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Jerry John Mihoren
University of Windsor

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LATE QUATERNARY INVERTEBRATE MACROFOSSILS
AND MICROFOSSILS FROM THE CENTRAL
ST. LAWRENCE LOWLAND, CANADA.

by

Jerry John Mihoren

A Thesis
submitted to the Faculty of Graduate
Studies through the Department of
Geology in Partial Fulfillment of
the Requirements for the Degree of
Master of Science at the University
of Windsor.

Windsor, Ontario, Canada.
1987
To Cynthia Margaret
LATE QUATERNARY INVERTEBRATE MACROFOSSILS AND MICROFOSSILS FROM THE CENTRAL ST. LAWRENCE LOWLAND, CANADA.

ABSTRACT

by

Jerry John Mihoren

Six marine pelecypod associations, one marine cirriped association, and eight marine foraminiferal associations were recognized in Late Quaternary sediments of the Russell, Alexandria, Winchester, and Cornwall map areas. Ostracodes were scarce in the samples used in this study. The distribution of the macrofossils and microfossils is related to paleosalinity and paleotemperature. The cold (\(\leq 4^\circ C\)), higher salinity (30 to 34\%) water, which occupied the deeper parts of the marine basin in the study area, was characterized by the *Portlandia arctica* and *Balanus hameri* macrofaunal associations, and the *Cassidulina reniforme*-dominant foraminiferal association.

The *Cassidulina reniforme-Elphidium clavatum-Haynesina orbicularis*-dominant, the *Haynesina orbicularis-Cassidulina reniforme-Elphidium clavatum-Elphidium sp.*-dominant, and the *Elphidium clavatum-Haynesina orbicularis-Cassidulina reniforme-Elphidium incertum/asklundi*-dominant foraminiferal associations also colonized the deeper-water settings of the study area where the water was cold (0\(^0\) to 13\(^0\)C) and salinity was 25 to 30\%_. The *Portlandia arctica, Hiatella arctica* and *Mytilus*
macrofaunal associations and the *Cytheropertera* spp.-dominant ostracode assemblages accompanied the deeper-water foraminiferal associations.

The shallower-water locations were occupied by cold (0° to 13°C) water with a salinity range of 15 to 25%. The foraminiferal associations characteristic of the shallower-water include the *Elphidium clavatum*-dominant, the *Haynesina orbicularis*-dominant, the *Haynesina orbicularis-Elphidium clavatum*-dominant, and the *Haynesina orbicularis-Elphidium clavatum-Elphidium* sp.-*Elphidium incertum/ashlundi*-dominant. The *Macoma balthica* and *Hiatella arctica* macrofaunal associations and *Sarsicytheridea bradii-Cytheropertera latissimum-Sarsicytheridea punctillata*-dominant, and the *Heterocyprideis sorbyana-Sarsicytheridea punctillata-Cytheromorpha maccheseyi*-dominant ostracode assemblages accompany the shallow-water foraminiferal associations.

Foraminifer diversity based on the Shannon-Weiner Information Function $[H(S)]$ ranged from 0.25 to 1.93. Foraminifer diversity does not appear to be directly related to salinity.
ACKNOWLEDGEMENTS

Special thanks goes to Mrs. Phyllis Butler who contributed many long hours typing the text and to Mr. Aubrey Butler for preparation of figures and tables and for photocopying services.

Thanks are extended to Mr. John Robinson who prepared the microfossils for the scanning electron micrographs and who instructed the author on the use of the scanning electron microscope. The author is also grateful to Mr. Brad MacLaren and his staff at Custom Colour (Windsor) who photographed and reproduced the microfossil plates, and to Miss Beth-Anne Melville who sketched the line drawings for the macrofossils.

I am especially grateful to my parents who have given support and encouragement throughout my academic career.

Finally, a great appreciation is extended to my wife, Cindy for her help, encouragement and support.
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INTRODUCTION

During the final retreat of the Laurentide Ice Sheet from eastern North America, marine water inundated the isostatically depressed Ottawa, St. Lawrence and Champlain Valleys, forming an arm of the Atlantic Ocean known as the Champlain Sea. Radiocarbon dates for marine pelecypods indicate that the marine episode began between 12,400 and 12,500 years BP near Quebec City, as early as 12,700 to 12,800 years BP in the lower Ottawa Valley, and between 11,800 and 12,000 years BP in the upper St. Lawrence and Champlain Valleys. Seals, whales, bryozoans, cirripeds, gastropods, pelecypods, sponges, holothurian sclerites, foraminifers, ostracodes and algae have been reported from Champlain Sea deposits. In some areas post-Champlain Sea deposits are characterized by freshwater pelecypods and gastropods. Radiocarbon dates for the freshwater molluscs indicate that the marine episode ended between 9,500 and 10,300 years BP.

This study deals with the distribution and paleoenvironmental significance of invertebrate macrofossils, foraminifers and ostracodes in Late Quaternary marine deposits of the Russell (31G/6), Alexandria (31G/7), Winchester (31G/3), and Cornwall (31G/2) map areas (Fig. 1). The study area is part of the central St. Lawrence Lowland. Topographic relief ranges from about 40 m to 130 m above present mean sea level. The most prominent topographic features are elongate ridges which trend north to south and...
Figure 1. Map of the study area (maximum extent of the Champlain Sea from Fulton, 1986).
northeast to southwest. The Late Quaternary deposits in the study area are underlain by Ordovician carbonates, sandstones and shales (Baer et al., 1977).

LATE QUATERNARY DEPOSITS

The Late Quaternary deposits in the study area are shown in Maps 1 to 4 (in pocket) which were reproduced from 1:50 000 surficial geology maps of Richard (1982a) for the Russell area (Map 1), Richard (1982b) for the Winchester area (Map 3), Gwyn and Lohse (1973) for the Alexandria area (Map 2), and Terasmae (1965) for the Cornwall area (Map 4). A generalized sequence consisting of glacial sediments (till and ice contact stratified drift) overlain by fossiliferous marine sediments (Champlain Sea sediments) which in turn are overlain by post-Champlain Sea sediments is recognized for the study area. A brief description of some of the late glacial and post-glacial sediments are presented below.

Till

MacClintock and Stewart (1965) described two tills from sections exposed during construction of the St. Lawrence Seaway near Cornwall. The lower red-brown till was named the Malone Till and the upper grey till was named the Fort Covington Till. Terasmae (1965) also recognized the two tills in the Cornwall area, however, he pointed out that only the Fort Covington Till (Units 1 and 2, Map 4) is exposed at the surface. Gwyn and Lohse (1973) also used the name Fort Covington Till (Unit 2, Map 2) for the till.
exposed in the Alexandria area. Richard (1982a, b) recognized one till (Unit 1) in the Russell (Map 1) and Winchester (Map 2) areas; he did not assign a formal name to the till.

Varved Clay

Rhythmically laminated silt and clay or varved clay is not shown on the surficial geology maps because it is not exposed at the surface. Terasmae (1965) reported varved clay in the Cornwall area and Gadd (1986) reported varved clay from cored sections in the Russell map area. Varved clay is exposed on the west bank of the South Nation River near Casselman in the Russell map area (Rodrigues and Gadd, 1986). At the Casselman site the varved clay is underlain by till and grades upwards into massive marine clay and silty clay. A list of reported occurrences of varved clay west of 74° W is presented in Table 1.

Champlain Sea Sediments

Champlain Sea deposits are characterized by marine invertebrate macrofossils and microfossils. Regions of low elevations in the study area, i.e. depressions between ridges, the marine deposits consist of massive clay and silty clay (Unit 3, Maps 1 to 4). At some sites the massive fine-grained sediments grade upward into red- and grey-banded clay and silty clay (Gadd 1976, 1977, 1986, and Fransham and Gadd 1977). The colour-banded fine-grained sediment is present in the Russell and Alexandria areas and was not observed in the Cornwall and Winchester areas; it is included in Unit 3.
Table 1. Glaciolacustrine deposits reported west of $74^\circ$ W longitude in the Champlain Sea basin.

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<td>Ottawa region, Ontario</td>
<td>Freshwater varved clays beneath marine deposits.</td>
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<td>South shore of St. Lawrence River near</td>
<td>Varved clays overlying Fort Covington Till.</td>
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<td>Terasmae (1965)</td>
<td>Cornwall to Brockville, north shore of St.</td>
<td>Varved clays grade upwards to marine clay.</td>
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<tr>
<td>Fransham and</td>
<td>Cored sections in the Ottawa Valley</td>
<td>Till and ice contact gravel overlain by varved clay which grade upwards into deep-water marine clay.</td>
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<td>Gadd (1977)</td>
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<td>Anderson et al.</td>
<td>Cored section near Ottawa</td>
<td>Freshwater ostracodes (Candona) present in laminated sediments; fossiliferous marine sediments observed above the laminated sediments.</td>
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<tr>
<td>Rodrigues and</td>
<td>Sparrowhawk Point, New York, south shore</td>
<td>Varved clay containing Candona sp. is overlain by marine clay.</td>
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<tr>
<td>Richard (1985)</td>
<td>of St. Lawrence River</td>
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<td>Rodrigues and Gadd</td>
<td>Casselman, Ontario</td>
<td>Till overlain by rhythmically laminated silt and clay (&quot;varves&quot;) which in turn are overlain by massive marine clay and silty clay. The &quot;varves&quot; contain Candona sp.</td>
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<td>(1986)</td>
<td></td>
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(Map 1). The marine deposits exposed at the surface on the topographically higher areas (ridges) include gravel and sand (Unit 5a, Maps 1 and 3; Unit 6, Map 2; Unit 5, Map 4) and sand (Unit 5b, Maps 1 and 3; Unit 4, Map 5 2 and 4).

**Fossiliferous Till**

Fossiliferous till containing broken shells of marine pelecypods have been reported from the study area. The distribution of the till-like material is not shown on the surficial geology maps. Coleman (1927, 1932) reported interglacial marine sand and gravel with articulated pelecypod valves, overlain by stoney till with broken pelecypod shells from the Cornwall area. Coleman (1927) concluded that ice must have scraped up part of the shell-bearing gravel, mixing it with other material undergoing transportation. The occurrence of fossiliferous till near Cornwall indicates that ice advanced into the Champlain Sea basin during the marine episode. However, MacClintock and Stewart (1965) concluded that the fossiliferous stoney till of Coleman (1932) was formed by waves and currents of the Champlain Sea.

Richard (1975a) reported fossiliferous till in the Winchester and Cornwall areas. Richard (1975b) pointed out that some of the shells in the till were broken and postulated that the "Newington ice lobe", which extended over the Prescott-Newington-Cornwall areas, advanced into the Champlain Sea, scooped up the marine shells, and redistributed them throughout the glacial sediment. He also concluded that the radiocarbon date of 11 100±100 years BP (GSC-2108) for shells of *Hiatella arctica* (Linné) in the till dates the
post-Fort Covington ice readvance postulated by Terasmae (1965) in the Cornwall area.

The origin and significance of Richard's fossiliferous till has been disputed by several workers. Dreimanis (1977) suggested that the fossiliferous till could be a wave-reworked and slumped exposure of the Fort Covington Till, containing marine shells admixed from younger, fossiliferous beach gravels. Harrison (1977) proposed that the till-like material was formed by coastal processes in the Champlain Sea. Gadd (1977, 1986) concluded that there is no evidence for the proposed readvance or for a significant hiatus in cored sections from the Ottawa Valley. Fullerton (1980) discounted the glacial origin of the till-like material and Hayward and French (1980) suggested that the diamicton may be part of a kettle-fill sequence.

Post-Champlain Sea Sediments

Post-Champlain Sea sediments overlie marine sediments and consist of alluvial and organic materials. The alluvial sediments including sand, silty sand, silty clay, and clay (Unit 6, Maps 1 and 3; Units 10 and 11, Map 2; Unit 7, Map 4) commonly occur in abandoned channels. The organic sediments include muck and peat (Unit 7, Maps 1 and 3; Unit 9, Map 2; Unit 8, Map 4) which are found in poorly drained areas. Terasmae (1965) reported aeolian sand (Unit 6) overlying Champlain Sea sediments in the Cornwall area (Map 4). The freshwater pelecypod *Lampsilis* has been reported from post-Champlain Sea sediments in the Cornwall area (Terasmae,
PREVIOUS WORK ON CHAMPLAIN SEA INVERTEBRATE FOSSILS

**Macrofossils**

Goldring (1922) examined the size variation of marine pelecypods from sites between Ottawa and Montreal and in the Champlain Valley. She observed that pelecypods from the Montreal area were larger in size compared to those from the Ottawa area to the west and the Champlain Valley to the south. She concluded that the size variation of the pelecypod shells was related to palaeosalinity, i.e. the larger shells from the Montreal area were related to higher-salinity water and the smaller shells from the Ottawa area and the Champlain Valley were related to lower-salinity water.

Elson and Elson (1959) divided the Champlain Sea episode into an early, cold *Hiatella* Phase and a later warmer *Mya* Phase. They concluded that salinity was highest during the early *Hiatella* Phase and lowest during the later *Mya* Phase. They also pointed out that post-Champlain Sea deposits are characterized by the freshwater pelecypod *Lampsilis*.

Elson (1969) reported that the early cold subarctic *Hiatella* (= *Hiatella arctica*) Phase lasted from about 11 800 years BP to between 10 800 and 10 600 years BP and the warmer boreal *Mya* (= *Mya arenaria*) Phase lasted from about 10 800 years BP to about 10 200 years BP.

Wagner (1970) presented the first detailed taxonomic
study of marine invertebrate fossils of the Champlain Sea. Wagner (1984) described and illustrated the invertebrate macrofossils from the Ontario portion of the Champlain Sea basin.

Hillaire-Marcel (1977, 1980) discussed the distribution and paleoecological significance of marine invertebrate macrofossils in Champlain Sea deposits of southern Quebec. He recognized the Balanus hameri cirriped community (association of this study) and seven pelecypod communities. Hillaire-Marcel (1980) concluded that the distribution of the Hiatella arctica, Macoma balthica, Macoma calcarea, Mya arenaria, Mya truncata, Mytilus edulis, and cirriped associations were related to substrate and hydrological conditions. He also pointed out that the communities succeeded each other in relation to decreasing water depth and changing bottom-water conditions as the sea shoaled.

Rodrigues and Richard (1983) described the distribution of six marine pelecypod associations, one marine cirriped association and one freshwater pelecypod association from late glacial and post-glacial sediments of the western Champlain Sea basin (west of 74° W). They recognized the marine Hiatella arctica, Macoma balthica, Mya arenaria, Mya truncata, Mytilus edulis, and Portlandia arctica pelecypod associations, the marine Balanus hameri cirriped association, and the freshwater Lampsilis pelecypod association. They observed that the macrofaunal associations replace each other upsection at many localities. The Balanus hameri or
*Hiatella arctica* or *Portlandia arctica* association commonly occurs at the base of the successions and the *Macoma balthica* or *Mya arenaria* association occurs at the top of the successions. At one site near Saint-Stanislas-de-Kostka, Quebec, marine pelecypod associations are replaced by the freshwater *Lampsilis* association. Rodrigues and Richard (1983) concluded that the successions of macrofossil associations were related to the increasing temperature and decreasing salinity of the bottom water and variations in the substrate.

Rodrigues and Richard (1985) compiled the radiocarbon dates for marine and freshwater pelecypods, cirripeds, whale bones, and marine algae which were reported by the Geological Survey of Canada Radiocarbon Dating Laboratory. They also presented nineteen unpublished radiocarbon dates for marine and freshwater invertebrate taxa from the western Champlain Sea basin. The radiocarbon dates were used to determine the stratigraphic ranges of the macrofaunal associations and to reconstruct the sequence of events for the marine episode in the western Champlain Sea basin. Rodrigues and Richard (1985) reported that more than one macrofaunal association were present during most of the marine episode. The *Portlandia arctica* and *Macoma balthica* associations colonized the western Champlain Sea basin between 12,800 and 11,600 years BP, and were also present during the middle and later parts of the marine episode. The *Balanus hameri*, *Hiatella arctica*, *Mya arenaria*, and *Mya truncata* associations colonized the western Champlain Sea basin during the middle
part of the marine episode (11 600 to 10 800 years BP) and were also present in the later part of the marine episode (10 800 to 10 100 years BP).

Rodrigues and Richard (1985) concluded that (1) the presence of more than one association during the marine episode and the successions of associations are related to salinity stratification of the Champlain Sea, (2) cold subarctic water, salinity 30 to 34 °, occupied the deeper parts of the basin and was overlain by cold, lower salinity water (<30°) at shallower depths, (3) cold subarctic and warmer boreal waters, salinity less than 20°, were contemporaneous at least between 11 100 and 10 500 years BP on the basis of the overlapping ranges of the boreal *Mya arenaria* association and the other pelecypod associations, (4) boreal water migrated into the basin at shallow depths along the south side of the Champlain Sea basin and did not migrate west of the Cornwall-Alexandria area, (5) cold, high-salinity water occupied the deeper parts of the western Champlain Sea basin until at least 10 800 years BP, *i.e.*, the youngest date for the *Balanus hameri* association which is restricted to the deeper parts of the basin, (6) the high-salinity water retreated from the basin and was replaced by lower-salinity water which eventually became fresh about 10 100 years BP, and (7) the *Lampsilis* association colonized post-Champlain Sea freshwater environments in some parts of the Champlain Sea basin.
Foraminifera

Some of the generic and specific names used in the discussion below are not the same as those of some Champlain Sea workers. The names were changed as follows, *Cassidulina reniforme* Nørvang = *Cassidulina crassa* d'Orbigny of Cronin (1977b, 1979a) and *Islandiella islandica* (Nørvang) of Fillon and Hunt (1974), *Elphidium clavatum* Cushman = *Elphidium excavatum* (Terquem) forma *clavata* Cushman of Cronin (1977b, 1979a) and Corliss et al. (1982), *Haynesina orbicularis* (Brady) = *Proelphidium orbicularare* (Brady) of Cronin (1977b, 1979a), Fillon and Hunt (1974) and Corliss et al. (1982), and *Islandiella helenae* Feyling-Hanssen and Buzas = *Islandiella teretis* (Tappan) of Fillon and Hunt (1974).

Fillon and Hunt (1974) examined the foraminiferal assemblages from three piston cores collected from Lake Champlain and proposed a zonation of Champlain Sea sediments based on the dominant species. The zones, in stratigraphic order, are characterized by (1) *Islandiella helenae*, (2) *Cassidulina reniforme* and *Islandiella helenae*, (3) *Haynesina orbicularis* and *Elphidium bartletti* Cushman, (4) *Elphidium clavatum* and *Haynesina orbicularis*, and (5) *Elphidium clavatum*. They suggested salinities of 30 - 33% for the *Islandiella helenae* and *Cassidulina reniforme - Islandiella helenae* zones, 22 - 28% for the *Haynesina orbicularis - Elphidium bartletti* and *Elphidium clavatum - Haynesina orbicularis* zones, and 18 - 24% for the *Elphidium clavatum* zone.
Cronin (1977b, 1979a) discussed the paleoenvironmental significance of foraminifers from Champlain Sea deposits exposed in southeastern Ontario, southern Quebec and Champlain Valley. Cronin (1979a) recognized two foraminiferal biofacies on the basis of Q-mode factor analysis of a data base, consisting of the per cent abundances of 68 species and 54 samples. The nearshore shallow-water (<30 m) biofacies is dominated by *Elphidium* spp. and *Haynesina orbicularis* and the offshore deeper (30 - 100 m) biofacies is dominated by *Cassidulina reniforme*, *Islandiella helena* and *Elphidium clavatum*.

Cronin (1979b) reported that foraminifer diversity $[H(S)]$ for the samples used in the above studies ranged from 0.14 to 2.48. He pointed out that diversity is consistently higher ($\geq 1.8$) in the deeper parts of the basin and suggested that salinity was the primary environmental factor influencing foraminifer diversity.

Corliss *et al.* (1982) described foraminiferal assemblages in two piston cores from Lake Champlain. They reported that *Cassidulina reniforme* and *Islandiella helena* were the dominant foraminifers during the early part of the Champlain Sea episode and were replaced by *Elphidium clavatum* and *Haynesina orbicularis* during the later part of the marine episode. Oxygen-isotopic data for *Haynesina orbicularis* from the initial phase of the sea range from 0.62 to 0.88%, decreasing to as low as -1.56% during the later part of the marine episode. Corliss *et al.* (1982) concluded that the
faunal and isotopic data indicated nearly normal marine conditions during the early part of the Champlain Sea episode and decreasing salinity and increasing temperature as the sea evolved.

Rodrigues (1987) recognized 15 groups of foraminiferal assemblages from Champlain Sea deposits between Pembroke and 74° W longitude. He named the groups of assemblages after the dominant species and concluded that salinity was a major factor controlling the distribution of the assemblages. Bottom water with salinity between 30 and 34% was characterized by *Astronomion gallowayi* Loeblich and Tappan, *Cassidulina reniforme*, *Islandiella helenae*, *I. norcrossi* (Cushman), and *Haynesina orbicularis*. Assemblages that colonized bottom water with salinity of 15 to 30% were characterized by *Cassidulina reniforme*, *Elphidium clavatum*, *E. incertum*/*asklundi* (Williamson)/Brotzen, *Eoeponidella pulchella* (Parker), *Haynesina orbicularis*, and *Pateoris hauerinoides* (Rhumbler). Low-salinity bottom water was characterized by *Elphidium* sp. *sensu* Rodrigues and Richard (1986), *E. clavatum*, and *Haynesina orbicularis*.

**Ostracoda**

Gunther and Hunt (1977) examined the ostracodes from 17 piston cores collected from Lake Champlain and recognized three ostracode assemblages. The assemblages, in stratigraphic order are characterized by (1) the freshwater (glacial Lake Vermont phase) *Candona subtriangulata* Benson and MacDonald, and low numbers of the marine *Cytheromorpha macchesneyi*
(Brady and Crosskey), (2) the marine (Champlain Sea phase) Cytheromorpha macchesneyi, Cytheropteron arcuatum Brady, Crosskey, and Robertson, Cytheropteron montrosiense Brady, Crosskey, and Robertson, Cytheropteron paralatissimum Swain, Heterocyprideis sorbyana (Jones), Cytheropteron vespertilio (Reuss), and Palmenella limicola (Norman), (3) the brackish-water (transition from Champlain Sea to post-Champlain Sea freshwater phase) Cytherissa lacustris (Sars) and Limnocythere friabilis Benson and MacDonald.

Cronin (1977a) discussed the paleoenvironmental significance of ostracodes from the Champlain Valley. He recognized three phases for the Champlain Sea episode. The Transitional Phase (12 500 to 11 600 years BP) was characterized by the freshwater Candona subtriangulata and the euryhaline Cytheromorpha macchesneyi. Cronin (1977a) interpreted this phase as having temperatures of -2°C to between 5 and 10°C and salinities of 0 to 18‰. The Hiatella arctica Phase (11 600 to between 11 000 and 10 600 years BP) was characterized by the new arrivals Cythere lutea O. F. Müller, Baffinicythere emarginata (Sars), Finmarchinella curvicosta Neale, Palmenella limicola, Acanthocythereis dunelmensis (Norman) and several species of Cytheropteron. Heterocyprideis sorbyana and Sarsicytheridea spp. were also abundant during the Hiatella arctica Phase. The Hiatella arctica Phase was interpreted as having water temperatures of 0°C to between 20°C and 22°C and salinities between 18 and 35‰. The Mya arenaria Phase (10 600 to 10 000 years BP) was characterized by Cytherura gibba (O. F. Müller), Cytheromorpha fuscata (Brady), Leptocythere castanea (Sars), Cyprinotus salinus (Brady), and Cyprideis torosa (Jones). This last phase was
interpreted as having temperatures of 5 to 30°C and salinities of 3 to 13%0.

Cronin (1979b) reported that the ostracode diversity for samples from southeastern Ontario, southern Quebec and Champlain Valley ranged from 0.15 to 2.29. He pointed out that the diversity is consistently higher in Ontario and Quebec and suggested that salinity was the primary environmental factor influencing ostracode diversity. Cronin (1981) illustrated 35 ostracode species from the Champlain Sea deposits of the same study area mentioned above.

Rodrigues (1984) and Anderson et al. (1985) reported freshwater ostracodes (Candona spp.) from rhythmically laminated silt and clay ("varves") in the Ottawa and St. Lawrence Valleys. Anderson et al. (1985) observed fossiliferous marine deposits overlying the "varves" and concluded that the freshwater deposits were evidence for a pre-Champlain Sea glaciolacustrine phase west of Montreal.

Rodrigues (1987) reported 9 groups of marine ostracode assemblages from Champlain Sea deposits west of 74°W longitude. The dominant species of the assemblages with respect to paleosalinity are 1) Cytheropteron arcuatum Brady, Crosskey and Robertson, C. paralatissimum Swain and C. pseudomontrosiense Whatley and Masson, paleosalinity 30 to 34%, 2) Cytheropteron latissimum (Norman), C. nodosum Brady, C. pseudomontrosiense Whatley and Masson, Heterocythereis sorbyana, Palmenella limicola and Sarsicytheridea punctillata (Brady), paleosalinity 15 to 30%, and 3) Cytheromorpha macchesneyi (Brady and
Crosskey), *Heterocyprideis sorbyana* and *Sarsicytheridea punctillata*, paleosalinity less than 15%. Rodrigues (1987) also recognized a freshwater *Candona* sp. assemblage which occurs in rhythmically laminated silt and clay (varves) underlying marine deposits in the deeper part of the Champlain Sea basin.

**FAUNAL INVESTIGATIONS IN THE STUDY AREA**

Rodrigues and Richard (1986) discussed the paleoecological significance of marine and freshwater invertebrate macrofossils and microfossils from Late Quaternary sediments of the Thurso, Russell, Winchester, and Morrisburg map areas. They recognized seven foraminiferal associations, five marine and one freshwater macrofaunal associations and five groups of ostracode assemblages. They concluded that the distribution of macrofaunal and microfaunal associations were controlled by salinity and substrate. The associations reported by Rodrigues and Richard (1986) are summarized in Table 2. This table shows the macrofauna and microfauna which are characteristic of high salinity (30 to 34%), intermediate salinity (20 to 30%) and low salinity (10 to 20%) bottom water.

Rodrigues and Gadd (1986) reported successions of macrofauna and microfauna from three sections located in the Russell map area (location of sections are shown on Map 1, in pocket). The Navan and Bearbrook sections were located on ridges and the Casselman section was located in the deeper part of the basin. The sediments in the Navan section contained high-salinity macrofauna and microfauna at the base.
Table 2. Late Pleistocene ostracode assemblages and cirriped, pelecypod, and foraminiferal associations from the western Champlain Sea basin (from Rodrigues and Richard, 1986)

<table>
<thead>
<tr>
<th>Foraminiferal Association</th>
<th>Number</th>
<th>Dominant Taxa</th>
<th>Diversity [HIS]</th>
<th>Ostracode Association</th>
<th>Abundant Species</th>
<th>Group</th>
<th>Lithology</th>
<th>Salinity of Bottom Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Elphidium clavatum</td>
<td>Range: 0.04-1.15</td>
<td>Mean: 0.65</td>
<td>Hiatella arctica</td>
<td>Cytheromorpha macchieveyi</td>
<td>B</td>
<td>Clayey sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elphidium clavatum</td>
<td>Range: 0.04-1.15</td>
<td>Mean: 0.65</td>
<td>Hiatella arctica</td>
<td>Cytheromorpha macchieveyi</td>
<td>B</td>
<td>Sandy clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elphidium clavatum</td>
<td>Range: 0.14-1.57</td>
<td>Mean: 0.94</td>
<td>Hiatella arctica</td>
<td>Cytheropoter latissimum</td>
<td>C</td>
<td>Sandy clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elphidium clavatum</td>
<td>Range: 1.42-1.31</td>
<td>Mean: 1.55</td>
<td>Hiatella arctica</td>
<td>Cytheropoter latissimum</td>
<td>C</td>
<td>Sandy clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elphidium clavatum</td>
<td>Range: 0.32-1.35</td>
<td>Mean: 1.17</td>
<td>Portlandia arctica</td>
<td>Cytheropoter pseudomontesiense</td>
<td>A</td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elphidium clavatum</td>
<td>Range: 1.26-1.59</td>
<td>Mean: 1.39</td>
<td>Hiatella arctica</td>
<td>Cytheropoter latissimum</td>
<td>C</td>
<td>Sandy clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cassidulina reniformis</td>
<td>Range: 0.76-1.13</td>
<td>Mean: 1.12</td>
<td>Portlandia arctica</td>
<td>Cytheropoter pseudomontesiense</td>
<td>A</td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Macoma balthica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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and lower salinity faunas towards the top of the section (Table 3). The Bearbrook section was originally described by Kovac (1985). Rodrigues and Gadd (1986) summarized the faunal data from the Bearbrook section and included the faunal data from the base of the section which were not reported by Kovac (1985). The macrofauna and microfauna observed in the Bearbrook section represented, in stratigraphic order, freshwater, low-salinity, high-salinity, and low-salinity, conditions (Table 4). The macrofossils and microfossils from the Casselman section were interpreted, in stratigraphic order, as freshwater, low-salinity, high-salinity, and low-salinity (Table 5).

Oxygen isotopic data ($\delta^{18}O$) for the foraminifer *Haynesina orbicularis* and the pelecypod *Hiatella arctica* were reported for the Bearbrook and Navan sections, respectively. The $\delta^{18}O$ values at the base of the Bearbrook section was 1.22% and the top -2.75%. The $\delta^{13}O$ values at the base of the Navan section was -0.75% and at the top -4.15%. Rodrigues and Gadd (1986) concluded that the decreasing $\delta^{18}O$ values up the sections were related to the decreasing salinity.

Rodrigues and Gadd (1986) described the size variation of *Hiatella arctica* for the Navan and Bearbrook sections. The size variation data were reported by Marentette (1986). In both sections the salinity decreases upsection. However, the two sections show distinct differences in the size variation of *Hiatella arctica*. In the Navan section *Hiatella arctica* were small in size at the base (mean height 7.2 mm, mean

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Table 3. Radiocarbon dates, eczones and inferred paleosalinity for section at Haven site, Russell map area (from Rodrigues and Richard, 1986 and Rodrigues and Gadd, 1988).

<table>
<thead>
<tr>
<th>Radiocarbon Date (years BP)</th>
<th>Macrafauna</th>
<th>Foraminifera</th>
<th>Ostracoda</th>
<th>Paleosalinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000-9000</td>
<td>Ctenoides aestivalis</td>
<td>Elphidium clavatum</td>
<td>Ostracoda case</td>
<td>15 to 25</td>
</tr>
<tr>
<td>7000-6100</td>
<td>Balanus arenicola</td>
<td>Cassidulina septemcostata</td>
<td>(Ostracoda case)</td>
<td>30 to 36</td>
</tr>
</tbody>
</table>

Eczones are named after the dominant species.

Table 4. Radiocarbon dates, eczones, and inferred paleosalinity for section at Bearbrook site, Russell map area (from Norman, 1969 and Rodrigues and Gadd, 1988).

<table>
<thead>
<tr>
<th>Radiocarbon Date (years BP)</th>
<th>Macrafauna</th>
<th>Foraminifera</th>
<th>Ostracoda</th>
<th>Paleosalinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000-9000</td>
<td>Ctenoides aestivalis</td>
<td>Elphidium clavatum</td>
<td>Ostracoda case</td>
<td>15 to 25</td>
</tr>
<tr>
<td>7000-6100</td>
<td>Balanus arenicola</td>
<td>Cassidulina septemcostata</td>
<td>(Ostracoda case)</td>
<td>30 to 36</td>
</tr>
</tbody>
</table>

Eczones are named after the dominant species.

Table 5. Eozones and inferred paleosalinity for section at Casselman site, Russell map area (from Rodrigues and Gadd, 1988).

<table>
<thead>
<tr>
<th>Type</th>
<th>Macrafauna</th>
<th>Foraminifera</th>
<th>Ostracoda</th>
<th>Paleosalinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Eozones case</td>
<td>Ctenoides aestivalis</td>
<td>Ostracoda case</td>
<td>15 to 25</td>
</tr>
<tr>
<td>Fontinalis water</td>
<td>Eozones case</td>
<td>Cassidulina septemcostata</td>
<td>(Ostracoda case)</td>
<td>&lt;30</td>
</tr>
</tbody>
</table>

Eozones are named after the dominant species.

'C. G. Rodrigues (per. comm., 1987)
length 14.4 mm) and larger towards the top of the section (mean height 8.5 mm, mean length 17.5 mm). In the Bearbrook section *Hiatella arctica* were small at the base (mean height 7.2 mm, mean length 13.7 mm), larger in the middle of the section (mean height 12.8 mm, mean length 25.2 mm), and small at the top (mean height 7.3 mm, mean length 14.7 mm). Rodrigues and Gadd (1986) concluded that the size of *Hiatella arctica* is not directly related to paleosalinity.

**RADIOCARBON DATES FROM THE STUDY AREA**

The radiocarbon dates for marine and freshwater invertebrate macrofossils from the study area are listed in Table 6. The positions of the sites at which the dated materials were collected are shown in Figure 2. Dates for marine shells range from 9910±150 years BP (BGS-258) to 11 200±100 years BP (GSC-2108). Examination of the radiocarbon dates indicates that some are anomalous. The date of 9910±150 years BP (BGS-258) for *Hiatella arctica* from an elevation of about 107 m at the Dornie site (site 4, Fig. 2) is the youngest date for marine fossils from the western Champlain Sea basin, i.e. west of 74°W. The Newington date of 11 200±100 years BP (GSC-2108) for *Hiatella arctica* (site 3, Fig. 2) from an elevation of 106 m and the dates of 11 000±90 years BP (GSC-3706) for *Balanus hameri* (Ascanius) from an elevation of 93 m, and 10 800±90 years BP, inner fraction (GSC-3743) for *Macoma balthica* (Linne) from an elevation of 95 m at the Navan site (No. 1, Fig. 2) suggest that the Dornie date is too young.
Table 6. Radiocarbon dates for marine and freshwater invertebrate fossils from the study area.

Positions of sites are shown in Figure 2.

<table>
<thead>
<tr>
<th>Site Number</th>
<th>Elevation (m a.s.l.)</th>
<th>Dated Material</th>
<th>Laboratory Number</th>
<th>$^{14}C$ Date (years BP)</th>
<th>$\delta^{13}C$ (‰)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Navan, Ontario</td>
<td>93</td>
<td>Balanus hameri (Ascanius)</td>
<td>GSC-3706</td>
<td>11 000±90</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>Bearbrook, Ontario</td>
<td>67</td>
<td>Balanus hameri</td>
<td>GSC-3983</td>
<td>$^{4} \text{C} 10 800±90$</td>
<td>$^{5} \text{C} 10 700±130$</td>
</tr>
<tr>
<td>3</td>
<td>Newington, Ontario</td>
<td>106</td>
<td>Hiatella arctica (Linne)</td>
<td>GSC-2108</td>
<td>11 200±100</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dornie, Ontario</td>
<td>107</td>
<td>Hiatella arctica</td>
<td>GSC-258</td>
<td>9910±150</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Glenroy, Ontario</td>
<td>79-80</td>
<td>Maia arenaria (Linne)</td>
<td>GSC-3845</td>
<td>10 700±100</td>
<td>-2.7</td>
</tr>
<tr>
<td>6</td>
<td>Russell, Ontario</td>
<td>70</td>
<td>More than one pelecypod species used for dating.</td>
<td>GSC-1553</td>
<td>10 000±320</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Crysler, Ontario</td>
<td>70</td>
<td>More than one pelecypod species used for dating.</td>
<td>GSC-2614</td>
<td>10 900±100</td>
<td>-2.1</td>
</tr>
<tr>
<td>8</td>
<td>Cornwall, Ontario</td>
<td>61</td>
<td>More than one pelecypod species used for dating.</td>
<td>3L-604C</td>
<td>10 600±200</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Bourget, Ontario</td>
<td>53</td>
<td>Lampsilis sp.</td>
<td>GSC-1968</td>
<td>10 200±90</td>
<td></td>
</tr>
</tbody>
</table>

1Geological Survey of Canada.
2Brock University Department of Geological Sciences.
3Lamont Laboratory.
4Inner fraction.
5Outer fraction.
*Freshwater pelecypod; other dated materials are marine.
Figure 2. Map of the radiocarbon dates for marine and freshwater invertebrate fossils from the study area.
The Chrysler (site 7, Fig. 2) and Russell (site 6, Fig. 2) dates of 10 900±100 years BP and 10 000±320 years BP respectively, for marine shells from the same elevation (70 m) are significantly different. The shells that yielded the older date may have been reworked from a higher elevation (Rodrigues and Richard, 1986).

The date of 10 200±90 years BP (GSC-1968) for the freshwater pelecypod *Lampsilis* sp. from an elevation of 53 m at the Bourget site (No. 9, Fig. 2) overlaps with the date of 10 000±320 years BP (GSC-1553) for *Macoma balthica* from an elevation of 70 m at site 6 and the date of 10 200±90 years BP, inner fraction (GSC-3907) for *Hiatella arctica* from an elevation of 69 m at the Bearbrook site (No. 2, Fig. 2). Rodrigues and Richard (1986) pointed out that the date for the freshwater pelecypod shells appears to be too old compared to dates for the marine pelecypod shells. They also suggested that the freshwater shells at the Bourget site may have been reworked from a higher elevation and the date of 10 200±90 years BP for the freshwater shells may not be incorrect.

DEGLACIATION OF OTTAWA-CORNWALL AREA

Prest (1970) concluded that the Laurentide Ice Sheet retreated from the upper St. Lawrence Valley in the south to the Ottawa Valley in the north. As the ice retreated, glacial lakes extended from the Lake Ontario basin into the western Champlain Sea basin. Clark and Karrow (1984) described a similar style of ice retreat for the western
Champlain Sea basin. The deglaciation model proposed by Prest (1970) explains the distribution of glaciolacustrine deposits ("varves") which overlie till and grade upwards into marine clay in the lower Ottawa Valley (Anderson et al., 1985 and Rodrigues and Gadd, 1986) and in the upper St. Lawrence Valley (Rodrigues and Richard, 1985).

Gadd (1980) proposed a model that requires a calving bay extending from the St. Lawrence estuary into the deeper Ottawa Valley while ice remained in the shallower upper St. Lawrence Valley and retained proglacial lakes in the Lake Ontario basin. The calving bay model explains the oldest radiocarbon dates (Fig. 3) for marine shells reported from the Ottawa Valley (>12 000 years BP) and the upper St. Lawrence Valley (<12 000 years BP).

Hillaire-Marcel (1977, 1981) and Karrow (1981) concluded that some of the radiocarbon dates for marine shells may be "too old" owing to the local influx of dead carbon from areas of carbonate-rich bedrock. Similarly, Anderson et al. (1985) considered the older radiocarbon dates from the Ottawa area as being too old. They proposed that the Champlain Sea commenced in the Ottawa Valley between 11 800 and 11 400 years BP based on the inferred ages for the correlative glacial lake phases of the Lake Ontario basin. Anderson (1986) proposed that the marine episode began between 11 700 and 11 200 years B.P. Chauvin et al. (1985) concluded that the calving bay in the lower St. Lawrence Valley did not advance west of Quebec City.
Figure 3. Map of the oldest radiocarbon dates for marine invertebrate fossils from the Ottawa, St. Lawrence, and Champlain Valleys.
METHODS

Samples for microfaunal analysis were collected from Late Quaternary deposits exposed in gravel and sand pits, drainage ditches, roadcuts, and along river banks. At each site the lithologic and macrofaunal data were recorded. The elevation for each site was estimated from 1:50 000 topographic maps with contour intervals of 25 feet. The macrofossil assemblages at the sites were assigned to macrofossil associations of Rodrigues and Richard (1983). Each macrofossil association is named after the dominant species of the assemblage.

The procedure for separating microfossils from the sediment samples was described by Rodrigues and Richard (1986). The samples were air-dried and a portion of the dried sample was weighed and disaggregated by soaking in water. The slurry was wet-sieved using a 62.5 μm sieve. The residue greater than 62.5 μm was cleaned ultrasonically, dried, weighed, and sieved using the 850, 425, 250, 180, 150, and 75 μm sieves. Foraminiferal tests and ostracode valves were picked from the 850 and 425 μm sieve fractions and were extracted from the 250, 180, 150, and 75 μm fractions by heavy liquid separation using a mixture of tetrabromoethane and acetone (density 1.90 g/cm³). Clay samples, which yielded small amounts of residue, were not floated. The foraminifers and ostracodes were picked from the floats and mounted on standard 60-grid micropaleontological slides. Foraminifers and ostracodes were also picked from the sinks and were mounted on separate slides. The number of
foraminiferal tests obtained from the sinks and floats are listed in Appendix I.

Foraminifers and ostracodes were identified to specific level using published references. Some foraminifers and ostracodes were identified to generic or family level. The number of specimens of each species or taxon was counted and the per cent abundance of each species or taxon in the samples were calculated by computer. The ostracode data were not analyzed quantitatively because ostracodes were not very abundant in many of the samples. The foraminiferal data base was analyzed quantitatively using the Fortran program, CLUSTR (Davis, 1973), which arranges the samples into groups characterized by the same dominant foraminiferal species or taxa. The sample groupings are then used as mappable faunal units.

The per cent abundances of each foraminiferal taxon in the samples were used as input data for the Fortran program CLUSTR which consists of three subroutines (DIST, WPGA, and DENDRO). Subroutine DIST calculates the correlation matrix of distance coefficients using the equation

\[ d_{ij} = \sqrt{\frac{\sum_{k=1}^{m} (X_{ik} - X_{jk})^2}{m}} \]

where \( d_{ij} \) is the distance coefficient, \( X_{ik} \) and \( X_{jk} \) are the per cent abundances of taxon \( k \) in samples \( i \) and \( j \), respectively, and \( m \) is the number of taxa used in the analysis. The values of the distance coefficient (\( d_{ij} \)) are always greater than or equal to 0.0. If \( d_{ij} \) is 0.0 then samples \( i \) and \( j \)
contain the same species or taxa with the same per cent abundances. If the per cent abundances of species or taxa are not equal then $d_{ij}$ is greater than 0.0. Subroutine WPGA performs weighted pair group cluster analysis and arranges the samples into groups based on similarities. The samples that are most similar are grouped first and the other samples are grouped in subsequent iterations. Subroutine DENDRO displays the results of the weighted pair group cluster analysis in the form of a dendrogram. Each cluster or group of samples are characterized by the same dominant species or taxa and represents a foraminiferal association. The associations are named after the dominant species or taxa which are characterized by mean abundances arbitrarily set at greater than 6%.

Foraminifer and ostracode species diversities were calculated using the Shannon-Wiener Information Function,

$$H(S) = - \sum_{i=1}^{S} p_i \ln p_i ,$$

where $H(S)$ is the diversity, $S$ is the number of species or taxa in the sample, $p_i$ is the proportion of the $i$th species or taxon, and $\ln$ is the natural logarithm. The contribution of rare species or taxa is minimized by using species proportions. When $S$ is equal to 1, $H(S)$ has a value of 0.00 (minimum value). The maximum value of $H(S)$ for a given $S$ occurs when the species or taxa have the same per cent abundance.

Descriptions of the foraminiferal and ostracode species
and taxa are presented under Systematic Paleontology. The dominant macrofaunal, foraminiferal, and ostracode species and taxa are illustrated in Plates 1 to 6. The line drawings of the foraminifers in Plates 1 were sketched from the scanning electron micrographs and photomicrographs illustrated by Rodrigues and Richard (1986). Line drawings of the macrofossils (Plates 5 and 6) were sketched from specimens collected from this study and also from photographs illustrated by Wagner (1984). The foraminiferal and ostracode photomicrographs (Plates 2, 3, and 4) were obtained by use of the SEMCO nanolab 7 scanning electron microscope. Illustrated specimens from this study were deposited in the Department of Geology at the University of Windsor and were assigned UWJM86 hypotype numbers which are given in the plate descriptions.

RESULTS

One hundred twenty-five samples were collected from 87 sites in the study area. Thirty-three samples from 28 sites yielded microfaunal assemblages with more than 100 foraminiferal tests. The macrofaunal, microfaunal, and lithologic data for the samples are listed in Table 7. Locations of the samples are shown in Figure 4 and in Maps 1 to 4 (in pocket).

Macrofaunal Associations

Six marine invertebrate macrofaunal associations are recognized for the study area. Five of the macrofaunal associations are characterized by pelecypods and the other is characterized by the cirriped *Balanus hameri*. The
Table 7. Macrofaunal, microfaunal, and lithologic data for samples.

<table>
<thead>
<tr>
<th>Map Sheet</th>
<th>Sample Number</th>
<th>Elevation (m.s.l.)</th>
<th>Lithology</th>
<th>Foraminiferida</th>
<th>Ostracoda</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1</td>
<td>89</td>
<td>Pebble Clay</td>
<td>Hiatella antice</td>
<td>23.46</td>
<td>283</td>
</tr>
<tr>
<td>R-2</td>
<td>89</td>
<td>Pebble Clay</td>
<td>Hiatella antice</td>
<td>26.10</td>
<td>3893</td>
</tr>
<tr>
<td>R-3</td>
<td>89</td>
<td>Pebble Clay</td>
<td>Hiatella antice</td>
<td>25.10</td>
<td>1620</td>
</tr>
<tr>
<td>R-4</td>
<td>89</td>
<td>Pebble Clay</td>
<td>Hiatella antice</td>
<td>25.80</td>
<td>1616</td>
</tr>
<tr>
<td>R-5</td>
<td>89</td>
<td>Pebble Clay</td>
<td>Hiatella antice</td>
<td>26.50</td>
<td>1338</td>
</tr>
<tr>
<td>R-6</td>
<td>89</td>
<td>Pebble Clay</td>
<td>Hiatella antice</td>
<td>26.70</td>
<td>148</td>
</tr>
</tbody>
</table>

1. Foraminiferida notations are for samples from different levels as a site.
2. Elevations are interpreted from 1:5000 topographic maps with a contour interval of 25 feet.
3. Elevations are not given for samples that are less than 10 m. of the lowest sample as a site.
4. Diversities are listed for samples containing more than 85 valves.
5. Microfossils were not observed at the level sampled.
Figure 4. Sample sites in the Russell, Alexandria, Winchester, and Cornwall map areas.
pelecypod associations are: *Hiatella arctica*, *Macoma balthica*, *Hiatella arctica-Macoma balthica*, *Portlandia arctica*, and *Mytilus edulis* associations.

Two other pelecypod associations have been reported from the study area. The marine *Mya arenaria* association occurs in the Cornwall and Alexandria map areas, and the freshwater *Lampsilis* association occurs in the Russell and Cornwall areas (Rodrigues and Richard, 1983).

**Foraminiferal Associations**

Fifty-three benthonic foraminiferal taxa were identified and a total of 52,617 foraminiferal tests were counted. The number of tests per sample ranged from 148 to 6755 and the number of taxa per sample ranged from 5 to 30. Foraminiferal species diversity $[H(S)]$ ranged from 0.25 to 1.93. The number of tests counted for each foraminiferal taxon is shown in Table 8 and the per cent abundance of each taxa is shown in Table 9. Eight sample groupings (clusters) are recognized from weighted pair group cluster analysis of 33 samples (Fig. 5). Each sample grouping represents one foraminiferal association and is named after the dominant species (Table 10).

Association 1, *Elphidium clavatum*-dominant (Fig. 6), consists of one sample (R-2C) from site R-2 in the Russell map area. Foraminifer diversity $[H(S)]$ for sample R-2C (clay) is 0.51. Association 1 is accompanied by the *Hiatella arctica* association.

Association 2, *Haynesina orbicularis*-dominant (Fig. 6), occurs in sand and pebbly sand in the Winchester map area.
Table 8. Counts for benthonic foraminiferal taxa in samples from the Russell, Alexandria, Winchester and Cornwall map areas.

<table>
<thead>
<tr>
<th>TAXON</th>
<th>Sample Number</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>123</td>
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<tr>
<td>2.</td>
<td>123</td>
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<tr>
<td>3.</td>
<td>123</td>
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<tr>
<td>4.</td>
<td>123</td>
</tr>
<tr>
<td>5.</td>
<td>123</td>
</tr>
</tbody>
</table>

Total number of specimens: 123
Total number of species: 10
Table 9. Per cent abundance of the benthonic foraminiferal taxa.

<table>
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<td>0.12</td>
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<td>0.12</td>
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<td>0.12</td>
<td>0.12</td>
<td>0.24</td>
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</tbody>
</table>

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Figure 5. Dendrogram of weighted pair group cluster analysis of 33 samples.
Table 10. Mean per cent abundance of dominant benthonic foraminiferal species.

<table>
<thead>
<tr>
<th>Foraminiferal Association</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cassidulina reniforme</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.5</td>
<td>75.1</td>
<td>43.9</td>
<td>7.4</td>
</tr>
<tr>
<td><em>Ephidium clavatum</em></td>
<td>89.7</td>
<td>6.3</td>
<td>13.8</td>
<td>10.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ephidium incertum/asklandi</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ephidium sp.</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.0</td>
<td>8.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hainesina orbicularis</em></td>
<td></td>
<td>92.9</td>
<td>75.5</td>
<td>57.0</td>
<td>45.1</td>
<td></td>
<td>19.1</td>
<td>21.0</td>
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<table>
<thead>
<tr>
<th>Number of samples</th>
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<th>3</th>
<th>11</th>
<th>3</th>
<th>2</th>
<th>7</th>
<th>2</th>
<th>4</th>
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<tbody>
<tr>
<td>Number of taxa per sample</td>
<td>11</td>
<td>5-8</td>
<td>8-15</td>
<td>9-15</td>
<td>12-30</td>
<td>12-25</td>
<td>15-20</td>
<td>12-20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foraminifer diversity [H(S)]</th>
<th>0.51 to 0.25</th>
<th>0.73 to 0.37</th>
<th>1.32 to 1.24</th>
<th>1.87 to 1.53</th>
<th>1.92 to 1.43</th>
<th>1.41 to 1.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean foraminifera diversity [H(S)]</td>
<td>0.51</td>
<td>0.32</td>
<td>0.96</td>
<td>1.43</td>
<td>1.90</td>
<td>1.03</td>
</tr>
</tbody>
</table>
Figure 6. Map showing the distribution of the foraminiferal associations, macrofossil associations and ostracode assemblages for the study area.
Foraminifer diversity for the three samples of Association 2, 0.25 to 0.37, is the lowest for the samples used in this study. Association 2 is accompanied by the *Hiatella arctica* and *Macoma balthica* associations.

Association 3, *Haynesina orbicularis-Elphidium clavatum*-dominant (Fig. 6) occurs in sandy substrates in the Winchester, Cornwall, and Alexandria map areas and is accompanied by the *Hiatella arctica*, *Macoma balthica*, and *Hiatella arctica-Macoma balthica* associations. The diversity for the eleven samples of Association 3 ranges from 0.73 to 1.24 with a mean value of 0.96.

Association 4, *Haynesina orbicularis-Elphidium clavatum-Elphidium* sp. - *Elphidium incertum/asklundi*-dominant (Fig. 6) is present in the Winchester, Cornwall, and Alexandria map areas. Diversity for the three samples of Association 4 range from 1.32 to 1.53 with a mean value of 1.43. Association 4 is accompanied by the *Hiatella arctica* association in pebbly sand, pebbly sandy clay, and sandy clay.

Association 5, *Haynesina orbicularis-Cassidulina reniforme-Elphidium clavatum-Elphidium* sp.-dominant (Fig. 6) occurs in sandy clay containing the *Hiatella arctica* association in the Russell map area. Diversity for the two samples of Association 5 are 1.87 and 1.92 with a mean value of 1.90.

Association 6, *Cassidulina reniforme*-dominant (Fig. 6), is present in the Winchester, Russell, Cornwall, and Alexandria map areas and is accompanied by the *Balanus hameri* association in pebbly sandy clay and the *Portlandia arctica* association
in clay. Diversity for the seven samples of Association 6 ranges from 0.46 to 1.43 with a mean value of 1.03. The abundance of Elphidium clavatum, Haynesina orbicularis, and Islandiella helenae is greater than 6% in some samples of Association 6.

Association 7, Cassidulina reniforme-Elphidium clavatum-
Haynesina orbicularis-dominant (Fig. 6), occurs in clay containing the Portlandia arctica association in the Winchester map area. Diversity of the two samples of Association 7 are 1.20 and 1.27 with a mean value of 1.24.

Association 8, Elphidium clavatum-Haynesina orbicularis-
Cassidulina reniforme-Elphidium incertum/asklundi-dominant (Fig. 6), is present in the Russell and Alexandria map areas. Diversity for the four samples of Association 8 ranges from 1.41 to 1.93 with a mean value of 1.62. Association 8 is accompanied by the Hiatella arctica association in pebbly clay and by the Mytilus edulis and Portlandia arctica associations in clay.

**Ostracode Assemblages**

Ostracodes were not very abundant in the samples from the study area. Only 1195 valves were counted. The number of valves per sample ranged from 0 to 389, and the number of taxa per sample ranged from 0 to 16. Five samples contained more than 80 valves (Fig. 6). The ostracode species diversity \([H(S)]\) for the five samples ranged from 1.48 to 2.11. The number of valves for each ostracode species from the samples is shown in Table 11. The dominant ostracode species and
Table II. Counts for ostracode species in samples from the Russell, Alexandria, Winchester and Cornwall map areas.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>SAMPLE NUMBER</th>
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<tbody>
<tr>
<td></td>
<td>R-2A</td>
</tr>
<tr>
<td>1. Acrotholpaexterioris</td>
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</tr>
<tr>
<td>2. Acrotholpaltaeniata</td>
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<td>3. Acrotholpaltaeniata</td>
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<td>4. Acrotholpaltaeniata</td>
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<td>5. Acrotholpaltaeniata</td>
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<td>14. Acrotholpaltaeniata</td>
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<tr>
<td>23. Acrotholpaltaeniata</td>
<td>1</td>
</tr>
<tr>
<td>24. Acrotholpaltaeniata</td>
<td>1</td>
</tr>
</tbody>
</table>

Total number of valves: 289
Total number of species: 21
accompanying foraminiferal and macrofaunal associations are shown in Table 12.

RECENT DISTRIBUTION OF SOME SPECIES OF THE FAUNAL ASSOCIATIONS

Modern distribution data for the dominant species of the macrofaunal and foraminiferal associations and ostracode assemblages of the study area can be used to infer paleosalinity and paleotemperature. The data are summarized in Appendices II to VI. Some of the references listed in the Appendices have not been used in the discussion below. The references not used include those that named the dominant foraminiferal species as other genera and species and also those which did not include illustrations of the foraminifers.

*Islandiella helenae* commonly occurs in cold (-2° to 4°C) and relatively high salinity (30 to 34‰) water along the continental margin of eastern Canada, in the Gulf of St. Lawrence, and in the Canadian Arctic (Appendix II). Rodrigues and Hooper (1982b) reported large numbers of *Islandiella helenae* (average abundance of 42.5%) from the Gulf of St. Lawrence in cold (-2° to 2.3°C) and high salinity (31.4 to 33.6‰) water at depths of 73 to 142 m. *Islandiella norcrossi* (Appendix III) also occurs along the continental margin of eastern Canada, in the Gulf of St. Lawrence and in the Canadian Arctic. *Islandiella norcrossi* lives in water with similar temperature and salinity ranges as those reported for *Islandiella helenae*.

*Cassidulina reniforme* (Appendix IV) has been reported on the Labrador Shelf, in the Gulf of St. Lawrence, Hudson
<table>
<thead>
<tr>
<th>Number</th>
<th>Foraminiferal Association</th>
<th>Macrofaunal Association</th>
<th>Ostracode Assemblage</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Elphidium clavatum</td>
<td>Hiattella arctica</td>
<td>Saricocytherida brasii</td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cytherellopteron latissimum</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Saricocytherida punctillata</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Hagensina orbicularis</td>
<td>Hiattella arctica</td>
<td>Mecocyclammina sotobana</td>
<td>Pebbly Sandy Clay</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td></td>
<td>Saricocytherida punctillata</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elphidium sp.</td>
<td>Hiattella arctica</td>
<td>Cytheromorpha macchianogi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elphidium aceratum/actuali</td>
<td>Hiattella arctica</td>
<td>(Ostracodes are rare)</td>
<td>Pebbly Sandy Clay</td>
</tr>
<tr>
<td>3</td>
<td>Hagensina orbicularis</td>
<td>Hiattella arctica</td>
<td>Macoma baltica</td>
<td>Pebbly Clay Sand</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Macoma baltica</td>
<td>(Ostracodes are rare)</td>
<td>Pebbly Clay Sand</td>
</tr>
<tr>
<td>2</td>
<td>Hagensina orbicularis</td>
<td>Hiattella arctica</td>
<td>Mucilus edulis</td>
<td>Pebby Clay Sand</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mucilus edulis</td>
<td>(Ostracodes are rare)</td>
<td>Pebby Clay Sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clay</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Elphidium clavatum</td>
<td>Hiattella arctica</td>
<td>Saricocytherida punctillata</td>
<td>Clayey Sand</td>
</tr>
<tr>
<td></td>
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<td>Hiattella arctica</td>
<td>Mecocyclammina sotobana</td>
<td></td>
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<td></td>
<td>Cassidulina reniforme</td>
<td>Hiattella arctica</td>
<td>Saricocytherida punctillata</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elphidium incertum/actuali</td>
<td>Hiattella arctica</td>
<td>Mecocyclammina sotobana</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Hiattella arctica</td>
<td>Cytheromorpha macchianogi</td>
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<tr>
<td></td>
<td></td>
<td>Hiattella arctica</td>
<td>Cytheromorpha macchianogi</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Hagensina orbicularis</td>
<td>Hiattella arctica</td>
<td>Pectinolida stelligera</td>
<td>Sandy Clay</td>
</tr>
<tr>
<td></td>
<td>Cassidulina reniforme</td>
<td>Hiattella arctica</td>
<td>Cytheromorpha macchianogi</td>
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<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Hiattella arctica</td>
<td>Cytheromorpha macchianogi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elphidium sp.</td>
<td>Hiattella arctica</td>
<td>Cytheromorpha macchianogi</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cassidulina reniforme</td>
<td>Pectinolida stelligera</td>
<td>(Ostracodes are rare)</td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td>Cassidulina reniforme</td>
<td>Pectinolida stelligera</td>
<td>(Ostracodes are rare)</td>
<td>Pebby Sandy Clay</td>
</tr>
</tbody>
</table>
Bay, the Canadian and Greenland Arctic, off the coast of Iceland, and on the Norwegian continental margin. *Cassidulina reniforme* occurs in water that has a salinity of 28 to 35%. It appears that *Cassidulina reniforme* can tolerate a relatively wide range of temperature, e.g. Rodrigues and Hooper (1982b) reported *Cassidulina reniforme* from the Gulf of St. Lawrence in water which has a temperature range of -2°C to more than 12°C. Most of the reported occurrences of *C. reniforme* however, are from waters which have a temperature range of -2°C to 6°C.

*Haynesina orbicularis* (Appendix V) occurs in shallow waters of the Gulf of St. Lawrence, Hudson Bay, the Canadian Arctic, and Prudhoe Bay, Alaska. *Haynesina orbicularis* was reported from waters which have a wide salinity range, 11 to 33%. McRoberts (1968) and Tapley (1969) reported that the abundance of *Elphidium orbiculare* (= *Haynesina orbicularis* of this paper) was highest in water with salinity greater than 20%. The temperature range reported for *Haynesina orbicularis* is -2°C to 13.5°C.

*Elphidium clavatum* (Appendix VI) occurs in the Gulf of St. Lawrence, Gulf of Alaska, Prudhoe Bay, Alaska, Beaufort Sea, on the continental shelf of eastern Canada, in the Arctic Ocean, and Baltic Sea. Wilkinson (1979) described the distribution of *Elphidium clavatum clavatum* Cushman as arctic-subarctic. *Elphidium clavatum* is considered to be euryhaline (11 to 35%) and eurythermal (-2°C to >12°C).

Very few references in the literature discuss the
temperature and salinity ranges for the macrofaunal and ostracode species. Appendix VII lists the modern and fossil occurrences of the dominant pelecypod and cirriped species. *Portlandia arctica* (Gray) has been reported from the Canadian Arctic and Beaufort Sea. Ellis (1960) observed *Portlandia arctica* living only in mud substrates where the water temperatures were less than 0°C and salinities were near 32‰. Rodrigues and Richard (1986) concluded that *Portlandia arctica* was euryhaline in the Champlain Sea.

*Hiatella arctica* occurs in Baffin Bay, north Atlantic Ocean, Arctic Ocean, Greenland, and west coast of Canada. Bousfield (1955) observed *Hiatella arctica* (*Saxicava arctica* of Bousfield) in the Miramichi Estuary, New Brunswick where the salinity was 12.5 to 25‰.

*Mytilus edulis* Linne was reported from the Canadian Arctic, off Newfoundland, and the west coast of Canada. Bousfield (1955) observed *Mytilus edulis* in the Miramichi Estuary, New Brunswick, where the salinity was 15 to 25‰. Ristich et al. (1977) reported *Mytilus edulis* in the Hudson River Estuary, New York, where the salinity was 18 to 30‰.

*Macoma balthica* (Linne) was reported from the Canadian Arctic, James Bay, Beaufort Sea, west coast of Canada, and the Miramichi Estuary, New Brunswick. Bousfield (1955) observed *Macoma balthica* from the Miramichi Estuary in water with salinity ranging from 4 to 18.5‰.

*Mya arenaria* Linne has been reported from the Miramichi Estuary of New Brunswick, the Hudson River Estuary, New York,
and Chaleur Bay. Bousfield (1955) and Ristich et al. (1977) reported *Mya arenaria* in waters with salinities as low as 5%. Recent occurrences for *Balanus hameri* (Ascanius) were not found in the literature. Hillaire-Marcel (1980) observed *Balanus hameri* in the Quebec portion of the Champlain Sea basin where he concluded that *B. hameri* colonized deep water environments with a temperature of about 0°C and salinity of about 30‰. Rodrigues and Richard (1986) concluded that *Balanus hameri* colonized the highest salinity bottom water (30 to 34‰) that was present in the western Champlain Sea basin.

The discussion above for the macrofauna indicates that *Portlandia arctica*, *Hiatella arctica*, *Mytilus edulis*, and *Macoma balthica* have an arctic – subarctic distribution and *Mya arenaria* has a boreal distribution. *Balanus hameri* is restricted to relatively high-salinity water (>30‰) and *Hiatella arctica*, *Mytilus edulis*, *Macoma balthica*, and *Portlandia arctica* can tolerate wider salinity ranges. *Mya arenaria* is capable of tolerating water with salinities as low as 5‰.

The dominant ostracode taxa (Appendix VIII) appear to be euryhaline. Congeners of *Cytheropteron* are reported to inhabit water of near normal marine conditions (Whatley and Masson, 1979). Rosenfeld (1977) concluded that *Cytheropteron latissimum* can tolerate salinities as low as 14‰.
PALEOSALINITY AND PALEOTEMPERATURE ESTIMATES FOR THE FAUNAL ASSOCIATIONS

Paleosalinity and paleotemperature for the faunal associations were obtained from the modern distribution data discussed above. The *Cassidulina reniforme*-dominant Association (No. 6, Table 13) colonized the deeper parts of the study area where the temperature was less than or equal to 4°C and salinity ranged from 30 to 34%. Association 6 is accompanied by the high-salinity *Balanus hamei* associations. The abundance of the high-salinity *Islandiella helenae* (mean per cent abundance 5.6%) is highest in Association 6.

The *Cassidulina reniforme*-Elphidium clavatum-*Haynesina orbicularis*-dominant Association (No. 7, Table 13), the *Haynesina orbicularis*-Cassidulina reniforme-Elphidium clavatum-*Elphidium* sp.-dominant Association (No. 5), and the *Elphidium clavatum*-Haynesina orbicularis-Cassidulina reniforme-Elphidium incertum/asklundi-dominant Association (No. 8) inhabited deep, cold (0°C to 13°C) water with a salinity range of 25 to 30%. The abundance of *Islandiella helenae* (mean per cent abundance 4.4%) and that of *Cassidulina reniforme* (mean per cent abundance 18%) are lower in Associations 5, 7, and 8 than in Association 6. Therefore, Associations 5, 7, and 8 colonized lower-salinity water (25 to 30%) by comparison with Association 6 (30 to 34%). The foraminiferal succession observed at site R-2 (Fig. 6) shows Association 5 overlying Association 6, and the foraminiferal succession at the Casselman site (Table 5) shows that Associations 5 and 7 replace Association 6. The successions
Table 13. Summary of the foraminiferal associations and accompanying macrofaunal associations, ostracode assemblages, and their inferred paleosalinity.

<table>
<thead>
<tr>
<th>Foraminiferal Association</th>
<th>Macrofaunal Association</th>
<th>Ostracode Assemblage</th>
<th>Lithology</th>
<th>Inferred Salinity (‰)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humber</td>
<td>Dominant Taxa</td>
<td>Diversity (H[S])</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Elphidium clavatum</td>
<td>0.510</td>
<td>Miastella acutic</td>
<td>Saccamargarida buadi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Saccamargarida ocellatum</td>
</tr>
<tr>
<td>2</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 0.747 to 0.871</td>
<td>Miastella acutic</td>
<td>Saccamargarida ocellatum</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mean: 0.620</td>
<td></td>
<td>Saccamargarida ocellatum</td>
</tr>
<tr>
<td></td>
<td>Elphidium sp.</td>
<td></td>
<td></td>
<td>Saccamargarida ocellatum</td>
</tr>
<tr>
<td>3</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 1.317 to 1.532</td>
<td>Miastella acutic</td>
<td>Metacrickipecten inletum</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mean: 1.425</td>
<td></td>
<td>Metacrickipecten inletum</td>
</tr>
<tr>
<td></td>
<td>Elphidium inexcavatum/astlundi</td>
<td></td>
<td></td>
<td>Metacrickipecten inletum</td>
</tr>
<tr>
<td>4</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 0.747 to 0.871</td>
<td>Miastella acutic</td>
<td>Saccamargarida ocellatum</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mean: 0.620</td>
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<td>Saccamargarida ocellatum</td>
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<tr>
<td></td>
<td>Elphidium sp.</td>
<td></td>
<td></td>
<td>Saccamargarida ocellatum</td>
</tr>
<tr>
<td>5</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 1.871 to 0.871</td>
<td>Miastella acutic</td>
<td>Cerithium oxyrhynchum</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mean: 1.894</td>
<td></td>
<td>Cerithium oxyrhynchum</td>
</tr>
<tr>
<td></td>
<td>Elphidium sp.</td>
<td></td>
<td></td>
<td>Cerithium oxyrhynchum</td>
</tr>
<tr>
<td>6</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 0.223 to 1.248</td>
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<td></td>
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<td>Mean: 1.025</td>
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<td></td>
<td>Elphidium sp.</td>
<td></td>
<td></td>
<td>Portlandia arctica</td>
</tr>
<tr>
<td>7</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 1.987 to 1.270</td>
<td>Portlandia arctica</td>
<td>(Ostracodes are rare)</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mean: 1.234</td>
<td></td>
<td>Portlandia arctica</td>
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<td>Portlandia arctica</td>
</tr>
<tr>
<td>8</td>
<td>Cassidulina tenuisforme</td>
<td>Range: 1.871 to 0.871</td>
<td>Miastella acutic</td>
<td>Portlandia arctica</td>
</tr>
<tr>
<td></td>
<td>Elphidium clavatum</td>
<td>Mean: 1.894</td>
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<td>Portlandia arctica</td>
</tr>
<tr>
<td></td>
<td>Elphidium sp.</td>
<td></td>
<td></td>
<td>Portlandia arctica</td>
</tr>
</tbody>
</table>

Pebbly Sandy Clay 30 - 34
show that Associations 5, 7, and 8 colonized lower salinity water compared to Association 6. The cold subarctic (0° to 13°C) *Portlandia arctica*, *Hiatella arctica* and *Mytilus edulis* pelecypod associations and the *Cytheropteron* spp. ostracode assemblages accompanied Associations 5, 7, and 8.

The *Elphidium clavatum*-dominant Association (No. 1, Table 13), the *Haynesina orbicularis*-dominant Association (No. 2), the *Haynesina orbicularis*-Elphidium clavatum-dominant Association (No. 3), and the *Haynesina orbicularis*-Elphidium clavatum-Elphidium sp.-*Elphidium incertum/asklundi*-dominant Association (No. 4) colonized shallower, cold (0° to 13°C) water with a salinity of 15 to 25%. The abundance of *Islandiella helenae* (mean per cent abundance 3.9%) and that of *Cassidulina reniforme* (mean per cent abundance 2.3%) are lower in Associations 1, 2, 3, and 4 than in Associations 5, 6, 7, and 8. Therefore, Associations 1, 2, 3, and 4 colonized lower-salinity water (15 to 25%). The faunal successions also support the lower salinity range for Associations 1 to 4, e.g. Association 3 was observed at the top of the sections at site C-2 (Fig. 6) the Bearbrook site (Table 4), and the Casselman site (Table 5). Association 1 occurred at the top of the section at site R-2 (Fig. 6) and an association (*Elphidium sp.*-Elphidium clavatum-Haynesina orbicularis-dominant) comparable to Association 4 occurred at the top of the Navan section (Table 3). The cold subarctic (0° to 13°C) *Hiatella arctica*, and *Macoma balthica* pelecypod associations accompanied Associations 1, 2, 3, and
4. Association 1 was accompanied by the *Sarsicytheridea bradii-Cythereopteron latissimum-Sarsicytheridea punctillata*-dominant ostracode assemblage and Association 4 was accompanied by the *Heterocyprideis sorbyana-Sarsicytheridea punctillata-Cytheromorpha macchesneyi*-dominant ostracode assemblage. *Cythereopteron latissimum* and *Cytheromorpha macchesneyi* are associated with lower-salinity water (Appendix VIII).

The distribution of the foraminiferal and macrofaunal associations and ostracode assemblages is shown in Figure 7 and the inferred salinity ranges for the associations are listed in Table 13. The temperature ranges for the foraminiferal associations excluding Association 6 can only be interpreted as cold subarctic (0° to 13°C) because all the dominant foraminifers and the accompanying ostracodes, and pelecypods have an arctic - subarctic distribution, and all are eurythermal.

**DISCUSSION**

Rodrigues and Richard (1983, 1985, and 1986) and Rodrigues (1987) concluded that the distribution of the invertebrate macrofossils and microfossils from the western Champlain Sea basin was related to the chemical and physical properties (salinity and temperature) of the bottom water and substrate. The results from this study support the conclusions of Rodrigues and Richard (1983, 1985, and 1986), and Rodrigues (1987).

Cronin (1979a) recognized two foraminiferal biofacies from the Champlain Sea basin. Associations 1, 2, 3, and 4
Figure 7. Map showing the distribution of the foraminiferal associations, macrofossil associations, ostracode assemblages and their inferred paleosalinity.
of this study which are characterized by *Elphidium clavatum*, *Haynesina orbicularis*, *Elphidium sp.*, and *Elphidium incertum/asklundi* are comparable to Cronin's shallow-water Biofacies 1 which is characterized by *Protelphidium orbiculare* (= *Haynesina orbicularis*), *Elphidium incertum* (= *Elphidium incertum/asklundi*), *Elphidium excavatum clavata* (= *Elphidium clavatum*), *Elphidium albiumbilicatum* (Weiss) (= *Elphidium sp.*) and *Elphidium subarcticum* Cushman. The macrofossils associated with Biofacies 1 included *Macoma balthica*, *Mya arenaria*, *Mytilus edulis* and *Hiatella arctica*. Associations 5, 6, 7, and 8 of this study which are characterized by *Cassidulina reniforme*, *Haynesina orbicularis*, *Elphidium clavatum*, *Elphidium incertum/asklundi*, and *Elphidium sp.* are comparable to Cronin's deeper-water Biofacies 2 which is characterized by *Cassidulina crassa* (= *Cassidulina reniforme*), *Islandiella helenae* and *Elphidium excavatum forma clavata* (= *Elphidium clavatum*). The macrofossils associated with Biofacies 2 include *Portlandia arctica* and *Balanus haueri*.

Cronin (1979b) concluded that foraminifer and ostracode species diversity \([H(S)]\) was related to salinity, i.e. diversity was lowest in low-salinity water and highest in high salinity water. Kovac (1985) and Rodrigues and Richard (1986) concluded that foraminiferal species diversity was not directly related to salinity. The results from this study support the conclusions by Kovac (1985) and Rodrigues and Richard (1986). The foraminiferal species diversity for the
high salinity (30 to 34%) Association 6 ranged from 0.46 to 1.43, whereas diversity of the Association 4 (salinity 15 to 25%) ranged from 1.32 to 1.53.

Rodrigues and Richard (1986) recognized seven foraminal associations from the Russell and Winchester map areas. Association 6 of this study, which is characterized by *Cassidulina reniforme*, is comparable to their Association 6 (*Cassidulina reniforme-Islandiella helenae-Haynesina orbicularris-dominant*). Association 7 of this study has the same dominant species as their Associations 4 and 7 (*Elphidium clavatum, Cassidulina reniforme, and Haynesina orbicularis*). Association 8 of this study which is characterized by *Elphidium clavatum, Haynesina orbicularis, Cassidulina reniforme, and Elphidium incertum/asklundi* is comparable to their Association 5 (*Elphidium clavatum-Elphidium incertum/asklundi-Haynesina orbicularis-dominant*). Association 3 is identical to their *Haynesina orbicularis-Elphidium clavatum-dominant Association 3*. Association 4 of this study (*Haynesina orbicularis-Elphidium clavatum-Elphidium sp.-Elphidium incertum/asklundi-dominant*) is comparable to their Association 2 which is characterized by *Elphidium sp.*, *Haynesina orbicularis*, and *Elphidium clavatum*. Rodrigues and Richard (1986) did not observe Association 1 (*Haynesina orbicularis-dominant*) and Association 5 (*Haynesina orbicularis-Cassidulina reniforme-Elphidium clavatum-Elphidium sp.*) of this study.
A sequence of events following the retreat of the Laurentide Ice Sheet was described by Rodrigues and Richard (1985) and Rodrigues (1986, 1987) for the western Champlain Sea basin. The sequence of events is summarized below.

The pre-Champlain Sea freshwater environment was characterized by varve-like rhythmtes containing the Candona ostracode association. Anderson et al. (1985) concluded that the rhythmtes are related to a glaciolacustrine phase preceding marine inundation of the western Champlain Sea basin. During the marine episode cold (subarctic) water, salinity (30 to 34‰) was present in the deeper parts of the Champlain Sea and was overlain by cold (subarctic) lower-salinity water (<30‰) at shallower depths. During the later part of the marine episode warmer (boreal) low-salinity water was present in some parts of the sea. The boreal, low-salinity water was characterized by Mya arenaria. As the sea shoaled the marine waters became progressively less saline and freshwater eventually replaced marine water. Lampsilis spp. colonized post-Champlain Sea freshwater environments east of Ottawa.

The macrofaunal and microfaunal data reported in this study and in the literature support the sequence of events described above. Pre-Champlain Sea freshwater varve-like rhythmtes containing a freshwater ostracode fauna were observed at the Bearbrook site (Map 1, in pocket and Table 4) and at the Casselman site (Map 1, in pocket and Table 5). High salinity water (25 to 34‰) characterized by Cassidulina
reniforme, Elphidium clavatum, Haynesina orbicularis, Elphidium sp., and Elphidium incertum/asklundi-dominant Associations 5, 6, 7, and 8 was present in the deeper parts of the study area (Table 13 and Fig. 7). Lower-salinity water (15 to 25‰) characterized by Haynesina orbicularis, Elphidium clavatum, Elphidium sp., and Elphidium incertum/asklundi-dominant Associations 1, 2, 3, and 4 was present in the shallower parts of the study area (Table 13, and Fig. 7). The boreal, low-salinity (<20‰) Mya arenaria was reported from beach deposits in the Cornwall and Alexandria map areas (Maps 2 and 4, in pocket) by Rodrigues and Richard (1983). The Post-Champlain Sea freshwater pelecypod Lampsilis was reported in the Russell map area by Gadd (1976) and in the Cornwall map area by Terasmae (1965) and Rodrigues (1987).

SUMMARY AND CONCLUSIONS

The distribution of the marine invertebrate macrofossils and microfossils of the Russell, Alexandria, Winchester and Cornwall map areas is related to salinity and temperature of the Champlain Sea. The marine Balanus hameri, Hiattella arctica, Macoma balthica, Hiattella arctica-Macoma balthica, Mytilus edulis and Portlandia arctica macrofaunal associations are present in marine deposits of the study area. The Portlandia arctica association was observed only in clay, the Balanus hameri association (based on one sample) in pebbly sandy clay, the Mytilus edulis association (based on one sample) in clay, and the other macrofaunal associations occurred in coarse—and fine-grained substrates. The Balanus
hameri association inhabited the deeper parts of the basin where the water was cold \((\leq 4^\circ C)\) with a salinity of 30 to 34\%. The other macrofaunal associations colonized water with a wider salinity range, e.g., *Portlandia arctica* association (25 to 34\%), *Hiatella arctica* association (15 to 30\%), *Mytilus edulis* association (25 to 30\%), and *Macoma balthica* association (15 to 25\%).

Weighted pair group cluster analysis for 33 samples yielded eight foraminiferal associations. The most abundant foraminiferal species of the associations were *Cassidulina reniforme*, *Elphidium clavatum*, and *Haynesina orbicularis*. The *Cassidulina reniforme*-dominant Association (No. 6) occupied the deeper parts of the basin where the water was cold \((\leq 4^\circ C)\) and salinity ranged from 30 to 34\%. The abundance of *Islandiella helenae* was highest in Association 6. The *Cassidulina reniforme*-Elphidium clavatum-Haynesina orbicularis-dominant (No. 7), the Haynesina orbicularis-Cassidulina reniforme-Elphidium clavatum-Elphidium sp.-dominant (No. 5) and the Elphidium clavatum-Haynesina orbicularis-Cassidulina reniforme-Elphidium incertum/asklundi-dominant (No. 8) also occupied the cold \((0^\circ \text{ to } 13^\circ C)\), deeper parts of the basin where the salinity was 25 to 30\%. The Elphidium clavatum-dominant (No. 1), the Haynesina orbicularis-dominant (No. 2), the Haynesina orbicularis-Elphidium clavatum-dominant (No. 3), and the Haynesina orbicularis-Elphidium clavatum-Elphidium sp.-Elphidium incertum/asklundi-dominant (No. 4) associations colonized
the shallower parts of the study area where the water was cold (0°C to 13°C) and salinity ranged from 15 to 25%.

Foraminiferal species diversity \([H(S)]\) for the samples used in this study ranged from 0.25 to 1.93. Diversity for Association 6, salinity 30 to 34%, range from 0.46 to 1.43 and diversity for Association 4, salinity 15 to 25%, range from 1.32 to 1.53. Therefore, foraminifer species diversity does not appear to be directly related to salinity.

Ostracodes were not abundant in the samples used in this study. The ostracodes which commonly occurred in the samples include *Heterocyprideis sorbyana*, *Sarsicytheridea bradii*, *S. punctillata*, *Cyperopteron arcuatum*, *C. champlainum*, *C. inflatum*, *C. nodosum*, and *Cytheromorpha macchesneyi*. Cogeners of *Cyperopteron* occurred in the deeper parts of the study area where the water was cold (0°C to 13°C) and salinity was 25 to 30%. *Cyperopteron latissimum* and *Cytheromorpha macchesneyi* were abundant in shallower parts of the study area (temperature 0°C to 13°C) and salinity 15 to 25%).
**TAXONOMY**

**PART A FORAMINIFERIDA**

**Introduction**

Foraminifers are assigned to the Kingdom Protista, Phylum Protozoa, Subphylum Sarcodina, Class Rhizopodea, and Order Foraminiferida. Foraminiferida are single-celled organisms which almost entirely live in marine to brackish waters. The protoplasm or soft tissue is enclosed within a shell or test. The test is commonly composed of secreted calcite however, some may be composed of organic matter, agglutinated particles or other secreted minerals such as aragonite. The test may consist of a single chamber or several interconnected chambers. One or more large openings called apertures and smaller wall perforations may be present. These openings allow the extension of the thread-like or branching pseudopodia through the test, allowing for locomotion and feeding. Reproduction is characterized by alteration of asexual and sexual generations. The gamont generation reproduces sexually and the schizont generation reproduces asexually.

Over thirty-five classifications have been proposed for this group of organisms. The classifications are summarized in Loeblich and Tappan (1964). The early classifications were based mainly on test morphology. More recent schemes attempt to use as many criteria as possible. One of the most complete and widely used classifications is the Treatise on Invertebrate Paleontology (Loeblich and Tappan, 1964). Since 1964, there have been some modifications to the Treatise classification. Some of the references with updates on the Treatise classification are listed in Loeblich and Tappan (1984). Loeblich and Tappan recently revised their classification and the material is being prepared for publication.

The taxa presented in this paper are arranged according to the classification of Loeblich and Tappan (1964). Their classification recognizes five suborders based on wall composition of the tests. Seventeen Superfamilies are distinguished within these suborders on the basis of the unilocular or multilocular nature of the tests and the character of the wall microstructure. The specimens from this study belong to the Suborders Miliolina and Rotaliina. The fifty-three taxa identified in this study represent six superfamilies and fifteen families. Thirty-eight taxa have been identified to the species level, and ten to the generic level. Specimens belonging to the Family Polymorphinidae were commonly found in the samples collected, but were few in number. This group of foraminifera is highly variable morphologically. Identification to the generic and species level was difficult.
and therefore, are grouped together under the general name polymorphinid. A few other specimens, which were not assigned to a generic or species level, were named discorbid, glandulinid 1, glandulinid 2, and rotalid 1. These specimens were very rare and only occurred at a few sites (three or less) in this study. The genera Glandulinoides Hu and Haynesina Banner and Culver were not recognized by Loeblich and Tappan (1964). Each of these genera are discussed in the Systematic Descriptions. The genus Pseudoparrella Cushman and ten Dam was placed in synonymy with Epistominella Husezima and Maruhasi by Loeblich and Tappan (1964).

Systematic Descriptions

Kingdom: PROTISTA
Phylum: PROTOZOA
Subphylum: SARCODINA Schmarda, 1871
Class: RHIZOPODEA VonSiebold, 1830
Order: FORAMINIFERIDA Eichwald, 1830
Suborder: MILIOLINA Delage and Hérouard, 1896
Superfamily: MILIOLACEA Ehrenberg, 1839
Family: MILIOLIDAE Ehrenberg, 1839
Genus: QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA SEMINULUM (Linné)

Serpula seminulum LINNÉ, 1785, p. 786, pl. 2, fig. 1.
Quinqueloculina seminulum (Linné). FEYLING-HANSSEN ET AL., 1971, p. 194, pl. 1, figs. 18-20.---MURRAY and WRIGHT, 1974, p. 121, pl. 3, figs. 19-21.---CRONIN, 1977b, p. 113, pl. 1, fig. 16.---CRONIN, 1979a, p. 791, pl. 1, fig. 3.

Description. Test ovate in outline, round to subtriangular in section, length about twice the width, periphery rounded; chambers quinqueloculine in plan, elongate; sutures distinct, depressed; wall calcareous, imperforate, opaque, smooth; aperture terminal, semicircular, a simple elongate tooth projects into the center of the aperture.

Genus: PATEORIS Loeblich and Tappan, 1953

PATEORIS HAUERINOIDES (Rhumbler)

Quinqueloculina subrotunda (Montagu) forma hauerinoides RHUMBLER, 1936, p. 206, 217, 226, text-figs. 167, 208-212.
Pateoris hauerinoides (Rhumbler). LOEBLICH and TAPPAN, 1953, p. 42, pl. 6, figs. 8-12.---FEYLING-HANSSEN ET AL., 1971, p. 198, pl. 2, figs. 13-16.---CRONIN, 1979a, p. 792, pl. 1, fig. 9.---RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig.14.

Description. Test circular to ovate in outline, compressed, length about equal to width, periphery rounded; final chambers added biserially in a single plane, final chambers overlap earlier chambers, all chambers elongate; sutures distinct,
slightly depressed; wall calcareous, imperforate, smooth, translucent; aperture a low arch at the end of the final chamber.

Discussion. Loeblich and Tappan (1953) described the chambers as quinqueloculine in the early portion of test. The quinqueloculine arrangement could not be seen from specimens observed from this study.

Genus: PYRGO Defrance, 1824

PYRGO WILLIAMSONI (Silvestri)

_Biloculina williamsoni_ SILVESTRI, 1923, p. 73.  
_Pyrco williamsoni_ (Silvestri). LOEBLICH and TAPPAN, 1953, p. 48, pl. 6, figs. 1-4.---FEYLING-HANSSEN ET AL., 1971, p. 196, pl. 2, figs. 8, 9, pl. 15, fig. 9.---CRONIN, 1979a, p. 792, pl. 1, fig. 8.

_Description_. Test ovate in outline, rounded in section, length about twice the width, periphery rounded; chambers biloculine in plan, oval, inflated; sutures distinct, depressed; wall calcareous, imperforate, smooth, porcelaneous; aperture at the end of the final chamber, oval, a bifid tooth at the base of the aperture projects into the center of the aperture.

Genus: TRILOCULINA d'Orbigny, 1826

TRILOCULINA TRIHEDRA Loeblich and Tappan

_Triloculina trihedra_ LOEBLICH and TAPPAN, 1953, p. 45, pl. 4, fig. 10.---FEYLING-HANSSEN ET AL., 1971, p. 196, pl. 2, fig. 7, pl. 15, fig. 8.---CRONIN, 1977b, p. 113, pl. 1 fig. 15.---CRONIN, 1979a, p. 792, pl. 1. figs. 5, 6.

_Description_. Test small, ovate in outline, triangular in section with subacute angles, sides of test are slightly convex; chambers triloculine in plan, moderately inflated; sutures distinct, slightly depressed, wall calcareous, imperforate, smooth, translucent; aperture terminal, ovate, with a short bifid tooth projecting into the aperture.

Suborder: ROTALIINA Delage and Hérouard, 1896  
Superfamily: _NODOSARIACEA_ Ehrenberg, 1838  
Family: _NODOSARIIDAE_ Ehrenberg, 1838  
Genus: DENTALINA d'Orbigny, 1839

DENTALINA sp.

_Description_. Test large, elongate, slightly arcuate, round in section, distinct basal spine on the proloculus; chambers 2 to 3 in number, uniserial, nearly equal in width
and height, final chamber inflated and tapering towards the aperture; sutures nearly horizontal and flush; wall calcareous, smooth, translucent to opaque; aperture terminal, not centered and radiate.

Discussion. Loeblich and Tappan (1953) described and illustrated *Dentalina pauperata* (d'Orbigny) which is similar to *Dentalina* sp. found in this study. Barker (1960) assigned *Dentalina pauperata* (d'Orbigny) to *Stilostomella pauperata* and concluded that *D. pauperata* of Loeblich and Tappan (1953) was not synonymous with *S. pauperata*. *Dentalina pauperata* of Loeblich and Tappan (1953) should therefore, be assigned to a new species of *Dentalina*.

Genus: LAGENA Walker and Jacob, 1798

LAGENA SEMILINEATA Wright

*LAGENA SEMILINEATA* WRIGHT, 1886, p. 320, pl. 20, fig. 7.---LOEBLICH and TAPPAN, 1953, p. 64, pl. 11, figs. 14-22.---FEYLING-HANSEN ET AL., 1971, p. 209, pl. 4, fig. 3.---CRONIN, 1977b, p. 115, pl. 2, fig. 24.---CRONIN, 1979a, p. 793, pl. 2, fig. 6.---RODRIGUES and RICHARD, 1986, p. 21, pl. 3, fig. 4.

Description. Test unilocular, flask-shaped, widest near the apiculate base and tapering to a long slender neck, wall calcareous, hyaline, lower half ornamented with grooves; aperture terminal at the end of a long slender neck, surrounded by a phialine lip.

Family: POLYMORPHINIDAE d'Orbigny, 1839

POLYMORPHINID

Description. Loeblich and Tappan (1964) described the Family Polymorphinidae as follows: Test multilocular, chambers in spiral or sigmoidal coil about longitudinal axis of growth, or biserial or uniserial, typically somewhat overlapping; aberrant forms may be irregular and attached; apertures all develop in same direction, terminal, radiate.

Discussion. The Polymorphinids observed in this study usually accounted for less than one per cent of the total percent abundance in any one sample. The highest percentage was 2.0 % in sample R-2C-1.

The chamber arrangement of the initial portion of the tests were difficult to determine. Juvenile specimens were easily confused with other species in this group. Descriptions and determinations to the generic and species levels were therefore not completed.
Further study of this group is necessary in order to assign specific names to these specimens. It would be helpful to examine the descriptions and plates of the Polymorphinids from Cushman and Ozawa (1930). This reference was not available to the author for review.

Comparison of the Polymorphinids from this study with the plates from Feyling-Hanssen et al. (1971) and Cronin (1979a) reveal that the following species may be present from this study: Guttulina australaca, Guttulina dawsoni, Guttulina glacialis, Guttulina lactea, Guttulina problem, Pseudopoly morphina soldani, Pseudopoly morphina suboblonga, and Pyrulina cylindroides.

Family: GLANDULINIDAE Reuss, 1860
Genus: ENTOLINGULINA Loeblich and Tappan, 1961

ENTOLINGULINA TRANSLUCIDA (Heron-Allen and Earland)

*Lingulina translucida* HERON-ALLEN and EARLAND, 1932, p. 387, pl. 12, figs. 9-11.
*Entolingulina translucida* (Heron-Allen and Earland), RODRIGUES and RICHARD, 1986, p. 20, pl. 3, fig. 3.

Description. Test ovate in outline, tapering slightly towards initial chamber, rounded at base and apertural end, compressed in section, periphery sub-rounded; chambers 2 to 3 in number, uniserially arranged, overlapping and increasing in size as added; sutures distinct, horizontal to slightly curved, depressed; wall calcareous, finely perforate, transparent, smooth; aperture a small, terminal, elongate slit, with a thin, curved entosolenian tube which extends about three-quarters the length of the final chamber.

Discussion. Loeblich and Tappan (1964) described the genera *Lingulina* d’Orbigny and *Entolingulina* Loeblich and Tappan. *Lingulina* has no entosolenian tube and *Entolingulina* has an entosolenian tube.

Genus: ESOSYRINX Loeblich and Tappan, 1953

ESOSYRINX CURTA (Cushman and Ozawa)

*Pseudopoly morphina curta* CUSHMAN, 1948, p. 52, pl. 5, figs. 17-19.

Description. Test ovate in outline, slightly compressed, rounded margins; chambers two to four in number, biserial in plan, overlapping earlier chambers; sutures distinct, slightly
depressed, oblique; wall calcareous, smooth, translucent; aperture terminal, radiate, with a straight entosolenian tube which is about one-fifth the length of the test, some specimens have a slightly longer entosolenian tube which is curved and attached to the wall of test.

GLANDULINA LAEVIGATA (d'Orbigny)

*Nodosaria (Glandulina) laevigata* d'ORBIGNY, 1826, p. 252, pl. 10, figs. 1-3.

*Glandulina laevigata* (d'Orbigny). LOEBLICH and TAPPAN, 1953, p. 81, pl. 16, figs. 2-5.---FEYLING-HANSSEN ET AL., 1971, p. 220, pl. 15, fig. 12.---CRONIN, 1977b, p. 115, pl. 2, fig. 6.---CRONIN, 1979a, p. 797, pl. 2, fig. 9.---TAYLOR ET AL., 1985, p. 20, pl. 1, figs. 1-4.

**Description.** Test ovate to fusiform in outline, circular in section; initial four chambers biserial, last two chambers uniserial, final chamber one-half to two-thirds the total length of test; sutures distinct, flush; wall calcareous, smooth, translucent to opaque, transparent just below aperture; aperture terminal, central, radiate, with a short, straight entosolenian tube.

Genus: GLANDULINOIDES Hu, 1977

GLANDULINOIDES ITTAI (Loeblich and Tappan)

*Ventalina ittai* LOEBLICH and TAPPAN, 1953, p. 56, pl. 10, figs. 10-12.---CRONIN, 1977b, p. 115, pl. 2, fig. 2.---CRONIN, 1979a, p. 792, pl. 1, fig. 13.

"Ventalina" ittai Loeblich and Tappan. RODRIGUES and RICHARD, 1986, p. 20, pl. 3, fig. 7.

**Description.** Test elongate, slightly arcuate, round in section; chambers uniserial, two in number, inflated, height greater than width, final chamber more elongate than initial chamber; sutures distinct, horizontal, slightly depressed; wall calcareous, smooth, translucent; aperture terminal, central, radiate, with a short entosolenian tube.

**Discussion.** Rodrigues and Richard (1986) pointed out that *Ventalina ittai* Loeblich and Tappan lacks the radiate aperture of *Ventalina* but has an entosolenian tube. They concluded that *Ventalina ittai* Loeblich and Tappan should be assigned to a new genus.
Taylor et al. (1985) described Glandulinoidea yunnanensis Hu as having horizontal sutures and a terminal, radiate aperture with a short, centrally positioned entosolenian tube. Specimens observed in this study have horizontal sutures and a terminal aperture with a short entosolenian tube. The present author concludes that Dentalina ittai Loeblich and Tappan (1953) are similar to the genus Glandulinoidea Hu and therefore should be assigned to Glandulinoidea.

**GLANDULINID 1**

**Description.** Test small, ovate in outline, compressed, periphery rounded; chambers few in number and increase rapidly in size as added, early chambers planispiral, later chambers uncoiled extending back towards the base on the inner margin; sutures distinct, flush; wall calcareous, transparent, surface smooth; aperture at the dorsal margin, radiate, with a long, curved, attached entosolenian tube which is widest near the aperture.

**Discussion.** Loeblich and Tappan (1953) described and illustrated Astacolus hyalacrulus and Astacolus sp. which are similar to Glandulinid 1 from this study. Glandulinid 1 differs from Astacolus hyalacrulus and Astacolus sp. by having a long, attached entosolenian tube. The specimens described by Loeblich and Tappan (1953) do not have entosolenian tubes.

**GLANDULINID 2**

**Description.** Test elongate, slightly arcuate, round in section; six chambers present, uniserial, increasing uniformly in size as added, sub-rectangular in shape, the final three chambers inflated; sutures distinct, slightly oblique, more depressed on the final chambers than the earlier ones; wall calcareous, perforate, smooth, translucent; aperture radiate, terminal, not centred, with an entosolenian tube.

**Discussion.** Glandulinid 2 is similar to Dentalina gibishereensis of Loeblich and Tappan (1953).

**Genus: LARYNGOSIGMA** Loeblich and Tappan, 1953

**LARYNGOSIGMA HYALASCIDEA** Loeblich and Tappan

_Laryngosigma hyalascidea_ LOEBLICH AND TAPPAN, 1953, p. 83, pl. 15, figs. 6-8.—FEYLING-HANSEN ET AL., 1971, p. 221, pl. 5, fig. 16.—CRONIN, 1977b, p. 115, pl. 2, fig. 7, CRONIN, 1979a, p. 798, pl. 2, fig. 11.

**Description.** Test elongate, tapering at both ends, ovate in section, periphery rounded; chambers biserially
arranged but not in a single plane, chambers elongate, slightly inflated, final two chambers larger than initial chambers and also overlapping initial chambers; sutures distinct, oblique, slightly depressed; wall calcareous, perforate, translucent to opaque, smooth; aperture terminal, rounded, radiate, with a short, straight entosolenian tube.

Discussion. See discussion for *Laryngosigma williamsoni*.

**LARYNGOSIGMA WILLIAMSONI** (Terquem)

Polymorphina williamsoni TERQUEM, 1878, p. 37.
Laryngosigma williamsoni (Terquem). LOEBLICH and TAPPAN, 1953, p. 84, pl. 16, fig. 1.

Description. Test elongate, tapering at both ends, slightly compressed in section, periphery rounded; chambers biserially arranged but not in a single plane, chambers long and narrow, initial chambers small, final two chambers large and overlap earlier chambers; sutures distinct, depressed, very oblique to nearly vertical; wall calcareous, perforate, translucent, smooth; aperture terminal, rounded, radiate, with a short entosolenian tube.

Discussion. A few juvenile specimens from this study have longer entosolenian tubes which are curved, and the lower extremity of the tubes are attached to the test wall.

This species is very similar to *Laryngosigma hyatuscidea*. *Laryngosigma williamsoni* is slightly more compressed and the sutures are nearly vertical. Distinction between these two species was very difficult and therefore, they were grouped together as *Laryngosigma* sp.

Genus: **OOLINA** d'Orbigny, 1839

**OOLINA ACUTICOSTA** (Reuss)

Lagena acuticosta REUSS, 1862, p. 305, pl. 1, fig. 4.---CUSHMAN, 1923, p. 5, pl. 1, figs. 1-3.
Lagena apiopleura LOEBLICH and TAPPAN, 1953, p. 59, pl. 10, figs. 14, 15.
Oolina acuticosta (Reuss). FEYLING-HANSSEN ET AL., 1971, p. 222, pl. 6, fig. 1, pl. 17, fig. 1.---CRONIN, 1977b, p. 115, pl. 2, fig. 15.---CRONIN, 1979a, p. 799, pl. 3, fig. 9.---RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 7.

Description. Test unilocular, pear-shaped in outline, round in section, rounded base; wall calcareous, translucent, surface ornamented with eight distinct longitudinal costae which extend up from a small ring at the base to about half way up the apertural neck; aperture terminal, rounded, at the
end of a short smooth apertural neck, with a short entosolenian tube.

Discussion. Loeblich and Tappan (1953) referred to this species as *Lagena apiopleura*. Todd and Low (1967) recognized the presence of a short entosolenian tube, and assigned *L. apiopleura* to *Oolina apiopleura*. Feyling-Hanssen et al. (1971) considered *Lagena apiopleura* synonymous with *Lagena acuticosta* and also recognized the presence of an entosolenian tube. They concluded that *Oolina apiopleura* should be referred to as *Oolina acuticosta*.

OOLINA CAUDIGERA (Wiesner)

*Lagena (Entosolenia) globosa* (Montagu) var. *caudigera* WIESNER, 1931, p. 119, pl. 18, fig. 214.

*Oolina caudigera* (Wiesner). LOEBLICH and TAPPAN, 1953, p. 67, pl. 13, figs. 1-3.—FEYLING-HANSSEN ET AL. 1971, p. 224, pl. 6, fig. 3.—CRONIN, 1979a, p. 709, pl. 3, fig. 7.

**Description.** Test unilocular, ovate, with a short basal spine; wall calcareous, smooth, translucent, finely perforate; aperture terminal, rounded, radiate, with a slightly curved entosolenian tube which is about three-quarters the length of the test, the entosolenian tube gradually widens away from the aperture and the lower extremity is flaring.

Discussion. Loeblich and Tappan (1953) described this species as having a long basal spine. The basal spine on the one specimen observed in this study was broken.

OOLINA HEXAGONA (Williamson)

*Entosolenia squamosa* (Montagu) var. *hexagona* WILLIAMSON, 1848, p. 20, pl. 2, fig. 23.

*Lagena hexagona* (Williamson). CUSHMAN, 1923, p. 24, pl. 4, fig. 6.

*Oolina hexagona* (Williamson). LOEBLICH and TAPPAN, 1953, p. 69, pl. 14, figs. 1, 2.—FEYLING-HANSSEN ET AL. 1971, p. 224, pl. 17, fig. 6.—CRONIN, 1977b, p. 115, pl. 2, figs. 16, 18.—CRONIN, 1979a, p. 799, pl. 3, fig. 7.—RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 12.

**Description.** Test unilocular, globular in outline, with a short, smooth neck, surface ornamented with irregular six sided reticulations giving a honey combed appearance; wall calcareous, translucent to opaque; aperture rounded, at the end of a short neck, with a short, straight entosolenian tube.

Discussion. The entosolenian tube cannot be seen through the test wall. One specimen was carefully broken to observe the tube.
OOLINA LINEATA (Williamson)

Entosolenia lineata WILLIAMSON, 1848, p. 18, pl. 2, fig. 18.
---CUSHMAN, 1948, p. 64, pl. 7, fig. 5.
Lagena lineata (Williamson). CUSHMAN, 1923, p. 31, pl. 5, fig. 10, pl. 6, figs. 5-8.
Oolina lineata (Williamson). LOEBLICH and TAPPAN, 1953, p. 70, pl. 13, figs. 11, 13.---FEYLING-HANSSSEN ET AL., 1971, p. 225, pl. 17, figs. 7, 8.---CRONIN, 1977b, p. 115, pl. 2, fig. 12.---RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 5.

Description. Test unilocular, globular to ovate, with a small basal spine, surface ornamented with very faint, numerous and closely spaced longitudinal striae which extend along the entire length of the test; wall calcareous, finely perforate, translucent to opaque; aperture rounded, radiate with a long, straight entosolenian tube which extends almost the entire length of the test, the entosolenian tube is flaring at the lower extremity.

Discussion. This species differs from Oolina caudigera (Wiesner) by having an ornamented surface, a shorter basal spine and an entosolenian tube which is straight and centrally positioned within the test chamber. The entosolenian tube of O. caudigera is slightly curved and situated closer to one side of the test wall.

OOLINA MELO d’Orbigny

Oolina meo d’Orbigny, 1839, p. 20, pl. 5, fig. 9.---LOEBLICH and TAPPAN, 1953, p. 71, pl. 12, figs. 8-15.---FEYLING-HANSSSEN ET AL., 1971, p. 226, pl. 6, fig. 5, pl. 17, fig. 9.---CRONIN, 1977b, p. 115, pl. 2, fig. 14.---RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 6.

Description. Test unilocular, globular to ovate in outline, with a short smooth neck, surface ornamented with 9 to 16 longitudinal ridges, 4 to 8 horizontal ridges are found between the longitudinal ridges, the horizontal ridges are straight to convex towards the aperture; wall calcareous, finely perforate, translucent; aperture terminal, rounded, at the end of a short neck, with a straight entosolenian tube which extends about one half the length of the test.

Discussion. One twinned specimen of this species was observed in sample R-2. The entosolenian tube is not visible through the test wall in most specimens.

OOLINA SQUAMOSA-SULCATA (Heron-Allen and Earland)

Lagena squamosa-sulcata HERON-ALLEN and EARLAND, 1932, p. 151, pl. 5, figs. 15, 19.
Oolina squamosa-sulcata (Heron-Allen and Earland). LOEBLICH and TAPPAN, 1953, p. 74, pl. 12, figs. 6, 7.—CRONIN, 1977b, p. 115, pl. 2, fig. 13.—CRONIN, 1979a, p. 800, pl. 3, fig. 5.—RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 11.

**Description.** Test unilocular, globular to ovate in outline, with a short smooth neck, surface ornamented with 11 to 12 longitudinal ridges, 4 to 6 horizontal ridges between the longitudinal ridges and only on the upper part of the test; wall calcareous, finely perforate, translucent; aperture terminal, rounded, at the end of a short neck, with a straight entosolenian tube which extends about one-third the length of the test.

**Discussion.** This species differs from Oolina melo d'Orbigny by having horizontal ridges only on the upper part of the test.

OOLINA WILLIAMSONI (Alcock)

Entosolenia williamsoni ALCOCK, 1865, p. 193
Lagena williamsoni (Alcock). CUSHMAN, 1923, p. 61, pl. 11, figs. 8, 9.
Lagena (Entosolenia) scalariiforme-sulcata WIESNER, 1931, p. 120, pl. 18, fig. 219.
Oolina scalariiforme-sulcata (Wiesner). LOEBLICH and TAPPAN, 1953, p. 72, pl. 13, fig. 7.
Oolina williamsoni (Alcock). FEYLING-HANSSEN ET AL., 1971, p. 227, pl. 18, figs. 1, 2.—CRONIN, 1977b, p. 115, pl. 2, fig. 19.—CRONIN, 1979a, p. 800, pl. 3, fig. 8.—RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 8.

**Description.** Test unilocular, globular to ovate in outline, tapering towards the aperture, surface ornamented with 6 to 10 longitudinal ridges which extend up from a small ring at the base to about three-quarters the length of the test, adjacent to the aperture the test is pitted; wall calcareous, finely perforate, translucent; aperture terminal, rounded, at the end of a very slight neck, with a straight entosolenian tube which extends about one-third the length of the test.

**Discussion.** Loeblich and Tappan (1953) assigned an arctic species to Oolina scalariiforme-sulcata (Wiesner). Cronin (1979a) pointed out that Oolina williamsoni and O. scalariiforme-sulcata were very similar and possibly conspecific.

Genus: FISSURINA Reuss, 1850

FISSURINA CUCURBITASEMA Loeblich and Tappan

Fissurina cucurbitasema LOEBLICH and TAPPAN, 1953, p. 76, pl. 14, figs. 10, 11.—TODD and LOW, 1967, p. 28, pl. 3, fig.
Description. Test unilocular, ovate in outline, compressed in section, base rounded to slightly tapering, narrow marginal keel extending along entire periphery; wall calcareous, perforate, translucent to opaque; aperture terminal, ovate, with a straight entosolenian tube which extends about one-half the length of the test.

Discussion. One larger specimen of this species had a longer entosolenian tube which gradually widened towards the lower end and was attached to the test wall.

FISSURINA LAEVIGATA Reuss

Fissurina laevigata REUSS, 1849, p. 366, pl. 46, fig. 1.
Lagena laevigata (Reuss). CUSHMAN, 1923, p. 28, pl. 5, figs. 1, 2.
Entosolenia laevigata (Reuss). CUSHMAN, 1944, p. 28, pl. 4, fig. 12.---CUSHMAN, 1948, p. 63, pl. 7, fig. 4.
Fissurina laevigata Reuss. FEYLING-HANSSEN, 1964, p. 314, pl. 15, figs. 17, 18.---RODRIGUES and RICHARD, 1986, p. 20, pl. 1, fig. 3.

Description. Test unilocular, ovate in outline, tapering towards aperture and rounded to slightly tapering at base, slightly compressed in section, periphery rounded and transparent; wall calcareous, perforate, translucent to opaque; aperture terminal, a narrow elongate slit, with an entosolenian tube which extends about one-third the length of the test.

FISSURINA MARGINATA (Montagu)

Vermiculum marginatum MONTAGU, 1803, p. 524.
Fissurina marginata (Montagu). LOEBLICH and TAPPAN, 1953, p. 77, pl. 14, figs. 6-9.---CRONIN, 1977b, p. 115, pl. 2, fig. 9.---CRONIN, 1979a, p. 798, pl. 2, figs. 16, 17.---RODRIGUES and RICHARD, 1986, p. 20, pl. 1, fig. 13.

Description. Test unilocular, ovate to nearly circular in outline, compressed in section, periphery keeled, keel narrow, extending along the entire periphery; wall calcareous, perforate, translucent to opaque; aperture terminal, slit like surrounded by a small clear collar, with a long entosolenian tube which is flared and attached at the lower end, the length of the entosolenian tube is about three-quarters the length of the test, in some specimens the tube almost reaches the base.

FISSURINA RENIFORMIS (Sidebottom)

Lagena reniformis SIDEBOTTOM, 1913, p. 204, pl. 18, fig. 15.---CUSHMAN, 1923, p. 49, pl. 9, figs. 7-11.
Description. Test small, unilocular, rounded to sub-rounded in outline, compressed in section, width slightly larger than length, periphery rounded and without a keel; wall calcareous, translucent, smooth, aperture terminal, slitlike, with a short entosolenian tube which tapers toward the lower extremity.

FISSURINA SERRATA (Schlumberger)

Lagena serrata SCHLUMBERGER, 1894, p. 238, pl. 3, fig. 7.
Entosolenia serrata (Schlumberger). CUSHMAN, 1948, p. 63, pl. 7, fig. 3.
Fissurina serrata (Schlumberger). LOEBLICH and TAPPAN, 1953, p. 78, pl. 14, fig. 5.---FEYLING-HANSSEN ET AL., 1971, p. 231, pl. 6, fig. 9, pl. 18, figs. 4, 5.---CRONIN, 1977b, p. 115, pl. 2, fig. 8.---CRONIN, 1979a, p. 798, pl. 2, figs. 19, 20.---RODRIGUES and RICHARD, 1986, p. 20, pl. 3, fig. 15.

Description. Test unilocular, ovate in outline, compressed in section, periphery keeled, keel perforate at regular intervals; wall calcareous, perforate, translucent; aperture terminal, rounded, at the end of a short neck, test is smooth and transparent around the apertural neck, aperture with a thin entosolenian tube which extends just less than one half the length of the test.

FISSURINA VENTRICOSA (Wiesner)

Lagena [Entosolenia] marginata var. ventricosa WIESNER, 1931, p. 120, pl. 19, fig. 22.

Description. Test unilocular, ovate in outline, compressed, with a very short basal spine, periphery without keel; wall calcareous, perforate, translucent to opaque, aperture terminal, slitlike, aperture with an entosolenian tube which extends just less than one half the length of the test, the lower extremity of the entosolenian tube is flared.

Genus: PARAFISSURINA Parr, 1947

PARAFISSURINA sp. A

Description. Test unilocular, ovate in outline, oval in section, slightly tapered and curved towards apertural end, periphery rounded; wall calcareous, coarsely perforate, translucent, smooth; aperture a terminal, eccentric, arched slit
with a hood or flap along one margin, aperture with an attached entosolenian tube which almost reaches the base of the test.

**PARAFISSURINA** sp. **B**

*Description.* Test unilocular, curved and ovate in outline, distinctly tapering towards apertural end, rounded in section, periphery rounded; wall calcareous, perforate, smooth, translucent to transparent in the upper half of the test and translucent to opaque in the lower half of test; aperture a terminal, eccentric, small rounded opening with a flap or hood along one margin, aperture with a thin entosolenian tube which extends just less than one half the length of the test.

*Discussion.* *Parafissurina* sp. A differs from *Parafissurina* sp. B by having a coarser perforated test and a longer entosolenian tube. The lower half of the test in *Parafissurina* sp. B is opaque, and the entire test of *Parafissurina* sp. A is translucent.

**Suborder:** ROTALIINA Delage and Hérouard, 1896  
**Superfamily:** BULIMINACEA Jones, 1875  
**Family:** TURRILINIDAE Cushman, 1927  
**Genus:** BULIMINELLA Cushman, 1911

**BULIMINELLA** sp.

*Description.* Test small, trochospiral, high-spired, tapering towards both extremities; spiral side high-spired with about two and one half whorls; chambers numerous, slightly inflated, long and narrow, increase in size as added, sutures oblique, slightly depressed to flush; spiral suture not very distinct, slightly depressed; umbilical side convex, 1 to 2 chambers in the last whorl visible; wall calcareous, perforate, translucent to opaque, smooth; aperture is circular, found in the face of the final chamber.

**Family:** BOLIVINITIDAE Cushman, 1927  
**Genus:** BOLIVINA d'Orbigny, 1839

**BOLIVINA** sp.

*Description.* Test small, elongate, widest at the final chamber and tapering towards initial chamber, straight or arcuate, oval in section, periphery rounded; chambers 10 to 12 in number, biserially arranged, increasing uniformly as added, the final 2 to 3 pairs of chambers are inflated; sutures slightly depressed, almost horizontal on initial portion of test and more oblique on later portion; wall calcareous, hyaline, coarsely perforate; aperture basal, loop-shaped, extending up from the base of the final chamber.

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Family: ISLANDIELLIDAE Loeblich and Tappan, 1964
Genus: ISLANDIELLA Nørvang, 1958

ISLANDIELLA HELENAE Feyling-Hanssen and Buzas

Pl. 1, figs. 8, 9

Cassidulina teretis Tappan, LOEBLICH and TAPPAN, 1953, p. 121, pl. 24, figs. 3, 4, (not Cassidulina teretis Tappan, 1951).

Islandiella teretis (Tappan). FEYLING-HANSSEN ET AL., 1971, p. 249, pl. 8, figs. 3-6, pl. 18, fig. 13.

Islandiella helenae FEYLING-HANSSEN and BUZAS, 1976, p. 155, figs. 1-4,--CRONIN, 1979a, p. 802, pl. 4, figs. 14, 15, --RODRIGUES ET AL., 1980, p. 49, pl. 1, figs. 1, 3, 5, pl. 4, figs. 3, 6, 9, pl. 6, figs. 1, 2,--RODRIGUES and RICHARD, 1986, p. 21, pl. 3, figs. 5, 6.

Description. Test biconvex, biumbonate, with a clear to opaque central boss, periphery even to slightly lobate on initial chambers and lobate on later chambers, periphery with a narrow, acute keel, keel absent on last two chambers; chambers biserial and enrolled, each chamber extends from the central boss on one side of the test across the periphery to about halfway to the boss on the opposite side, chambers are rectangular in outline on the side where they reach the umbilicus and are small triangular shaped on the opposite side, the rectangular and triangular portions of the chambers alternate from side to side so that each side of the test consists of 4 to 5 pairs of alternating rectangular and triangular shaped chambers; sutures distinct, flush, straight to gently curved; wall calcareous, radial in polarized light, perforate, smooth, translucent to opaque; aperture forms an elongate opening parallel to the periphery; along the outer margin of the aperture is a lip which is formed by the infolded chamber wall, along the opposite margin of the aperture is a narrow ridge, this ridge does not extend into the aperture; on the same margin as the ridge there is a tongue which projects into the aperture from the posterior corner and a plate which projects into the aperture from the anterior corner.

Discussion. Rodrigues et al. (1980) described and illustrated the apertures of the genera Islandiella and Cassidulina. Their descriptions of the apertural structures have aided in the identification of these genera.

The aperture of Islandiella has a lip along one margin of the aperture. The lip is formed by the infolding of the chamber wall. A long narrow ridge extends along the opposite margin of the aperture. This ridge does not extend into the aperture. Along the same margin as the ridge, there is a tongue which projects from the posterior corner of the aperture, and a plate which projects from the anterior corner of the aperture.
**ISLANDIELLA NORCROSSI (Cushman)**

*Pl. 1, Figs. 5, 6*

*Cassidulina norcrossi* CUSHMAN, 1933, p. 7, pl. 2, fig. 7.---
LOEBLICH and TAPPAN, 1953, p. 120, pl. 24, fig. 2.

*Islandiella norcrossi* (Cushman). FEYLING-HANSSEN ET AL., 1971, p. 248, pl. 8, figs. 1, 2.---CRONIN, 1977b, p. 113, pl. 1, fig. 14.---CRONIN, 1979a, p. 802, pl. 4, figs. 16, 17.---RODRIGUES ET AL., 1980, p. 49, pl. 4, figs. 1, 4, 7, 10, pl. 6, figs. 8, 9.---RODRIGUES and RICHARD, 1986, p. 21, pl. 3, figs. 1, 2.

**Description.** Test biconvex, biumbonate, with a clear to opaque central boss, periphery even on initial chambers and slightly lobate on later chambers, periphery with an acute keel, keel absent on last chamber; chambers planispirally coiled, 7 to 9 in number, in side view chambers are triangular in shape and increase in size as added; sutures distinct, flush, slightly curves; wall calcareous, radial in polarized light, finely perforate, translucent, smooth; aperture is an elongate opening parallel to the periphery; on one side of the aperture the infolding of the chamber wall forms a lip, on the opposite side a narrow ridge, a tongue and a plate are present, the tongue projects into the aperture from the posterior corner and the plate projects from the anterior corner.

**Discussion.** The tongue and plate structures of this species are not as distinct as those found in the aperture of *Isandielia helenae*.

**Family:** UVIGERINIDAE Haeckel, 1894

**Genus:** TRIFARINA Cushman, 1923

*TRIFARINA HUGHESI* (Galloway and Wissler)

*Uvigerina hughesi* GALLOWAY and WISSLER, 1927, p. 76, pl. 12, fig. 5.

*Angulogerina fluens* TODD in Cushman and Todd, 1947, p. 67, pl. 16, figs. 6, 7.---LOEBLICH and TAPPAN, 1953, p. 112, pl. 20, figs. 10-12.

*Trijarina fluens* (Todd). FEYLING-HANSSEN ET AL., 1971, p. 242, pl. 7, figs. 12-15, pl. 18, fig. 10.---CRONIN, 1979a, p. 801, pl. 4, fig. 10.

*Trijarina hughesi* (Galloway and Wissler). RODRIGUES and HOOPER, 1982b, p. 348, pl. 2, figs. 1, 5, 13-15.---RODRIGUES and RICHARD, 1986, p. 21, pl. 1, fig. 10.

**Description.** Test triserial, elongate, earlier portion of test circular to ovate in section, later portion of test subtriangular in section; chambers 9 in number, earlier chambers inflated, later chambers compressed and have sub-rounded margins; chambers smooth except for earlier chambers which have very faint longitudinal costae, the costae do not extend across the sutures; sutures distinct and depressed.
sutures in the earlier portion of the test are not very
distinct; wall calcareous, perforate; aperture terminal,
rounded, on a short neck, the rim of the neck has a thickened
lip.

Discussion. Rodrigues and Hooper (1982b) placed
_Trijarina fluens_ (Todd) in synonymy with _T. hughesi_.

Rodrigues and Hooper (1982b) recognized seven recent
benthonic foraminiferal associations in the Gulf of St.
Lawrence. The associations were primarily related to the
water mass. The water mass layers in the Gulf of St. Lawrence
are: Zone A of the Upper Layer (0m to 60m), Zone B of the
Upper Layer (60m to 125m), the Transitional Zone (125m to 200m),
Zone A of the Deep Layer (200m to 400m) and Zone B of the
Deep Layer (below 400m). The _Trijarina hughesi_ association
ranged from the upper part of the Transitional Zone to the
upper part of the Deep Layer. Specimens of _T. hughesi_ in
the Upper Layer had costate ornamentation which varied from
poorly to well-developed and the chambers in the latter part
of the test were moderately compressed on one side with
subrounded margins. Specimens from the Transitional Zone
and Deep Layer had well-developed costae and chambers which
were compressed on one side and had angular margins in the
latter part of the test.

Specimens of _Trijarina hughesi_ from this study have
poorly developed costate ornamentation and are very similar
to the specimens found in the Upper Layer of the Gulf of St.
Lawrence.

Superfamily: DISCORBACEA Ehrenberg, 1838
Family: DISCORBIDAE Ehrenberg, 1838
Genus: BUCCELLA Andersen, 1952

**BUCCELLA CALIDA** (Cushman and Cole)

_Eponides frigida_ (Cushman), var. calida CUSHMAN and COLE, 1930,
p. 98, pl. 13, fig. 13.

_Buccella frigida_ (Cushman) forma calida (Cushman and Cole).
FEYLING-HANSSEN, 1976, pl. 1, figs. 6, 7, pl. 2, figs. 7-9.

275, pl. 2, figs. 6-10.—-_RODRIGUES_ and _RICHARD_, 1986, p.
20, pl. 1, fig. 15.

_Description_. Test trochospiral, periphery rounded,
gently lobate on earlier chambers, later chambers more dist­
inctly lobate; umbilical side flat, 5 to 8 chambers visible;
sutures depressed, radial and straight to gently curved; a
pustulose coating covers the umbilical area, sutures and
chambers; spiral side convex, about two and one half to three
whorls and 7 to 16 chambers visible, chambers increase in size
as added; chamberal sutures flush on earlier portion of test
and depressed on the later portion, spiral suture flush in
initial whorls and depressed in the outer whorl; wall calcareous, finely perforate, smooth on spiral side; primary aperture extraumbilical interiomarginal, often obscured by pustulose coating, supplementary sutural apertures on the umbilical side are situated about halfway between the umbilical area and the periphery, the supplementary apertures are often obscured by pustulose coating.

Discussion. The supplementary sutural apertures are often obscured by a pustulose coating and therefore were not observed in all specimens from this study.

**BUCCELLA FRIGIDA** (Cushman)

*Pulvinulina frigida* Cushman, 1922, p. 144.
*Eponides frigida* Cushman, 1941, p. 37, pl. 9, figs. 16, 17.—Cushman, 1948, p. 71, pl. 8, fig. 7.
*Buccella frigida* (Cushman). Loeblich and Tappan, 1953, p. 115, pl. 22, figs. 2, 3.—Feyling-Hanssen et al., 1971, p. 253, pl. 8, figs. 12-14.—Cronin, 1977b, p. 113, pl. 1, fig. 8.—Cronin, 1979a, p. 803, pl. 5, figs. 4, 7, 8.

Description. Test trochospiral, periphery rounded, even on earlier chambers, later chambers lobate; umbilical side convex, 6 to 8 chambers visible; sutures flush to slightly depressed, thickened, radial and gently curved, a pustulose coating covers the umbilical region and sutures but does not extend up the entire length of the sutures; spiral side more convex than umbilical side, about two and one half whorls and 9 to 16 chambers visible, chambers increase in size as added; chamberal sutures flush on earlier portion of test and slightly depressed on the later portion, spiral suture flush in initial whorls and depressed in the outer whorl; wall calcareous, finely perforate, smooth on the spiral side; primary aperture extraumbilical interiomarginal, often obscured by pustulose coating, supplementary sutural apertures on the umbilical side are situated about halfway between the umbilical area and the periphery, supplementary apertures are often covered by pustulose coating.

Discussion. This species differs from *Buccella calida* by having a biconvex test and a pustulose coating covering the umbilical area and sutures on the umbilical side of the test. *Buccella calida* has a flat umbilical side and a pustulose coating which covers most of the umbilical side of the test.

**DISCORBID**

Description. Test small, trochospiral, periphery sub-rounded to acute, even on earlier chambers and becoming slightly lobate on later chambers; umbilical side flat to concave, 11 to 12 chambers visible, chambers gradually increase in size as added; chamberal sutures distinct, straight
to very slightly curved, flush in the initial portion of the
test and slightly depressed in later portion; spiral side
very slightly convex, involute, about two whorls and 11 to 12
chambers visible, chambers gradually increase in size as
added, final two chambers slightly inflated; chamberal sutures
distinct, straight to very slightly curved, flush, spiral
suture flush; wall calcareous, perforate, transparent, smooth;
primary aperture an extraulimbical interiomarginal slit, supplen-
tary sutural apertures on the later chambers can be seen
on the umbilical side of the test, the sutural apertures are
curved slitlike openings which do not reach the periphery.

Genus: EOPONIDELLA Wickenden, 1949

**Eoponidella pulchella** (Parker)

P. *pulchella* PARKER, 1952, p. 420, pl. 6, figs. 18-20.

*P. pulchella* (Parker). LESLIE, 1965, p. 156, pl. 9,
figs. 9a,b,c.

*E. pulchella* (Parker). RODRIGUES and RICHARD, 1986,
P. 20, pl. 1, fig. 4.

Description. Test small trochospiral, periphery sub-
rounded, even on earlier chambers and even to very slightly
lobate on later chambers, umbilical side flat, may be slightly
depressed in center, 4 to 6 chambers visible, each chamber
has an ovate to sub-triangular supplementary chamber which
radiates from the umbilical region out towards the periphery
but not quite reaching it, the 4 to 6 supplementary chambers
form a stellate arrangement; sutures thin, depressed; spiral
side convex, about three whorls and 12 to 14 chambers visible,
chambers sub-triangular in shape, increase in size as added,
chamberal sutures oblique, thin, flush on earlier portion of
test and slightly depressed on later portion, spiral suture
flush in initial whorls and slightly depressed in final whorl;
wall calcareous, coarsely perforate, transparent, smooth;
aperture forms a broad extraumbilical interiomarginal arch.

Genus: PSEUDOPARRELLA Cushman and ten Dam, 1948

**Pseudoparrella takayanagii** (Iwasa)

*Epistominella takayanagii* Iwasa, 1955, p. 16, text-fig. 4.—
LESLIE, 1965, p. 160, pl. 9, fig. 10.—SCHAFER and COLE,
1978, p. 27, pl. 8, fig. 3.

*P. takayanagii* (Iwasa). RODRIGUES, 1980, p. 310,
pl. 3-18, figs. 2,3.

Description. Test small, trochospiral, periphery rounded,
even on earlier chambers and lobate on later chambers; umbilical
side convex, 7 to 9 chambers visible; sutures flush to very
slightly depressed, thickened, radial and straight; spiral side
more convex than umbilical side, about three whorls and 14 to 21
chambers visible, chambers increase in size as added; chamberal sutures oblique, thickened, flush on earlier portion of test and depressed on the later portion, spiral suture flush; wall calcareous, finely perforate, transparent and smooth; aperture a narrow elongate opening parallel and close to the periphery.

Discussion. *Pseudoporcella* was placed in synonymy with *Epistomina* by Loeblich and Tappan (1964).

Genus: ROSALINA d'Orbigny, 1826

**ROSALINA sp. A**

Description. Test trochospiral, periphery rounded, slightly lobate, umbilical side flat, depressed in centre, four inflated chambers visible; sutures radial, straight to slightly curved, depressed; spiral side convex, about three whorls and 9 to 14 chambers visible, chambers increase in size as added; chamberal sutures thin, slightly depressed, spiral suture flush in initial whorls and depressed in final whorl; wall calcareous, coarsely perforate, translucent to opaque; primary aperture a low arch which is extraumbilical interiomarginal, a supplementary sutural aperture on the umbilical side is adjacent to the primary aperture and it extends into the umbilicus.

**ROTALID 1**

Description. Test small, trochospiral, periphery rounded, distinctly lobate; umbilical side flat with a very small depressed umbilical region, 4 to 5 inflated chambers visible; sutures radial, depressed, slightly curved; spiral side slightly convex, two whorls and 6 to 8 chambers visible, chambers increase in size as added; chamberal sutures thin, flush in earlier portion of test and depressed in later portion, spiral suture flush in initial whorl and depressed in final whorl; wall calcareous, coarsely perforate, translucent, smooth; primary aperture a small, low arch, extraumbilical interiomarginal.

Discussion. Only six specimens were observed in this study. The specimens were found on the Russell Map Sheet Area at Site R-2. The literature review did not lead to a generic and species level determination. These specimens are assigned to the Rotalid group.
Superfamily: SPIRILLINACEA Reuss, 1862
Family: SPIRILLINIDAE Reuss, 1862
Genus: PATELLINA Williamson, 1858

PATELLINA CORRUGATA Williamson

*PateLLina corrugata* WILLIAMSON, 1858, p. 46, pl. 3, figs. 86-89.—LOEBLICH and TAPPAN, 1953, p. 114, pl. 21, figs. 4, 5.—CRONIN, 1979a, p. 803, pl. 4, fig. 11.

Description. Test trochospiral, round in outline, periphery even, acute, with a narrow keel; spiral side convex, about two to three whorls and 2 chambers visible; initial chamber (proloculus) globular, final chamber tubular and trochospirally coiled, the final chamber is partially subdivided by internal secondary transverse septa, the secondary septa are commonly present only in the last whorl but some specimens may have secondary septa throughout the final chamber; spiral suture distinct, flush to very slightly depressed; umbilical side flat to slightly concave, secondary septa visible in last whorl; wall calcareous, translucent, smooth; aperture on the umbilical side test, forms a low arch near the centre of the test.

Discussion. The aperture of this species is very difficult to observe with the binocular microscope. Loeblich and Tappan (1964) described the aperture of *P. corrugata* as a low arch under exterior margin of scroll-like median septum of final chamber at center of test.

Superfamily: ROTALIACEA Ehrenberg, 1839
Family: ELPHIDIIDAE Galloway, 1933
Genus: ELPHIDIUM De Montfort, 1808

ELPHIDIUM ASKLUNDI Brötzen

*Elphidium asklundi* BRÖTZEN in Hessland, 1943, p. 267, figs. 109, 110.—FEYLING-HANSEN ET AL., 1971, p. 270, pl. 10, figs. 20, 21, pl. 11, figs. 1-5.—HANSEN and LYKKE-ANDERSEN, 1976, p. 15, pl. 12, figs. 10-12, pl. 13, fig. 1.—FEYLING-HANSEN, 1980, p. 279, pl. 2, figs. 21, 22. *Elphidium cf. E. asklundi* Brötzen. CRONIN, 1979a, p. 804, pl. 5, fig. 12.

Description. Test planispiral, involute, periphery rounded to sub-rounded, even to slightly lobate in initial chambers and lobate on later chambers, umbilicus not depressed or slightly depressed, covered with fine tuberculation; chambers 8 to 10 visible, increase uniformly in size as added, chambers become more inflated as added; sutures distinct, depressed, gently curved but less distinct and not as depressed at periphery, sutures with 3 to 5 ponticuli, ponticuli do not

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occur at periphery, depressed parts of sutures often covered with fine tuberculation; wall calcareous, perforate, opaque, granular in polarized light; aperture interiomarginal, a row of pores at the base of the apertural face, aperture often obscured by tuberculation.

**ELPHIDIUM INCERTUM** (Williamson)

*Polystomella umbilicatula* var. *incerta* WILLIAMSON, 1853, p. 41, pl. 3, fig. 82a.

*Elphidium incertum* (Williamson). CUSHMAN, 1948, p. 56, pl. 6, fig. 7.---BUZAS, 1966, p. 592, pl. 72, figs. 1-6.---FEYLING-HANSSEN ET AL., 1971, p. 277, pl. 12, figs. 11, 12, pl. 21, figs. 8, 9.---HANSEN and LYKKE-ANDERSEN, 1976, p. 15, pl. 12, figs. 5-9.---CRONIN, 1977b, p. 113, pl. 1, figs. 1, 2.---CRONIN, 1979a, p. 808, pl. 6, figs. 12, 13.

Description. Test planispiral, involute, periphery rounded to sub-rounded, even to slightly lobate in initial chambers and lobate on later chambers, test compressed in section; umbilicus not depressed or very slightly depressed, covered with fine tuberculation, chambers 8 to 10 visible, increase uniformly in size as added, chambers become more inflated as added; sutures distinct, depressed, gently curved, suture less distinct and not as depressed at periphery, some specimens have flush sutures on the initial portion of the test, suture with 3 to 5 ponticuli, ponticuli do not occur at periphery, depressed parts of the sutures often covered with fine tuberculation; wall calcareous, perforate, translucent to opaque, granular in polarized light; aperture interiomarginal, a row of pores at the base of the apertural face, aperture often obscured by tuberculation.

Discussion. Buzas (1966) described transparent-translucent forms and opaque forms of *Elphidium incertum*. He mentioned that some of the transparent-translucent forms had opaque bands along both sides of the sutures. *Elphidium incertum* could be confused with *E. subarcticum* Cushman, however *E. subarcticum* has optically radial walls and *E. incertum* has optically granular walls.

Feyling-Hanssen ET AL. (1971) illustrated *E. incertum* and *E. asklundi*, but complete descriptions were not given. They described *E. asklundi* as being milk-white in colour and having sutures with irregular double rows of pores. *E. incertum* was described as resembling *E. asklundi* and that sometimes it was difficult to separate the two species.

Hansen and Lykke-Andersen (1976) mentioned that *E. asklundi* appears to be identical to *E. incertum*. They tentatively regarded these two species separate because *E. asklundi*, is larger in size compared to *E. incertum*.
Cronin (1979a) identified specimens that he compared to *E. asklundi* but mentioned that the double row of pores were not always visible. He described *E. incertum* as being quite variable morphologically and that it could be confused with *E. asklundi*.

Specimens examined from this study are translucent or opaque. The opaque specimens are milk-white in colour and have single rows of pores along the sutures. A few opaque specimens have double rows of pores along the sutures, which is said to be characteristic of *E. asklundi*. The translucent forms appear to be identical to the opaque specimens. The only difference observed between these two species is the translucent specimens are compressed in section and the opaque specimens are more rounded in section.

The above discussion indicates that there is no clear distinction between these two species. The present author has followed Rodrigues and Richard (1986) and referred the species to the *Elphidium incertum/asklundi* complex.

**ELPHIDIUM CLAVATUM Cushman**

Pl. 1, Figs. 3, 4, Pl. 2, Figs. 3, 5

*Elphidium incertum* (Williamson) var. *clavatum* CUSHMAN, 1930, p. 20, pl. 7, fig. 10.

*Elphidium clavatum* Cushman. LOEBLICH and TAPPAN, 1953, p. 98, pl. 19, figs. 8-10.---BUZAS, 1966, p. 591, pl. 71, figs. 1-8.---FEYLING-HANSSEN ET AL., 1971, p. 273, pl. 11, figs. 10-13, pl. 20, figs. 5-8.---RODRIGUES and HOOPER, 1982a, p. 411, text-figs. 2, 3.---RODRIGUES and HOOPER, 1982b, p. 343, pl. 3, figs. 1-16.---RODRIGUES and RICHARD, 1986, p. 20, pl. 2, figs. 1, 2, 5, 6, 9, 10.


*Elphidium excavatum* (Terquem) forma *clavata* Cushman. FEYLING-HANSSEN, 1972, p. 339, pl. 1, figs. 1-9, pl. 2, figs. 1-9.---MILLER ET AL., 1982, p. 124, pl. 1, figs. 5-8, pl. 2, figs. 3-8, pl. 3, figs. 3-8, pl. 4, figs. 1-6, pl. 5, figs. 4-8, pl. 6, figs. 1-5.

*Elphidium clavatum clavatum* Cushman. WILKINSON, 1979, p. 634, pl. 1, fig. 1.

Description. Test planispiral, involute, periphery rounded to sub-acute, even in initial portion of test and lobate on the later part; umbilicus has one rounded boss or the umbilicus is covered by extensions of the chamber wall; 8 to 12 chambers visible, increase uniformly in size as added; sutures slightly depressed, gently curved, thickened, extend across periphery; in smaller specimens the sutures do not extend across the periphery in the earlier portion of the
test; ponticuli 2 to 3, thin; test yellowish-brown or white in colour, translucent to opaque; wall calcareous, perforate, radial in polarized light; aperture interiomarginal, a row of pores at the base of the apertural face, often obscured by tuberculation.

Discussion. This species has been reported in the literature as being highly variable morphologically. Feyling-Hanssen (1972) considered Polystomella excavata Terquem, P. striatopunctata var. selseyensis Heron-Allen and Earland, Elphidium clavatum and E. lidoense Cushman to be conspecific. He used the name Elphidium excavatum for these species and described four different forms (E. excavatum forma clavata, E. excavatum forma alba, E. excavatum forma selseyensis E. excavatum forma lidoense). Miller et al. (1982) also considered E. clavatum to be E. excavatum and they recognized five forms (E. excavatum forma magna, E. excavatum forma excavata, E. excavatum forma selseyensis, E. excavatum forma clavata and E. excavatum forma lidoensis).

Wilkinson (1979) considered that Polystomella excavata Terquem (1875, pl. 2, figs. 2a-b, 2c-d, and the neotype described by Levy et al. 1975) and Elphidium clavatum Cushman were distinctly different. He described P. excavata as having an excavated umbilicus and non-granular sutures. E. clavatum was characterized by possessing one or more umbilical bosses and heavily granular sutures and umbilicus. Wilkinson (1979) concluded that Polystomella excavata Terquem (1875, pl. 2, figs. 2e-f), P. striatopunctata var. selseyensis Heron-Allen and Earland, Elphidium lidoense Cushman and E. subclavatum Cushman were conspecific. He subdivided the species E. clavatum into eight subspecies (Elphidium clavatum clavatum Cushman, E. clavatum subclavatum Gudina, E. clavatum lobatum, E. clavatum lidoense Cushman, E. clavatum selseyense, E. clavatum nudum, E. clavatum terminatum and E. clavatum album Feyling-Hanssen.

Rodrigues and Hooper (1982a) examined illustrations of Polystomella excavata from Terquem (1875) and concluded that two forms were present. One form (Terquem 1875, pl. 2, figs. 2a-b, 2e-f) was characterized as having an umbilical boss or an open umbilicus and ponticuli on the peripheries. They considered this form as Elphidium williamsoni Haynes. The second form (Terquem 1875, pl. 2, figs. 2c-d) was characterized as having a small umbilicus and no ponticuli on the periphery. This form was considered to be Polystomella striatopunctata var. selseyense Heron-Allen and Earland.

Rodrigues and Hooper (1982a) considered the subspecies described by Wilkinson (1979) as the Elphidium clavatum complex and divided it into two groups. Group one included Elphidium clavatum clavatum, E. clavatum terminatum, E. clavatum lidoense, E. clavatum lobatum and E. clavatum subclavatum. Specimens belonging to Group 1 were character-
ized by having 2 to 3 ponticuli on the last two to three sutures. Group two included *E. clavatum album* and *E. clavatum nudum*. Specimens belonging to this second group have ponticuli on each suture.

Rodrigues and Hooper (1982a) did not observe the Group 1 forms from the Gulf of St. Lawrence. They described the Gulf of St. Lawrence specimens as being most similar to *Elphidium excavatum forma clavata* and *E. excavatum forma alba* which were described by Feyling-Hanssen (1972). Rodrigues and Hooper (1982a) concluded that their forms could not be differentiated into Feyling-Hanssen's formae and therefore, named their specimens as *Elphidium clavatum*.

Specimens from this study are named *Elphidium clavatum* after Rodrigues and Hooper (1982a). They most resemble the Group 1 forms from Rodrigues and Hooper (1982a), *Elphidium excavatum forma clavata* (pl. 1, figs. 5-6, pl. 2, figs. 3-8, pl. 4, fig. 3 from Miller et al. 1982), *E. clavatum subclavatum* (pl. 1, fig. 2, pl. 2, figs. 1-3, from Wilkinson, 1979), *E. clavatum terminatum* (pl. 1, fig. 7, pl. 2, fig. 4, from Wilkinson, 1979), and *E. excavatum forma clavata* (pl. 1, fig. 7, pl. 2, figs. 4, 8 from Feyling-Hanssen, 1972).

**ELPHIDIIDUM SUBARCTICUM Cushman**

*Elphidium subarcticum* CUSHMAN, 1944, p. 27, pl. 3, figs. 34, 35.—LOEBLICH and TAPPAN, 1953, p. 139, pl. 19, figs. 5-7.—FEYLING-HANSSEN ET AL., 1971, p. 280, pl. 13, figs. 3-7, pl. 22, fig. 9.—CRONIN, 1977b, p. 113, pl. 1, figs. 1, 2.—CRONIN, 1979a, p. 808, pl. 6, figs. 8, 9.—RODRIGUES and RICHARD, 1986, p. 20, pl. 2, figs. 3, 4.

Description. Test planispiral, involute, slightly compressed, periphery rounded, lobate; umbilicus slightly depressed, opaque; chambers 6 to 8 visible, increase uniformly in size as added, earlier chambers slightly inflated and later chambers inflated; sutures distinct, depressed, gently curved, extend across periphery, a wide opaque band on both sides of sutures, the opaque band extends across the periphery, 6 to 8 ponticuli on the sutures, ponticuli also on the periphery; wall calcareous, perforate, translucent, radial in polarized light; aperture a low interiomarginal equatorial arch often obscured by tuberculation.

**ELPHIDIIDUM sp.**

*Elphidium sp.* RODRIGUES and RICHARD, 1986, p. 25, pl. 2, figs. 13, 14.
Description. Test planispiral, periphery rounded, even on earlier portion of test and slightly lobate on later portion, umbilicus depressed and covered with a pustulose coating; chambers 8 to 10 visible, compressed in section, very slightly increasing in size as added; sutures distinct, curved, depressed but even to slightly depressed at periphery, sutures covered with a pustulose coating which is widest near the umbilical region and tapering towards the periphery; wall calcareous, perforate, translucent to opaque, radial in polarized light; aperture an interiomarginal slit, often obscured externally by tuberculation.

Discussion. Weiss (1954) described *N. p. Cushman subsp. albiumbilicatum*. This species is characterized by having many ponticuli along the sutures. Feyling-Hanssen et al. (1971), Hansen and Lykke-Andersen (1976), and Cronin (1979a) described the species *Elphidium albiumbilicatum* (Weiss) and placed it in synonymy with *N. pauciloculorum* Cushman subsp. *albiumbilicatum* Weiss. The specimens identified as *E. albiumbilicatum* in the above studies differ from the specimens described by Weiss (1954) by having few or no ponticuli. *E. albiumbilicatum* (Weiss) should therefore, not be placed in synonymy with *N. pauciloculorum* Cushman subsp. *albiumbilicatum* Weiss.

Specimens observed in this study are characterized as having many ponticuli along the sutures. Rodrigues and Richard (1986) described and illustrated *Elphidium* sp. from their Champlain Sea deposits which are the same as the specimens from this study. The present author has followed Rodrigues and Richard (1986) and referred the species to *Elphidium* sp.

Genus: HAYNESINA Banner and Culver, 1978

*HAYNESINA ORBICULARIS* (Brady)

*Nonionina orbicularis* BRADY, 1881, p. 415, pl. 21, fig. 5.
*Elphidium orbiculare* (Brady). LOEBLICH and TAPPAN, 1953, p. 102, pl. 19, figs. 1-4.

*Protoelphidium orbiculare* (Brady). FEYLING-HANSSEN ET AL., 1971, p. 239, pl. 14, figs. 8-11, pl. 24, figs. 6-3. --- CRONIN, 1977b, p. 113, pl. 1, fig. 5. --- CRONIN, 1979a, p. 808, pl. 6, figs. 1-3.
*Haynesina orbicularis* (Brady). RODRIGUES and RICHARD, 1986, p. 21, pl. 2, figs. 15, 16.
Description. Test planispiral, involute, slightly compressed in section, periphery rounded, even to slightly lobate on earlier portion of test and lobate on later portion; umbilicus narrow, opaque, often covered with tubercles, may be depressed in some specimens, chambers 7 to 11 visible, increase uniformly in size as added, slightly inflated in earlier portion of test and inflated in later portion; sutures distinct, gently curved (convex towards aperture), slightly depressed in the earlier portion of test and depressed in the later portion, sutures extend across periphery, tubercles may be found around and in sutures; test white in colour, translucent to opaque; wall calcareous, perforate, radial in polarized light; aperture interiomarginal, a row of pores at the base of the apertural face, often obscured by tuberculation.

Discussion. Banner and Culver (1978) described *Protelepniusium* Haynes as having a large and heavily tuberculate umbilicus. The umbilicus is also filled with imperforate umbilical flaps. *Haynesina* has a smaller umbilicus and true supplementary latero-umbilical apertures.

The genus *Elpidium* de Montfort is characterized by having a cribrate interiomarginal aperture, and intercameral lacuna which is closed to the exterior of the test. *Elpidium* also has ponticuli along the sutures. The intercameral lacuna in *Haynesina* is open to the exterior of the test, and no ponticuli are present on the sutures.

Banner and Culver (1978) reported the primary aperture of *Haynesina* as being a single interiomarginal low arch which is symmetrical about the equatorial plane. Specimens of *Haynesina orbicularis* examined from this present study have apertures which are interiomarginal, a row of pores at the base of the apertural face.

Rodrigues and Richard (1986) identified specimens from the Champlain Sea as *Haynesina orbicularis*. Specimens from this study are identical to the ones described by Rodrigues and Richard (1986).

Superfamily: ORBITOIDACEA Schwager, 1876
Family: CIBICIDIDAE Cushman, 1927
Genus: CIBICIDES de Montfort, 1808

**CIBICIDES LOBATULUS** (Walker and Jacob)

*Nautilus lobatus* WALKER and JACOB in Adams, 1798, p. 642, pl. 14, fig. 36.
*Cibicides lobatus* (Walker and Jacob), CUSHMAN, 1948, p. 78, pl. 8, fig. 14.—FEYLING-HANSSEN ET AL., 1971, p. 260, pl. 9, figs. 9-14.—CRONIN, 1977b, p. 113, pl. 1, fig. 9. ---CRONIN, 1979a, p. 803, pl. 5, figs. 1-3.
Description. Test trochospiral, periphery sub-rounded with an imperforate keel, even on initial chambers and lobate on later chambers; umbilical side convex, involute, 8 to 10 chambers visible, gradually increase in size as added, later chambers slightly inflated; sutures gently curved, flush in initial part of test and slightly depressed in later part of test; spiral side flat, about two whorls and 10 to 18 chambers visible, chambers gradually increase in size as added; chamberal sutures gently curved, limbate, flush to raised, sutures on the later portion of test may be slightly depressed; spiral suture thickened, flush to slightly raised; wall calcareous, coarsely perforate on spiral side and finely perforate on umbilical side, translucent to opaque; aperture an extramarginal interiomarginal slit which extends along the spiral suture on the spiral side of the test.

Superfamily: CASSIDULINACEA d'Orbigny, 1839
Family: CAUCASINIDAE Bykova, 1959
Genus: FURSENKOINA Loeblich and Tappan, 1961

FURSENKOINA LOEBLICHI (Feyling-Hanssen)
Pl. 2. Fig. 13
Bulimina exilis Brady. CUSHMAN, 1948, p. 62, pl. 7, fig. 1.---LOEBLICH and TAPPAN, 1953, p. 110, pl. 20, figs. 4, 5
(not Bulimina elegans d'Orbigny var. exilis Brady, 1884).
Virgulina loeblichi FEYLING-HANSSEN, 1954, p. 191, pl. 1, figs. 14-18, text-fig. 3.---FEYLING-HANSSEN ET AL., 1971, p. 238, pl. 7, figs. 1-5.---CRONIN, 1977b, p. 115, pl. 2, fig. 23.
---CRONIN, 1979a, p. 801, pl. 4, figs. 1-3, 5.

Description. Test elongate, straight to arcuate, tapering towards initial chamber, final chamber tapering towards apertural end, oval to rounded in section; chambers numerous, inflated, biserially arranged throughout test and twisted in early portion of test; initial chambers about equal in width and height, later chambers greater in height than width, chambers increase rapidly in size as added; sutures depressed, slightly oblique in initial part of test and distinctly oblique in later part of test; wall calcareous, finely perforate, translucent to opaque, surface smooth, may have one or two short spines on the proloculus; aperture an elongate opening which extends up from the base of the final chamber to the top of the final chamber, a lip formed by the infolding of the final chamber surrounds the aperture.
Discussion. Loeblich and Tappan (1964) reported that *Fursenkoina* is synonymous with *Virgulina* d’Orbigny. They also pointed out that many authors have erroneously reported that *Virgulina* (=*Fursenkoina*) has a triserial initial stage.

Family: CASSIDULINIDAE d’Orbigny, 1839
Genus: CASSIDULINA d’Orbigny, 1826

CASSIDULINA RENIFORME Nørvang

*Cassidulina crassa* d’Orbigny var. *reniforme* Nørvang, 1945, p. 41, text-fig. 6, e-h.
*Cassidulina islandica* Nørvang. LOEBLICH and TAPPAN, 1953, p. 118, pl. 24, fig. 1 (not *Cassidulina islandica* Nørvang, 1945).
*Cassidulina crassa* d’Orbigny. FEYLING-HANSSEN ET AL., 1971, p. 245, pl. 7, figs. 18, 19.—CRONIN, 1977b, p. 113, pl. 1, fig. 13.—CRONIN, 1979a, p. 802, pl. 4, fig. 12 (not *Cassidulina crassa* d’Orbigny, 1839).
*Cassidulina reniforme* (Nørvang). RODRIGUES ET AL., 1980, p. 58, pl. 2, figs. 2, 4, 6, pl. 3, figs. 3, 6, 9, 11, pl. 5, figs. 10-12.—RODRIGUES and RICHARD, 1986, p. 20, pl. 3, figs. 9, 10.

Description. Test lenticular, periphery rounded, even on initial chambers and slightly lobate on later chambers or even throughout test; chambers inflated, biserial, enrolled, each chamber extends from the umbilicus on one side of the test across the periphery to about halfway to the umbilicus on the opposite side, chambers are sub-rectangular in outline on the side where they reach the umbilicus and are sub-triangular shaped on the opposite side, the sub-rectangular and triangular portions of the chambers alternate from side to side so that each side of the tests consists of 4 to 5 pairs of alternating sub-rectangular and triangular shaped chambers; sutures distinct in translucent specimens and difficult to distinguish in opaque specimens, sutures curved, flush to slightly depressed; wall calcareous, granular in polarized light, perforate, smooth, translucent to opaque; aperture an elongate opening parallel to the periphery; along one margin of the aperture is a lip which is formed by the infolding of the final chamber wall, along the opposite margin is a flap that covers or partially covers the aperture.

Discussion. The chamber arrangement of *Cassidulina reniforme* and *islandiella helena* Feyling-Hanssen and Buzas are very similar. *Cassidulina reniforme* differs from *I. helena* by having a optically granular wall, a rounded periphery and inflated chambers. The aperture of *C. reniforme* is also different from the aperture of *I. helena*. Rodrigues ET AL. (1980) described the aperture of *Cassidulina* as an elongate opening parallel to the periphery, along one margin of the aperture the chamber wall is infolded to form a lip.
and a flap extends along the opposite margin of the aperture. This flap covers or partially covers the aperture.

Rodrigues et al. (1980) mentioned that many authors have misidentified C. reniforme as Cassidulina crassa d'Orbigny and as Islandiella islandica (Nørvang). Rodrigues et al. (1980) concluded that the apertural structures, the granular wall and the more compressed test in edge view of C. reniforme distinguishes this species from I. islandica.

Rodrigues et al. (1980) found it difficult to determine the exact character of Cassidulina crassa from d'Orbigny's figures. The same authors reviewed work by Heron-Allen and Earland (1932) and Boltovskoy (1959, 1978) and recommended that Cassidulina crassa in Heron-Allen and Earland (1932, pl. 9, figs. 26-28) be used as the type illustration for C. crassa. Rodrigues et al. (1980) suggested that C. crassa should be assigned to the genus Globocassidulina because the position of the aperture in C. crassa is angulomarginal, that is, it extends up the apertural face.

Family: NONIONIDAE Schultze, 1854
Genus: ASTRONION Cushman and Edwards, 1937

ASTRONION GALLOWAYI Loeblich and Tappan
Pl. 2, Figs. 9, 10

Astronion stellatum CUSHMAN and EDWARDS, 1937, p. 32, pl. 3, fig. 9-11 (not Nonionina stellata Terquem, 1882).
Astronion stelligerum (d'Orbigny). CUSHMAN, 1948, p. 55, pl. 6, fig. 6 (not Nonionina stelligera d'Orbigny, 1839).
Astronion gallowayi LOEBLICH and TAPPAN, 1953, p. 90, pl. 17, figs. 4-7.---FEYLING-HANSSEN ET AL., 1971, p. 266, pl. 10 figs. 10-12.---HANSEN and LYYKE-ANDERSEN, 1976, p. 24, pl. 22, figs. 5-9.---CRONIN, 1977b, p. 113, pl. 1, fig. 11.---CRONIN, 1979a, p. 804, pl. 5, figs. 10, 11.---
RODRIGUES and RICHARD, 1986, p. 20, pl. 1, figs. 1, 2.

Description. Test planispiral, involute, compressed in section, periphery rounded, lobate, even on initial chambers of smaller specimens; supplementary chambers cover the umbilicus and extend along the sutures but do not reach the periphery, supplementary chambers give the umbilical region a stellate appearance; chambers 8 to 10 visible, inflated, increase gradually in size as added; sutures distinct, curved, depressed; wall calcareous, coarsely perforate, finely perforate on supplementary chambers, translucent to opaque; test yellowish brown or white in colour; primary aperture is an arched, interiomarginal slit that extends to the umbilicus on each side of the test; supplementary apertures are slightly curved, elongate slits found at the outer margin of each supplementary chamber.
TAXONOMY

PART B  OSTRACODA

Introduction

Ostracodes are assigned to the Phylum Arthropoda, Subphylum Mandibulata, Class Crustacea, and Subclass Ostracoda. Ostracodes are characterized by having a segmented soft body covered by a rigid, jointed exoskeleton of chiton, several pairs of jointed appendages, and a bivalved protective shell (carapace) in which the living ostracode is enclosed.

The ostracode carapace is commonly ovate, kidney-shaped or bean-shaped and consists of a right valve and a left valve. The two valves are articulated or joined along the dorsal margin by a hinge. The hinge commonly consists of teeth, sockets, ridges and grooves. The valves are held closed by a series of transverse adductor muscles which are generally attached to the inside of the valves in the central or antero-central position. In well preserved ostracode valves a cluster of small spots (muscle scars) can be found in the central region of the inside of the valves. These spots represent the sites in which the adductor muscles were attached to the valves. The nomenclature and orientation of an ostracode carapace, and the main internal features of a carapace are illustrated in Fig. 8 and 9, respectively.

The taxa presented in this study are arranged in accordance with the classification of the Treatise on Invertebrate Paleontology, Benson et al. (1961). The terminology used for the ostracode hinge types conform with those outlined by Van Morkhoven (1962).

The ostracodes observed in this study belong to the Order PODOCOPIDA and Suborder PODOCOPINA. Originally this order was defined by zoologists on the basis of the soft parts. In recent years paleontologists have used the carapace morphology for classification of fossil taxa. The type of hingement, muscle scar pattern and the outline of the carapace are the important morphological features used in the classification of the Podocopids.

The Superfamilies Cypridacea and Cytheracea are represented in this study. Superfamily Cypridacea are characterized by having smooth, thin valves and commonly an adont hinge. The genus Cydonia is the only representative of this Superfamily in this study. The Superfamily Cytheracea shows a great range in form and ornamentation. The classification of this group is based largely on the type of hingement and muscle scar pattern. Specimens from this study represent eight Families (Cytheridae, Cytherideidae, Hemicytheridae, Trachyleberididae, Cytheruridae, Loxoconchidae, Paradoxostomatidae and Schizocytheridae).
Figure 8. Nomenclature and orientation of an ostracode valve (right valve, external surface). (Modified from Benson et al., 1961)

Figure 9. Left valve of an ostracode, internal surface, showing the important structural elements of the calcareous parts. (Modified from Van Morkhoven, 1962)
Systematic Descriptions

Phylum: ARTHROPODA Siebold and Stannius, 1845
Subphylum: MANDIBULATA Clairville, 1798
Class: CRUSTACEA Pennant, 1777
Subclass: OSTRACODA Latreille, 1806
Order: PODOCOPIDA G. W. Müller, 1894
Suborder: PODOCOPINA Sars, 1866
Superfamily: CYPRIDACEA Baird, 1845
Family: CYPRIDIDAE Baird, 1845

CANDONA SP.

Description. In lateral view the valves are elongate, subtrapezoid in shape; anterior margin symmetrically rounded, posterior margin tapering and asymmetrically rounded; dorsal margin convex; ventral margin straight to slightly sinuous; surface smooth, finely punctate; valves are thin; inner lamella wide at the anterior and posterior margins; marginal pore canals few, evenly spaced; hinge adont; normal pores small, few and scattered; central muscle scars consist of a vertical row of three scars with two more scars situated immediately behind; one larger elongated scar lies above this group; two mandibular scars are located in front of and below the adductor muscle scars; two frontal scars are situated above the mandibular scars; the frontal scars appear to be fused together.

Discussion. The adont hinge is characterized by having no hinge teeth, the dorsal edge of one valve fits into a dorsal groove in the other valve (Van Morkhoven, 1962).

Superfamily: CYTHERACEA Baird, 1850
Family: CYTHERIDAE Baird, 1850
Genus: CYTHERE O. F. Müller, 1785

CYTHERE LUTEA O. F. Müller

Cythere lutea O. F. MÜLLER 1785, p. 65, pl. 7, figs. 3, 4.—NEALE and HOWE, 1975, p. 425, pl. 4, fig. 11.—ROSENFELD, 1977, p. 14, pl. 1, figs. 1, 2.—CRONIN, 1981, p. 395, pl. 4, figs. 7, 8.—RODRIGUES and RICHARD, 1986, p. 33, pl. 6, figs. 4-6.

Description. In lateral view left valve is ovate in shape, right valve is subtrapezoid in shape; anterior margin asymmetrically rounded; posterior margin of left valve symmetrically rounded, right valve with caudal process which is situated centrally or just below center; ventral margin sinuate; dorsal margin convex to straight; surface smooth with large pits around the apertures of the normal pores and numerous punctae in between; a ridge is situated along the
ventral region of the valves; inner lamella wide, widest anteriorly; marginal pore canals moderate in number, widely spaced, slightly sinuous and very distinct; hinge merodont/entomodont; normal pores numerous, large and scattered; central muscle scars consist of a nearly vertical row of four adductor scars; a crescent-shaped frontal scar is located in front of the uppermost adductor scar and an oval mandibular scar in front of the lower adductor scar.

Discussion. The merodont/entomodont hinge is characterized by having crenulated terminal and median elements. The right valve of Cythere lutea has two terminal crenulated teeth and a median crenulated ridge. The left valve has two terminal sockets and a median groove.

Family: CYTHERIDEIDAE Sars, 1925
Genus: HETEROCYPRIDEIS Elofson, 1941

HETEROCYPRIDEIS SORBYANA (Jones)
PI. 3, Figs. 1, 2
Cytherea sorbyana JONES, 1856, p. 44, pl. 4, fig. 6.
----RODRIGUES and RICHARD, 1986, p. 29, pl. 4, figs. 4-6.

Description. In lateral view the valves are elongate-subtrapezoid in shape; anterior end broad and rounded; posterior end tapered and rounded; dorsal margin strongly convex; ventral margin sinuous; surface coarsely pitted, pits are arranged in rows parallel to the margins of the valves; anterior margin denticulate (6-8 spines); one small spine is situated at the postero-ventral corner of the right valve; inner lamella wide, widest at the anterior margin; marginal pore canals numerous, straight and evenly spaced; hinge merodont/entomodont, straight to very slightly curved; normal pores numerous, large and scattered; central muscle scars consist of a slightly curved, vertical row of four adductor scars; a crescent-shaped frontal scar is situated in front of the uppermost adductor scar; an elongate and curved mandibular scar is located in front of the lowermost adductor scar.

Genus: SARSICYTHERIDEA Athersuch, 1982

SARSICYTHERIDEA BRADII (Norman)
PI. 3, FIG. 3
Cytherea bradii NORMAN in Brady, 1865, pp. 192, 193.
Sarsicytheridea bradii (Norman). AITHERSUCH, 1982, p. 241, pl. 7, figs. 2, 4, pl. 8, figs. 1-4, figs. 7a, 8c-e.----RODRIGUES and RICHARD, 1986, p. 29, pl. 4, figs. 10, 11, 12.
Description. In lateral view the valves are elongate-reniform (kidney-shaped); anterior margin broadly rounded; posterior margin obliquely rounded above and slightly more narrowly rounded below; dorsal outline convex; ventral margin in both valves has a concavity just in front of the middle; surface smooth; inner lamella wide, widest anteriorly; marginal pore canals numerous, widely spaced and straight; hinge merodont/entomodont; normal pores numerous, large, rounded, evenly scattered, normal pores appear as white, opaque spots on the valves; central muscle scars consist of a slightly inclined row of four adductor scars; in front of the uppermost adductor scar is a V-shaped frontal scar; below the frontal scar is an elongate mandibular scar.

SARSICYTHERIDEA MACROLAMINATA (Elofson)


Description. In lateral view the valves are elongate and nearly tear drop shaped; anterior end almost evenly rounded; posterior end is obliquely rounded, slightly convex dorsally and very narrowly rounded ventrally; the dorsal margin is convex, converging towards the posterior ventral margin; ventral margin almost straight with a small concavity near the middle; surface smooth; inner lamella wide, widest anteriorly; marginal pore canals numerous, straight and evenly spaced; hinge merodont/entomodont; normal pores numerous, large, horse-shoe shaped and scattered; central muscle scars consist of a slightly inclined row of four adductor scars; in front of the uppermost adductor scar is a V-shaped frontal scar; vertically below the frontal scar is an elongate, oblique mandibular scar.

Discussion. Athersuch (1982) assigned Cytheridea punctillata Brady, Cy. macrolaminata Elofson and Cythere bradii Norman to the genus Sarsicytheridea. Sarsicytheridea macrolaminata was not described or illustrated by Athersuch (1982).

S. macrolaminata differs from S. bradii by having large horse-shoe shaped normal pores. S. bradii has large rounded normal pores.

SARSICYTHERIDEA PUNCTILLATA (Brady)

Cytheridea punctillata BRADY, 1865, p. 189, pl. 9, figs. 9, 11. Eucytheridea punctillata (Brady). VAN DEN BOLD, 1961, p. 294, pl. 9, figs. 1-9, text-figs. 14-20.—ROSENFELD, 1977,p.
22, pl. 4, figs. 57-60.—CRONIN, 1981, p. 396, pl. 2, figs. 6-8, pl. 3, figs. 7-9.

*Sarsicytheridea punctillata* (Brady).  ATHERSUCH, 1982, p. 241, pl. 6, figs. 7-11, pl. 7, figs. 1, 3, 5, fig. 8f.—RODRIGUES and RICHARD, 1986, p. 29, pl. 4, figs. 7-9.

**Description.** In lateral view the valves are elongate-subtrapezoid in shape, lateral view of juveniles are tear-drop shaped; anterior margin obliquely rounded dorsally and regularly rounded in the lower two-thirds; posterior margin slightly convex in the upper part and narrowly rounded at the lower part; dorsal margin very slightly convex, sloping down towards the posterior end; ventral margin almost straight, with a small concavity in the middle; surface is pitted with rounded to pentagonal-triangular shaped pits, the pits are irregularly distributed; inner lamella wide at the anterior and posterior margins; marginal pore canals numerous, straight and closely spaced; hinge merodont/entomodont; normal pores numerous, large round and scattered; central muscle scars consist of a slightly oblique row of four adductor scars, the upper one is rounded and the others are elongate; in front of the uppermost adductor scar is a V-shaped frontal scar; vertically below the frontal scar is an elongate oblique mandibular scar.

**Discussion.** The pitted surface of *Sarsicytheridea punctillata* distinguishes this species from *S. bradli* and *S. macrolaminata*.

**Genus:** FINMARCHINELLA Swain, 1963

FINMARCHINELLA LOGANI (Brady and Crosskey)

*Cythere logani* BRADY and CROSSKEY, 1871, p. 63, pl. 2, figs. 8, 9.

*Finmarchinella curvicosta* NEALE, 1974, p. 90, pl. 1, figs. 1-3, pl. 2, figs. 3, 7-9, 13.—NEALE and HOWE, 1975, p. 418, pl. 1, figs. 2, 6.—CRONIN, 1977b, p. 117, pl. 3, figs. 13, 14.

*Finmarchinella logani* (Brady and Crosskey).  CRONIN, 1981, p. 398, pl. 8, figs. 1, 2.—RODRIGUES and RICHARD, 1986, p. 33, pl. 6, figs. 14, 15.

**Description.** In lateral view the valves are elongate-subreniform in shape; anterior margin asymmetrically rounded; posterior margin with an antero-ventral caudal process; dorsal margin slightly convex; ventral margin straight to very gently sinuous; surface reticulate, three lobes present; one located postero-dorsal, one central and one postero-ventral; valves are thickly calcified and transparent; inner lamella widest at anterior and postero-ventral margins; marginal pore canals numerous, thin, straight, closely spaced on the anterior margin and more widely spaced on the posterior margin; hinge merodont/entomodont; normal pores numerous,
large and scattered; central muscle scars difficult to
distinguish but appear to be a vertical row of four elongate
adductor scars; a poorly developed eye-spot is situated in
the antero-dorsal position of the valves.

Discussion. Cronin (1981) indicated that Finmarchinella
curvicosta Neale is a junior synonym of Cythere logani Brady
and Crosskey.

Family: TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Genus: ACANTHOCYTHEREIS Howe, 1963

ACANTHOCYTHEREIS DUNELMENSIS (Norman)

Cythereis dunelmensis Norman in Brady, 1865, p. 193.

Cythereis dunelmensis (Norman). Norman, 1865, p. 22, pl. 7,
figs. 1-4.

Acanthocytthereis dunelmensis (Norman). Neale and Howe, 1975,
p. 413, pl. 1, figs. 11, 13-16. ---Rosenfeld, 1977, p. 23,
pl. 5, figs. 65-68. ---Cronin, 1981, p. 400, pl. 8, figs.
1, 2.

Description. In lateral view the valves are elongate-
subreniform in shape; anterior margin symmetrically rounded;
posterior margin tapering and symmetrically rounded; dorsal
margin straight; ventral margin slightly convex; surface
reticulate and coarsely spinose; short spines are located
on the posterior, anterior and ventral margins; inner lamella
moderately wide to narrow; marginal pore canals few, straight
and widely spaced; hinge amphidont/lobodont; normal pores
few, small and scattered; central muscle scars were not
observed because of the highly ornamented surface of the
valves.

Discussion. The hinge elements on the right valve
consist of a round posterior tooth, an elongate crescent
shaped anterior tooth and socket, and a median groove which
is divided into two parts. The hinge elements on the left
valve consist of an anterior tooth and socket, a posterior
socket and a median ridge.

Family: CYTHERURIDAE G. W. Müller, 1894
Genus: CYTHERURA Sars, 1865

CYTHERURA SIMILIS Sars

Cytherura similis Sars, 1865
Semicytherura similis (Sars). Rosenfeld, 1977, p. 33, pl. 9,
figs. 107-110, text-figs. 22, 23.
Cytherura similis Sars. Cronin, 1981, p. 402, pl. 5, figs. 5,
7, 8. ---Rodrigues and Richard, 1986, p. 33, pl. 6, fig. 9.

Description. In lateral view the valves are elongate-
sub-rhombooidal in shape; anterior margin asymmetrically rounded; posterior margin drawn out into a caudal process, caudal process is situated centrally or just above the centre; dorsal margin straight to slightly convex; ventral margin straight to very slightly concave; surface punctate and covered with a network of fine raised lines; inner lamella widest at the anterior margin; ten marginal pore canals are situated at the anterior margin; hinge merodont/entomodont; normal pores few, small and scattered; central muscle scars consist of a vertical row of four adductor scar, two mandibular scars are in front of and below the adductor scars, one frontal scar is situated in front of the uppermost adductor scar.

Discussion. Cronin (1981) pointed out that *Semicytherura* Wagner differs from *Cytherura* Sars by having an anteriorly extended inner lamella. Cronin also mentioned that other authors have stated that the development of the inner lamella is variable. Cronin tentatively assigned his Champlain Sea specimens to the genus *Cytherura*.

Specimens from this study are similar to the specimens illustrated by Cronin (1981) and therefore have been assigned to *Cytherura similis*.

Genus: CYTHEROPTERON Sars, 1866

**CYTHEROPTERON ARCUATUM** Brady, Crosskey and Robertson

*Cytheropteron arcaatum* BRADY, CROSSKEY and ROBERTSON, 1874, p. 203, pl. 8, figs. 16-18, pl. 14, figs. 19-22.—WHATLEY and MASSON, 1979, p. 229, pl. 1, figs. 1-5.—CRONIN, 1981, pl. 402, pl. 7, figs. 1, 2.—RODRIGUES and RICHARD, 1986, p. 33, pl. 6, fig. 11.

Description. Roughly ovoid in lateral view; anterior margin asymmetrically rounded; posterior margin tapering and caudate, the extremity of the caudal process is rounded and situated below centre; dorsal margin highly convex; ventral margin slightly sinuous; surface smooth; an ala is situated on the mid-ventral position of the valves; the alae are directed towards the postero-ventral position, the extremity of the ala is slightly curved with two rounded nodes which are separated by a small indentation; inner lamella moderately wide at the anterior margin and narrow along the other margins; marginal pore canals few in number, widely spaced and very faint; hinge merodont/entomodont; normal pores numerous, small and scattered; central muscle scars consist of a vertical row of four elongate adductor muscle scars.

**CYTHEROPTERON BICONVEXA** Whatley and Masson

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Cytheropteron biconvexa WHATLEY and MASSON, 1979, p. 229, pl. 3, figs. 9, 10, 14-16, 18-20.

Description. Small and thin shelled, sub-pyriform or almost pear-shaped in lateral view; anterior margin symmetrically rounded; posterior margin tapering with a central caudal process, the extremity of the caudal process is rounded; dorsal margin convex, sloping down to the posterior margin; ventral margin slightly convex; surface of the valves is smooth, two distinct curved ribs are present; one rib extends from the mid-dorsal position to the leading edge of the alar projection forming an anteriorly convex arc, the other rib forms a dorsally convex loop which almost touches the dorsal margin, the termination of this loop is at the base of each side of the alar projection; the ala on each valve is situated ventrally, the extremity of the ala forms a single rounded node which is directed towards the postero-ventral position; inner lamella moderately wide at the anterior margin and narrow at the other margins; marginal pore canals were not observed; hinge merodont/entomodont; normal pores few, very small and scattered; central muscle scars consist of a vertical row of four elongate adductor scars.

CYTHEROPTERON CHAMPLAINUM Cronin
Pl. 4, Figs. 3, 4

Cytheropteron paralatissimum Swain. NEALE and HOWE, 1975, p. 429, pl. 6, figs. 7, 9, pl. 7, fig. 6, (not Cytheropteron paralatissimum Swain, 1963).

Cytheropteron champlainum CRONIN, 1981, p. 404, pl. 8, figs. 7, 8.---RODRIGUES and RICHARD, 1986, p. 31, pl. 5, figs. 4-6.

Description. In lateral view the carapace is ovate to subrhomboidal in shape; anterior margin obliquely rounded in the upper third and regularly rounded in the lower two-thirds; posterior margin caudate, the extremity of the caudal process is rounded and situated centrally; dorsal margin highly convex; ventral margin sinuous; surface of the valves is punctate; alae are well developed on the mid-ventral position of the valves, the extremity of the ala forms a slightly curved ridge; inner lamella wide, widest anteriorly; marginal pore canals few in number, widely spaced and faint; hinge merodont/entomodont, strongly curved; normal pores numerous, small, scattered; central muscle scars consist of an almost vertical row of four adductor scars which appear to be undivided; the frontal scar is V-shaped and is situated in front of the uppermost adductor scar.

CYTHEROPTERON INFLATUM Brady, Crosskey and Robertson
Pl. 4, Figs. 5, 6

Cytheropteron inflatum BRADY, CROSSKEY and ROBERTSON, 1874, p. 204, pl. 8, figs. 24-27, pl. 14, figs. 26-29.---WHATLEY and
MASSON, 1979, p. 237, pl. 8, figs. 8, 13-16.---CRONIN, 1981, p. 404, pl. 7, figs. 3, 4.---RODRIGUES and RICHARD, 1986, p. 31, pl. 5, figs. 7-9.

Description. In lateral view the valves are elongate and roughly ovoid in shape; anterior margin obliquely rounded in the upper one-third and regularly rounded in the lower two-thirds; posterior margin caudate, the extremity of the caudal process is rounded and centrally positioned; the valves are strongly inflated ventro-laterally; dorsal margin highly convex; ventral margin sinuous; surface of the valves is slightly pitted; a smooth rim surrounds the margin of the valves, this rim is widest on the posterior, anterior and ventral margins; the alae appear to be weakly developed because of the overall inflated nature of the valves; the ventral surface of the ala has a few slightly curved longitudinal ribs; inner lamella wide, widest anteriorly; marginal pore canals few in number and widely spaced; hinge merodont/entomodont, strongly curved; normal pores numerous, small, scattered; central muscle scars consist of an almost vertical row of four adductor scars which appear to be fused together; the frontal scar is V-shaped and is situated in front of the uppermost adductor scar.

CYTHEROPTERON LATISSIMUM (Norman.)

Cythere latissima NORMAN, 1865, p. 19, pl. 6, figs. 5-8.


Description. In lateral view the valves are elongate and subrhomboidal in shape, moderately inflated ventro-laterally; anterior margin asymmetrically rounded; posterior margin caudate, the caudal process is situated centrally and the extremity is rounded; dorsal margin is convex; ventral margin sinuous; surface of valves is punctate; alae not well developed, forming a slight extension along the ventral margin of the valves; inner lamella wide, widest anteriorly; marginal pore canals few in number and widely spaced; hinge merodont/entomodont, slightly curved; normal pores numerous, small and scattered; central muscle scars consist of an almost vertical row of four adductor scars; the frontal scar was not observed.

Discussion. Cytoperon latissimum differs from C. champlainum by having a less developed ala. The valves of C. champlainum are more ovate in shape compared to C. latissimum.

CYTHEROPTERON NEALEI Cronin
*Cytheropteron* sp. nov. NEALE and HOWE, 1975, p. 429, pl. 6, fig. 5.  

Description. In lateral view the valves are elongate-subrhomboidal; anterior margin asymmetrically rounded to nearly symmetrically rounded; posterior margin with a central positioned caudal process; dorsal margin convex, sloping down towards the posterior margin, ventral margin straight to slightly sinuous; central dorsal and central positions of the valves are concave; surface finely punctate, anterior margin appears to be finely reticulate; well developed alae on both valves, the extremity of the alae consist of two rounded nodes separated by a small depression; the node closest to the posterior of the valve is larger than the node closest to the anterior of the valve; inner lamella wide anteriorly, very narrow along the other margins; marginal pore canals very faint, few in number and widely spaced; hinge merodont/entomodont, straight to slightly curved; normal pores numerous, small and scattered; central muscle scars appear to be a vertical row of four adductor scars.

*CYTHEROPTERON NODOSUM* Brady


Description. In lateral view valves are elongate, ovate to subrhomboidal in shape; anterior margin obliquely rounded and regularly rounded in the lower two-thirds; posterior margin caudate, the extremity of the caudal process is rounded and situated centrally, dorsal margin highly convex, ventral margin sinuous; the valves are strongly inflated ventrolaterally; surface of the valve is coarsely punctate; two large knobs are present on the valves; one positioned postero-dorsal, the other antero-dorsal; well developed alae form a slightly curved ridge along the ventral margin, the extremity of the alae is highest towards the posterior end; inner lamella wide, widest anteriorly; marginal pore canals few in number and widely spaced; hinge merodont/entomodont, strongly curved; normal pores numerous, small and scattered; central muscle scars consist of a vertical row of four adductor scars; in front of the uppermost adductor scar is a V-shaped frontal scar.

*CYTHEROPTERON PARALATISSIMUM* Swain

*Cytheropteron paralatissimum* SWAIN, 1963, p. 817, pl. 95, fig. 12, text-fig. 8b. — CRONIN, 1981, p. 408, pl. 7, fig. 6. — RODRIGUES and RICHARD, 1986, p. 33, pl. 6, fig. 12.
**Cytheropteron excavaolatum** WHATLEY and MASSON, 1979, p. 235, pl. 1, figs. 6-10, 13.

**Description.** In lateral view the valves are ovate in shape; anterior margin asymmetrically rounded to nearly symmetrically rounded; posterior margin caudate, extremity of caudal process is rounded and situated centrally; dorsal margin convex; ventral margin slightly sinuous; surface of the valves smooth to very slightly pitted; the alae are well developed with the extremity forming a sharp point which is directed towards the posterior end, the ala has a slight depression in the central position; inner lamella very narrow; marginal pore canals not visible; hinge merodont/entomodont, strongly curved; normal pores numerous, small and scattered; central muscle scars consist of a vertical row of four adductor scars and a V-shaped frontal scar which is situated next to the upper most adductor muscle scar.

**Discussion.** Whatley and Masson (1979) illustrated the species *Cytheropteron excavaolatum*. Cronin (1981) stated that this species may be the same as *C. paralatissimum*. *C. excavaolatum* and *C. paralatissimum* appear to be very similar and therefore, are considered synonymous.

**CYTHEROPTERON PSEUDOMONTROSIENSE** Whatley and Masson

*Cytheropteron montrosiense* BRADY, CROSSKEY and ROBERTSON, 1874, (part), p. 205, pl. 8, figs. 33-36.

*Cytheropteron pseudomonrtrosiense* WHATLEY and MASSON, 1979, p. 247, pl. 2, figs. 5, 7-10, 13, 14.—CRONIN, 1981, p. 404, pl. 6, figs. 5, 7.—RODRIGUES and RICHARD, 1986, p. 31, pl. 5, figs. 1-3.

**Description.** In lateral view the valves are sub-triangular in shape; anterior margin is obliquely rounded and regularly rounded in the lower two-thirds; posterior margin is caudate, the extremity of the caudal process is rounded and situated below centre; dorsal margin is convex and sloping down to the posterior end; ventral margin is straight to very slightly sinuous; surface of the valves are ornamented with polygonal or reticulations that are arranged with an overall concentric pattern; the alae are weakly developed, very broadly rounded, the ventral surface of the ala has a few straight longitudinal ribs; a narrow, smooth rim is found along the anterior and posterior margins; inner lamella wide, extends along the anterior and ventral margins, widest along anterior margin; marginal pore canals not visible; hinge merodont/entomodont; normal pores small and very faint; central muscle scars consist of a vertical row of four adductor scars.

**CYTHEROPTERON SIMPLEX** Whatley and Masson

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**Cytheropteron simplex** WHATLEY and MASSON, 1979, p. 252, pl. 2, figs. 11, 12, 15-21.---CRONIN, 1981, p. 406, pl. 6, figs. 6, 8.

**Description.** In lateral view the valves are ovate in shape, strongly inflated ventrolaterally; anterior margin symmetrically rounded; posterior margin symmetrically tapering to form a central positioned caudal process, the extremity of the caudal process is rounded; dorsal margin convex; ventral margin convex; surface of the valves smooth to very finely punctate; the alae are poorly developed forming a slightly curved ridge; inner lamella wide, widest anteriorly; marginal pore canals few in number and widely spaced; hinge merodont/entomodont, strongly curved; normal pores numerous, small, widely spaced and scattered; central muscle scars consist of an almost vertical row of four adductor muscle scars.

**Discussion.** *Cytheropteron simplex* differs from *C. pseudomontrosiense* Whatley and Masson by having subdued ornamentation. *C. pseudomontrosiense* has very distinct ornamentation.

**Family:** LOXOCONCHIDAE Sars, 1925

**Genus:** CYTHEROMORPHA Hirschmann, 1909

**CYTHEROMORPHA MACCHESNEYI** (BRADY and CROSSKEY)

*Cythere macchesneyi* BRADY and CROSSKEY, 1871, p. 62, pl. 2, figs. 1, 2.

*Cytheromorpha macchesneyi* (BRADY and CROSSKEY). NEALE and HOWE, 1975, p. 442, pl. 3, figs. 5, 6.---CRONIN, 1981, p. 410, pl. 9, figs. 5-8.---RODRIGUES and RICHARD, 1986, p. 33, pl. 6, figs. 1-3.

**Description.** In lateral view the valves are elongate, subreniform in shape; anterior margin nearly symmetrically rounded; posterior margin asymmetrically rounded and not as broadly rounded as anterior margin; dorsal margin straight to slightly convex; ventral margin sinuous; surface of valves reticulate; inner lamella narrow, slightly wider anteriorly; marginal pore canals few, evenly spaced, thin and straight; hinge amphidont; normal pores numerous, small, crescent shaped and scattered; central muscle scars consist of an almost vertical row of four elongate adductor scars, slightly above and anterior to the adductor scars is a crescent shaped fulcrum point.

**Discussion.** The hinge of the right valve has a small anterior tooth surrounded dorsally by a crescent shaped socket, the median element is a narrow, finely crenulated groove, and the posterior tooth is bilobate with a small socket in the centre of this tooth. The hinge on the left valve has a small anterior socket surrounded dorsally by a crescent shaped tooth, the median element is a crenulated ridge, and the posterior
hinge element is an elongate, bilobate socket with a small

tooth in the centre of this socket.

Genus: ROUNDDSTONIA Neale, 1973

ROUNDDSTONIA GLOBULIFERA (Brady)

Cythere globulifera BRADY, 1868, p. 406, pl. 31, fig. 42.
Roundstonia globulifera (Brady). NEALE, 1973, p. 125, pl. 1,
figs. 1-16.---NEALE and HOWE, 1975, p. 426, pl. 5, fig.
13.---CRONIN, 1981, p. 410, pl. 11, figs. 3, 5-7.---
RODRIGUES and RICHARD, 1986, p. 31, pl. 5, fig. 16.

Description. In lateral view the valves are elongate

and subtrapezoid in shape; anterior margin asymmetrically
rounded; posterior margin tapering and almost symmetrically
rounded; dorsal margin straight; ventral margin sinuous;
surface reticulate, the reticulations occur in rows parallel
to the margins; the reticulations in the central position of
the valves are less pronounced and arranged in an irregular
pattern; five knobs are found on the valves; three large
knobs are located along the dorsal margin, one small knob
located at the antero-ventral position, and one very large
knob at the postero-ventral position; inner lamella moderately
wide; marginal pore canals few, thin, straight and widely
spaced; hinge amphidont/heterodont; normal pores numerous,
small, scattered; central muscle scars consist of an almost
vertical row of four elongate muscle scars; the muscle scars
are difficult to distinguish because of the reticulated
surface of the valves.

Discussion. The hinge of the right valve consists of a
posterior tooth and socket, one anterior socket and a median
groove. The hinge elements of the left valve consist of a
large anterior tooth, one small posterior tooth and socket,
and a smooth median ridge.

Family: PARADOXOSTOMATIDAE Brady and Norman, 1889

Genus: SCLEROCHILUS Sars, 1865

SCLEROCHILUS CONTORTUS (Norman)

Cythere contorta NORMAN, 1862, p. 48, pl. 2, fig. 15.
Sclerochilus contortus (Norman). NEALE and HOWE, 1975, p. 422,
pl. 3, figs. 7, 8.---SIDIQUI and GRIGG, 1975, p. 378, pl. 2,
fig. 18.---ROSENFELD, 1977, p. 38, pl. 10, fig. 124.---
CRONIN, 1981, p. 410, pl. 1, figs. 7, 8.---RODRIGUES and
RICHARD, 1986, p. 31, pl. 5, figs. 17, 18.

Description. In lateral view the valves are elongate-
eniform; anterior and posterior margins rounded; dorsal
margin strongly convex; ventral margin sinuous; valves
strongly compressed laterally, highest in or behind the
middle; valves thin, fragile and smooth; inner lamella wide
at anterior margin, narrower ventrally and posteriorly, marginal pore canals numerous, short, straight and evenly spaced; hinge adont, no hinge teeth, the dorsal edge of one valve fits into a dorsal groove in the other valve; normal pores numerous and scattered; central muscle scars consist of a row of five elongate adductor scars, a subrounded frontal scar and an elongate mandibular scar.

Family: SCHIZOCYTERIDAE Howe, 1961
Genus: PALMENELLA Hirschmann, 1916

PALMENELLA LIMICOLA (Norman)

Cythereis limicola NORMAN, 1865, p. 20, pl. 6, figs. 1-4.
Palmenella limicola (Norman). NEALE and HOWE, 1975, p. 426, pl. 5, figs. 7, 8.—SIDDQUI and GRIGG, 1975, p. 378, pl. 2, fig. 14.—ROSENFELD, 1977, p. 15, pl. 1, figs. 1-4.—CRONIN, 1981, p. 412, pl. 11, figs. 1, 2, 4.—RODRIGUES and RICHARD, 1986, p. 33, pl. 6, figs. 13, 16.

Description. In lateral view the valves are elongate and subrectangular in shape; anterior margin asymmetrically rounded; posterior margin symmetrically rounded; dorsal margin straight to concave, marked by raised cardinal angles; ventral margin slightly convex; surface of the valves smooth and punctate, the central posterior position appears reticulate; dorsal-central region of the valves are compressed and have a large knob in the centre; two prominent knobs are found in the antero-dorsal position and two knobs in the postero-dorsal position; along the ventral margin is a sinuous ridge with two small depressions; inner lamella very wide; marginal pore canals few, thin, sinuous and widely spaced; hinge amphidont/schizodont; normal pores very numerous, small and scattered; central muscle scars consist of a vertical row of four widely spaced adductor scars, on the anterior side of the lowermost adductor scar are two mandibular scars, the upper one is V-shaped and the lower one is rounded.

Discussion. The hinge elements of the right valve consist of a median groove, a large anterior tooth with a socket on the posterior side of this tooth, and a large posterior tooth. The hinge elements of the left valve consist of a crenulated median ridge which is divided into a short antero-median element and a longer postero-median element, a rounded anterior tooth with a socket on the anterior side of this tooth, and a posterior socket.
PLATE 1

Line diagrams of the dominant foraminiferal species.
PLATE 1

(Line diagrams of the dominant foraminiferal species).

*1  Elphidium incertum/asklundii (Williamson/Brotzen), Sample 8E, Plate 2, fig. 7 of Rodrigues and Richard (1986), x 55.

*2  Elphidium incertum/asklundii (Williamson/Brotzen), Sample 8E, Plate 2, fig. 11 of Rodrigues and Richard (1986), x 65.

*3  Elphidium clavatum Cushman, Sample 31, Plate 2, fig. 1 of Rodrigues and Richard (1986), x 100.

*4  Elphidium clavatum Cushman, Sample 31, Plate 2, fig. 9 of Rodrigues and Richard (1986), x 105.

**5,6  Islandiella norcrossii (Cushman), Sample 8A, Plate 3, figs. 1, 2 of Rodrigues and Richard (1986), x 80.

*7  Haynesina orbicularis (Brady), Sample 8E, Plate 2, fig. 15 of Rodrigues and Richard (1986), x 80.

**8,9  Islandiella helenae Feyling-Hanssen and Buzas, Sample 22A, Plate 3, figs. 5, 6 of Rodrigues and Richard (1986), x 60.

**10,11  Cassidulina reniforme Nørvang, Sample 22A, Plate 3, figs. 9, 10 of Rodrigues and Richard (1986), x 50.

* Line diagrams for the species were drawn from the Scanning Electron Micrographs of Rodrigues and Richard (1986).

** Line diagrams for the species were drawn from the Photomicrographs of Rodrigues and Richard (1986).
PLATE 2

Scanning electron micrographs of the dominant foraminiferal species.
PLATE 2  
(Scanning Electron Micrographs)  

1  *Cassidulina reniforme* Nørvang, UWJM86F01, Sample A-6, x 140  

2  *Cassidulina reniforme* Nørvang, UWJM86F02, Sample A-6, x 140  

3  *Elphidium clavatum* Cushman, UWJM86F03, Sample R-2C, x 140  

4  *Elphidium subarcticum* Cushman, UWJM86F04, Sample W-3, x 50  

5  *Elphidium* sp., UWJM86F05, Sample W-3, x 80  

6  *Elphidium clavatum* Cushman, UWJM86F06, Sample A-3, x 50  

7  *Haynesina orbicularis* (Brady), UWJM86F07, Sample W-3, x 80  

8  *Haynesina orbicularis* (Brady), UWJM86F08, Sample W-3, x 100  

9  *Astronomion gallowayi* Loeblich and Tappan, UWJM86F09, Sample R-2A, x 100  

10 *Astronomion gallowayi* Loeblich and Tappan, UWJM86F10, Sample R-2A, x 100  

11  *Elphidium incertum/asklundii* (Williamson)/Brotzen, UWJM86F11, Sample W-3, x 50  

12 *Oolina melo* d'Orbigny, UWJM86F12, Sample R-2, x 30, specimen is twinned  

13  *Fursenkoina loeblichii* (Feyling-Hanssen), UWJM86F13, Sample C-2A, x 100, specimen has two short spines on the proloculus  

*Oolina melo and Fursenkoina loeblichii are not dominant foraminiferal species.*
PLATE 3

Scanning electron micrographs of the dominant ostracode species.
PLATE 3
(Scanning Electron Micrographs)

1. *Heterocyprideis sorbyana* (Jones), UWJM8601, Sample R-1, × 90 LV

2. *Heterocyprideis sorbyana* (Jones), UWJM8602, Sample R-1, × 90 RV

3. *Sarsicytheridea bradii* (Norman), UWJM8603, Sample R-2C, × 100 LV

4. *Sarsicytheridea macrolaminata* (Elofson), UWJM8604, Sample R-1, × 90 LV

5. *Sarsicytheridea macrolaminata* (Elofson), UWJM8605, Sample R-1, × 90 RV

6. *Sarsicytheridea punctillata* (Brady), UWJM8606, Sample R-1, × 90 LV

7. *Sarsicytheridea punctillata* (Brady), UWJM8607, Sample R-1, × 90 RV

LV........Left valve
RV........Right valve
PLATE 4

Scanning electron micrographs of the dominant ostracode species.
PLATE 4
(Scanning Electron Micrographs)

1  *Cythereopteron arcuatum* Brady, Crosskey and Robertson, UWJM8608, Sample R-2B-1, x 125 LV

2  *Cythereopteron arcuatum* Brady, Crosskey and Robertson, UWJM8609, Sample R-2B-1, x 125 RV

3  *Cythereopteron champlainum* Cronin, UWJM8610, Sample R-1, x 90 LV

4  *Cythereopteron champlainum* Cronin, UWJM8611, Sample R-1, x 90 RV

5  *Cythereopteron inflatum* Brady, Crosskey and Robertson, UWJM8612, Sample R-1, x 90 LV

6  *Cythereopteron inflatum* Brady, Crosskey and Robertson, UWJM8613, Sample R-1, x 90 RV

7  *Cythereopteron latissimum* (Norman), UWJM8614, Sample R-1, x 100 LV

8  *Cythereopteron latissimum* (Norman), UWJM8615, Sample R-1, x 100 RV

9  *Cythereopteron nodosum* Brady, UWJM8616, Sample R-1, x 90 LV

10  *Cythereopteron nodosum* Brady, UWJM8617, Sample R-1, x 90 RV

LV.......Left valve
RV.......Right valve
PLATE 5

Line drawings of the dominant pelecypods.
PLATE 5
(Line drawings of the dominant pelecypods)

1. *Macoma balthica* (Linne), UWJM86MF01, Sample W-5, exterior of right valve, x 2

2. *Macoma balthica* (Linne), UWJM86MF01, Sample W-5, interior of right valve, x 2

3. *Hiatella arctica* (Linne), UWJM86MF02, Sample W-1, exterior of right valve, x 2

4. *Hiatella arctica* (Linne), UWJM86MF02, Sample W-1, interior of right valve, x 2

5. *Portlandia (Portlandia) arctica* (Gray), sketch from photograph in Wagner (1984), p. 24, fig. B, exterior of right valve, x 4

6. *Portlandia (Portlandia) arctica* (Gray), sketch from photograph in Wagner (1984), p. 24, fig. A, interior of left valve, x 4

7-9. *Mytilus edulis* Linne, sketches from photographs in Wagner (1984), p. 25, fig. A. Fig. 7, exterior of left valve, x 1 Fig. 8, interior of left valve, x 1 Fig. 9, exterior of right valve, x 1
PLATE 6

Line drawings of Balanus hameri
and Mya arenaria.
PLATE 6

(Line drawings of *Balanus hameri* and *Mya arenaria*)

1. *Balanus hameri* (Ascanius), sketch from photograph in Wagner (1984), p. 32, fig. E, side view of adult specimen, x 1

2. *Mya arenaria* Linné, UWJM86MF03, specimen from the Cornwall Map Area, interior of left valve, x 1

3. *Mya arenaria* Linné, UWJM86MF03, specimen from the Cornwall Map Area, exterior of left valve, x 1

4. *Mya arenaria* Linné, sketch from diagram in Wagner (1984), p. 20, fig. 7, hinge of left valve showing the characteristic chondrophore, magnification unknown

5. *Mya arenaria* Linné, UWJM86MF04, specimen from the Cornwall Map Area, interior of right valve, x 2

6. *Mya arenaria* Linné, UWJM86MF04, specimen from the Cornwall Map Area, exterior of right valve, x 2
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CUSHMAN, J. A. and COLE, W. S. 1930. Pleistocene foraminifera from Maryland. Contributions from the Cushman Laboratory for Foraminiferal Research, 6, pt. 4, pp. 94-100.


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135


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APPENDIX I

Heavy liquid separation
APPENDIX I

Heavy Liquid Separation

A mixture of tetrabromomethane and acetone was used (density 1.9 g/cm³).

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Float</th>
<th>Sink</th>
<th>Percentage of Foraminifera which floated</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1</td>
<td>231</td>
<td>52</td>
<td>81.67%</td>
</tr>
<tr>
<td>R-2A</td>
<td>1181</td>
<td>177</td>
<td>87.07%</td>
</tr>
<tr>
<td>R-2B-1</td>
<td>1066</td>
<td>188</td>
<td>85.07%</td>
</tr>
<tr>
<td>A-1A</td>
<td>957</td>
<td>160</td>
<td>85.7%</td>
</tr>
<tr>
<td>A-1B</td>
<td>616</td>
<td>331</td>
<td>65.17%</td>
</tr>
<tr>
<td>A-2</td>
<td>218</td>
<td>28</td>
<td>88.67%</td>
</tr>
<tr>
<td>A-4</td>
<td>188</td>
<td>82</td>
<td>69.67%</td>
</tr>
<tr>
<td>A-5</td>
<td>735</td>
<td>60</td>
<td>92.37%</td>
</tr>
<tr>
<td>A-7</td>
<td>298</td>
<td>22</td>
<td>93.17%</td>
</tr>
<tr>
<td>W-1</td>
<td>1251</td>
<td>108</td>
<td>92.12%</td>
</tr>
<tr>
<td>W-2</td>
<td>620</td>
<td>174</td>
<td>78.12%</td>
</tr>
<tr>
<td>W-3</td>
<td>2101</td>
<td>412</td>
<td>83.67%</td>
</tr>
<tr>
<td>W-4</td>
<td>1500</td>
<td>209</td>
<td>87.87%</td>
</tr>
<tr>
<td>W-5</td>
<td>392</td>
<td>108</td>
<td>84.57%</td>
</tr>
<tr>
<td>W-7</td>
<td>1167</td>
<td>159</td>
<td>88.07%</td>
</tr>
<tr>
<td>C-1</td>
<td>528</td>
<td>32</td>
<td>94.3%</td>
</tr>
<tr>
<td>C-2B</td>
<td>1262</td>
<td>615</td>
<td>67.27%</td>
</tr>
<tr>
<td>C-3</td>
<td>162</td>
<td>41</td>
<td>79.97%</td>
</tr>
<tr>
<td>C-4</td>
<td>192</td>
<td>19</td>
<td>91.07%</td>
</tr>
<tr>
<td>C-5</td>
<td>340</td>
<td>16</td>
<td>95.57%</td>
</tr>
<tr>
<td>C-6</td>
<td>539</td>
<td>231</td>
<td>70.07%</td>
</tr>
</tbody>
</table>

Average: 80.07%

Four samples which were floated contained ostracodes. The percentage of ostracodes that floated ranged from 0% to 11.67% in these samples. (Therefore, ostracodes were picked from the residue that sank in the heavy liquid).

Gibson and Walker (1967) used carbon tetrachloride (density 1.597 g/cm³) to separate recent fossils from residue. The highest percentage of foraminifera which floated was 71.37%. The higher density heavy liquid mixture used in this study appears to be more efficient. Rodrigues and Richard (1986) used the same density mixture.

Note, for best results:

1. Samples should be sieved using 850, 425, 250, 180, 150, and 75 um sieves. The residue in each sieve size should be floated separately.

2. Pouring the residue into the heavy liquid should be done very slowly.
APPENDIX II

Recent occurrences of Islandiella helenaec recorded in the literature
**APPENDIX II**

Recent Occurrences of *Islandiella helenae* recorded in the Literature

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Islandiella helenae</em></td>
<td>Williamson <em>et al.</em> (1984)</td>
<td>Continental margin of Nova Scotia</td>
<td>Temperature 5 to 12°C, Salinity 34.5%. 150 to 220m depth 70 to 100% mud substrate. occurs in the central shelf basin complex.</td>
</tr>
<tr>
<td></td>
<td>Guilbault (1982)</td>
<td>St. Lawrence and Cape Breton Island, Nova Scotia</td>
<td>reported that <em>I. helenae</em> can be found living in the Gulf of St. Lawrence in water less than 100m depth, Temperature 0°C, Salinity 30 to 33%.</td>
</tr>
<tr>
<td></td>
<td>Vilks <em>et al.</em> (1982)</td>
<td>South East Labrador Shelf</td>
<td>occurs in cold waters of the inner shelf Labrador Current. Salinity 33 to 34%, Temperature 0 to 2°C, 212 to 369m depth.</td>
</tr>
<tr>
<td></td>
<td>Rodrigues and Hooper (1982b)</td>
<td>Lake Melville</td>
<td>one occurrence at 154m depth, Salinity greater than 28%.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gulf of St. Lawrence</td>
<td>reported as Eurytopic (occurs in all water mass layers in the Gulf) most abundant in Association 2 (restricted to shelf in finer sandy mud, 73 to 142m depth, Temperature -2 to 2.3°C, Salinity 31.4 to 33.6%). Average percent abundance 42.5%. In Association 4, depth 138 to 211m, Temperature 1.0 to 4.0°C, Salinity 33 to 34.3%. Average percent abundance 13.4%. In Association 3, depth 72 to 149m, Temperature -2 to 2.6°C, Salinity 31.4 to 33.7%. Average percent abundance 7.9%.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>ORIGINIAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Islandiella helena</em> continued</td>
<td>Rodrigues and Hooper (1982b) continued</td>
<td></td>
<td>In Association 1, depth 55 to 128m, Temperature -2 to 2°C, Salinity 30.7 to 33.5%. Average percent abundance 6.5%. Note: waters less than 55m were not sampled.</td>
</tr>
<tr>
<td><em>Islandiella teretis</em></td>
<td>Schafer and Cole (1982)</td>
<td>Continental Slope and Rise of Newfoundland</td>
<td>Commonly living on the Upper Slope (300 to 700m), Salinity about 34%. Water is cold and seasonally variable. Labrador Current water mass.</td>
</tr>
<tr>
<td></td>
<td>Vilks et al. (1979)</td>
<td>Beaufort Shelf</td>
<td>Occurs in offshore waters. Low abundance on the continental shelf in water less than 100m depth. On the continental slope at depths greater than 500m it amounts to 20 to 40% of the total fauna. Found in low numbers in water with salinities less than 33%.</td>
</tr>
<tr>
<td></td>
<td>Schafer and Cole (1978)</td>
<td>Chaleur Bay, Gulf of St. Lawrence</td>
<td>Occurs in the eastern part of the bay and in the deep open Gulf. 56 to 80m depth. Temperature 4 to 6°C. In the Gulf of St. Lawrence Islandiella is prominent at 50 to 300m depth.</td>
</tr>
<tr>
<td></td>
<td>Johnson and Calverley (1976)</td>
<td>Northern Yukon</td>
<td>Associated with more marine conditions (inner shelf conditions).</td>
</tr>
<tr>
<td></td>
<td>Hooper (1975)</td>
<td>Lower St. Lawrence Estuary</td>
<td>Occurs in low numbers. Assemblage 1 (Deep water mass layer, 274 to 400m)</td>
</tr>
<tr>
<td>Taxon</td>
<td>Author(s)</td>
<td>Location</td>
<td>Environment and Remarks</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------------------</td>
<td>---------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Islandiella teretis</td>
<td>Hooper (1975)</td>
<td>155 to 324m, Temperature 4 to 5°C, Salinity 34.6%&lt;sup&gt;0&lt;/sup&gt;. Assemblage 5 (Deep water mass layer, 155 to 324m, Temperature 4 to 5°C, Salinity 34.6%&lt;sup&gt;0&lt;/sup&gt;). Assemblage 3 (18 to 91m depth, Temperature -1 to 8°C, Salinity 21 to 32%&lt;sup&gt;0&lt;/sup&gt;).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sen Gupta (1971)</td>
<td>Tail of the Grand Banks of Newfoundland</td>
<td>55 to 137m, Salinity 33°&lt;sup&gt;0&lt;/sup&gt;. Temperature less than 4°C. Maximum living population was 49.4% at 113m depth.</td>
</tr>
<tr>
<td></td>
<td>Sen Gupta and McMullen (1969)</td>
<td>Grand Banks of Newfoundland</td>
<td>Less than 200m depth, often less than 100m depth.</td>
</tr>
<tr>
<td></td>
<td>Vilks (1969)</td>
<td>Canadian Arctic</td>
<td>Occurs in greater abundance in deeper water (26% of total population at 193m and 33°&lt;sup&gt;0&lt;/sup&gt; at 297m). Salinity about 31.5 to 34.6°&lt;sup&gt;0&lt;/sup&gt;. Temperature about -1.0 to 0°C.</td>
</tr>
<tr>
<td></td>
<td>Vilks (1968)</td>
<td>Magdalen Shallows, Gulf of St. Lawrence</td>
<td>40 to 90m depth. Salinity 30.78 to 32.38°&lt;sup&gt;0&lt;/sup&gt;. Temperature at 50m depth in Spring was 0°C. Occurred at 14 sites, maximum abundance was 19.2% at 60m depth.</td>
</tr>
<tr>
<td>Cassidulina teretis</td>
<td>Lagoe (1979a)</td>
<td>Arctic Ocean</td>
<td>350 to 900m (Atlantic Water Mass Layer), Temperature 0 to -3°C, Salinity 34 to 35.1°&lt;sup&gt;0&lt;/sup&gt;.</td>
</tr>
<tr>
<td></td>
<td>Bartlett (1964)</td>
<td>Atlantic Continental Shelf, South East Nova Scotia</td>
<td>Occurs in fine sand and silt and mixtures of both. Highest frequency from deeper waters. Salinity 31.64 to 32.45°&lt;sup&gt;0&lt;/sup&gt;, Temperature 3 to 9°C.</td>
</tr>
</tbody>
</table>
**APPENDIX II (continued)**

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cassidulina teretis</em></td>
<td><em>Green</em> (1960)</td>
<td>Central Arctic Basin, North Coast of Ellesmere Island</td>
<td>Shelf fauna (433 to 510m depth). Temperature 0.03 to 0.5°C. Salinity 34.8 to 34.9%o.</td>
</tr>
</tbody>
</table>

*References without plates.*
APPENDIX III

Recent occurrences of Islandiella norcrossi recorded in the literature
## APPENDIX III

Recent Occurrences of *Islandersella norcrossi* recorded in the Literature

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Islandersella norcrossi</em></td>
<td>Guilbault (1982)</td>
<td>St. Lawrence Bay and Cape Breton Island, Nova Scotia</td>
<td>reported that <em>I. norcrossi</em> can be found living today in the Gulf of St. Lawrence at depths less than 100m, Temperature 0°C, Salinity 30 to 33‰.</td>
</tr>
<tr>
<td></td>
<td>Rodrigues and Hooper (1982b)</td>
<td>Gulf of St. Lawrence</td>
<td>reported as a Eurytopic species (occurs in all water mass layers in the Gulf, but not abundant). Upper Layer (Zone A) 0 to 60m depth, -2 to 12°C and higher, Salinity less than 33‰. Upper Layer (Zone B) 60 to 125m depth, -2 to 1°C, Salinity 31 to 33‰. Transition Zone, 125 to 200m depth, 1 to 4°C, Salinity 33 to 34‰. Deep Layer (Zone A) 200 to 400m, 4 to 4.9°C, Salinity 34 to 34.8‰. Deep Layer (Zone B) below 400m, 4.1 to 4.5°C, Salinity 34.6 to 34.9‰.</td>
</tr>
<tr>
<td><em>Cassidulina norcrossi</em></td>
<td>Lagoe (1979a)</td>
<td>Arctic Ocean</td>
<td>350 to 900m depth, Temperature 0 to -3°C, Salinity 34 to 35.1‰.</td>
</tr>
<tr>
<td></td>
<td>Phleger (1952)</td>
<td>Canadian Arctic Greenland Arctic</td>
<td>occurs in the Wellington Channel (West coast of North Devon Island), highest occurrences: 44% of total benthonic population at 155m depth and 43% at 137m depth.</td>
</tr>
</tbody>
</table>

*References without plates.*
APPENDIX IV

Recent occurrences of *Cassidulina reniforme* recorded in the literature
APPENDIX IV

Recent occurrences of *Cassidulina reniforme* recorded in the Literature

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cassidulina reniforme</em></td>
<td>Vilks <em>et al.</em> (1982)</td>
<td>South East Labrador Shelf Lake Melville</td>
<td>Depth 70 to 370m, Salinity greater than 33% to 34%. Ranges from 5 to 15% of the total population on the Labrador inner shelf. Arenaceous fauna dominant. <em>C. reniforme</em> present, Salinity greater than 28%.</td>
</tr>
<tr>
<td></td>
<td>Guilbault (1982)</td>
<td>St. Lawrence Bay and Cape Breton Island, Nova Scotia</td>
<td><em>C. reniforme</em> present. Reported that <em>C. reniforme</em> occurs in the Gulf of St. Lawrence in waters less than 100m depth, Temperature 0°C, Salinity 30 to 33%.</td>
</tr>
<tr>
<td></td>
<td>Rodrigues and Hooper (1982b)</td>
<td>Gulf of St. Lawrence</td>
<td>Considered Eurytopic (occurs in all water mass layers in the Gulf) Upper Layer (Zone A) 0-60m depth, -2 to 12°C and higher, salinity less than 33%. Upper Layer (Zone B) 60 to 125m depth, -2 to 10°C, Salinity 31 to 33%. Transitional Zone 125 to 200m depth, 1 to 4°C, Salinity 33-34%. Deep Layer (Zone A) 200 to 400m depth, 4 to 4.9°C, Salinity 34 to 34.8%. Deep Layer (Zone B) below 400m depth, 4.1 to 4.5°C, Salinity 34.6 to 34.9%.</td>
</tr>
<tr>
<td></td>
<td>Sejrup <em>et al.</em> (1981)</td>
<td>Norwegian Continental margin</td>
<td>700m - 1200m depth biofacies Temperature usually less than 0°C, Salinity around 34.92%, occurs as 7 to 30% of total population.</td>
</tr>
<tr>
<td>ORIGINAL AUTHOR'S TAXON</td>
<td>AUTHORS</td>
<td>LOCATION</td>
<td>ENVIRONMENT AND REMARKS</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------</td>
<td>----------</td>
<td>------------------------</td>
</tr>
<tr>
<td><em>Cassidulina islandica</em></td>
<td><em>Lagoe (1979a)</em></td>
<td>Arctic Ocean</td>
<td>350-900m (Atlantic water mass layer), Temperature 0 to 3°C, Salinity 34 to 35.1%</td>
</tr>
<tr>
<td></td>
<td><em>Hooper (1975)</em></td>
<td>Lower St. Lawrence Estuary</td>
<td>dominant species in the watermass layer (Assemblage 5). Temperature 4 to 5°C, Salinity 34.6%. 155 to 324m depth.</td>
</tr>
<tr>
<td></td>
<td><em>Bartlett (1964)</em></td>
<td>Atlantic Continental Shelf, S.E. Nova Scotia</td>
<td>occurs at most stations. Salinity 31.58 to 32.45%, Temperature 3 to 9°C. Highest occurrence at station 17 in 80m of water, Salinity 32.23%, Highest frequency in fine silt and pebble substrates.</td>
</tr>
<tr>
<td>Leslie (1963)</td>
<td>Hudson Bay</td>
<td>abundant at one site (41%), Temperature -1 to -2°C, Salinity about 32%, 65m depth.</td>
<td></td>
</tr>
<tr>
<td>Phleger (1952)</td>
<td>Canadian and Greenland Arctic</td>
<td>occurs in Dundas Harbour (South shore of North Devon Island), 19% to 33% of total population in water depths of 40m and 38m respectively. In Baffin Bay it occurs mainly in water less than 250m.</td>
<td></td>
</tr>
<tr>
<td><em>Cassidulina Crassa var. reniforme</em></td>
<td>Cushman (1948)</td>
<td>Arctic, off Iceland</td>
<td>occurs at 38 to 94m, 180m, and down to 260m depth.</td>
</tr>
<tr>
<td><em>Islandiella islandica</em></td>
<td>Williamson et al. (1984)</td>
<td>Continental margin off Nova Scotia</td>
<td>Salinity 31.8 to 34.4%, occurs mainly on the shelf banks.</td>
</tr>
<tr>
<td>Schäfer and Cole (1978)</td>
<td>Chaleur Bay, Gulf of St. Lawrence</td>
<td>Salinity about 30 to about 32%. Temperature 4 to 6°C, 56 to 80m depth, occurs in parts of the Bay that are constantly exposed to open Gulf bottom water.</td>
<td></td>
</tr>
</tbody>
</table>
### APPENDIX IV (continued)

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Islandiella islandica</em> continued</td>
<td><em>Johnson and Calverley (1976)</em></td>
<td>Northern Yukon</td>
<td>Associated with more marine conditions. (inner-shelf conditions)</td>
</tr>
<tr>
<td></td>
<td>Sen Gupta (1971)</td>
<td>Tail of the Grand Banks of Newfoundland</td>
<td>Salinity $33 \pm 1%$, Temperature usually less than $4^\circ C$, but may reach greater than $8^\circ C$, occurred at depths of 67m to 145m.</td>
</tr>
<tr>
<td></td>
<td><em>Sen Gupta and McMullen (1969)</em></td>
<td>Grand Banks of Newfoundland</td>
<td>Most widespread species. Occurs in water less than 200m depth and often less than 100m depth.</td>
</tr>
<tr>
<td></td>
<td><em>Vilks (1969)</em></td>
<td>Canadian Arctic</td>
<td>Dominant in the deep-water zone (193m to 460m depth), Salinity 33.75 to 34.6%, Temperature about $0^\circ C$.</td>
</tr>
<tr>
<td></td>
<td><em>Sen Gupta (1967)</em></td>
<td>Grand Banks of Newfoundland</td>
<td>Most abundant and widespread species. Highest frequency at about 100m depth.</td>
</tr>
</tbody>
</table>

*References without plates.*
APPENDIX V

Recent occurrences of *Haynesina orbicularis* recorded in the literature
**APPENDIX V**

Recent Occurrences of *Haynesina orbicularis* recorded in the Literature

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Haynesina orbicularis</em></td>
<td>Rodrigues and Hooper (1982b)</td>
<td>Gulf of St. Lawrence</td>
<td>occurs in the Upper Water Mass Layer where depths range from 55m to 125m. Temperature -2.0°C to 1.0°C, Salinity less than 33‰. The Upper Water Mass Layer undergoes considerable thermal and salinity variations. Note: waters less than 55m were not sampled.</td>
</tr>
<tr>
<td><em>Protelphidium orbicularare</em></td>
<td>Scott et al. (1980)</td>
<td>Miramichi River Estuary, New Brunswick</td>
<td>Average salinity 24.8‰, Depth usually less than 55m.</td>
</tr>
<tr>
<td></td>
<td>Lagoe (1979b)</td>
<td>Prudhoe Bay Alaska</td>
<td>less than 6m depth, Temperature 2 to 10°C, Salinity 14-17‰, and 22-30‰.</td>
</tr>
<tr>
<td></td>
<td>Schafer and Cole. (1978)</td>
<td>Chaleur Bay, Gulf of St. Lawrence</td>
<td>Chaleur Bay: Salinity 11 to 32‰, common in warm water, subtidal environment in the bay (less than 70m), Decreases in number in the deep bay. In the Gulf of St. Lawrence; most prominent at depths less than 10m.</td>
</tr>
<tr>
<td></td>
<td>Scott et al. (1977)</td>
<td>Miramichi River Estuary, New Brunswick</td>
<td>common near the mouth of the Miramichi (marginal marine environment). Average Salinity 24.8‰.</td>
</tr>
<tr>
<td>Taxon</td>
<td>Authors</td>
<td>Location</td>
<td>Environment and Remarks</td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Johnson and Calverley (1976)</td>
<td>Northern Yukon</td>
<td>Associated with near-shore, intertidal and outer estuarine conditions.</td>
</tr>
<tr>
<td></td>
<td>Vilks (1969)</td>
<td>Canadian Arctic</td>
<td>Occurrence rare at 17m and 31m depth.</td>
</tr>
<tr>
<td></td>
<td>Vilks (1968)</td>
<td>Magdalen Shallows, Gulf of St. Lawrence</td>
<td>Ranges from 0.4% to 2.1% of total population, in 64m and 55m depth, respectively.</td>
</tr>
<tr>
<td></td>
<td>Leslie (1965)</td>
<td>Hudson Bay</td>
<td>26m to 212m depth, most abundant at depths less than 130m along coastal regions of the Bay. Temperature 2.98 to -1.56°C, Salinity 25.99% to 32.81%, substrate with about 50% sand.</td>
</tr>
<tr>
<td><em>Elphidium orbicularare</em></td>
<td>Schafer (1969)</td>
<td>West Coast of Hudson Bay and James Bay</td>
<td>Reported living in this area.</td>
</tr>
<tr>
<td></td>
<td>Tapley (1969)</td>
<td>Miramichi Estuary, New Brunswick</td>
<td>Occurs in the lower reaches of the river and in the entire bay. Salinity 23 to 25.1%. The number of <em>E. orbicularare</em> drops when the salinity is less than 20%.</td>
</tr>
<tr>
<td></td>
<td>McRoberts (1968)</td>
<td>Northumberland Strait</td>
<td>Salinity greater than 20%. Depth 18.3m. Occurs in the western portion of the strait in outer estuaries and inner lagoons.</td>
</tr>
<tr>
<td></td>
<td>Sen Gupta (1967)</td>
<td>Grand Banks of Newfoundland</td>
<td>Occurs in waters less than 100m. depth.</td>
</tr>
<tr>
<td>ORIGINAL AUTHOR'S TAXON</td>
<td>AUTHORS</td>
<td>LOCATION</td>
<td>ENVIRONMENT AND REMARKS</td>
</tr>
<tr>
<td>------------------------</td>
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</tr>
<tr>
<td><em>Elphidium orbiculare</em></td>
<td>Bartlett (1965)</td>
<td>Shallow waters of the Atlantic Provinces of Canada</td>
<td>common in quiet, slightly brackish marine environment. Salinity 12.63 to 32.6%. Highest living/total ratios in the intertidal zone and near shore shallow waters (100m depth).</td>
</tr>
<tr>
<td></td>
<td>Leslie (1963)</td>
<td>Hudson Bay</td>
<td>occurs as 2 to 5% of total population. Below 25m depth where salinity is about 32%.</td>
</tr>
</tbody>
</table>
APPENDIX VI

Recent occurrences of *Elphidium clavatum* recorded in the literature
## APPENDIX VI

Recent Occurrences of *Elphidium clavatum* Recorded in the Literature

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elphidium clavatum</em></td>
<td>Rodrigues and Hooper (1982a,b)</td>
<td>Gulf of St. Lawrence</td>
<td>considered Eurytopic (occurs in all water mass layers of the Gulf) Upper part Zone A of the Upper Layer: 18 to 50 m depth, Temperature -2°C to greater than 12°C, Salinity less than 32%. Upper Layer: 55 to 125 m depth, Temperature -2 to 1°C, salinity less than 33%. Transitional Zone: 125 to 200 m depth, Temperature 1 to 4°C, Salinity 33 to 34%. Deep Layer (Zone A): 200 to 400 m depth, Temperature 4 to 9°C, Salinity 34 to 34.8%. Deep Layer (Zone B): 400 to 520 m depth, Temperature 4.1 to 4.5°C, Salinity 34.6 to 34.9%. Attains a maximum in Zone A of the Upper Layer at depths less than 50 m and also in the deep layer between 270 and 520 m.</td>
</tr>
<tr>
<td></td>
<td>Bergen and O'Neil (1979)</td>
<td>Gulf of Alaska</td>
<td>Littoral zone (beach samples) 90% of the fauna. Most specimens occur in less than 90 m depth and under seasonal fluctuations.</td>
</tr>
<tr>
<td></td>
<td>Lagoe (1979b)</td>
<td>Prudhoe Bay, Alaska</td>
<td>less than 6 m depth Temperature 2 to 10°C, Salinity 14 to 17% and 22 to 30%.</td>
</tr>
<tr>
<td><em>Vilks et al.</em> (1979)</td>
<td>Beaufort Shelf</td>
<td>greater than 40% of the total population adjacent to delta. Decreases in</td>
<td></td>
</tr>
<tr>
<td>Taxon</td>
<td>Authors</td>
<td>Location</td>
<td>Environment and Remarks</td>
</tr>
<tr>
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</tr>
<tr>
<td>Elphidium clavatum</td>
<td>*Vilks et al. (1979)</td>
<td>number offshore. Distributed in nearshore waters which are directly influenced by runoff of the Mackenzie River. Inner shelf - Estuarine, mean depths of 41, 47, and 49m.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*Hooper (1975)</td>
<td>Lower St. Lawrence Estuary</td>
<td>occurs in the Upper Water Mass Layer: 0 to 80m depth, Temperature -1 to 8°C, Salinity 21 to 32‰. Assemblage 3: 0 to 91m, E. clavatum is 29.54% of total population. Assemblage 1 (Deep Water Mass Layer): 274 to 400m depth, Temperature 4 to 55°C, Salinity 34.6‰, E. clavatum occurs as 8% of total population.</td>
</tr>
<tr>
<td></td>
<td>Sen Gupta (1971)</td>
<td>Tail of the Grand Banks</td>
<td>water depth varies between 50 and 80m, Salinity 33± 1‰, Temperature -0.9 to 8.3°C. The highest living population is 65.8% at a water depth of 68m.</td>
</tr>
<tr>
<td></td>
<td>*Sen Gupta and McMullen (1969)</td>
<td>Grand Banks of Newfoundland</td>
<td>less than 200m depth and often less than 100m. E. clavatum occurs at 90% of stations sampled.</td>
</tr>
<tr>
<td></td>
<td>*Schafer (1969)</td>
<td>West coast of Hudson Bay and James Bay</td>
<td>more abundant in the tidal-flats.</td>
</tr>
<tr>
<td></td>
<td>*Hooper (1968)</td>
<td>Continental Shelf of Eastern Canada</td>
<td>reported at 56 to 74m and 58 to 165m depth. Described as an ubiquitous species.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Original Author's Taxon</th>
<th>Authors</th>
<th>Location</th>
<th>Environment and Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cribrodonion excavatum clavatum</strong></td>
<td>Scott et al. (1980)</td>
<td>Miramichi Estuary, New Brunswick</td>
<td>Occurs usually in less than 5m depth. Temperature 0 to 20°C, Salinity 22 to 28%, average 24.8%. Estuary-marginal marine zone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chezzetcook Inlet, Nova Scotia</td>
<td>Annual Temperature range 0 to 22°C. Salinity 25 to 32%. Upper Estuarine and Open Bay Zone (Open Bay, Salinity average 31.4%).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restigouche Estuary, New Brunswick</td>
<td>Salinity average 27.2%. Transitional Zone (between Upper Estuarine and Marginal Marine).</td>
</tr>
<tr>
<td><strong>Elphidium incertum &quot;complex&quot;</strong></td>
<td>*Scott et al. (1977)</td>
<td>Miramichi Estuary, New Brunswick</td>
<td>Salinity ranges from 22 to 28%, average 24.8%. Temperature 0 to 20°C. Dominant in the Open Bay (=Marginal Marine)</td>
</tr>
<tr>
<td></td>
<td>*Tapley (1969)</td>
<td>Miramichi Estuary, New Brunswick</td>
<td><em>Elphidium</em> fauna decrease in number when salinity is below 20%. Station 57 (beach intertidal zone), less than 5m depth, average salinity 24%. Station 42, 5m depth, Salinity 17.5%, <em>E. clavatum</em> dominant.</td>
</tr>
<tr>
<td></td>
<td>*Bartlett (1965)</td>
<td>Shallow waters of the Atlantic</td>
<td>Salinity 12.63 to 32.67%. <em>Elphidium</em> fauna increase in species and specimens from the intertidal zone to depths of 40m. Highest living/total ratios in the intertidal zone and nearshore, shallow waters (10m).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provinces of Canada</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elphidium clavatum</em></td>
<td><em>McRoberts (1968)</em></td>
<td>Western portion of the Northumberland Strait</td>
<td>less than 18.3m depth, Salinity greater than 20%. Dominant in outer estuaries and inner lagoons.</td>
</tr>
<tr>
<td></td>
<td>Loeblich and Tappan (1953)</td>
<td>Point Barrow Alaska</td>
<td>occurs at 21.6m depth.</td>
</tr>
<tr>
<td><em>Elphidium excavatum forma clavata</em></td>
<td><em>Guilbault (1982)</em></td>
<td>St. Lawrence Bay Cape Breton Island, Nova Scotia</td>
<td>reported living in the Gulf of St. Lawrence between 20m and 100m depth, Temperature 0°C, Salinity 30 to 33‰.</td>
</tr>
<tr>
<td></td>
<td>Miller et al. (1982)</td>
<td></td>
<td>provides a summary table of the occurrence of <em>Elphidium excavatum forma clavata</em> from the literature.</td>
</tr>
<tr>
<td></td>
<td>Vilks et al. (1982)</td>
<td>South East Labrador Shelf</td>
<td>occurs as 5 to 40% of the total population. (40% at 97m depth, and about 5% at 230m and 340m depth). Salinity about 33 to 34‰, Temperature 0 to 2°C.</td>
</tr>
<tr>
<td></td>
<td>Feyling-Hanssen (1972)</td>
<td>Arctic and Subarctic waters of North America</td>
<td>occurs in shallow to moderate depth of water.</td>
</tr>
<tr>
<td><em>Elphidium excavatum</em></td>
<td>Wefer (1976)</td>
<td>Western Baltic Sea</td>
<td>Temperature less than 10°C, Salinity greater than 20‰. (maximum depth sampled about 27m).</td>
</tr>
<tr>
<td><em>Elphidium excavatum</em></td>
<td><em>Culver and Buzas (1980)</em></td>
<td>North American Atlantic Coast</td>
<td>reported as an ubiquitous species.</td>
</tr>
</tbody>
</table>
APPENDIX VI (continued)

<table>
<thead>
<tr>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elphidium incertum</em> /</td>
<td>Schafer and Cole (1978)</td>
<td>Chaleur Bay, Gulf of St. Lawrence</td>
<td>Temperature 0 to 19°C, Salinity 11 to 32%, Shallow Bay species (less than 20m), In the deep bay numbers decrease.</td>
</tr>
<tr>
<td><em>Elphidium clavatum</em> &quot;complex&quot;</td>
<td><em>Schafer (1976)</em></td>
<td>St. Georges Bay, Nova Scotia</td>
<td>Salinity 29.2%, Temperature 13.5°C, water depth 15m.</td>
</tr>
<tr>
<td><em>Elphidium clavatum</em> &quot;complex&quot;</td>
<td><em>Bartlett (1964)</em></td>
<td>Atlantic Continental Shelf, S.E. Nova Scotia</td>
<td>Salinity 31.64 to 32.45%, Temperature 3 to 9°C, Abundant up to a depth of 100m, 3.1% of total population at 120m, and 26% at 28m.</td>
</tr>
<tr>
<td><em>Elphidium clavatum-incertum</em></td>
<td><em>Lagoe (1979a)</em></td>
<td>Arctic Ocean</td>
<td>17 to 350m depth, occurrence rare and rather sporadic, Temperature near 0°C, Salinity 28 to 32%.</td>
</tr>
<tr>
<td><em>Elphidium clavatum</em></td>
<td>Wilkinson (1979)</td>
<td>Southern limit, Gulf of Maine</td>
<td>Arctic-Subarctic distribution, Temperature 0 to 5°C, generally below 10°C in the warmest months.</td>
</tr>
</tbody>
</table>

*Elphidium clavatum* are different in form compared to the specimens from the Champlain Sea sediments.

*References without plates.
APPENDIX VII

Occurrences of the dominant macrofaunal taxa
# APPENDIX VII

**Occurrences of the dominant macrofaunal taxa**

*Recent Occurrences*

<table>
<thead>
<tr>
<th>TAXON</th>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Balanus hameri</strong></td>
<td>Balanus hameri</td>
<td>Rodrigues and Richard (1986)</td>
<td>Champlain Sea</td>
<td>colonized the highest salinity bottom water of the Champlain Sea. Occurred in pebbly clayey sand and pebbly sandy clay.</td>
</tr>
<tr>
<td></td>
<td>Balanus hameri</td>
<td>Hillaire-Marcel (1980)</td>
<td>Post-glacial seas of Quebec</td>
<td>Temperature about 0°C. Salinity greater than 30%.</td>
</tr>
<tr>
<td></td>
<td>*Wagner (1984)</td>
<td></td>
<td>Beaufort Sea</td>
<td>occurs in waters 6.5m to 25.9m depth.</td>
</tr>
<tr>
<td></td>
<td>Portlandia arctica</td>
<td>Hillaire-Marcel (1980)</td>
<td>Post-glacial seas of Quebec</td>
<td>Temperature about 0°C. Salinity about 30%.</td>
</tr>
<tr>
<td></td>
<td>*Lubinsky (1980)</td>
<td></td>
<td>Canadian Arctic</td>
<td>abundant in waters 10 to 400m deep</td>
</tr>
<tr>
<td></td>
<td>Portlandia arctica</td>
<td>*Ellis (1960)</td>
<td>Arctic, North America</td>
<td>50 to 500m depth. Only on mud substrates. Temperatures negative, Salinity near 32%.</td>
</tr>
<tr>
<td></td>
<td>Portlandia sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hiatella arctica</strong></td>
<td>Hiatella arctica</td>
<td>Hillaire-Marcel (1980)</td>
<td>Post-glacial seas of Quebec</td>
<td>0 to 100m depth euryhaline and eurythermal. shallow, nearshore environments.</td>
</tr>
<tr>
<td></td>
<td>*Schafer and Wagner (1978)</td>
<td></td>
<td>Chaleur Bay, Gulf of St. Lawrence</td>
<td></td>
</tr>
</tbody>
</table>

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# APPENDIX VII (continued)

<table>
<thead>
<tr>
<th>TAXON</th>
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<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hiatella arctica</em> continued</td>
<td><em>Hiatella arctica</em></td>
<td><em>Clarke (1974)</em></td>
<td>Baffin Bay, Northern North Atlantic</td>
<td>30-95 fathoms depth (180 to 570 feet)</td>
</tr>
<tr>
<td></td>
<td><em>Hiatella arctica</em></td>
<td>Elson (1969)</td>
<td>Champlain Sea Sediments</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Hiatella arctica</em></td>
<td><em>Bernard (1967)</em></td>
<td>West coast of Canada</td>
<td>30-250 fathoms depth (180 to 1500 feet)</td>
</tr>
<tr>
<td></td>
<td><em>Saxicava arctica</em></td>
<td><em>Bousfield (1955)</em></td>
<td>Miramichi Estuary, N.B.</td>
<td>Salinity 12.5 to 25%. Water depth 24 feet</td>
</tr>
<tr>
<td></td>
<td><em>Saxicava arctica</em></td>
<td><em>LaRocque (1953)</em></td>
<td>Arctic Ocean, Greenland</td>
<td>1 to 100 fathoms (6 to 600 feet)</td>
</tr>
<tr>
<td><em>Macoma balthica</em></td>
<td><em>Macoma balthica</em></td>
<td><em>Wagner (1984)</em></td>
<td>Beaufort Sea Miramichi Inner Bay Strait of Canso</td>
<td>4m depth. 1.5 to 10m depth.</td>
</tr>
<tr>
<td></td>
<td><em>Macoma balthica</em></td>
<td>Hillaire-Marcel (1980)</td>
<td>Post-glacial Seas of Quebec</td>
<td>44m depth. intertidal (5-6m) and deeper Temperature greater 8°C to 10°C.</td>
</tr>
<tr>
<td></td>
<td><em>Macoma balthica</em></td>
<td><em>Lubinsky (1980)</em></td>
<td>Canadian arctic James Bay</td>
<td>down to 20m depth</td>
</tr>
<tr>
<td></td>
<td><em>Macoma balthica</em></td>
<td>Elson (1969)</td>
<td>Champlain Sea Sediments</td>
<td>down to 60m depth</td>
</tr>
<tr>
<td></td>
<td><em>Macoma balthica</em></td>
<td></td>
<td></td>
<td>concluded from other studies; <em>M. balthica</em> can tolerate salinities as low as 6%.</td>
</tr>
</tbody>
</table>
### APPENDIX VII (continued)

<table>
<thead>
<tr>
<th>TAXON</th>
<th>ORIGINAL AUTHOR'S TAXON</th>
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<th>ENVIRONMENT AND REMARKS</th>
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</thead>
<tbody>
<tr>
<td><em>Macoma balthica</em> continued</td>
<td><em>Macoma balthica</em></td>
<td><em>Bernard (1967)</em></td>
<td>West Coast of Canada</td>
<td>Intertidal to 5 fathoms (30 feet).</td>
</tr>
<tr>
<td></td>
<td><em>Macoma balthica</em></td>
<td><em>Bousfield (1955)</em></td>
<td>Miramichi Estuary, N.B.</td>
<td>Salinity 4 to 18.5%.</td>
</tr>
<tr>
<td></td>
<td><em>Macoma balthica</em></td>
<td><em>Abbott (1954)</em></td>
<td>General occurrence or distribution</td>
<td>common in intertidal and deep water.</td>
</tr>
<tr>
<td><em>Macoma balthica</em></td>
<td><em>Macoma balthica</em></td>
<td>Hillaire-Marcel (1980)</td>
<td>Post-glacial Seas of Quebec off Newfoundland</td>
<td>intertidal</td>
</tr>
<tr>
<td><em>Macoma balthica</em></td>
<td><em>Mytilus edulis</em></td>
<td><em>Lubinsky (1980)</em></td>
<td>Hudson River Estuary, N.Y.</td>
<td>sublittoral to a depth of 50m.</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td><em>Mytilus edulis</em></td>
<td><em>Ristich et al. (1977)</em></td>
<td>Canadian Arctic</td>
<td>Salinity 18 to 30%.</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td><em>Mytilus edulis</em></td>
<td><em>Andrews (1972)</em></td>
<td>Champlain Sea Sediments</td>
<td>not restricted to intertidal environment. Is however, considered to prefer shallow water.</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td>Elson (1969)</td>
<td></td>
<td>West coast of Canada</td>
<td>concluded from other studies that <em>M. edulis</em> lives in waters with: Temperatures 2 to 20°C, Salinities as low as 5%.</td>
</tr>
<tr>
<td><em>Mytilus edulis</em></td>
<td><em>Bernard (1967)</em></td>
<td></td>
<td></td>
<td>Intertidal to 5 fathoms depth (30 feet)</td>
</tr>
<tr>
<td>TAXON</td>
<td>ORIGINAL AUTHOR'S TAXON</td>
<td>AUTHORS</td>
<td>LOCATION</td>
<td>ENVIRONMENT AND REMARKS</td>
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<tr>
<td>Mi/taa</td>
<td>Mi/taa</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mi/aacnaa-ta</td>
<td>Mi/aacnaa-ta</td>
<td>*Jaguar (1984)</td>
<td>Miramichi Inner Bay Strait of Canso</td>
<td>1.5m depth</td>
</tr>
<tr>
<td>Mi/aacnaa-ta</td>
<td>Mi/aacnaa-ta</td>
<td></td>
<td></td>
<td></td>
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<td>Mi/aacnaa-ta</td>
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<tr>
<td>Mi/aacnaa-ta</td>
<td>Mi/aacnaa-ta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mya arenaria</td>
<td>Mya arenaria</td>
<td>Hillaire-Marcel (1980)</td>
<td>Post-glacial Seas of Quebec</td>
<td>Intertidal. Temperatures greater than 12°C.</td>
</tr>
<tr>
<td>Mya arenaria</td>
<td>Mya arenaria</td>
<td>*Schafer and Wagner (1978)</td>
<td>Chaleur Bay, Gulf of St. Lawrence</td>
<td>Shallow nearshore environment.</td>
</tr>
<tr>
<td>Mya arenaria</td>
<td>Mya arenaria</td>
<td>*Ristich et al (1977)</td>
<td>Hudson River Estuary, N.Y.</td>
<td>Salinity 18 to 30% (polyhaline) may extend into the mesohaline waters (5-18%).</td>
</tr>
<tr>
<td>Mya arenaria</td>
<td>Mya arenaria</td>
<td>Elson (1969)</td>
<td>Champlain Sea Sediments</td>
<td>concluded from other studies that M. arenaria needs summer temperatures greater than 5°C, Salinity may be as low as 5%.</td>
</tr>
<tr>
<td>Mya arenaria</td>
<td>Mya arenaria</td>
<td>*Bernard (1967)</td>
<td>West coast of Canada</td>
<td>Intertidal to 15 fathoms (90 feet).</td>
</tr>
<tr>
<td>Mya arenaria</td>
<td>Mya arenaria</td>
<td>*Bousfield (1955)</td>
<td>Miramichi Estuary, N.B.</td>
<td>24 feet depth. Salinity 15 to 25%, occasionally 6.5 and 12.5%.</td>
</tr>
</tbody>
</table>
APPENDIX·VIII

Recent and fossil occurrences of the dominant ostracode taxa
## APPENDIX VIII

### Recent and fossil occurrences of the dominant ostracode taxa

*Recent occurrences

<table>
<thead>
<tr>
<th>OSTRACODE TAXON</th>
<th>ORIGINAL AUTHOR'S TAXON</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>ENVIRONMENT AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cytheromorpha macchesneyi</em></td>
<td><em>Cytheromorpha macchesneyi</em></td>
<td>Rodrigues and Richard (1986)</td>
<td>Champlain Sea Sediments, Ont. and Que.</td>
<td>Present in cold, low salinity bottom water (10 to 20%).</td>
</tr>
<tr>
<td><em>Cythere lutea</em></td>
<td><em>Cythere lutea</em></td>
<td>Gunther and Hunt (1977)</td>
<td>Lake Champlain Sediments, Vermont.</td>
<td>Temperature 0 to 23°C, Salinity 10 to 34%.</td>
</tr>
<tr>
<td></td>
<td><em>Cythere lutea</em></td>
<td>Rosenfeld (1977)</td>
<td>Baltic Sea</td>
<td>6 to 19m depth, Salinity 17 to 25%.</td>
</tr>
<tr>
<td></td>
<td><em>Cythere lutea</em></td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments, Ont., Queb., Vermont, New York</td>
<td>Temperature 0 to about 22°C, Salinity 10 to 35%.</td>
</tr>
<tr>
<td><em>Cythereopteron arcuatum</em></td>
<td><em>Cythereopteron arcuatum</em></td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to 13°C, Salinity 28 to 35%.</td>
</tr>
<tr>
<td><em>Cythereopteron champlainum</em></td>
<td><em>Cythereopteron champlainum</em></td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to 13°C, Salinity 28 to 35%.</td>
</tr>
<tr>
<td><em>Cythereopteron inflatum</em></td>
<td><em>Cythereopteron inflatum</em></td>
<td>Whatley and Masson (1979)</td>
<td>Great Britain</td>
<td>Only found from waters of normal marine salinity, and noted at depths of 50 to 1000m.</td>
</tr>
<tr>
<td></td>
<td><em>Cythereopteron inflatum</em></td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to about 13°C, Salinity 28 to 35%.</td>
</tr>
<tr>
<td>Ostracode Taxon</td>
<td>Original Author's Taxon</td>
<td>Authors</td>
<td>Location</td>
<td>Environment and Remarks</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------</td>
<td>------------------------------</td>
<td>------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>*Cytheropteron latissimum</td>
<td>*Cytheropteron latissimum</td>
<td>Whatley and Masson (1979)</td>
<td>Great Britain</td>
<td>Shallow water, near normal marine salinity, in a wide variety of substrates.</td>
</tr>
<tr>
<td></td>
<td>*Cytheropteron latissimum</td>
<td>Rosenfeld (1977)</td>
<td>Baltic Sea</td>
<td>10 to 44m depth, Salinity 14 to 30%</td>
</tr>
<tr>
<td></td>
<td>*Cytheropteron latissimum</td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to about 22°C.</td>
</tr>
<tr>
<td>*Cytheropteron nodosum</td>
<td>*Cytheropteron nodosum</td>
<td>Whatley and Masson (1979)</td>
<td>Great Britain</td>
<td>Marine species, most abundant in shallow to moderately deep water.</td>
</tr>
<tr>
<td></td>
<td>*Cytheropteron nodosum</td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Salinity about 25 to 35%.</td>
</tr>
<tr>
<td>*Eucytheridea bradii</td>
<td>*Eucytheridea bradii</td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to about 22°C.</td>
</tr>
<tr>
<td>*Eucytheridea punctillata</td>
<td>*Eucytheridea punctillata</td>
<td>Rosenfeld (1977)</td>
<td>Baltic Sea</td>
<td>13 to 72m depth, Salinity 6 to 30%</td>
</tr>
<tr>
<td></td>
<td>*Eucytheridea punctillata</td>
<td>Gunther and Hunt (1977)</td>
<td>Lake Champlain Sea Sediments</td>
<td>Temperature 0 to 18°C.</td>
</tr>
<tr>
<td></td>
<td>*Eucytheridea punctillata</td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to about 23°C. Salinity about 10 to 35%. Same as <em>E. bradii</em>. above.</td>
</tr>
<tr>
<td></td>
<td>*Eucytheridea punctillata</td>
<td>Van den Bold (1961)</td>
<td>General Occurrences</td>
<td></td>
</tr>
<tr>
<td>OSTRACODE TAXON</td>
<td>ORIGINAL AUTHOR'S TAXON</td>
<td>AUTHORS</td>
<td>LOCATION</td>
<td>ENVIRONMENT AND REMARKS</td>
</tr>
<tr>
<td>-------------------------</td>
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<td>--------------------------</td>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Heterocyprideis sorbyana</td>
<td>Heterocyprideis sorbyana</td>
<td>Gunther and Hunt (1977)</td>
<td>Lake Champlain Sediments</td>
<td>Temperature 0°C to 17.5°C, Salinity 2 to 35%</td>
</tr>
<tr>
<td></td>
<td>*Heterocyprideis sorbyana</td>
<td>Rosenfeld (1977)</td>
<td>Baltic Sea</td>
<td>16 to 110m depth, Salinity 6 to 20%</td>
</tr>
<tr>
<td></td>
<td>Heterocyprideis sorbyana</td>
<td>Cronin (1977b)</td>
<td>Champlain Sea Sediments</td>
<td>Temperature below 0°C to about 22°C, Salinity 2 to 35%</td>
</tr>
</tbody>
</table>
VITA AUCTORIS

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N9A 6Y2

SUMMARY OF BACKGROUND

1977-1981, Honours B.Sc. (Geology)
September, 1981 to April, 1983 - Graduate Student Teaching
Assistant- University of Windsor, Windsor, Ontario.
Preparation and explanation of introductory paleontology
laboratory exercises.
September, 1983-April, 1984 - Sessional lecturer- University
of Windsor, Windsor, Ontario. Instructor for first year
Geology course (85-136) for first year engineering
students.
September, 1984 - May, 1987 - Laboratory demonstrator-
University of Windsor, Windsor, Ontario. Preparation
and explanation of introductory geology laboratory
exercises.

EXPERIENCE

Field and Laboratory Assistant - 1978, University of Windsor,
Windsor, Ontario. Paleomagnetic studies.
Uranium exploration project in the Northwest Territories.
Oil Exploration - 1980, Amoco, Canada, Calgary, Alberta.
Subsurface mapping project.

AWARDS


PERSONAL

Canadian citizen, married, excellent health.
SURFICIAL GEOLOGY OF THE
RUSSELL MAP AREA

Map 1
SURFICIAL GEOLOGY OF THE
ALEXANDRIA MAP AREA
Map 2
LENOX

CENOZOIC
QUATERNARY
RECENT

Alluvium: unsubdivided sand, silt, gravel.
Older Alluvium: sandy silt and very silty sand.
 Suspended deposits: peat, muck, organic silt, marl.
Windblown deposits: fine to very fine sand.
Deltaic deposits: medium to fine sand.

PLEISTOCENE
WISCONSINAN

Harine beach, bar, and spit sediments: cobble- to boulder-sized gravel usually rich in abundant fossils.
Marine shallow-water sediments: fine sand with some fossils.
Marine intermediate- or confined-water sediments rhythmically interbedded clay and sandy clayey silt.
Marine deep-water sediments: clay rich with fossils.
Fort Covington Till: cobbly to bouldery sandy silt till.

PALEOZOIC
ORDOVICIAN

Bedrock

Reference: Gwyn and Loise (1973)

A-1 Sample Site

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SURFICIAL GEOLOGY OF THE
WINCHESTER MAP AREA

Map 3
SCIENTIFIC GEOLOGY OF THE

CENTRAL...

Kilometres

CE N O Z O I C

QUADRAT 'M' P O L A R M A L M S E A D E P O S I T S

OLIFL T DEPOSITS: mainly mud and peat in bog, fen, swamp, and poorly drained areas

ALUVIAL DEPOSITS: silty sand, silt, minor gravel, dispersed organic matter and root

Silty sand, silt, and clay deposits of former Champlain and St. Lawrence Oceans in many of the drowned basins and well-developed channels

UNCONFORMITY DEPOSITS

CHAMPAIGN SEA SEDIMENT:

PHI NEAR SHORE SEDIMENT: gravel, sand, and coarse material, generally well sorted in modern and ancient beaches; commonly fossiliferous; nature of sediment controlled by underlying materials (gravel, sand and boulders)

IC, FINE - TO MEDIUM- GRAINED SAND, CARBONATE AND FOSSILIFEROUS; NEAR SHORE SAND generally occurs as a sheet or as bars or spits associated with glaciomarine deposits

DELTAIC AND ESTUARINE DEPOSITS: medium-to-fine-grained sand, commonly fossiliferous, lies outside abandoned channels; most deposit is a combined strip delta and plain that developed as water level fell; developed in part in a residual lake (Lamplough Lake) where shown to contain freshwater fossils

OFFSHORE MARINE DEPOSITS: massive blue-grey clay, silty clay and silt; calcareous and fossiliferous; locally overlain by thin sands

ICE-CONTACT STRATIFIED DRIFT: gravel and sand, poorly to very well sorted and bedded, mainly in small, channel and free deposits; basaltic and igneous rocks generally arenaceous; thin deposits of gravel, sand and silt; some are calcareous and fossiliferous; in areas where till has been weathered, till is generally overlain by marl or beach deposits

TILL: sandy, silty and clayey deposit, dark grey or brown, often calcareous, with or without interbedded carbonaceous lenses of peat. Generally found in areas that were under ice or were close to the ice margin during the last glacial period. Tills are often underlain by a thin layer of organic matter consisting of gravel, sand and silt

L.I. glacial till, mottled colour

L.I. clayey till

L.I. till, foliated

L.I. tills, transgressive, local till on top of L.I. till

REFERENCES: Richard (1982b)

Sample Site

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SURFICIAL GEOLOGY OF THE
CORNWALL MAP AREA
Map 4
**SURFACE GEOLOGY OF THE ERMALIL NAVIO AREA**

**LEGEND**

### DEPOSITS

**LEGEND**

- **Pleistocene and Recent deposits**
  - Peat and muck: includes poorly drained areas supporting fen, swamp, and marsh vegetation
  - **Stratified deposits**
    - Stratified sand and silt clay: thickness at least 4 feet; commonly underlain by soft clay
  - Aeolian sand
  - Sand derived from glacial till by wave wash and blown into dunes along ancient beaches

### DEPOSITS OF THE KUWAUKEA SEA

- **Beach gravel**
  - Near-shore sand deposits
    - Beach gravel, fossiliferous: beach gravel near shore deposits
    - Marine sand, commonly fossiliferous
    - Marine clay and silt, fossiliferous; locally overlain by a thin layer of sand
  - **Glacial Till**
    - till; fossiliferous
  - Fort Covington till: compact, grey, to buff, sandy till; includes bouldery, washed till on hills and slopes
  - Halone till (lower till): very compact, blue-grey, clay till

### PALEOZOIC FORMATIONS

**PALEOZOIC DEPOSITS**

- Limestone, shale, dolomite, sandstone:
  - Includes areas of beach with thin cover of surficial deposits

**Reference:** Terasmae (1965)

- **C-1 Sample Site**
  - Age: Holocene (from Rodrigues and Hitchcock, 1983)