LATE QUATERNARY GLACIAL TO MARINE SUCCESSIONS IN THE CENTRAL ST. LAWRENCE LOWLAND

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INTRODUCTION

The Central St. Lawrence Lowland includes the area between the Ottawa and St. Lawrence Rivers, straddles the St. Lawrence as far as Quebec City, and extends a short distance beyond the north shore only (Bostock, 1970). Marine water from the Atlantic Ocean inundated the Central St. Lawrence Lowland and Champlain Valley during the final retreat of the Laurentide Ice Sheet from eastern North America, forming the Champlain Sea (Fig. 1). The purpose of this paper is to describe the lithologic and invertebrate faunal successions at two sites in the lowland and to discuss the significance of the successions.

SPARROWHAWK POINT SITE

A ten-metre section of glacial and marine sediments is exposed in the shore cliffs on the south side of the St. Lawrence River between Ogdensburg and Waddington (Fig. 1). The sediments are divided into the following units, (1) massive stony till, (2) rhythmically laminated silt and clay ("varves"), (3) massive mud, and (4) sand (Fig. 2). Unit 1 is equivalent to the Fort Covington Till of MacClintock and Stewart (1965) and is overlain disconformably by Unit 2. The contact between Units 2 and 3 is gradational and the contact between Units 3 and 4 is abrupt. The succession from till to massive mud was also reported by MacClintock and Stewart (1965) and Terasmae (1965) from sections exposed near Cornwall during the St. Lawrence Seaway Project.

Unit 1 is unfossiliferous. Ostracodes are present in Units 2, 3, and 4. Foraminifers are absent in Unit 2 and are present in Units 3 and 4. Invertebrate macrofossils are common in Unit 3 and in the lower part of Unit 4. Portlandia arctica (Gray) is the most abundant macrofossil in Unit 3 and is accompanied by Cylichna alba Brown, Macoma calcarea (Gmelin), and Hiatella arctica (Linné). Macoma balthica (Linné) is present in the lower part of Unit 4.

Radiocarbon dates, 11 900 ± 100 years BP (GSC-3767) and 11 300 ± 100 years BP (GSC-3788), were obtained for shells of Portlandia arctica from the lower part of Unit 3 and for shells of Macoma balthica from the lower part of Unit 4 respectively (Rodrigues and Richard, 1985). At one spot along the shore the laminated sediments are truncated and underlain by massive mud which in turn is underlain by laminated sediments. Rodrigues (1987) proposed that the presence of massive mud below laminated sediments is related to post depositional slumping. Radiocarbon dates of 11 900 ± 100 years BP (GSC-3767) for

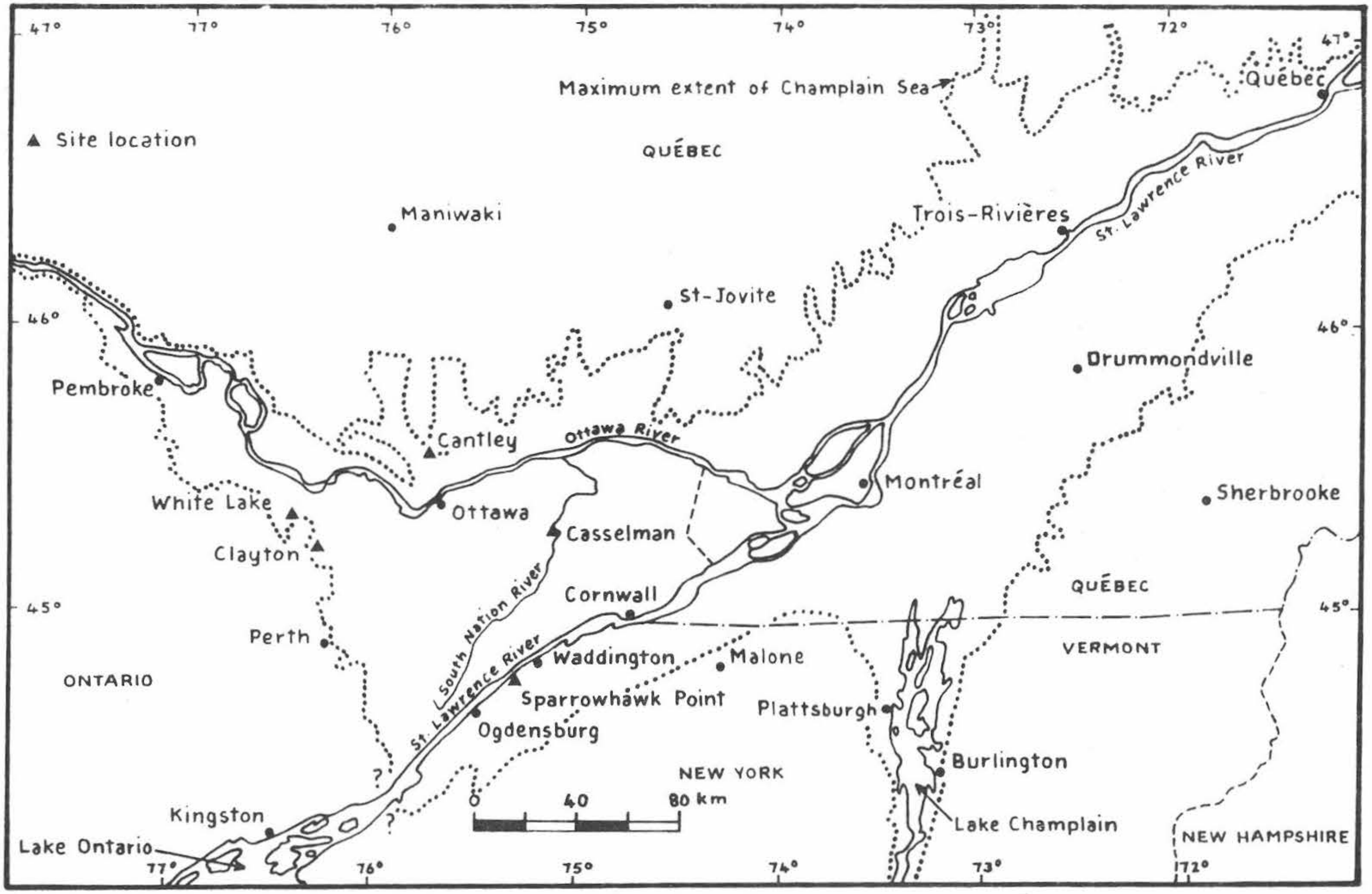

Figure 1. Map showing maximum extent of Champlain Sea and locations of site discussed in text.

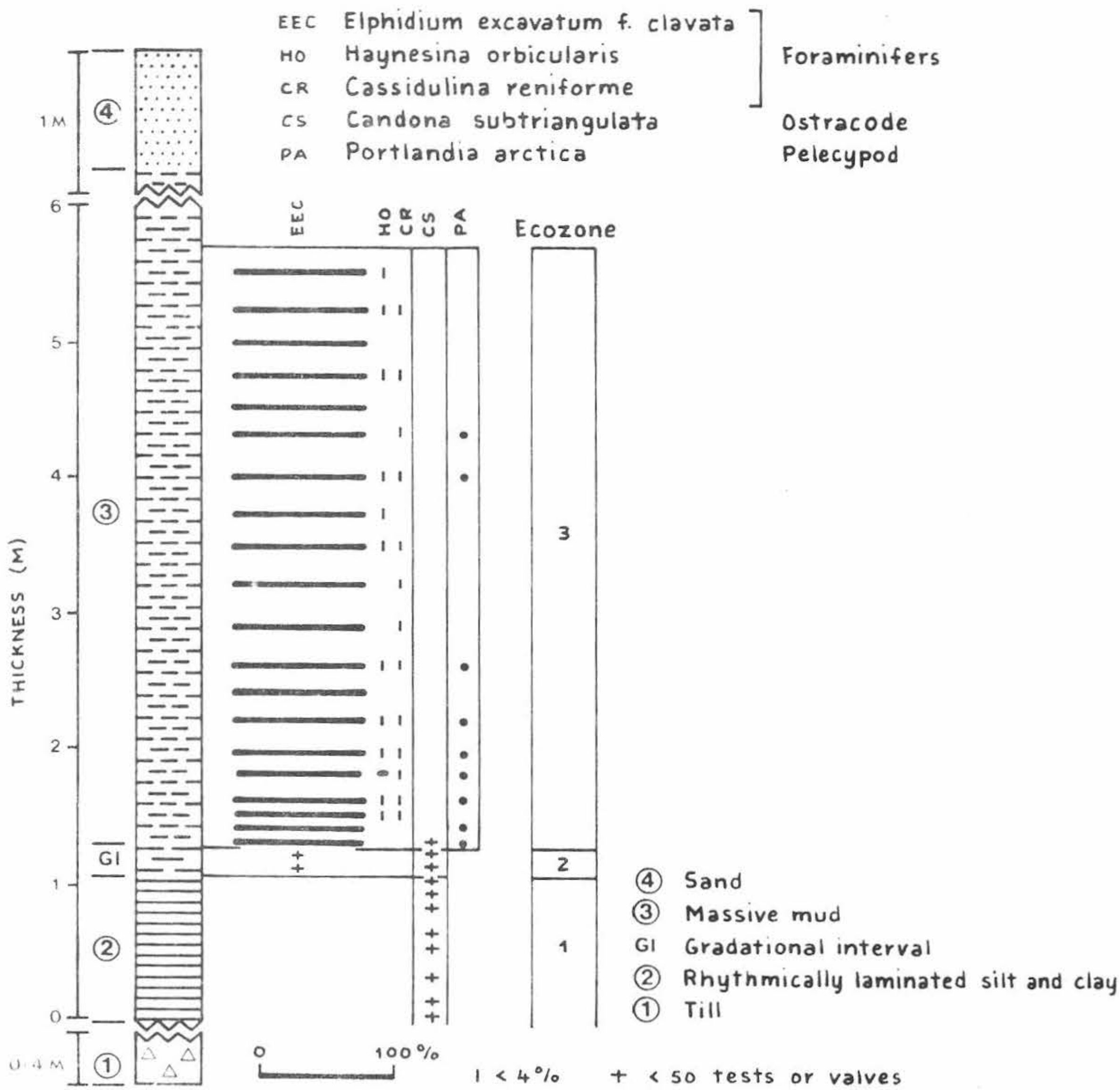

Figure 2. Distribution of selected invertebrate fossils at Sparrowhawk Point site. Foraminiferal abundance data based on samples containing >110 tests.

Portlandia arctica from the lower part of the massive mud overlying the laminated sediments and 11 900 ± 140 years BP (GSC-4044) for the same pelecypod species from the massive mud below the laminated sediments, are consistent with the slumping hypothesis.

Three ecozones are recognized on the basis of foraminiferal and ostracode assemblages from 30 samples which were collected from 6 m of section (Fig. 2). Ecozone 1 is characterized by the ostracode Candona subtriangulata Benson and MacDonald and is restricted to the rhythmically laminated silt and clay (Unit 2). Ecozone 2 contains low numbers of the foraminifer Elphidium excavatum (Terquem) forma clavata Cushman and Candona subtriangulata; it is associated with the gradational interval between Unit 2 and the massive mud (Unit 3). Elphidium excavatum forma clavata-dominant foraminiferal assemblages characterize Ecozone 3. The foraminifers Cassidulina reniforme Nørvang, Haynesina orbicularis (Brady) and Polymorphinids (species of the Family Polymorphinidae) are also present in Ecozone 3. The ostracodes Cytheromorpha macchesneyi (Brady and Crosskey) and Cytheropteron pseudomontrosiense Whatley and Masson are present throughout Ecozone 3, whereas Cytheropteron paralatissimum Swain occurs in the lower part and Roundstonia globulifera (Brady) occurs in the middle and upper parts of Ecozone 3. Portlandia arctica is the most common invertebrate macrofossil in Ecozone 3.

The laminated sediments (Unit 2) characterized by Candona subtriangulata (Ecozone 1) were deposited in a glacial lake which occupied the area during early stages of ice retreat (Fig. 3). The interval between Unit 2 and the massive mud (Unit 3) containing the Elphidium excavatum forma clavata - Candona subtriangulata assemblages (Ecozone 2) were deposited in low salinity bottom-water during the early part of the marine episode. The salinity of the bottom-water was highest (<25o/oo) during deposition of Unit 3 which is characterized by Elphidium excavatum forma clavata - dominant foraminiferal assemblages and the pelecypod Portlandia arctica (Ecozone 3).

The inferred freshwater environment for the rhythmically laminated silt and clay ("varves") is based on the modern and fossil occurrences of Candona subtriangulata. Congeners of Candona live in freshwater environments, i.e. lakes and rivers (Delorme, 1970). Identical Candona subtriangulata assemblages were reported from the Late Pleistocene Sheboygan Member of the Lake Michigan Formation (Burke, 1987). The presence of Canadona subtriangulata and Elphidium excavatum forma clavata in Ecozone B (Fig. 2) indicates that C. subtriangulata can survive in marine environments characterized by low salinity. This does not imply that the varve-like rhythmites containing Candona subtriangulata were deposited in a marine environment. The distinction between freshwater and marine environments is based on the total fossil assemblage, rather than the presence of a single species in the assemblage. Thus, assemblages containing only Candona subtriangulata are related to freshwater conditions, whereas assemblages containing C. subtriangulata plus marine ostracodes and/or foraminifers are related to low salinity conditions during the early part of the Champlain Sea episode in the Central St. Lawrence Lowland.

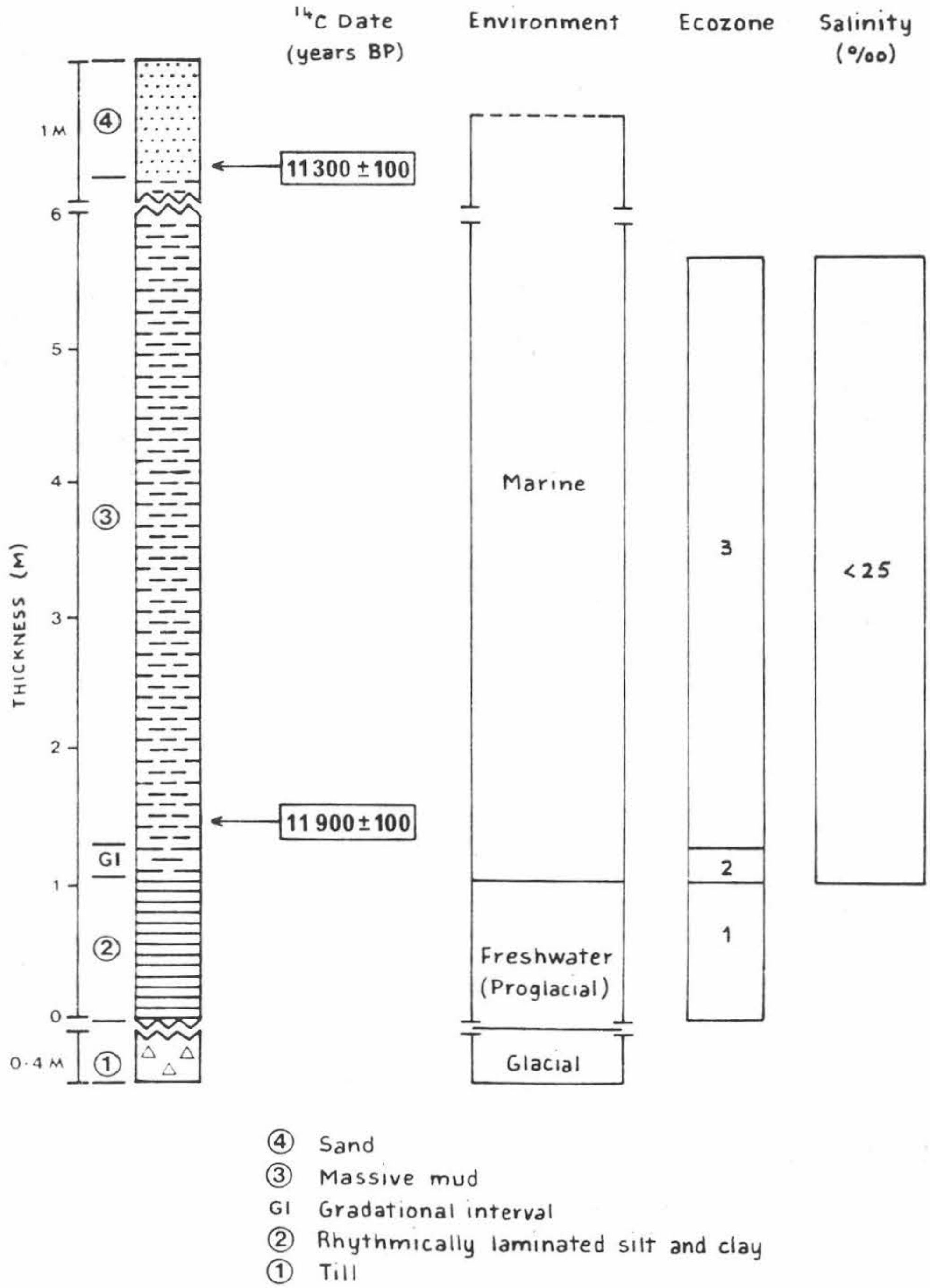

Figure 3. Chronology and paleoenvironmental interpretation for section at Sparrowhawk Point site. Top of section is about 84 m a.s.l.

Cronin (1977) described assemblages containing *Candona subtriangulata*, marine ostracodes, and foraminifers from deposits near the maximum extent of the Champlain Sea in the Champlain Valley. He also concluded that the assemblages are related to low salinity conditions during the early part of the marine episode.

CASSELMAN SITE

About 17 m of glacial and post-glacial sediments are exposed along the west bank of the South Nation River, northwest of the town of Casselman (Fig. 1). The sediments rest unconformably on Ordovician carbonate rocks. The glacial and post-glacial sediments are divided into the following units, (1) till, (2) rhythmically laminated silt and clay ("varves"), (3) massive mud, and (4) red- and grey-banded mud (Fig. 4). The contacts between Units 2 and 3 and Units 3 and 4 are gradational. The succession from Unit 2 to Unit 4 was described by Fransham and Gadd (1977) and Gadd (1977, 1986) from boreholes in the deeper parts of the lower Ottawa Valley.

Unit 1 is unfossiliferous. Foraminifers are absent in Unit 2 and are present in Units 3 and 4. Ostracodes occur in Units 2, 3 and 4. The pelecypods *Macoma calcarea*, *Mytilus edulis* Linné, *Portlandia arctica* and *Yoldiella* sp., and the sponge *Tethya logani* Dawson are present in Unit 3. Invertebrate macrofossils were not observed in Units 2 and 4.

Six ecozones are recognized on the basis of foraminiferal and ostracode assemblages from 22 samples which were collected from Unit 2 and Unit 3 and the gradational interval between the units (Fig. 4). The varve-like rhythmites (Unit 2) and the lower part of the gradational interval between Unit 2 and the massive mud (Unit 3) are assigned to Ecozone A which is characterized by the ostracode *Candona subtriangulata*. Foraminifers and ostracodes are present in low numbers in Ecozone B which is restricted to the upper part of the gradational interval between Unit 2 and Unit 3. Ecozones C to F are associated with Unit 3. *Cassidulina reniforme* and *Islandiella helenae* Feyling-Hanssen and Buzas are the characteristic species of foraminiferal assemblages from Ecozone C. *Cassidulina reniforme*, *Elphidium excavatum* forma *clavata* and *Haynesina orbicularis* are the most abundant species in Ecozones D and E. The abundance of *Cassidulina reniforme* is lower and that of *Elphidium excavatum* forma *clavata* is higher in Ecozone E by comparison with their abundances in Ecozone D. *Cassidulina reniforme* is absent and *Haynesina orbicularis* is the most abundant species in Ecozone F. *Portlandia arctica* is the most common invertebrate macrofossil and ostracodes are rare in Ecozones C to F. Foraminifers and ostracodes are present in low numbers in the upper part of Unit 3 and in the lower part of the colour-banded mud (Unit 4).

The *Candona subtriangulata* assemblages of Ecozone A are related to freshwater conditions (Fig. 5). Marine conditions are inferred for Ecozones B to F which are characterized by foraminifers. Ecozone B represents a transition from freshwater to maximum salinity conditions.

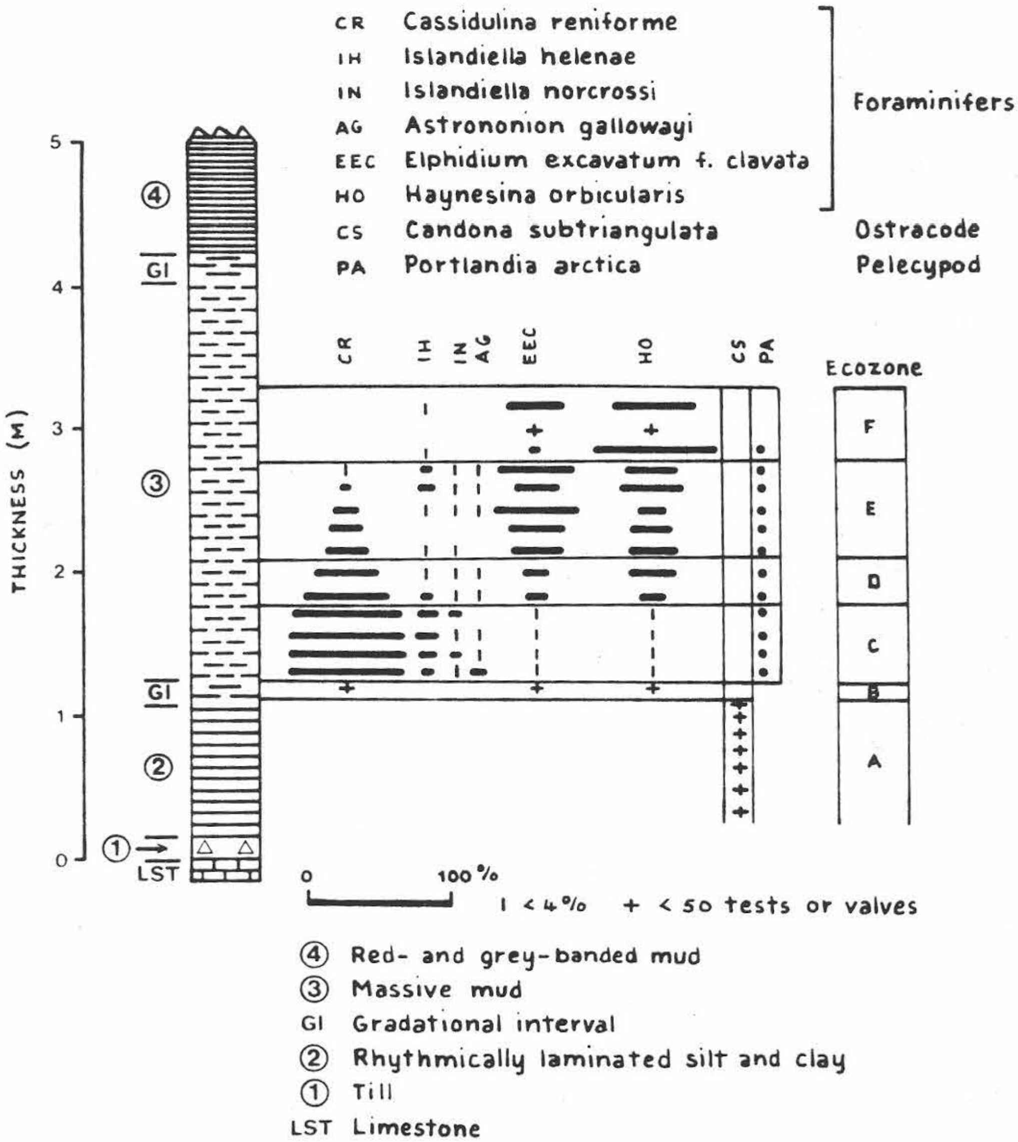

Figure 4. Distribution of selected invertebrate fossils at Casselman site. Foraminiferal abundance data based on samples containing >170 tests.

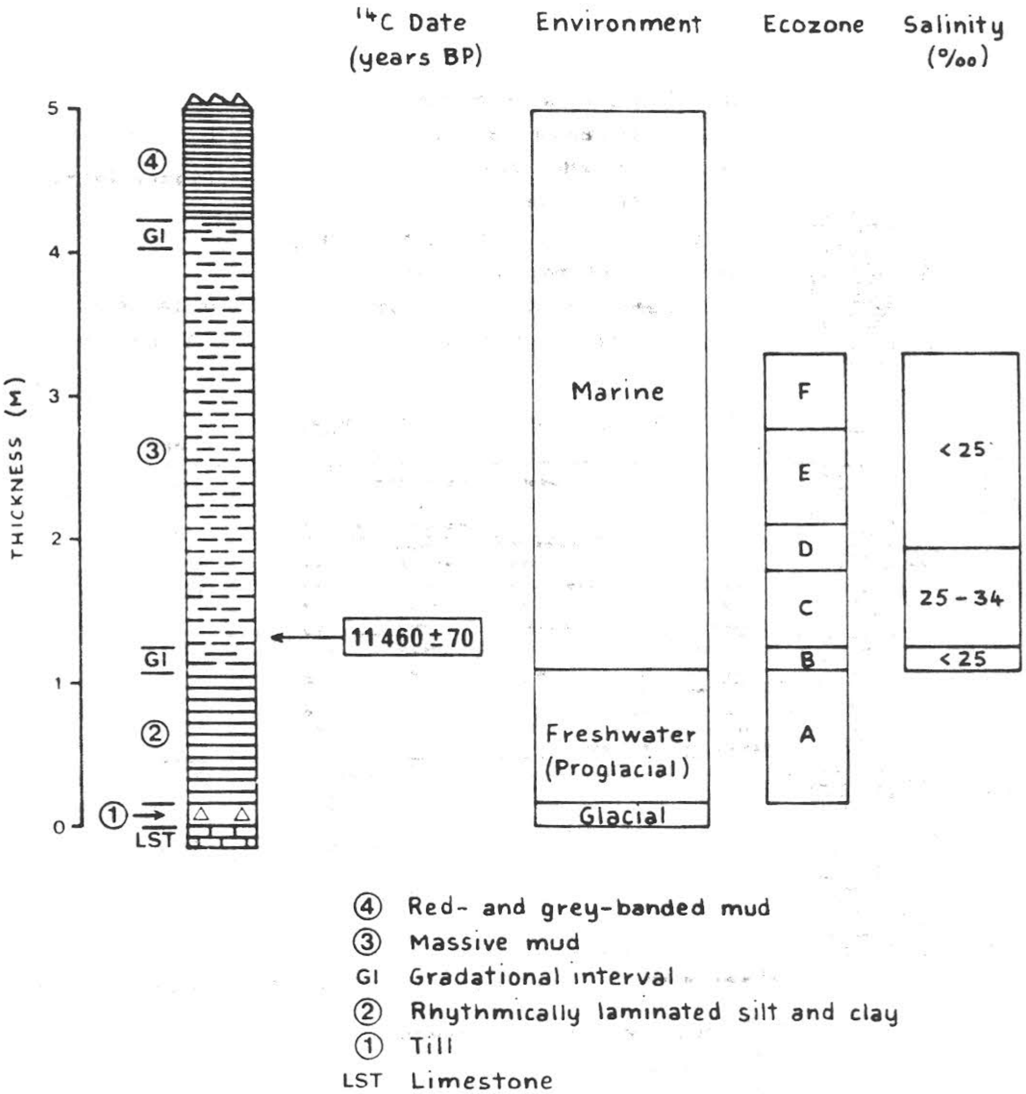

Figure 5. Chronology and paleoenvironmental interpretation for section at Casselman site. Top of section is about 61 m a.s.l.

Salinity was <25^{o}/oo in Ecozone B and from the upper part of Ecozone D to Ecozone F. Maximum salinity conditions (25-34^{o}/oo) existed from Ecozone C to the lower part of Ecozone D.

The rhythmically laminated silt and clay (Unit 2) was deposited in a glacial lake which occupied the area during the early stages of deglaciation. The massive mud (Unit 3) and the upper part of the gradational interval between Unit 2 and Unit 3 were deposited during the Champlain Sea episode. Low salinity water replaced freshwater during the deposition of the gradational interval between Unit 2 and Unit 3. Maximum salinity conditions were followed by decreasing salinity during deposition of Unit 3. The lower part of colour-banded mud (Unit 4) was deposited under relatively low salinity conditions during regression of the Champlain Sea.

A radiocarbon date of 11 460 ± 70 years BP (TO-702) was obtained for foraminifers from the base of Unit 3, i.e. the base of the maximum salinity Ecozone C (Fig. 5). The date indicates that maximum salinity water arrived at the Casselman site ca. 11 500 to 11 400 years BP. TO-702 is younger than the date of 11 900 ± 100 years BP (GSC-3767) for Portlandia arctica from the lower part of the massive mud (Unit 3, Fig. 3) which overlies varve-like rhythmites at the Sparrowhawk Point Site.

COMPARISON OF FAUNAL ASSEMBLAGES

The invertebrate faunal assemblages indicate a succession from glacial to glaciolacustrine to marine conditions at the Sparrowhawk Point site in the upper St. Lawrence Valley and at the Casselman site in the lower Ottawa Valley. The glacial deposits consist of unfossiliferous, massive, stony till. The glaciolacustrine environment is characterized by rhythmically laminated silt and clay ("varves") containing Candona subtriangulata. Foraminifers are absent in the varve-like rhythmites. Portlandia arctica is the most abundant pelecypod in the massive, fine-grained, marine sediments overlying the laminated sediments. However, the foraminiferal assemblages from the marine sediments at the sites are significantly different (Figs. 2 and 4). The differences in the foraminiferal assemblages are related to the salinity of the water which covered the sites during the Champlain Sea episode. Salinity was <25^{o}/oo at the Sparrowhawk Point site (Fig. 3). Low salinity conditions (<25^{o}/oo) were followed by maximum salinity conditions (25-34^{o}/oo) and then decreasing salinity conditions (<25^{o}/oo) at the Casselman site (Fig. 5).

The highest salinity water (25-34^{o}/oo) was present in the deep parts of the Champlain Sea, e.g. Casselman site, and lower salinity water occupied the shallow parts of the sea, e.g. Sparrowhawk Point site. The maximum salinity water reached its upper depth limit (UDL) during the early stages of the marine transgression and retreated from the Central St. Lawrence Lowland during regression of the sea. Maximum salinity foraminiferal assemblages are not present at the Sparrowhawk

Point site because it was above the UDL of the maximum salinity layer. The absence of maximum salinity foraminiferal assemblages at the site may be related to outflow of freshwater from the Lake Ontario basin into the upper St. Lawrence Valley.

DEGLACIATION OF CENTRAL ST. LAWRENCE LOWLAND

Some workers, e.g. Antevs (1925), Prest (1970), Goldthwait (1971), LaSalle (1981), and Clark and Karrow (1984), concluded that a glacial lake occupied part of the Central St. Lawrence Lowland before the Champlain Sea. Thomas (1977) proposed that the area was deglaciated by calving of the Laurentide Ice Sheet and that a calving bay extended up the St. Lawrence Valley from Quebec City to Lake Ontario (Fig. 1). Gadd (1980) agreed with the concept of a calving bay in the Central St. Lawrence Lowland, however he proposed that the calving bay extended into the deeper Ottawa Valley west of Montreal. The succession from rhythmically laminated silt and clay to marine sediments at the Sparrowhawk Point and Casselman sites and the *Candona subtriangulata* assemblages in the varve-like rhythmites, are evidence for a glacial lake in the Central St. Lawrence Lowland before the Champlain Sea. Anderson *et al.* (1985), Naldrett (1987), Parent (1987), and Rodrigues (in press) have also reported *Candona subtriangulata* assemblages from varve-like rhythmites which are overlain conformably by marine sediments at other sites in the lowland.

Glacial Lake Iroquois and glacial Lake Vermont occupied the Lake Ontario basin and Champlain Valley respectively, before deglaciation of the western part of the Central St. Lawrence Lowland. The glacial lake in the Lake Ontario basin expanded into the lowland as ice retreated from the upper St. Lawrence Valley into the lower Ottawa Valley and merged with the glacial lake in the Champlain Valley. *Candona subtriangulata* migrated into the Central St. Lawrence Lowland from the Lake Ontario basin and reached the Champlain Valley after the glacial lakes in the lowland and Champlain Valley were confluent. Water levels fell in the Lake Ontario basin, Champlain Valley, and along the northwest slope of the Adirondack Mountains as the body of freshwater in the Central St. Lawrence Lowland increased in size. Marine waters of the Champlain Sea replaced the freshwater in the lowland and Champlain Valley after ice retreated from the Quebec City area.

The names Lake Frontenac (Antevs, 1925), Lake St. Lawrence (Goldthwait, 1971), Lake Chambly (LaSalle, 1981), and Lake *Candona* (Parent and Occhietti, in press *fide* Parent, 1987) were used for the glacial lake which was present in the Central St. Lawrence Lowland before the Champlain Sea. The name Lake St. Lawrence has priority over the other names. Glacial Lake St. Lawrence correlates with the Belleville or Trenton phase of glacial Lake Iroquois and with the Fort Ann phase of glacial Lake Vermont.

AGE OF CHAMPLAIN SEA

The oldest radiocarbon dates in the western part of the Central St. lawrence Lowland are on the pelecypod Macoma balthica from the Clayton, White Lake and Cantley sites (Fig. 1). Richard (1974) reported a radiocarbon date of 12 800 ± 220 years BP (GSC-1859) for shells from the Clayton site. Radiocarbon age determinations on a second collection of shells from the same unit at the Clayton site were done at the Radiocarbon Dating Laboratory of the Geological Survey of Canada (GSC) and at Isotrace Laboratory, University of Toronto (TO). The GSC dates for the second collection are 12 800 ± 100 years BP outer fraction and 12 700 ± 100 years BP inner fraction (GSC-2151; Richard, 1978). The TO date for the same collection is 12 180 ± 90 years BP (TO-245; Fulton and Richard, 1987). The discrepancy between GSC-2151 ad TO-245 is puzzling. Radiocarbon dates for shells from the White Lake site are 12 100 ± 100 years BP outer fraction, 12 200 ± 100 years BP middle fraction, and 12 100 ± 100 years BP inner fraction (GSC-3110; Rodrigues and Richard, 1983). Romanelli (1975) reported a date of 12 200 ± 160 years BP (GSC-1646) for shells from the Cantley site.

The Clayton, White Lake and Cantley sites are at or near the maximum extent of the Champlain Sea. The radiocarbon dates for Macoma balthica from the sites are significantly older than the date of 11 460 ± 70 years BP (TO-702) for foraminifers from the base of the maximum salinity Ecozone C at the Casselman site (Fig. 5). If the radiocarbon dates are taken at face value then marine water arrived in the Ottawa region by at least 12 200 to 12 000 years BP and maximum salinity water migrated into the region at least 600 radiocarbon years after the beginning of the Champlain Sea in the western part of the Central St. Lawrence Lowland. However, the transition from freshwater to maximum salinity conditions (Ecozone B, Fig. 5) appears to have been rapid at the Casselman site. Thus, the radiocarbon dates for Macoma balthica may be "too old" (see Hillaire-Marcel, 1981 and Karrow, 1981).

Anderson (1987, in press) and Rodrigues (in press) concluded that marine water entered the lower Ottawa and upper St. Lawrence Valleys ca. 11 500 to 11 000 years BP. The radiocarbon date (11 460 ± 70 years BP) for foraminifers from the base of the maximum salinity Ecozone C at the Casselman site is compatible with the younger age proposed for the Champlain Sea in the western part of the Central St. Lawrence Lowland.

CONCLUSIONS

There is considerable controversy concerning the Late Quaternary deglaciation of the Central St. Lawrence Lowland and age of the Champlain Sea. Invertebrate faunal data from rhythmically laminated silt and clay ("varves") which are overlain conformably by marine sediments indicate that a glacial lake occupied part of the lowland during early stages of ice retreat. Some workers accept the oldest radiocarbon dates (mean values > 12 000 years BP) at face value and other workers consider the dates to be "too old".

REFERENCES

Anderson, T.W., 1987, Terrestrial environments and age of Champlain Sea based on pollen stratigraphy of the Ottawa-Lake Ontario region, in Fulton, R.J., ed., Quaternary of the Ottawa region: Geological Survey of Canada Paper 86-23, p. 31-42.

_____, in press, Late Quaternary pollen stratigraphy of the Ottawa Valley-Lake Ontario region and its application in dating the Champlain Sea, in Gadd, N.R., ed., The Late Quaternary development of Champlain Sea basin: Geological Association of Canada Special Paper 35.

Anderson, T.W., Mott, R.J., and Delorme, L.D., 1985, Evidence for a pre-Champlain Sea glacial Lake phase in Ottawa Valley, Ontario, and its implications, in Current Research, Part A: Geological Survey of Canada Paper 85-1A, p. 239-245.

Antevs, E., 1925, Retreat of the last ice-sheet in eastern Canada: Geological Survey of Canada, Memoir 146, 142 p.

Bostock, H.S., 1970, Physiographic subdivisions of Canada, in Douglas, R.J.W., ed., Geology and Economic Minerals of Canada: Geological Survey of Canada, Economic Geology Report No. 1, Chapter II, p. 9-30.

Burke, C.D., 1987, The effect of Late Quaternary climatic changes and glacioisostatic rebound on lake level fluctuations and benthos of Lake Michigan: Palaios, v. 2, p. 514-522.

Clark, P., and Karrow, P.F., 1984, Late Pleistocene water bodies in the St. Lawrence Lowland, New York, and regional correlations: Geological Society of America Bulletin, v. 95, p. 805-813.

Cronin, T.M., 1977, Late-Wisconsin marine environments of the Champlain Valley (New York, Quebec): Quaternary Research, v. 7, p. 238-253.

Delorme, L.D., 1970, Freshwater ostracodes of Canada. Part III. Family Candonidae: Canadian Journal of Zoology, v. 48, p. 1099-1127.

Fransham, P.B., and Gadd, N.R., 1977, Geological and geomorphological controls on landslides in Ottawa Valley, Ontario: Canadian Geotechnical Journal, v. 14, p. 531-539.

Fulton, R.J., and Richard, S.H., 1987, Chronology of Late Quaternary events in the Ottawa region, in Fulton, R.J., ed., Quaternary of the Ottawa region: Geological Survey of Canada Paper 86-23, p. 26-30.

Gadd, N.R., 1977, Offlap sedimentary sequences in Champlain Sea, Ontario and Quebec, in Report of Activities, Part A: Geological Survey of Canada Paper 77-1A, p. 379-380.

_____, 1980, Late-glacial regional ice-flow patterns in eastern Ontario: Canadian Journal of Earth Sciences, v. 17, p. 1439-1453.

_____, 1986, Lithofacies of Leda clay in the Ottawa basin of the Champlain Sea: Geological Survey of Canada Paper 85-21, 44 p.

Goldthwait, J.W., 1971, The St. Lawrence Lowland, in Gadd, N.R., Geology of the Central St. Lawrence Lowland (with selected passages by J.W. Goldthwait): Geological Survey of Canada, Memoir 359, p. 118-149.

Hillaire-Marcel, C., 1981, Late-glacial regional ice-flow patterns in eastern Ontario: Discussion: Canadian Journal of Earth Sciences, v. 18, p. 1385-1386.

Karrow, P.F., 1981, Late-glacial regional ice-flow patterns in eastern Ontario: Discussion: Canadian Journal of Earth Sciences, v. 18, p. 1386-1390.

LaSalle, P., 1981, Géologie des dépôt meubles de la région de Saint-Jean-Lachine: Ministère de l'Energie et des Ressources, Rapport Préliminaire, DPV-780, 13 p.

MacClintock, P., and Stewart, D.P., 1965, Pleistocene geology of the St. Lawrence Lowland: New York State Museum and Science Service, Bulletin No. 394, 152 p.

Naldrett, D.L., 1987, Pre-Champlain Sea glacial lake sedimentation in the Ottawa Valley, Ontario, Canada: International Union for Quaternary Research XIIth International Congress, Programme with Abstracts, p. 231.

Parent, M., 1987, The Asbestos-Valcourt and Sherbrooke area, in Lamothe, M., ed., Pleistocene stratigraphy in the St. Lawrence Lowland and the Appalachians of southern Québec: A field guide: Université de Montréal, Collection Environnement et Géologie, v. 4, p. 102-139.

Parent, M., and Occhietti, S., in press, Late Wisconsinan deglaciation and Champlain Sea invasion in the middle St. Lawrence Valley, Quebéc, in Gadd, N.R., ed., The Late Quaternary development of Champlain Sea basin: Geological Association of Canada Special Paper 35.

Prest, V.K., 1970, Quaternary geology of Canada, in Douglas, R.J.W., ed., Geology and Economic Minerals of Canada: Geological Survey of Canada, Economic Geology Report No. 1, Chapter XII, p. 676-764.

Richard, S.H., 1974, Surficial geology mapping: Ottawa-Hull area (Parts of 31 F, G), in Report of Activities, Part B: Geological Survey of Canada Paper 74-1B, p. 218-219.

_____, 1978, Age of Champlain Sea and "Lampsilis Lake" episode in the Ottawa-St. Lawrence Lowlands, in Current Research, Part C: Geological Survey of Canada Paper 78-1C, p. 121-128.

Rodrigues, C.G., 1987, Late Pleistocene invertebrate macrofossils, microfossils and depositional environments of the western basin of the Champlain Sea, in Fulton, R.J., ed., Quaternary of the Ottawa region: Geological Survey of Canada Paper 86-23, p. 16-23.

_____, in press, Late Quaternary invertebrate faunal associations and chronology of the western Champlain Sea basin, in Gadd, N.R., ed., The Late Quaternary development of Champlain Sea basin: Geological Association of Canada Special Paper 35.

Rodrigues, C.G., and Richard, S.H., 1983, Late glacial and postglacial macrofossils from the Ottawa-St. Lawrence Lowlands, Ontario and Quebec, in Current Research, Part A: Geological Survey of Canada Paper 83-1A, p. 37-379.

_____, 1985, Temporal distribution and significance of Late Pleistocene fossils in the western Champlain Sea basin, Ontario and Quebec, in Current Research, Part B: Geological Survey of Canada Paper 85-1B, p. 401-411.

Romanelli, R., 1975, The Champlain Sea episode in the Gatineau River Valley and Ottawa area: Canadian Field-Naturalist, v. 89, p. 356-360.

Terasmae, J., 1965, Surficial geology of the Cornwall and St. Lawrence Seaway Project area, Ontario: Geological Survey of Canada, Bulletin 121, 54 p.

Thomas, R.H., 1977, Calving bay dynamics and ice sheet retreat up the St. Lawrence Valley system: Géographic Physique et Quaternaire, v. XXXI, p. 347-356.