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.
QUATERNARY DEPOSITS AND GLACIATION

The only Quaternary deposits which predate Late Wisconsinan (in this area) are fluvial sands which contain organic materials, clay, and underlying till, that are all overlain by till at Pointe Fortune on the Ontario-Québec border (Veillette and Nixon, 1984). These deposits might relate to a Wisconsinan interstadie or they might be older.

The last ice which occupied the area was of Late Wisconsinan age and supposedly was part of the same ice mass that extended to the Late Wisconsinan terminal moraine in New Jersey. At the time of the glacial maximum, flow through this area apparently was mainly north to south. During waning glacial stages, topographical control dominated and flow became strongly lobate (Gadd, 1980a; 1980b). Major lobes moved south and southwestward in the Lake Champlain valley and in the St. Lawrence Valley east of Valleyfield; south from Ottawa; southwestward into the Lake Ontario basin; and southeastward in the Ottawa Valley, upstream from Ottawa (Fig. 2 and Fig. 3).

Till deposited during the Late Wisconsinan is the most extensive Quaternary sediment in the area (Fig. 4). The till is generally sandy and the texture of the finer than 2 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)
that upper parts of the till sheet in many areas may be of flowtill origin (Kettles and Shilts, in press).

Glaciofluvial sediments are abundant in the region. Eskers are common on the Frontenac Arch to the south and in the Madawaska Highland to the west; outwash fans and pitted outwash plains are common at the northern limit of the Champlain Sea; and subaqueous outwash, possibly in the form of eskers, fans, and interlobe moraines, are abundant within the basin of the Champlain Sea. Several detailed studies have been carried out on deposits immediately south of Ottawa and it has been concluded that these consist of overlapping facies of subaqueous fans deposited within or at the mouth of meltwater conduits (Rust and Romanelli, 1975; Rust, 1977; Cheel, 1982; and Rust, in press). Imbricate boulder gravel and horizontally stratified gravel are sediments which generally were deposited within or adjacent to the mouths of these conduits; sand facies, including cross-bedded, coarse, pebbly sand, medium grained, massive sand and ripple-drift units that fine upwards from sand to silt, were deposited on the fan aprons; and massive sand, in many places containing ball and pillow structures, were deposited as mass flow deposits in the channels of the subaqueous fans (Fig. 7). Most other glaciofluvial 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 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 the Ottawa Region (from Kettles and Shilts, in press) (A). Per cent carbonate in till.

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

Figure 7: Depositional model for subaqueous fans south of Ottawa. Dashed line represents margins of meltwater conduit in ice; for simplicity, ice contact features are omitted. A: Gravel 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 channel (from Rust, 1977)
Gatineau Valley whereas 11.9 ka is the oldest date in the upper St. Lawrence Valley; it also provides a means of retaining a proglacial lake in the Lake Ontario basin while the Champlain Sea occupied the Ottawa area. Chauvin et al. (1985), however, argue that the calving bay in the St. Lawrence did not advance upstream from Quebec City. The conventional or "window blind" retreat best explains the distribution of lacustrine deposits which underlie Champlain Sea sediments and the pattern of glaciofluvial ridges.

**Development of the Champlain Sea**

Whatever the style of ice retreat, deglaciation was followed by submergence of the area by the Champlain Sea, an arm of the Atlantic Ocean that extended up the St. Lawrence River into the isostatically depressed lower Ottawa and upper St. Lawrence valleys. The upper limit of marine submergence apparently slopes up to the north from about 120 m at the southwest extremity of the marine basin, to 200 m near Ottawa, and to 274 m in the north. It also slopes down to the west from Ottawa, reaching 165 m near the western extremity of the basin (Fig. 3). Over at least the northern and western parts of the area, the ice margin retreated in marine waters and thus 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 14C 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
## Table 1 Radiocarbon dates from the Ottawa region (from Fulton and Richard, in press).

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<th>No.</th>
<th>Site Name</th>
<th>Brev. (m.a.l.)</th>
<th>Lab. No.</th>
<th>Age (years BP)</th>
<th>Material Dated</th>
<th>SPCC</th>
<th>Collector</th>
<th>Reference</th>
<th>Comment</th>
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<td>A. Dates from beach and nearshore sediments.</td>
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<td></td>
<td></td>
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<td>1.</td>
<td>Clayton</td>
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<td>GSC-2151</td>
<td>1 12 600 ± 100</td>
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<td>S.H. Richard and W. Blake, Jr.</td>
<td>Richard 1978</td>
<td>Marine limit</td>
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<td>2.</td>
<td>Cartley</td>
<td>194</td>
<td>GSC-1646</td>
<td>1 12 200 ± 100</td>
<td>Macoma balthica</td>
<td>-0.2</td>
<td>R. Romanelli</td>
<td>Romanelli, 1975</td>
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<td>3.</td>
<td>White Lake</td>
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<td>GSC-3110</td>
<td>1 12 100 ± 100</td>
<td>Macoma balthica (Linne)</td>
<td>-0.6</td>
<td>S.H. Richard</td>
<td>Rodrigues and Richard, 1983</td>
<td>Marine limit</td>
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<td>4.</td>
<td>Martinville</td>
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<td>GSC-1772</td>
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<td>Macoma balthica</td>
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<td>Lowdon and Blake, 1973</td>
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<td>5.</td>
<td>Millard</td>
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<td>Richard, 1980</td>
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<td>GSC-3523</td>
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<td>C.G. Rodrigues and S.H. Richard</td>
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<td>Shavville</td>
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<td>1.7</td>
<td>R.J. Fulton</td>
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<td>20 m below marine limit (?)</td>
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<td>Westmeath</td>
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<td>15a.</td>
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<td>75</td>
<td>GSC-2261</td>
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<td>Mya truncata Linne</td>
<td>-0.8</td>
<td>C.G. Rodrigues and S.H. Richard</td>
<td>Rodrigues and Richard, 1985</td>
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<td>17.</td>
<td>Deschênes</td>
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<td>GSC-2189</td>
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<td>1.3</td>
<td>S.H. Richard</td>
<td>Richard, 1978</td>
<td>Low level</td>
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<td>18.</td>
<td>Russell</td>
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<td>GSC-1593</td>
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<td>B. Dates from high level fine grained marine sediments.</td>
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<td>23.</td>
<td>Luzerne</td>
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<td>GSC-3997</td>
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<td>0.7</td>
<td>S.H. Richard</td>
<td>Unpublished</td>
<td>Maximum for emergence</td>
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<td>C. Dates from glaciomarine(?), glacifluvial(?) and glacial(?) sediments.</td>
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<td>24a.</td>
<td>Twin Elm</td>
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<td>GSC-3641</td>
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<td>Portlandia arctica (Gray)</td>
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<td>S.H. Richard</td>
<td>Blake, 1983</td>
<td>Marine day interbedded with glacifluvial (?) gravel</td>
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<td>25.</td>
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<td>GSC-2448</td>
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<td>Hiatella arctica</td>
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<td>S.H. Richard</td>
<td>Gadd, 1973</td>
<td>Sands (glacioluvial) with ball and pillow structure</td>
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<td>Cazaville</td>
<td>71</td>
<td>GSC-3882</td>
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<td>Hiatella arctica</td>
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<td>S.H. Richard</td>
<td>Rodrigues and Richard, 1985</td>
<td>From diamict</td>
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<tr>
<td>28.</td>
<td>Wakefield</td>
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<td>160</td>
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<td>S.H. Richard</td>
<td>Rodrigues and Richard, 1985</td>
<td>From glaciomarine diamict</td>
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</table>
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 *Canadona*; and thick, extensive, marine sediments were deposited in the Champlain Sea basin during deglaciation (Fig. 4). The glaciolacustrine 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 dependent 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>
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<th>No.</th>
<th>Site Name</th>
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<th>Age (years BP)</th>
<th>Material</th>
<th>Δ14C (%)</th>
<th>Collector</th>
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<td>30</td>
<td>Sparrowhawk Point</td>
<td>76</td>
<td>GSC-3767</td>
<td>11 900 ± 100</td>
<td>Portlandia arctica</td>
<td>0.2</td>
<td>Rodrigues and S.H. Richard</td>
<td>Rodrigues and Richard, 1985</td>
<td>Marine clay overlying rhythmically laminated sediments</td>
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<td>33</td>
<td>Pembroke</td>
<td>139</td>
<td>GSC-90</td>
<td>10 870 ± 130</td>
<td>Marine shells</td>
<td></td>
<td>J. Terasme</td>
<td>Dyck and Fyles, 1963</td>
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<td>34</td>
<td>Vankleek Hill</td>
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<td>GSC-3235</td>
<td>10 300 ± 90</td>
<td>Lampsis radiata</td>
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<td>S.H. Richard</td>
<td>Lowdon and Blake, 1981</td>
<td>Early Ottawa R. terrace</td>
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<td>35</td>
<td>Bourget</td>
<td>53</td>
<td>GSC-1968</td>
<td>10 200 ± 90</td>
<td>Lampsis sp.</td>
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<td>N.R. Gadd</td>
<td>Gadd, 1976</td>
<td>Alluvium in abandoned channel</td>
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<td>36</td>
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<td>60</td>
<td>GSC-546</td>
<td>8 830 ± 190</td>
<td>Marly gyttja</td>
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<td>R. J. Mott</td>
<td>Lowdon et al., 1967</td>
<td>Basal organic in channel</td>
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<td>37</td>
<td>Ottawa</td>
<td>70</td>
<td>GSC-547</td>
<td>8 220 ± 150</td>
<td>Woody peat</td>
<td></td>
<td>N.R. Gadd and J. Terasme</td>
<td>Lowdon et al., 1967</td>
<td>Dates channel filling</td>
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<td>38</td>
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<td>46</td>
<td>GSC-4099</td>
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<td>Gyttja</td>
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<td>R. McNeeley, S.R. Brown and J.P. Smol</td>
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<td>39</td>
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<td>7 870 ± 160</td>
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<td>J. Terasme</td>
<td>Lowdon et al., 1967</td>
<td>Dates channel filling</td>
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1Outer fraction. 2Inner fraction. 3Middle fraction.  
GSC = Geological Survey of Canada  
To = IsoTrace (University of Toronto)  
*Originally IsoTrace normalized this date to Δ14C = 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.*

Table 1 Radiocarbon dates from the Ottawa region (from Fulton and Richard, in press).
Table 2 Pollen stratigraphy Ottawa Valley – St. Lawrence River – Lake Ontario region (from Anderson, in press)

<table>
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<th>ka</th>
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<td>BQ (GSC-3464)</td>
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<tr>
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<td>BQ (GSC-3460)</td>
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<td>LR (GSC-649)</td>
<td>Populus</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>LP (GSC-3088)</td>
<td>Herb-Shrub</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

- **Control date**: Date considered too old
- **Date considered too young**: 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, 1985)
  - HS Hinchinbrook Site (Delage et al., 1985)
  - LP Lambs Pond (unpublished)
  - WB Waterton Bog (unpublished)
  - MB Mer Bleue Bog (Camfield, 1969)
  - MK McKay Lake (R. McNeely, pers. comm., 1985)
  - ML McLachlan Lake (unpublished)
  - PL Pink Lake (Mott and Farley-Gill, 1981)
  - RL Ramsay Lake (Mott and Farley-Gill, 1981)
  - S3 Ottawa Site 3 (Mott and Camfield, 1969)

Deposited over finer Champlain Sea deposits in many parts of the basin during marine regression, and spits 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 macrofamal 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 

- **Control date**: Date considered too old
- **Date considered too young**: 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, 1985)
  - HS Hinchinbrook Site (Delage et al., 1985)
  - LP Lambs Pond (unpublished)
  - WB Waterton Bog (unpublished)

Carbon-14 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 macrofamal 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
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

suckers (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 groenlandica), and bearded (Erignathus barbatus) seals (Harington, 1981, 1983; Penhallow, 1900; Wagner, 1984).

Figure 9: Temporal distribution of some macrofaunal associations in the western basin of the Champlain Sea. Ranges are based on available radiocarbon dates and may not represent the total ranges for the associations (from Rodrigues, in press)

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

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

Of special interest from a paleontological point of view are the many excellently preserved fossils found in concretions from Champlain Sea deposits. Table 4 lists fossils that have been collected from concretions and one site, Green Creek 10 km east of Ottawa, has provided 15 species of vertebrates, 20 species of invertebrates and 27 species of plants. Specimens range from small, delicate shrimp-like crustaceans, flying insects, and bird feather impressions to spectacular skeletons of a 24 inch long

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).

<table>
<thead>
<tr>
<th>Foraminiferal Assemblage</th>
<th>Macrofaunal Association</th>
<th>Ostracode Assemblage</th>
<th>Salinity of Bottom Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Dominant Species</td>
<td>No. Dominant Species</td>
<td>No. Dominant Species</td>
<td></td>
</tr>
<tr>
<td>15 Elphidium sp.</td>
<td>8 Mya arenaria</td>
<td>9 Cytheromorpha macchesneyi</td>
<td></td>
</tr>
<tr>
<td>Haynesina orbicularis</td>
<td>3 Macoma balthica</td>
<td>8 Cytheromorpha macchesneyi</td>
<td></td>
</tr>
<tr>
<td>Elphidium sp.</td>
<td></td>
<td></td>
<td>Low (&lt;15 %)</td>
</tr>
<tr>
<td>Haynesina orbicularis</td>
<td>3 Macoma balthica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>4 Hiatella arctica</td>
<td>6 Sarsicytheridea punctillata</td>
<td></td>
</tr>
<tr>
<td>Haynesina orbicularis</td>
<td>3 Macoma balthica</td>
<td>8 Cytheromorpha macchesneyi</td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>2 Portlandia arctica</td>
<td>7 Cytheropteron latissimum</td>
<td></td>
</tr>
<tr>
<td>Haynesina orbicularis</td>
<td>4 Hiatella arctica</td>
<td>Sarsicytheridea punctillata</td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>5 Mytilus edulis</td>
<td></td>
<td>Intermediate (15-30 %)</td>
</tr>
<tr>
<td>Haynesina orbicularis</td>
<td>2 Portlandia arctica</td>
<td>2 Cytheropteron pseudomontrosiense</td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>7 Mya truncata</td>
<td>5 Cytheropteron pseudomontrosiense</td>
<td></td>
</tr>
<tr>
<td>Haynesina orbicularis</td>
<td>5 Mytilus edulis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Macoma calcarea</td>
<td>3 Macoma balthica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>4 Hiatella arctica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>4 Hiatella arctica</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elphidium clavatum</td>
<td>4 Hiatella arctica</td>
<td>5 Sarsicytheridea punctillata</td>
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</tr>
<tr>
<td>Cassidulina reniforme</td>
<td>4 Hiatella arctica</td>
<td>Cytheropteron nodosum</td>
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</tr>
<tr>
<td>Elphidium clavatum</td>
<td>4 Hiatella arctica</td>
<td>4 Hiatella arctica</td>
<td></td>
</tr>
<tr>
<td>Cassidulina reniforme</td>
<td>3 Macoma balthica</td>
<td>3 Cytheroperon arcuatum</td>
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<tr>
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<td>Palmenella limicola</td>
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</tr>
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</tr>
<tr>
<td>Cassidulina reniforme</td>
<td>2 Portlandia arctica</td>
<td>2 Cytheroperon pseudomontrosiense</td>
<td></td>
</tr>
<tr>
<td>Islandiella heleneae</td>
<td>3 Macoma balthica</td>
<td>1 Balanus hameri</td>
<td></td>
</tr>
<tr>
<td>Cassidulina reniforme</td>
<td>1 Balanus hameri</td>
<td></td>
<td>High (30-34 %)</td>
</tr>
<tr>
<td>Islandiella heleneae</td>
<td>1 Balanus hameri</td>
<td></td>
<td></td>
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</table>
Table 4. Animal and Plant Species Contained in Nodules of Champlain Sea Age.

<table>
<thead>
<tr>
<th>ANIMALS</th>
<th>PLANTS</th>
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<tbody>
<tr>
<td><strong>Vertebrates</strong></td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td><strong>Acer saccharinum</strong></td>
</tr>
<tr>
<td>Cisco</td>
<td>Ideas</td>
</tr>
<tr>
<td>Lake trout</td>
<td>Yellow birch</td>
</tr>
<tr>
<td>Capelin</td>
<td>Water-shield</td>
</tr>
<tr>
<td>Rainbow smelt</td>
<td>Brome grass</td>
</tr>
<tr>
<td>Longnose sucker</td>
<td>Sedge</td>
</tr>
<tr>
<td>Atlantic cod</td>
<td>Round-leaved sundew</td>
</tr>
<tr>
<td>Atlantic tomcod</td>
<td>Water-weed</td>
</tr>
<tr>
<td>Spoonhead sculpin</td>
<td>Algae</td>
</tr>
<tr>
<td>Deepwater sculpin</td>
<td><strong>Boles</strong></td>
</tr>
<tr>
<td>Benny-like fish</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Lumpfish</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Threespine stickleback</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td><strong>Birds</strong></td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Feather impressions</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td><strong>Mammals</strong></td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Harp seal</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Small seal</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>American marten</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td><strong>Invertebrates</strong></td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td><strong>Marine Worms</strong></td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Planktonic polychaete</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td><strong>Marine Molluscs</strong></td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Gastropod</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Pelecypod</td>
<td><strong>Sugar maple</strong></td>
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<tr>
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<tr>
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<tr>
<td>Pelecypod</td>
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</tr>
<tr>
<td>Pelecypod</td>
<td><strong>Sugar maple</strong></td>
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<tr>
<td>Crustaceans</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Barnacle</td>
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</tr>
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<td>Isopod</td>
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<td>Pelagic euphausid</td>
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</tr>
<tr>
<td><strong>Insects</strong></td>
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</tr>
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<td>Marchfly</td>
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</tr>
<tr>
<td>Mayfly</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Beetle</td>
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</tr>
<tr>
<td>Beetle</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Pill beetle</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Caddisfly</td>
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</tr>
<tr>
<td><strong>Echinodermata</strong></td>
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</tr>
<tr>
<td>Asteroid</td>
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</tr>
<tr>
<td>Ophiuroid</td>
<td><strong>Sugar maple</strong></td>
</tr>
<tr>
<td>Ophiuroid</td>
<td><strong>Sugar maple</strong></td>
</tr>
</tbody>
</table>

*Record requires verification
**Taxonomic position uncertain
SALINITY

MACROFAUNAL ASSOCIATION

FORAMINIFERAL ASSEMBLAGE

OSTRACODE ASSEMBLAGE

<table>
<thead>
<tr>
<th>SALINITY (%)</th>
<th>ASSOCIATION</th>
<th>ASSEMBLAGE</th>
<th>ASSEMBLAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (&lt;15)</td>
<td>3 8</td>
<td>14 15</td>
<td>8 9</td>
</tr>
<tr>
<td>Intermediate (15-30)</td>
<td>1 2 4 5 6 7</td>
<td>7 8 9 10</td>
<td>2 3 4 5 6 7</td>
</tr>
<tr>
<td>High (30-34)</td>
<td>1 1</td>
<td>11 12 13</td>
<td>1</td>
</tr>
</tbody>
</table>

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 cut 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 from the Great Lakes (ca. 4.6 ka) (Fig. 12; Fulton and Richard, in press).

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

Anderson (in press; Table 2) provides information on the pattern of vegetation colonization and evolution in the region. The first vegetation established following deglaciation, as represented by pollen, was a herb-shrub tundra. In the south, spruce began arriving about 11.7 ka and by 11.0 ka southern parts of the region were dominated by spruce-poplar woodlands. In areas immediately to the west and north of the Champlain Sea basin, poplar was the first tree to migrate into the area and it dominated the vegetation between about 10.9 and 10.2 ka
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.

ACKNOWLEDGMENTS

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