LATEST PLEISTOCENE-HOLOCENE PALEOCEANOGRAPHIC TRENDS
ON THE INNER SCOTIAN SHELF OFF THE SOUTH SHORE OF NOVA SCOTIA:
BENTHONIC FORAMINIFERAL EVIDENCE

by

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DALHOUSIE UNIVERSITY, DEPARTMENT OF GEOLOGY

B.Sc. HONOURS THESIS

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ABSTRACT

Two piston cores, 78-005-112 and 77-002-15, from the Inner Scotian Shelf off the South Shore of Nova Scotia provide the basis for a micropaleontological study of paleoceanographic trends. The study of benthonic foraminifera provides an accurate determination of paleoenvironments because certain species are restricted to narrow ranges of physical and chemical parameters.

The basal unit of core 78-005-112, with an Elphidium excavatum f. clavata - Cassidulina reniforme faunal assemblage, represents a "warm" ice margin fauna. A barren zone, which overlies the basal faunal assemblage, may signify a rapid change in environment with rapid deposition. A decrease in the ice margin fauna suggests latest glacial or early post-glacial conditions. An assemblage with the co-dominant species of Islandiella teretis and Globobulimina auriculata represents the mid-Holocene hypsithermal. The agglutinated foraminifera of the surface assemblage have been statistically related to Inner Labrador Current water. The Holocene paleoceanography is similar to that reported for offshore basins.

The faunal assemblage of the basal unit of core 77-002-15 represents a shallow, warmer water type of ice margin. An overlying sequence barren of fauna may be related to increased sedimentation rates or lower pH conditions. This event is followed by restricted bay fauna which gradually changes to an open bay assemblage, without Eggerella advena. The fauna of the surface assemblage suggests nearshore conditions, with the addition of some shelf fauna. A radiocarbon date of 14,000 ± 200 BP was obtained from the base of the core (400-425 cm). The significance of this date lies in its age and its position relative to sea level. It has been suggested that sea level was 110 m lower than present at 14,000 BP. However, the marine fauna indicates that sea level could not have been 110 m lower at 14,000 BP.
ACKNOWLEDGEMENTS

I sincerely thank all people who helped me during the progress of this thesis. In particular, I thank Dr. D. B. Scott, especially for help in the initial identification of species and for the use of his reprints. I also thank: C. Younger, who provided information on taking X-rays, core splitting and processing techniques; V. Baki, for his help in obtaining a foraminiferal percentage printout; B. Deonarine, for kindly taking the SEM photographs; J. Marsters, for her help with the word processor; and, A. Jennings, for the use of reprints. And last, but not least, I sincerely thank F. McCarthy for critically reading drafts of this thesis and for her encouragement and insight throughout.
INTRODUCTION

Foraminifera are members of the Phylum Protozoa. The common denominator of all the members of this phylum is their unicellular, or acellular, organization. The phylum is divided into classes on the basis of the type of locomotor apparatus present (Boersma, 1977). Because foraminifera are non-flagellate and possess flowing protoplasmic extensions termed pseudopodia, they are placed in the Class Sarcodina.

Foraminifera have two modes of life: planktonic and benthonic. Benthonic foraminifera, of which there are reported to be 10,000 living species, live on the sea bottom or in the water directly above it. Benthonic foraminifera live at all depths of the ocean -- from the marginal marine zones to the abyssal plain (Boltovskoy and Wright, 1976).

Benthonic foraminiferal assemblages are controlled by parameters whose variability and importance change depending on the environment. Environmental variability is high in marginal marine environments and physical parameters (temperature, salinity, elevation relative to sea level, or a temporal variation of these parameters) are the strongest influence on assemblage composition. Due to the sensitivity of some benthonic species to their environment, these species are useful in the reconstruction of paleoenvironments.

By using two piston cores, 78-005-112 and 77-002-15 (see Figure 1), it is the aim of the present work to reconstruct the glacial-postglacial paleoceanography of the inner shelf off Nova
Figure 1: Location of seismic and reflection profiles and cores in study area (Piper et al., 1986).
Scotia through benthonic foraminiferal assemblages.

PREVIOUS INVESTIGATIONS

There have been relatively few publications dealing with foraminiferal distribution off Nova Scotia, however, the distributions are well known. Bartlett (1964a,b) documented foraminiferal occurrences in St. Mary’s Bay and Mahone Bay and, to some extent, on the Inner Scotian Shelf.

Analysis and documentation of the data available for recent foraminifera on the Atlantic Canadian continental shelf indicates locality concentrations (Williamson, 1983). Other areas studied on a localized scale have included the following: Bartlett (1964a) on the southeast continental shelf; Barbieri and Medioli (1969) on the Scotian shelf; Walker (1976), inshore, near Halifax; Clark (1971) off Clam Bay; Scott et al. (1980) off Chezzetcook; and Cole and Ferguson (1975) on Canso Strait foraminifera. A recent foraminiferal study by Williamson (1983) presents an overall synthesis of regional distribution on the continental margin off Nova Scotia.

Mapping of surficial sediments on the Scotian margin, which detailed the distribution of shelf lithologies and sediment facies, was completed by the Geological Survey of Canada (King, 1970; MacLean and King, 1971; Drapeau and King, 1972; Fader et al., 1977; MacLean et al., 1977; King and Fader, 1986). Piper et al. (1986) have completed a thorough investigation of the marine geology off the South Shore, Nova Scotia.
There have been several studies of the physical oceanography of the eastern Canadian margin. Characteristics of waters on the Scotian Shelf are best described by McLennan (1954) and Houghton et al. (1978).

**PHYSICAL SETTING**

**Physiography**

The west-southwest trend of the Nova Scotia coastline is approximately parallel to both the strike of the Meguma basement and the continental shelf break. At sea, this structural trend is represented by a series of ridges and depressions which are well developed to the south of Lunenburg as far seaward as the 50 m isobath. Between Port Hebert and Liverpool Bay, a transverse south-southeast trend dominates seafloor relief (Piper et al., 1986)

Seaward of the 60 m isobath, the submarine topography becomes irregular with few linear trends. The physiography is also characterized by locally discontinuous, sinuous valleys 1 to 2 km wide and 20 to 50 m deep that, in places, widen into flat-floored basins. These basins slope gently seaward and can occur in a variety of water depths. Isolated shoals rise above the flat-floored basins between the valleys (Piper et al., 1986)

The Scotian Shelf is characterized by a well-defined, rough inner shelf which is an offshore continuation of the land area (King and Fader, 1986). The three main sediment types which are distinguished include muds, sands and gravels.
In the nearshore region, predominantly muddy sediments are restricted to sheltered bays. Muds, possibly equivalent to the LaHave Clay of King (1970), also accumulate in basins, with sandy-muds or muddy-sands at basin margins close to major sand bodies (Piper et al., 1986). Predominantly sandy sediments, possibly equivalent to the sand facies of King's (1970) Sable Island Sand and Gravel, are found in basins on the innermost part to the shelf, never more than 4 km from the shore. In most such basins, there is a rapid seaward transition to sandy-gravel of gravelly-sands. The gravelly sediments may be equivalent to the gravel facies of the Sable Island Sand and Gravel (Piper et al., 1986).

**Oceanography**

Two major current systems carry the continental shelf water off Canada in a southerly direction. The Labrador Current flows over the continental margin off Labrador and over the Grand Banks. The components of the Labrador Current are derived from the West Greenland Current, waters that originate in northern Baffin Bay, with a small but important Hudson Bay component along the inner shelf (Scott et al., 1984). Some Labrador Current water flows into the study area through the Cabot Strait (Fig. 2). This cold, relatively fresh water (<< 33 parts per thousand) continues off Nova Scotia as the southwest-flowing Nova Scotia Current (Williamson, 1983).

The general surface circulation on the Scotian Shelf is cyclonic. The Nova Scotia Current flows to the southwest along
Figure 2: Modern surface oceanographic current patterns present today in the study area (Scott et al., 1984).
the inner shelf and is then entrained by the northeast-flowing Gulf Stream along the continental margin.

On the Scotian Shelf, both regional temperature and salinity differences in bottom waters are determined by the proportions of the various source waters that have been included in the mixing process (Scott et al., 1984). Waters along the Inner Scotian Shelf are dominated by the colder Cabot Strait (Gulf of St. Lawrence) waters which also contain considerable additions of water from the Inner Labrador Current. The Inner Scotian Shelf bottom water, in particular, is established from the surface water from the Cabot Strait, and has a salinity of 31.8 % and a temperature range of 3 to 6 degrees Celsius (Williamson, 1983).

**Acoustic Stratigraphy**

Piper et al. (1986) have provided a summary of the acoustic stratigraphy south of Cross Island. Four main acoustic stratigraphic units have been discerned. These units overlie a widespread, discontinuous till unit which rests directly on bedrock and has been termed the early till. Seismic reflection profiles for cores 78-005-112 and 77-002-15 are shown in Figures 3 and 4, respectively.

Unit a is a transparent draped acoustic unit. This unit is composed of cohesive laminated clays passing down into sands and gravels.

Unit b is well stratified and thins rapidly southwards. This unit is probably composed of sands and gravels.

Unit c, a ponded stratified unit, rests unconformably on
Figure 3: Seismic reflection profile through core 78-005-112 showing bedrock (B), till (T) and acoustic units a and d (Piper et al., 1986).
Figure 4: Seismic reflection profile through core 77-002-15 showing bedrock (B) and acoustic units a, b, c and d.
Core 77-002-15 is 500 m south of the profile in a location with a similar acoustic sequence: vertical bar shows the approximate projection (Piper et al., 1986).
units a and b. Unit c is comprised of cohesive clays passing down into sands and gravels.

Finally, unit d is a ponded, acoustically transparent unit of muds which are probably equivalent to the LaHave Clay (King, 1970).

METHODS

The two piston cores, 77-002-15 and 78-005-112, were X-rayed to provide information on features not seen at the surface of the working half of the core. The sedimentology of the cores was then described using the Munsell soil colour charts.

Ten cubic centimeter samples were extracted from the core at 20 cm intervals. Samples were also extracted above and below sedimentological boundaries. The samples were then wet-sieved through a 500 micron screen to retain sediment clasts, shell fragments and larger foraminiferal specimens. A 63 micron screen, placed below the 500 micron screen, allowed for the retention of the foraminifera. The use of a 63 micron screen is reliable for the retention of smaller species and juvenile species (Schroder et al., 1987). The samples were stored in a mixture of distilled water and denatured alcohol.

In samples containing excess amounts of sand after sieving, a float and sink procedure was used. Sediments were first dried, then sprinkled into carbon tetrachloride to float off the foraminifera, while the denser clastics sank.

Samples with more than 600 specimens were split, using an
Otto microsplitter, into a fraction containing approximately 300 individuals. It has been statistically estimated that a minimum of 300 species must be counted to detect a species that constitutes one percent of the total population with a certainty of 95 percent. Therefore, ecological information obtained from low population counts must be carefully evaluated (Williamson, 1983).

Foraminifera were counted using a binocular microscope at 40x magnification. A type slide was prepared to indicate different species types in the two cores. The photographs of key species were taken at the Bedford Institute of Oceanography using a Cambridge Stereoscan 180 S.E.M. with Polaroid 55 N/P film.
RESULTS

Core 78-005-112

Core 78-002-112 (lat. 44 02.5’N; long. 64 08.55’W) is one of four cores collected 25 km offshore from Cape LaHave in 120 m of water. The core was taken from a sediment-filled valley near the southwest corner of the detailed area south of Cross Island.

From 5.41 to 5.15 m subbottom (msb), there is a short interval with low numbers of species and individuals. This interval is characterized by less than 15 specimens per sample (see Figure 5; Table 1).

The zone from 5.00 to 3.20 msb is represented by several taxa. Numbers of specimens are low (27-116 specimens/20cc), but higher than the lower most section. The most abundant species is Cibicides lobatulus, with lesser percentages of Elphidium excavatum formae (clavata, magna), Islandiella islandica, Elphidium subarcticum, Cassidulina reniforme and Haynesina orbiculare.

From 3.12 to 2.96 msb, species diversity increases significantly with notable additions to the fauna of Nonionellina labradorica and Trifarina fluens; no one species dominates.

The interval from 2.79 to 2.40 is marked by an abrupt decrease in the number of individuals to levels too low for characterization of the fauna.

Starting at 2.22 msb, total populations become abruptly more abundant. Elphidium excavatum f. clavata dominates a long sequence from 2.22 to 0.98 msb. From 2.22 to 1.60 msb, this taxon
Figure 5: Foraminiferal abundances and percentage occurrences of key species in core 78-005-112.
Table I: Percentage occurrences of foraminiferal species in core 78-05-112 (X = less than 1%, planktonics were not differentiated into species).
comprises 83 to 95 percent of the assemblage. This interval is also characterized by an increased abundance of Cassidulina reniforme.

Percentages of E. excavatum f. clavata range from 33 to 60 percent from 1.39 to 0.98 msb. This interval is characterized by increased amounts of Islandiella teretis and Cibicides lobatulus, together with low but significant percentages of Nonionellina labradorica and Globobulimina auriculata. The number of individuals increases dramatically during this interval.

In a short interval from 0.80 to 0.40 msb, Islandiella teretis is the dominant species, with Buliminia marginata, G. auriculata, N. labradorica and E. excavatum f. clavata as sub-dominants. There are also lesser, but important, percentages of Brizalina subaenariensis.

Between 0.20 and 0.07 msb, E. excavatum f. clavata decreases with a resulting increase in N. labradorica. From 0.02 to 0 msb, Saccammina atlantica dominates with Ammobaculites spp. in a low number assemblage.

Core 77-002-15

Core 77-002-15 (lat. 44 16.05′N; long. 64 08.55′W) was collected from an inner shelf basin, five km southeast of Cross Island, in 66 m water depth.

The interval from 5.43 to 2.62 msb is dominated by three species: Elphidium excavatum f. clavata, Eggerella advena and Cassidulina reniforme. There are also significant percentages of
Figure 6: Foraminiferal abundances and percentage occurrence of key species in core 77-002-15.
Table II: Percentage occurrences of foraminiferal species in core 77-002-15 (X = less than 1%, planktonics were not differentiated into species).
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<tr>
<td>Saccammina yuana</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>planktonica</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Buccella frigida near the top and bottom of this interval (see Figure 6; Table II), and persistent but low occurrences of Trochammina spp. Part of the core, from 5.00 to 4.50 msb, is missing.

From 2.48 to 1.80 msb, there is a barren or near-barren sequence except for small numbers of E. excavatum f. clavata and Elphidium excavatum f. selseyensis from 2.02 to 2.00 msb, and small numbers of E. advena from 1.82 to 1.80 msb. The interval from 2.48 to 1.80 msb is characterized by high organic content.

From 1.60 to 0.92 msb, there is a long sequence in which the two main species are E. excavatum f. clavata and B. frigida. There are also lesser percentages of E. advena, C. reniforme and C. lobatulus. At the bottom of this interval, the percentages of E. excavatum f. clavata and B. frigida are greater, but decrease toward the top of the interval. At the top of this interval, the percentages of E. advena, Trochammina squamata and T. ochracea increase.

From 0.80 to 0.20 msb, the dominant species are E. excavatum f. clavata and B. frigida, often comprising up to 80 percent of the fauna. There are minor of C. lobatulus and E. advena.

From 0.13 to 0.08 msb, the dominant species are E. excavatum f. clavata, E. advena and Islandiella islandica. Islandiella teretis, B. frigida and Nonionellina labradorica are present, but with smaller percentages. There are also increased percentages of T. ochracea and T. squamata.
SIGNIFICANCE OF FORAMINIFERAL FAUNAS

Core 78-005-112

This core exhibits a biostratigraphic sequence which has been observed in other cores on this shelf; however, this core is in relatively shallow water. A late glacial fauna is dominated (30-90 percent) by Elphidium excavatum f. clavata; an early post-glacial fauna dominated by Islandiella teretis; a mid-Holocene fauna which contains Nonionellina labradorica and Globobulimina auriculata with reduced E. excavatum clavata; and, finally, an agglutinated low-number fauna in the late Holocene (Scott et al., 1984).

Elphidium excavatum f. clavata - Cassidulina reniforme assemblages dominate late glacial deposits in nearshore zones on both sides of the Atlantic Ocean (Vilks, 1981).

At present, the distribution of E. excavatum f. clavata may represent over 20 percent of the total population in areas that are characterized by winter ice and by surface waters having reduced salinities (for example, arctic and cold-temperate waters). Some of these areas include the continental shelf off southeastern Beaufort Sea (Vilks et al., 1979), Hudson Bay (Leslie, 1965) and Bay of Fundy (Scott and Medioli, 1980). Surface sediments, however, on the continental shelf off Nova Scotia and Labrador are almost barren of E. excavatum f. clavata, while in sub-surface fossil sediments there are increasing percentages of the E. excavatum f. clavata assemblage. Scott et al. (1984) have suggested that the large amounts of meltwater
occurring along the former ice margin produced an estuarine-like environment.

The basal unit, from 5.41 to 3.76 msb, is dominated by *Cibicides lobatulus*. The distribution of this species, as well as *Islandiella islandica*, seems to be constrained by the character of the local substrate, which is a function of energy in the environment. In particular, these two species are restricted to coarse sand, gravel and rough bedrock (Williamson et al., 1984). Significant correlations have been made with *I. islandica* with higher salinity and percent gravel.

Starting at 3.22 msb, the assemblage of *E. excavatum* f. *clavata* and *C. reniforme* dominates the core. It has been proposed that the *E. excavatum* f. *clavata* - *C. reniforme* fauna represents a "warm" ice margin fauna (Vilks, 1981; Scott and Medioli, 1980). This fauna represents an adjacent ice margin where sea-water temperatures were relatively high as compared with present-day glacial marine environments in the Canadian Arctic (Scott et al., 1984).

The barren zone from 2.79 to 2.40 msb may signify a rapid change in environment with rapid deposition. This is supported by the higher diversity fauna below this level and the lower diversity, typical ice-margin fauna above it.

From 2.22 to 0.70 msb, the co-dominance of *E. excavatum* f. *clavata* and *C. reniforme* represents the "warm" ice margin environment. From 1.39 to 0.98 msb, the decrease in percentage of *E. excavatum* f. *clavata* and *C. reniforme* species, together with
increased I. teretis, G. auriculata and N. labradorica suggests latest glacial or early post-glacial conditions. Because there are no modern analogues, the temperature and salinity which the E. excavatum f. clavata - C. reniforme assemblage typifies is unknown. However, the increase in other species suggests increases in salinity; that is, there is less meltwater.

From 0.80 to 0.07 msb, the co-dominant species of the assemblage are I. teretis and G. auriculata, with the subdominant species N. labradorica, Bulimina marginata and Brizalina subaenariensis. Elphidium excavatum f. clavata is greatly reduced. This assemblage presently occurs over a large part of the Emerald and LaHave Basins. This assemblage has been statistically related to normal marine salinities (34-35 parts per thousand) and warmer waters (8-12 C) (Williamson, 1984). Scott et al. (1984) have related a similar assemblage on the northern Scotian shelf to the mid-Holocene hypsithermal.

The increase in Saccammina atlantica toward the top of the core may be explained by an area of intense temperature and salinity gradients (Williamson, 1984). In present-day waters, this gradient is explained by the juxtaposition of slope-derived central basin waters with water of the Labrador and Nova Scotia currents.

The surface assemblage is dominated by S. atlantica and Ammobaculites spp. This faunal type has been statistically related to cold (1-2 C) and relatively fresh (31-33 parts per thousand) water of Inner Labrador current origin which now flows
across the inner Scotian Shelf (Mudie et al., 1983).

Core 77-002-15

The assemblage of the basal unit, from 5.43 to 2.62 msb, is similar to the restricted bay fauna discussed by Bartlett (1964b) or the open bay fauna of Scott et al. (1980). The open bay fauna is characterized by species like Eggerella advena and E. excavatum f. clavata, but not the C. reniforme which occurs in the interval. This interval is additionally characterized by the presence of shallow water, nearshore forms such as Trochammina squamata, Trochammina ochracea, Buccella frigida and Cibicides lobatulus. The combination of E. excavatum f. clavata and C. reniforme suggests a warm ice margin and the additional species may represent a shallow, warmer water type of ice margin.

At present, on the continental shelf off Nova Scotia, Eggerella advena is restricted to Chedabucto, Gaberous, Mahone and St. Margeret’s Bays and to shallow banks off Sable Island; however, it is a common estuary species (Scott et al., 1980). This species is strongly correlated with depth and percent sand; the species is inversely correlated with percent mud.

From 3.01 to 1.80 msb, there is a sequence barren or nearly barren of fauna. The sparseness of the foraminiferal tests may indicate the occurrence of conditions too severe for biological activity (Vilks, 1969). Also, the sedimentation rate may have increased during this time, thereby diluting the tests. This interval is characterized by a large amount of organic matter.
This organic matter may have caused low pH conditions that dissolved the calcareous forms.

From 1.60 to 0.92 msb, the fauna represents the restricted bay fauna described by Bartlett (1964b). However, the increased percentages of *Buccella frigida*, *Cassidulina reniforme* and *Cibicides lobatulus* indicate an increasing open bay influence.

From 0.82 to 0.20 msb, there is an open bay assemblage, without *Eggerella advena*. This assemblage closely resembles the open bay assemblage of Bartlett (1964b). From 0.13 msb to the surface, additional species such as *Cibicides lobatulus*, *Fissurina marginata*, *Globobulimina auriculata* and *Nonionellina labradorica* suggest nearshore conditions. However, this interval is characterized by the addition of shelf fauna such as *Astrononion gallowayi*, *Trifarina fluens*, *Islandiella islandica* and *Haynesina orbiculare*.

A radiocarbon date of 14,000 + 200 BP (I-10467) was obtained from total organic carbon in the mud from the base of the core (400-425 cm). Palynological samples taken from the base of the core contained low numbers of pre-Quaternary palynomorphs and very little reworked thermally altered kerogen. These facts help support the validity or accuracy of the radiocarbon date (Piper et al., 1986). The significance of this date lies in its age and its position relative to sea level.
DISCUSSION

Core 78-005-112

The Holocene paleoceanography that is observed in core 78-005-112 is similar to the paleoceanography reported in offshore basins. Distinct Late Pleistocene-Holocene paleoceanographic events have been observed, for example, in the Emerald and Canso Basins (Scott et al., 1984; Vilks and Rashid, 1976).

In the Canso Bank Basin, core 80-004-33 is 11 m in length and contains a complete Holocene section. The basal unit of core 80-004-33 (1060-1064 cm) is dominated by an *E. excavatum* f. *clavata* - *C. reniforme* assemblage. This section can probably be related to the early post-glacial section of core 78-005-112 from 1.06 to 0.98 msb. Other paleoceanographic events that may be correlated between the two cores include an early post-glacial phase, the Holocene hypsithermal, and the present-day climatic cooling influence of the Inner Labrador Current.

Core 77-002-15

In present day conditions, *Eggerella advena* is the most common arenaceous foraminiferal species in bay environments. *E. advena* is also characteristic of the nearshore biofacies where it is frequently associated with *Elphidium* spp. (Bartlett, 1964b).

The significance of *E. advena* in the glacial sequence of core 77-002-15 is that it has not been observed in other ice margin fauna. The presence of *E. advena* may be related to the physical
conditions of at the core site (for example, the nature of the substrate). The occurrence of this species with the ice margin fauna may also be related to the water level.

The basal unit of core 77-002-15, from 5.43 to 2.62 msb, is characterized by open bay fauna. However, this interval is also typified by nearshore foraminifera. The nearshore area is usually marked by coarser substrates (silts, sands and gravels), lower temperature and turbulence. The open bay biofacies, with its greater depths, is a dumping area for taxa transported from landward biofacies - this may explain the occurrence of nearshore fauna with bay fauna. The presence of nearshore fauna with the "warm" ice margin fauna may indicate the deposition of tests in shallower water than the ice margin fauna is usually deposited.

The period from 16,000 to 10,000 BP represents the period of lowest sea level, its subsequent transgression, and the disappearance of ice influence in the offshore (King and Fader, 1986). The age of a submarine terrace, which marks the position of the lowest sea level, has been dated as between 15,100 and 14,465 BP (King and Fader, 1986). Milliman and Emery (1968) suggested that the lowest stand of 125 m occurred at 15,000 BP. King and Fader (1986) have estimated that low stand of elevation at 14,000 BP was 110 m lower than at present. The marine sequence of core 77-002-15 occurs at 66 m below present sea level. At 14,000 BP in core 77-002-15, the faunal assemblage is comprised of E. excavatum f. clavata, Eggerella advena and Cassidulina reniforme. The presence of marine fauna suggests that sea level
could not have been more than about 60 m lower than present, not 110 m lower as suggested by (King and Fader, 1986).

Piper et al. (1986) have stated that the deposition of mud at 14000 BP in core 77-002-15 may be due to either a 60 m lowering of sea level or ice-damping of waves at a time when sea level was high. The former explanation is consistent with the hypothesis of gradual rise in sea level.

CONCLUSIONS

78-005-112:
- a late-glacial fauna is dominated by an *Elphidium excavatum f. clavata* - *Cassidulina reniforme* assemblage.
- the onset of the early post-glacial is represented by the presence of *Islandiella teretis*.
- the mid-Holocene hypsithermal is represented by a faunal assemblage comprised of co-dominants *Globobulimina auriculata* and *Nonionellina labradorica* as well as *Islandiella teretis, Bulimina marginata* and *Brizalina subaenariensis*.
- the modern foraminiferal assemblage in core 78-005-112 is dominated by agglutinated foraminifera, such as *Saccammina atlantica*, which have been related to waters of the Inner Labrador Current.

77-002-15:
- an open bay fauna dominates the basal unit of this core, with species such as *Eggerella advena* and *Elphidium excavatum f. clavata*. The nearshore foraminifera present indicate a shallower,
warm water type of ice margin.

- a barren section is followed by a restricted bay fauna, with increasing open bay influences towards the top of the core.
- the surface fauna indicates nearshore conditions.
- marine fauna indicate that sea level could not have been more than about 60m lower than present.

Regarding both cores:

- in both cores, periods of environmental stress or high sedimentation rate have resulted in a sequence barren or nearly barren of fauna. The high sedimentation rate may be related to the large amounts of meltwater occurring along the former ice margin, producing estuarine-like conditions. The large amount of organic material in core 77-002-15 suggests that pH was lowered, thereby dissolving the calcareous tests.
Systematic Taxonomy

The following foraminiferal species have been compared with the type collection of M. Williamson. Other primary references have included Williamson (1983), Vilks (1969) and Scott (1987). The format for the systematic taxonomy follows the Ocean Drilling Program format. The 39 benthonic species are listed in alphabetical order with respect to genus name. Specimens of the Lagena, Oolina and Ammobaculites families were identified to genus level only.

Ammobuculites spp. Cushman, 1910

Astrononion gallowayi Loeblich and Tappan
Astrononion gallowayi Loeblich and Tappan, 1953, p. 90, pl. 17, figs. 4-7.

Bolivina pseudoplicata Heron-Allen and Earland
Bolivina pseudoplicata Heron-Allen and Earland, 1930, p. 81, pl. 3 figs. 36-40.

Brizalina pseudopunctata (Hoeglund)
(Plate 1, Fig. 9)
Bolivina pseudopunctata Hoeglund, 1947, p. 273, pl. 24, fig. 5, pl. 32, figs. 23, 24.
Brizalina subaenariensis (Cushman)
(Plate 1, Fig. 10)
Bolivina subaenariensis Cushman, 1922a, p. 46, pl. 7, fig. 6.

Buccella frigida (Cushman)
Pulvinulina frigida Cushman, 1922b, p. 144.

Bulimina aculeata d’Orbigny
(Plate 1, Fig. 3)
Bulimina aculeata d’Orbigny, 1826, p. 269, no. 7.

Bulimina marginata d’Orbigny
Bulimina marginata d’Orbigny, 1826, p. 269, pl. 12, figs. 10, 12.

Buliminella elegantissima (d’Orbigny)
Bulimina elegantissima d’Orbigny, 1839, p. 51, pl. 7, figs. 13, 14.

Cassidulina reniforme Norvang
(Plate 2, Figs. 11, 12)
Cassidulina crassa d’Orbigny var. reniforme Norvang, 1945, p. 41, text figs. 6c-h.

Cibicides lobatulus (Walker and Jacob)
Nautilus lobatulus Walker and Jacob in Kanmacher, 1798, p. 642, pl. 14, fig. 36.
Cribrostomides crassimargo (Norman)
Haplophragmium crassimargo Norman, 1892, p.17.

Eggerella advena (Cushman)
Verneuilina advena Cushman, 1922a, p. 141.

Elphidium bartletti (Cushman)
Elphidium bartletti Cushman, 1933, p. 4, pl. 1, fig. 9.

Elphidium excavatum (Terquem) formae
Formae used in this paper are informed taxonomic designations that are described in detail in Miller et al., 1982.

Elphidium subarcticum Cushman
(Plate 1, Fig. 18)
Elphidium subarcticum Cushman, 1944, p. 27, pl. 3, figs. 34, 35.

Epistominella exigua (Brady)
(Plate 2, Figs. 8, 9)
Pulvinulina exigua Brady, 1884, p. 696, pl. 103, figs. 13, 14.

Epistominella takayanagii Iwasa
(Plate 2, Figs. 5-7)
Epistominella takayanagii Iwasa, 1955, p. 16, 17, text figs. 4a–c.
Fissurina marginata (Montagu)

Vermiculum marginatum Montagu, 1803, p. 524.

Fursenkoina fusiformis (Williamson)

(Plate 1, Figs. 12, 13)
Bulimina pupoides d’Orbigny var. fusiformis Williamson, 1858, p. 64, pl. 5, figs. 129, 130.

Fursenkoina loeblichi (Williamson)

Glabratella wrightii (Brady)
Discorbina auriculata Brady, 1881, p. 413, pl. 21, fig. 6.

Globobulimina auriculata (Bailey)
Bulimina auriculata Bailey, 1851, p. 12, pl. 1, figs. 25-27.

Guttulina lactea

Haynesina orbiculare (Brady)
Nonionia orbiculare Brady, 1881, p. 415, pl. 21, fig. 5.

Islandiella teretis (Tappan)

(Plate 2, Fig. 13)
Cassidulina teretis Tappan, 1951, p. 7, pl. 1, figs. 30a-c.
Islandiella islandica (Norvang)
Cassidulina islandica Norvang, 1945, p. 41, text-figs. 7-8.

Lagena spp. Walker and Jacob
Genus Lagena Walker and Jacob in Kanmacher, 1798.

Nonionella turigida (Williamson)
(Plate 1, Figs. 21, 22)
Rotalina turigida Williamson, 1858, p. 50, pl. 4, figs. 95-97.

Nonionellina labradorica (Dawson)
Nononina labradorica Dawson, 1860, p. 191, fig. 4.

Oolina spp.
Genus Oolina

Patellina corrugata Williamson
Patellina corrugata Williamson, 1858, p. 46, pl. 3, figs. 86-89.

Quinqueloculina seminulum (Linne)
Serpula seminulum Linne, 1758, p. 786.

Reophax gracilis (Kiaer)
Nodulina gracilis Kiaer, 1900, p. 24, text-figs. 1-2.
Reophax scorpiurus (de Montfort)

Reophax scorpiurus de Montfort, 1808, p.330.

Rosalina columbiensis (Cushman)

Discorbis columbiensis Cushman, 1925, p. 43, pl. 6, fig. 13.

Saccammina atlantica (Cushman)

Proteonina atlantica Cushman, 1944, p. 5, pl. 1, fig. 4.

Spiroplectammina biformis (Parker and Jones)

Textularia agglutinans d’Orbigny var. biformis Parker and Jones, 1865, p. 370, pl. 15, figs. 23, 24.

Textularia earlandi Parker

Textularia earlandi Parker, 1952a, p. 458 (footnote).

Trifarina fluens (Todd)

Anglogerina fluens Todd in Cushman and Todd, 1947, p. 67, pl. 16, figs. 6, 7.

Trochammina "inflata"?

Trochammina inflata (Montagu), Williamson, 1983, p. 212, pl. 2, figs. 12, 13.
**Trochammina ochracea** (Williamson)

*Rotalina ochracea* Williamson, 1858, p. 5, pl. 4, fig. 112, pl. 5, fig. 113.

**Trochammina squamata** Parker and Jones

*Trochammina squamata* Parker and Jones, 1865, p. 407, pl. 15, figs. 30, 31a-c.
1. *Elphidium excavatum* f. *clavata* Cushman
2. *Brizalina subaenariensis* Cushman
3. *Eggerella advena* (Cushman)
4. *Buccella frigida* (Cushman)
5. *Quinqueloculina seminulum* (Linne)
6. *Cibicides lobatulus* (Walker and Jacob)
7. *Elphidium bartletti* (Cushman)
8. *Saccammina atlantica* (Cushman)
9. *Fursenkoina fusiformis* (Williamson)
10. *Trifarina fluens* (Todd)
11. *Islandiella teretis* (Tappan)
12. *Globobulimina auriculata* (Bailey)
13. *Nonionellina labradorica* (Dawson)
14. *Cassidulina reniforme* Norvang
REFERENCES


Linne, C. 1758. *Systema naturae per regna tria naturae, secundum classed, ordines, genera, cum characteribus, differentiis, synonymis, ocis (Vol. 1) (10th ed.): Lipsiae (G. Engelmann), 1-824.*


Vilks, G. 1969. Recent foraminifera in the Canadian Arctic. Micropalaeo., v. 15, p. 35-60.


APPENDIX
**CORE 78-005-112**  
**DEPTH IN CORE** 0-100 cm  
**LOCATION** Inner Station Shift  
**WATER DEPTH** 12 cm  
**Described by:** Stephen Masters

**SMEAR DISTURB**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5.5</td>
<td>0-5.5 dark olive gray (5Y 3/2) <em>sand</em> mud</td>
</tr>
<tr>
<td>5.5-10</td>
<td>5.5-10 dark gray (5Y 4/1) <em>mud</em> with lenses of sand</td>
</tr>
<tr>
<td>10-15</td>
<td>10-15 olive gray (5Y 4/2) <em>wispy laminated</em></td>
</tr>
<tr>
<td>15-20</td>
<td>mud with indications of X-laminations</td>
</tr>
<tr>
<td>20-60</td>
<td><em>w/ darker bands (organic?)</em></td>
</tr>
<tr>
<td>60-70</td>
<td>grading from 56-103 into mud w/ sand lenses</td>
</tr>
<tr>
<td>70-100</td>
<td>70-100 sedimentary clasts</td>
</tr>
<tr>
<td>100-120</td>
<td>100-120 sand clasts</td>
</tr>
</tbody>
</table>

**SAMPLE RECORD**

**GENERAL COMMENTS:**  
Munsell Soil Color Chart

---

Sample record includes a table with depth intervals and corresponding descriptions, along with a Munsell Soil Color Chart.
CORE 78-005-112  DEPTH IN CORE 100-200 cm
LOCATION Inner Section Shelf
WATER DEPTH 120 m  Described by: Stephen Masters

SMEAR DISTURB

DESCRIPTION
- 34-103 olive gray (5Y 4/2) wispy laminated mud grading from 76-103 into mud with sand lenses
- 103-150 dark grayish brown (10YR 4/2) silt? clayey mud
- X-rays show darker banding ill with lighter banding (bioturbation?)

SAMPLE RECORD

- 150-300 dark grayish brown (10YR 4/2) to dark gray (10YR 4/1) clayey mud with blocky and horsetail bands or laminations from 262-300

187-244 zone of dry crust (shells?)

General comments: Munsell Soil Color Chart
CORE 78-005-112  DEPTH IN CORE 700 - 300
LOCATION Inner Section Shelf
WATER DEPTH 120m  Described by Stephen M. Berres

SAMPLE RECORD

SMEAR DISTURB

DESCRIPTION

202-300 alternating black and orange bands (or laminae)

217-shell fragment

-150-300 dark greyish brown (10YR 4/2) to
dark gray (10YR 4/1)
clayey mud with
black and orange bands
or laminae from
202-300

157-217 zone
of clasts or
shells

257-260 cm
long shells

General comments: 
Munsell Soil Color Chart
**CORE 78-005-1/2**  
**DEPTH IN CORE** 300-400 cm  
**LOCATION** Inner Section Shelf  
**WATER DEPTH** 120 m  
**Described by:** Stephen Marsfors

<table>
<thead>
<tr>
<th>Sampling Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>300-303 cm</td>
<td>void</td>
</tr>
<tr>
<td>303-330.5 cm</td>
<td>dark gray (10 YR 4/1)</td>
</tr>
<tr>
<td></td>
<td>silty to sandy mud with black and orange banding (pitted)</td>
</tr>
<tr>
<td></td>
<td>also sandy (~2 cm) layers</td>
</tr>
<tr>
<td>330-373 cm</td>
<td>sandy clast from 343-330.5</td>
</tr>
<tr>
<td></td>
<td>dark sand (2.0%) with some mud to 410, sediment unsorted with clasts up to 2cm in diameter; clasts sub-rounded to sub-rounded; clasts (1cm/layer ~ 2cm)</td>
</tr>
</tbody>
</table>
General comments:

CORE 75-005-112  DEPTH IN CORE 400 - 500 cm
LOCATION Inner Section Shelf  Described by Stephen Morstorp
WATER DEPTH 12 m

DESCRIPTION
- 350 - 450 sand (2.0%) with some mud to 410 sand, sediment unsorted with clasts ranging in diam. from 1 mm/2 mm to 2 cm; clasts subangular to subrounded; sorting better from 423 - 450.

SAMPLE RECORD

- 450 - 541 marine upwards sequence
- 450 - 470 - fairly well sorted sand (2.0 to 1.5 %) w/ a few clasts up to 4 cm in length, some mud, clasts subangular
- 470 - 500 - poorly sorted sequence with sand (1.0 %) to clasts which are up to 10 cm in length

end of section
CORE 74-005-H2
DEPTH IN CORE 500-541 cm
LOCATION Inner Section Shelf
WATER DEPTH 120 m

Described by: Stephen Masters

SAMPLE RECORD

DESCRIPTION

- 500-541 very poorly sorted sequence of sand (2.0%) to clasts
  pebbles which are up to 4 cm in length; clasts subangular to
  subrounded
- Overall, from 530-
  541 the sequence gets progressively poorer in sorting and involves a
  definite gradation from sand to pebbles/rocks

General comments:
General comments: 'Small Silty Color Change'
CORE 77-002-15

DEPTH IN CORE 100-200cm

LOCATION Inner Shihor Shelf

WATER DEPTH 66m

Described by Stephen Hirsters

DESCRIPTION

0-10cm sand

10-150cm silic.

gray (5Y 4/12) mud

150-300cm silic.

gray (5Y 4/12) mud

SAMPLE RECORD

0

SMEAR

DISTURB

General comments: Notable Sediment Changes
Core 77-002-18  
Depth in core: 200-300 cm  
Location: Inner Station Shelf  
Water depth: 66 m  
Description:  
200-300 cm silt 
Gray (SY 4/12) mud  

Sample record:  
278 cm, shell fragment  

General comments: Mussel Silt Line Chart
CORE 77-C002-45
DEPTH IN CORE 50-400 cm
LOCATION Inner Slope Shelf
WATER DEPTH 66 m

DESCRIPTION
300-400 cm olive
5Y 4/3 red

330 cm sedentary
clast (same in
distance)

SAMPLE
RECORD

GENERAL COMMENTS: Mossell Soil Color Chart
General comments:
CORE 77-002-15P  DEPTH IN CORE 500-543 cm
LOCATION Inner section shelf Described by: Stephen Horstens
WATER DEPTH 66 m

DESCRIPTION
500-543 gray (5Y 5/6) - very dark gray (5Y 3/1) mud
w/ transition to sandy mud at bottom of core

SAMPLE
RECORD

GENERAL COMMENTS:

5/3 oil, etc
5/5 oil, etc