body of water (based on distribution of salinity dependant foraminiferal assemblages, Rodrigues and Richard, 1986). The next lithofacies consists of rhythmically bedded couplets of grey, silty clay and red clay, that is considered to be related to deltaic deposition and to represent a coarsening upward sequence in a gradation from marine conditions at the base to freshwater conditions at the top. The stratigraphically highest unit associated with deposition in the Champlain Sea ranges from clay to sand in texture. The finer sediments display slump structures, whereas sandy beds display small scale current structures. Erosional breaks and cut and fill structures are scattered throughout this highest unit. This lithofacies is interpreted as being the upper unit of a prograding delta.

Fine grained sediments associated with deposition in the Champlain Sea reach thicknesses of about 100 m adjacent to and north of the present location of the Ottawa River. These are located in deeper parts of the basin and where large quantities of fine grained sediment were supplied to the basin as ice retreated from the northern limit of the Champlain Sea basin and from the deep valleys that extend northward into the Laurentian Highlands. Beach sands and gravels were deposited wherever suitable parent material was present at the limit of the Champlain Sea and around features that projected through the cover of fine sediment within the basin. In addition, a thin layer of littoral and sublittoral sands was

Table 2 Pollen stratigraphy Ottawa Valley – St. Lawrence River – Lake Ontario region (from Anderson, in press)



Control date
Date considered too old
Date considered too young

Sources of control dates

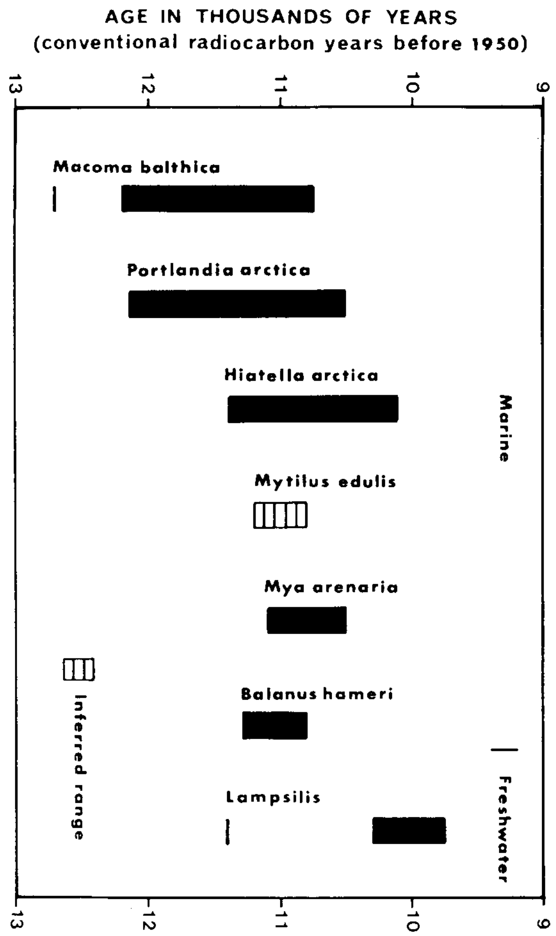
AL Atkins Lake (Terasmae, 1980)
BQ Bay of Quinte (Anderson and Lewis, 1985)
HB Harrowsmith Bog (Terasmae, 1968)
HS Hinchinbrook Site (Delage *et al.*, 1985)
LP Lambs Pond (unpublished)
LR Little Round Lake (Terasmae, 1980)
MB Mer Bleue Bog (Camfield, 1969)
MK McKay Lake (R. McNeely, pers. comm., 1985)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

deposited over finer Champlain Sea deposits in many parts of the basin during marine regression, and spits, bars and aprons of sand were built on and distributed around ridges of glaciofluvial deposits that projected through the fine grained basin fill.

Paleontology of Champlain Sea sediments

Several successions of macro and microfossils have been described from Champlain Sea deposits (Rodrigues and Richard, 1983; 1985; 1986; and Rodrigues, in press). In total, eight marine and one freshwater macrofaunal associations are recognized, *Balanus hameri*, *Hiatella arctica*, *Macoma balthica*, *Macoma calcarea*, *Mya arenaria*, *Mya truncata*, *Mytilus edulis*, *Portlandia arctica* and *Lampsilis*. The temporal distribution of seven of these associations is shown in Fig. 9. The ranges are based on ^{14}C age determinations on the dominant fossil of the associations except for the range of *Mytilus edulis* association which is inferred from the presence of the association at sites at which other species have been dated. There is only one published date for *Macoma calcarea* association, 10.6 ka, and for the *Mya truncata* association, 10.3 ka. The succession of macrofaunal associations is described by Rodrigues (in press) and his results are summarized in Fig. 10.

Fifteen groups of foraminiferal assemblages and eight groups of ostracode assemblages are recognized (Table 3). The freshwater ostracode *Candona* occurs in low numbers in Champlain Sea basin deposits and is commonly the only invertebrate microfossil in the rhythmically laminated sediments underlying marine deposits in the Ottawa and upper St. Lawrence valleys. Successions of the foraminiferal assemblages and at some sites successions of ostracode assemblages accompany the



gure 9: Temporal distribution of some macrofaunal associa-
ns in the western basin of the Champlain Sea. Ranges are
ised on available radiocarbon dates and may not represent the
al ranges for the associations (from Rodrigues, in press)

ıccessions of macrofaunal associations. The assemblages listed in Table 3 are numbered in order of elative succession. The sequences of macrofaunal associations and microfaunal assemblages represent short term ıccessions that are noncyclical at the sites examined in ıe western Champlain Sea basin.

Modern distribution data for some of the domiant foraminiferal species have been used to reconstruct ıe paleosalinity for Champlain Sea assemblages Rodrigues in press). These results are synthesized in able 3 and Fig. 11.

Of special interest from a paleontological point of iew are the many excellently preserved fossils found in oncretions from Champlain Sea deposits. Table 4 lists ssils that have been collected from concretions and one ite, Green Creek 10 km east of Ottawa, has provided 15 pecies of vertebrates, 20 species of invertebrates and 27 pecies of plants. Specimens range from small, delicate hrimp-like crustaceans, flying insects, and bird feather npressions to spectacular skeletons of a 24 inch long sucker (*Catostomus catostomus*) and an American marten (*Martes americana*). Capelin (*Mallotus villosus*) are among the commonest fish skeletons found in the nodules. There is some question as to the age of the concretions relative to the age of the fossils and the enclosing sediment and the degree of contemporaneity of the fossils is uncertain but Gadd (1980c) places the age of the Green Creek site at about 10.2 ka. In addition to fossils enclosed in concretions, a variety of large mammal vertebrates has been found in Champlain Sea sediments of this region. These include remains of white whales (*Delphinapterus leucas*), harbour porpoises (*Phocoena phocoena*), bowhead whales (*Balaena mysticetus*), humpback whales (*Megaptera novaeangliae*), as well as ringed (*Phoca hispida*), harp (*Phoca groendlandica*), and bearded (*Erignathus barbatus*) seals (Harington, 1981, 1983; Penhallow, 1900; Wagner, 1984).

Evolution of Champlain Sea and Holocene events

The successions and distribution of macrofaunal associations and microfaunal assemblages indicate that cold (subarctic) high salinity water occupied the deeper parts of the basin and was overlain by cold lower salinity water at shallower depths. The high salinity water was present as far west as Arnprior in Ottawa Valley and near Cornwall in upper St. Lawrence Valley; it was present in

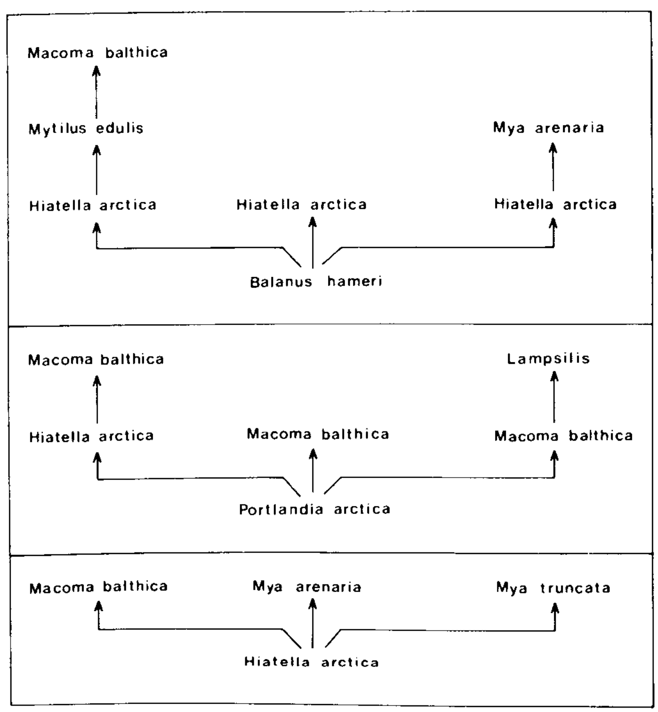


Figure 10: Some successions of macrofaunal associations in late glacial and postglacial sediments of the western basin of the Champlain Sea (from Rodrigues, in press)

Table 3 Paleosalinity for microfaunal assemblages and macrofaunal associations from western basin of the Champlain Sea (from Rodrigues, in press).

Foraminiferal Assemblage		Macrofaunal Association		Ostracode Assemblage		Salinity of Bottom Water
No.	Dominant Species	No.	Dominant Species	No.	Dominant Species	
15	Elphidium sp. Haynesina orbicularis	8	Mya arenaria			Low (<15 ‰)
		3	Macoma balthica			
14	Elphidium sp. Haynesina orbicularis Elphidium clavatum	3	Macoma balthica	9	Cytheromorpha macchesneyi	
				8	Cytheromorpha macchesneyi Heterocyprideis sorbyana Sarsicytheridea punctillata	
13	Elphidium clavatum Haynesina orbicularis Elphidium sp.	4	Hiatella arctica	6	Sarsicytheridea punctillata Heterocyprideis sorbyana	Intermediate (15-30 ‰)
		3	Macoma balthica	8	Cytheromorpha macchesneyi Heterocyprideis sorbyana Sarsicytheridea punctillata	
12	Elphidium clavatum	4	Hiatella arctica	7	Cytheropteron latissimum Sarsicytheridea punctillata	
		2	Portlandia arctica	2	Cytheropteron pseudomontrosiense	
11	Elphidium clavatum Haynesina orbicularis	4	Hiatella arctica	9	Cytheromorpha macchesneyi	
		3	Macoma balthica			
		2	Portlandia arctica			
		4	Hiatella arctica	7	Cytheropteron latissimum Sarsicytheridea punctillata	
		5	Mytilus edulis			
		2	Portlandia arctica	2	Cytheropteron pseudomontrosiense	
10	Pateoris hauerinoides Elphidium clavatum	2	Portlandia arctica	2	Cytheropteron pseudomontrosiense	
9	Haynesina orbicularis Elphidium clavatum	7	Mya truncata	7	Cytheropteron latissimum Sarsicytheridea punctillata	
		5	Mytilus edulis			
		3	Macoma balthica			
		4	Hiatella arctica			
8	Haynesina orbicularis Elphidium clavatum Eoeponidella pulchella	6	Macoma calcarea			
		4	Hiatella arctica	6	Sarsicytheridea punctillata Heterocyprideis sorbyana	
7	Elphidium clavatum Elphidium incertum/ asklundi Haynesina orbicularis	4	Hiatella arctica	5	Sarsicytheridea punctillata Cytheropteron nodosum Heterocyprideis sorbyana	
6	Haynesina orbicularis Cassidulina reniforme Elphidium clavatum	4	Hiatella arctica			
		3	Macoma balthica			
5	Elphidium clavatum Cassidulina reniforme Haynesina orbicularis	4	Hiatella arctica	4	Cytheropteron nodosum Cytheropteron inflatum	
		2	Portlandia arctica	3	Cytheropteron arcuatum Palmenella limicola	
				2	Cytheropteron pseudomontrosiense	
4	Cassidulina reniforme	2	Portlandia arctica	2	Cytheropteron pseudomontrosiense	High (30-34 ‰)
3	Cassidulina reniforme Islandiella helenae Haynesina orbicularis	4	Hiatella arctica			
		3	Macoma balthica			
		1	Balanus hameri			
2	Cassidulina reniforme Islandiella helenae	2	Portlandia arctica	1	Cytheropteron paralatissimum Cytheropteron arcuatum Cytheropteron pseudomontrosiense	
1	Cassidulina reniforme Astrononion gallowayi Islandiella norcrossi	1	Balanus hameri			

Table 4. Animal and Plant Species Contained in Nodules of Champlain Sea Age.

ANIMALS

Vertebrates	
Fishes	
Cisco	**Coregonus artedii** or **C. Zenithicus**
Lake trout	**Salvelinus namaycush**
Capelin	**Mallotus villosus**
Rainbow smelt	**Osmerus mordax**
Longnose sucker	**Catostomus catostomus**
Atlantic cod	**Gadus morhua**
Atlantic tomcod	**Microgadus tomcod**
Spoonhead sculpin	**Cottus ricei**
Deepwater sculpin	**Myoxocephalus thompsoni**
Benny-like fish	Blenniodea
Lumpfish	**Cyclopterus lumpus***
Threespine stickleback	**Gasterosteus aculeatus** (**trachurus** form)
Birds	
Feather impressions	Aves
Mammals	
Harp seal	**Phoca groenlandica**
Small seal	**Phoca** sp.
American marten	**Martes americana**
Invertebrates	
Marine Worms	
Planktonic polychaete	**Nereis pelagica**
Marine Molluscs	
Gastropod	**Cylichna alba**
Pelecypod	**Macoma balthica**
Pelecypod	**Portlandia arctica**
Pelecypod	**Portlandia lenticula**
Pelecypod	**Hiatella arctica**
Pelecypod	**Mytilus edulis**
Pelecypod	**Nucula tenuis**
Crustaceans	
Barnacle	**Balanus crenatus**
Isopod	**Mesidotea sabini**
Pelagic euphausid	Euphausiacea (near **Meganyctiphanes**)
	Estheria dawsonii**
Insects	
Marchfly	**Bibio** sp.
Mayfly	Ephemeridae
Beetle	**Fornax ledensis***
Beetle	**Tenebrio calculensis***
Beetle	**Byrrhus ottawaensis***
Pill beetle	Byrrhidae (**Cytilus** or **Byrrhus**)
Caddisfly	**Phryganea ejecta***
Echinoderns	
Asteroid	**Crossaster papposus**
Ophiuroid	**Ophiura** sp.
Ophiuroid	**Ophiocoma** sp. or **Amphiura** sp.

PLANTS

Sugar maple	**Acer saccharinum**
Alder	**Alnus** sp.
Yellow birch	**Betula alleghaniensis (B. lutea)**
Water-shield	**Brasenia schreberi (B. peltata)**
Brome grass	**Bromus ciliatus**
Sedge	**Carex magellanica**
Round-leaved sundew	**Drosera rotundifolia**
Water-weed	**Elodea canadensis**
Algae	**Encyonema prostratum (Cymbella prostratum)**
Water horsetail	**Equisetum fluviatile (E. limosum)**
Dwarf horsetail	**Equisetum scirpoides**
Wood horsetail	**Equisetum sylvaticum**
Aquatic moss	**Fontinalis** sp.
Rockweed	**Fucus digitatus**
Huckleberry	**Gaylussacia baccata (G. resinosa)**
Bog moss	**Hypnum fluitans**
Rice grass	**Oryzopsis asperifolia**
Balsam poplar	**Populus balsamifera**
Large-toothed aspen	**Populus grandidentata**
Pondweed	**Potamogeton pectinatus**
Pondweed	**Potamogeton perfoliatus**
Pondweed	**Potamogeton pusillus**
Pondweed	**Potamogeton rutilans****
Silverweed	**Potentilla anserina**
Willow	**Salix** sp.
Narrow-leaved cattail	**Typha latifolia**
American eel-grass	**Valisneria americana (V. spiralis)**

*Record requires verification
**Taxonomic position uncertain

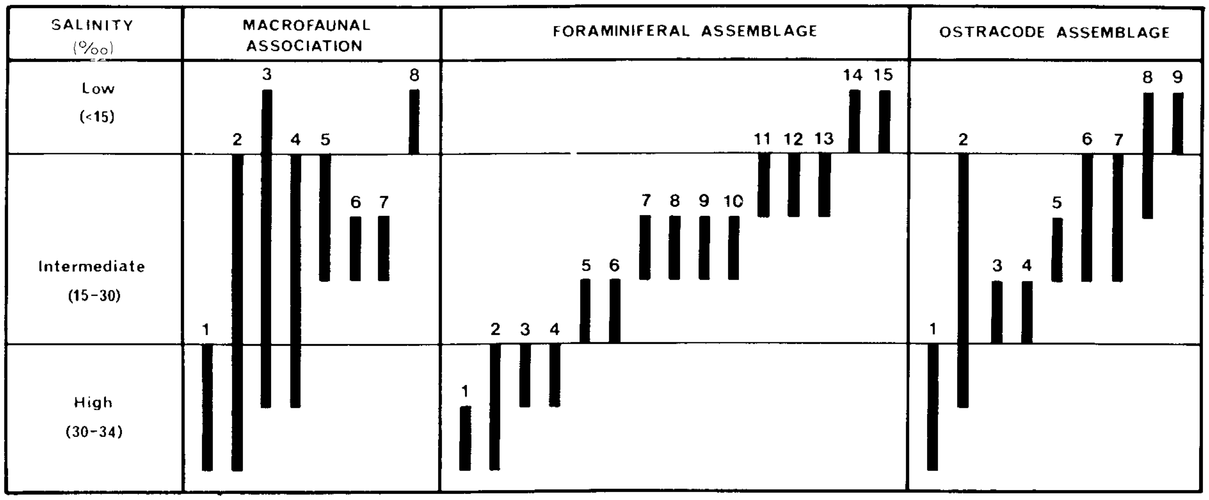


Figure 11: Distribution of late glacial and postglacial macrofaunal associations and microfaunal assemblages with respect to salinity in the western basin of the Champlain Sea. Number codes relate to associations and assemblages listed in Table 3 (from Rodrigues, in press)

the western basin of the Champlain Sea until ca. 10.5 ka. Warmer (boreal) low salinity water migrated along the southern margin of the basin ca. 11.1 ka but did not penetrate west of Cornwall. During the later part of the marine episode the waters became progressively less saline.

It is generally assumed that because of isostatic rebound, the Champlain Sea was regressing from the time of its inception. Accompanying regression, a delta prograded eastward in the Ottawa Valley. Marine water was still present at Pembroke near the western end of the basin at 10.9 ka (33 of Table 1) but the delta front had probably reached Russell, 150 km to the east, by 10 ka (18 of Table 1; Fulton and Richard, in press). There are however problems with the interpretation of radiocarbon dates because dates on freshwater shells seem to indicate that the delta moved through the area as much as 300 years earlier. It is also possible that we are trying to work at a level of resolution that is beyond the capability of shell radiocarbon dates. Uplift continued after the marine episode and the Ottawa River and its tributaries c[illegible] channels in and terraced the Champlain Sea sediments and the deltaic deposits.

The retreating ice sheet and outflow from glacial lakes to the west and north supplied a variable flow of meltwater to the Ottawa River during the middle to later part of the marine episode and the early phases of channel cutting (Catto *et al.*, 1982). Prime events which would have had profound effects on the flow of water into the Ottawa Valley area are: opening of channels from the Great Lakes (after ca. 11.3 ka); eastward overflow of Lake Agassiz (ca. 10.8 ka); closing of eastward flow from Lake Agassiz and then re-opening (ca. 9.9 ka and 9.5 ka respectively); end of flow from Lake Agassiz and Lake Barlow-Ojibway (ca. 8 ka) and ending of overflow fror the Great Lakes (ca. 4.6 ka) (Fig. 12; Fulton and Richard in press).

Little detailed information has been publishe on isostatic rebound. The marine limit is tilted from th south towards the north but because of uncertainties i timing of deglaciation and in how to interpret the she radiocarbon dates, the tilt could be as much as 1.6 m/kn or as little as 0.5 m/km (Fulton and Richard, in press Data from a single site in the lower Gatineau River valle indicate uplift of ca. 60 m between deglaciation an 11.1 ka. Because the Champlain Sea had apparently re gressed from the western basin shortly after 10 ka, dat are available for only the early part of postglacial reboun (Fig. 13). Based on the shape of the emergence curve rapid rebound was still occurring at 10 ka when sea leve was only 70 m above present. Because of this it is possibl that the region was raised above its present elevatio before falling back to current levels (Fulton and Richard in press). Submergence of Holocene Ottawa River chan nels and ponding of lakes in segments of the Ottaw Valley excavated by Holocene stream erosion are geo logical evidence that late Holocene subsidence may hav occurred.

Anderson (in press; Table 2) provides informa tion on the pattern of vegetation colonization and evolu tion in the region. The first vegetation established follow ing deglaciation, as represented by pollen, was a herb shrub tundra. In the south, spruce began arriving abou 11.7 ka and by 11.0 ka southern parts of the region wer dominated by spruce-poplar woodlands. In areas imme diately to the west and north of the Champlain Sea basin poplar was the first tree to migrate into the area and i dominated the vegetation between about 10.9 and 10.2 k

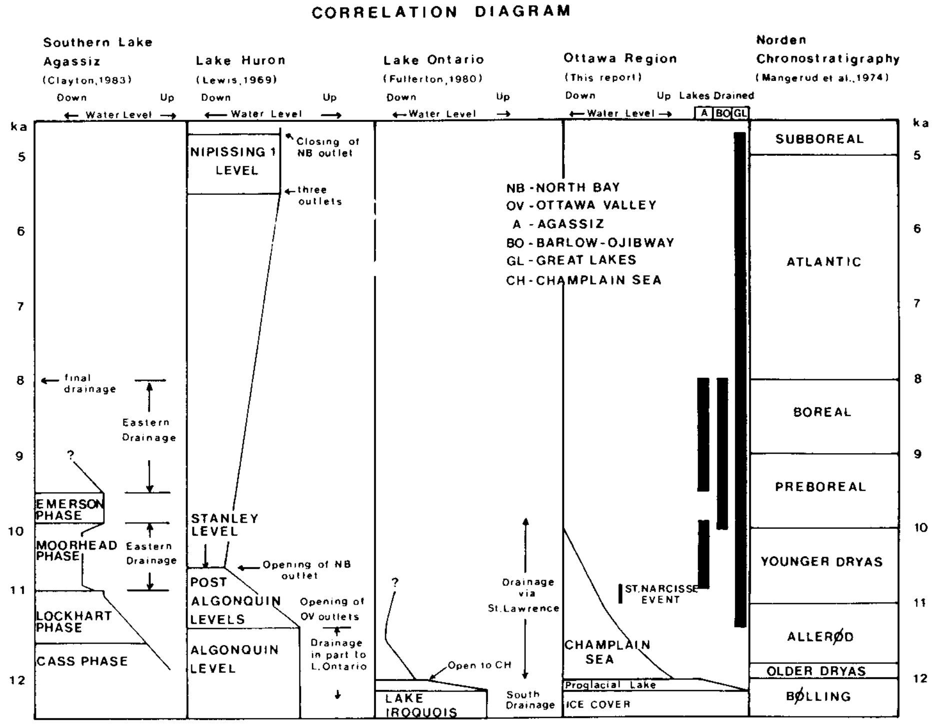


Figure 12: Correlation diagram showing time relationship between events of the western basin of the Champlain Sea and those in the southern Lake Agassiz, Lake Huron and Lake Ontario basins (from Fulton and Richard, in press)

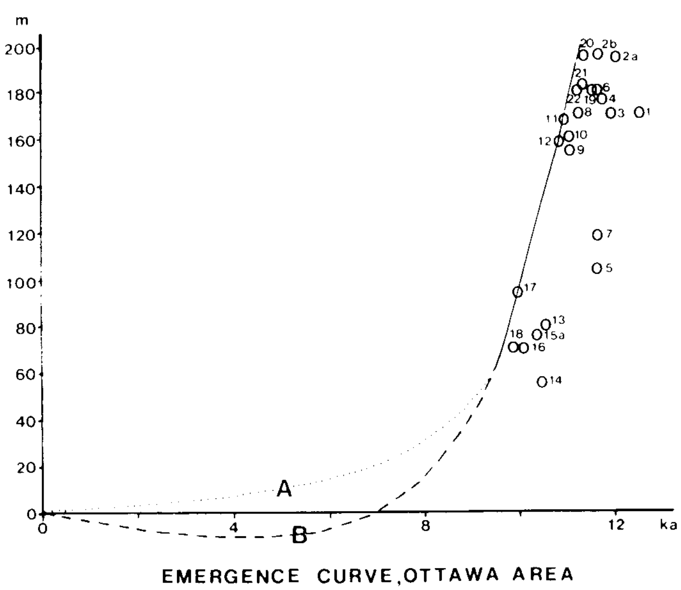


Figure 13: Emergence curve for the Ottawa area. Hypothetical extension A shows the shape of the curve if the area has only been subject to isostatic rebound; extension B is drawn such that the curve is more similar in shape to emergence curves from other areas, but suggests the area has undergone a period of submergence (from Fulton and Richard, in press)

when it was replaced by spruce. Shortly after 10 ka pine and birch arrived on the scene and pine dominated the vegetation for about 1.5 ka although during the last third of this period hemlock and maple arrived in the area. Hemlock was the dominant species 7.5 to 4.8 ka although white pine and birch remained prominent. At about 4.8 ka hemlock was suddenly and drastically reduced possibly as the result of a forest pathogen (Davis, 1981). Beech and maple populations migrated northwards at this time, probably to occupy openings left by hemlock. Shade intolerant hardwoods such as elm, ash, hickory and basswood were common, and from 4.8 to 3.5 ka the area supported a mixed conifer-hardwood forest with white pine, white and yellow birch, maple and beech as dominant taxa. The hemlock population increased again and by 3.5 ka the modern hemlock-white pine-mixed hardwood vegetation was established. Day Excursion J provides further descriptions of the modern vegetation of the region.

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