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FORAMINIFERAL DISTRIBUTION ON SELECTED BANK AREAS OF THE SCOTIAN SHELF AND HOLOCENE HISTORY OF INNER CHEDABUCTO BAY: FORAMINIFERAL EVIDENCE; AS A CONTRIBUTION TO ASSESSMENT OF THE MARINE AGGREGATE POTENTIAL OF THE SCOTIAN SHELF

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ABSTRACT

Thirty-five surface samples and two vibrocore samples from the outer bank regions of the Scotian Shelf (The Slipper, Western Gully, Middle Bank, Banquereau and Artimon Bank) have been analysed for benthonic and planktonic foraminifera. Five assemblages and six subassemblages based on living / total numbers are recognized. These assemblages (and subassemblages) are: an Adercotryma glomerata - Atlantiella atlantica assemblage, an Eggerella advena assemblage, an Eggerella advena - Adercotryma glomerata subassemblage, an Eggerella advena - Lobatula lobatalus subassemblage, an Eggerella advena - Atlantiella atlantica subassemblage, an Eggerella advena - Trochammina spp. - subassemblage, an Eoeponidella pulchella - Eggerella advena subassemblage, a Cibicidoides spp. assemblage, a Cibicidoides spp. - Islandiella algida subassemblage, an Islandiella algida - agglutinated species assemblage and a Cribroelphidium albiumbilicatum assembage (vibrocore sample only). The surficial assemblages are in good agreement with those defined by Williamson (1983, 1985) and Williamson et al. (1984) and the distribution of these assemblages is also consistent with the distribution patterns defined by Williamson (1983, 1985) and Williamson et al. (1984).

One surface sample, three triggerweight core samples and 12 piston core samples were analysed from one station site in Chedabucto Bay. Two benthonic foraminiferal assemblages (and three subassemblages of one of these assemblages) were recognized. These assemblages (and subassemblages) are: an Eggerella advena - Lagenammina atlantica - Spiroplectammina biformis subassemblage, an Eggerella advena - Spiroplectammina biformis - agglutinated species subassemblage, an Eggerella advena - Spiroplectammina biformis subassemblage, an Eggerella advena assemblage and an Eggerella advena - Astrononion hamadaense - Cibicidoides spp. subassemblage. The sequence in which these assembages (and subassemblages) occur downcore (or upcore) infer changes in water depth, salinity, degree of mixing with oceanic waters and sea level.

The interpretation of the environments of deposition, based on the foraminiferal content of the bottom 70 cm of the core, do not fully agree with the coastal observations, and surficial sediments and seismo-stratigraphic interpretation of the bay floor (Forbes et al., 1995; Shaw et al., 1995). For the period 6-10 ka, the foraminifera indicate deeper water depths, a higher and later sea-level low stand (-29 m at about 8.3 ka) than suggested by Forbes et al. (1995) and Shaw et al. (1995). The foraminifera also indicate that there may have been a period of RSL rise from 10.5 to 8.3 ka, similar to the sequence of events inferred by Scott and Medioli (1982) and Scott et al. (1987b) from a core collected off the southern shore of Nova Scotia.

For the period 0-6 ka, the interpretation based on foraminifera, the inferred environments of deposition, water depths, and relative sea-level are in good agreement with those of Scott et al. (1987b), Forbes et al. (1995) and Shaw et al. (1995). With these inferred changes in water depth, a relative sea level (RSL) curve is constructed for Chedabucto Bay.

The core interval 250-325 cm needs to be subsampled to try and further refine the estimated minimum water depth and find the sea-level reversal or pivot point, if present.

INTRODUCTION

The Scotian Shelf is characterized by deep central shelf basins and shallow outer shelf banks. Studies of Quaternary paleo-oceanography have concentrated on sediments in basins, which are as much as 250 m deep and contain a well-developed sequence of stratified, fine-grained muds representative of Late Quaternary depositional environments (King and Fader, 1986).

By contrast, little has been done on the outer banks. The most prominent of the outer banks are Sable Island Bank and Banquereau. They are as much as 100 km wide and fringe the shelf edge. The banks are demarcated by the 120 m isobath, have an average depth of 60 m and are emergent at Sable Island (Amos and Knoll, 1987). These outer banks are composed of coarser sediment which makes it difficult, if not impossible, to sample using conventional piston coring techniques. The upper sediments on the banks are the products of reworked glacial debris and thus represent a condensed and incomplete record of Late Quaternary sedimentation (Amos and Knoll, 1987).

The outer Scotian Shelf, particularly the area around Sable Island, has been an area of active petroleum exploration for the past 25 years. The surficial geology of the banks has been mapped by King (1967, 1970), King and MacLean (1970), MacLean and King (1971), Drapeau and King (1972), Jacques, McClelland Geosciences, inc. (1982), Boyd et al. (1988) and McLaren (1988). On the basis of seismic profiles and limited samples, these authors proposed that the banks consist of a continuous layer of sand and gravel of Holocene age, formed by reworking of glacial and glaciomarine sediments during a marine transgression (Fader, 1989).

Assessment of the marine aggregate potential of the bank areas of the Scotian Shelf, for the marine aggregate industry is currently underway, under a three year Canada - Nova Scotia Cooperation Agreement on Mineral Development, commonly known as the MDA-3. This study was sponsored by the NSMDA - 3 program under the scientific leadership of Mr. Gordon B.J. Fader of the Geological Survey of Canada - Atlantic.

The purpose of this study was two-fold. The foraminiferal content of seabed samples was evaluated to assess the maturity and source of the sand and gravel deposits. As these deposits have been interpreted to represent reworked glacial sediments, it was important to determine what proportion of foraminifera are relict as compared to the modern population. It was also desirable to understand the relative percentage of foraminiferal tests within the sand fraction to determine their effects on the strength and quality of concrete made with this material.

Previous foraminiferal surface distribution studies have been completed for the Scotian Shelf (i.e. Williamson, 1983, 1985; Williamson et al., 1984; Medioli et al., 1986), but sample coverage for Banquereau and Middle Bank has been sparce (Williamson, 1983, 1985; Williamson et al.,1984); other studies (i.e. Medioli et al., 1986) have concentrated on other bank areas (i.e. Sable Island Bank); where many samples were barren of foraminifera or contained unusually low diversity faunas. Many of the bank areas are presently areas of non-deposition / erosion and the surficial sediments and bedforms are not in equilibrium with the current hydrodynamic regime. Williamson et al. (1984) have completed a factor analysis establishing the distribution pattern of 8 foraminiferal assemblages (7 modern, 1 relict) and the hydrodynamic regime and substrate conditions of each. Foraminiferal analysis of samples recently collected from Banquereau and Middle Bank can also aid in distinguishing between those areas that are or are not in equilibrium with present day conditions.

Amos and Knoll (1987) have established a Quaternary stratigraphy (within the context of King and Fader, 1986) for Banquereau; Amos and Miller (1990) applied this stratigraphy to Sable Island Bank. Miller (1989a, 1989b, 1993) has completed foraminiferal analysis of samples from six geotechnical boreholes on Sable Island Bank and Miller (in press) has completed foraminiferal analysis of samples from five geotechnical boreholes on Banquereau; determining the foraminiferal content of the seven members of the upper two surficial formations. These studies provide a basis for comparison; foraminiferal analysis of surface samples may indicate the presence of reworked material either from any of the underlying members or bedrock, or as the result of lateral transport of surficial material.

The second purpose of the study was to provide an environmental / biostratigraphic interpretation of piston cores and vibrocores collected through granular sand and cohesive sediments to determine the sea-level history and depositional environment of specific areas of the shelf. Such data is critical to the development of ideas and models on the sea-level and transgressive history, and of the formation of potential aggregate deposits.

SCOTIAN SHELF

Bedrock Geology

The bedrock geology of the Scotian Shelf has been extensively studied, reported on and well summarized (King and MacLean, 1976; King, 1980; King and Fader, 1986). Cretaceous rocks overlie Pennsylvanian and older rocks and form the bedrock beneath part of the Laurentian Channel and much of the shelf north of Sable Island (King and MacLean, 1976). Rocks of Cretaceous age have been dredged north of Sable Island and Sable Island Bank (King and MacLean, 1970; King et al., 1970). Tertiary strata unconformably overlie the Cretaceous rock and form the bedrock underlying the outer Scotian Shelf. These strata thicken seaward. MacLean and King (1971) include in this unit all material overlying the Cretaceous strata and underlying recognizable Pleistocene deposits; and this may include early Pleistocene material. Oligocene and Miocene material have been found out-cropping in The Gully (Scotian Shelf) (Marlowe, 1965, 1969; Marlowe and Bartlett, 1967). There has been several cycles of erosion (some of which were subaerial) since deposition of the Cretaceous strata, particularly during the Late Cretaceous and Early Tertiary, resulting in deposition of Tertiary strata on an eroded Cretaceous surface. Another period of subaerial erosion took place following deposition of Tertiary strata and prior to the onset of Pleistocene glaciation (MacLean and King, 1971). These erosional surfaces are a major controlling factor in the topography of the shelf today (MacLean and King, 1971).

Geomorphology and Physiography

Glacial erosion has modified the coastal plain landforms. Evidence for this is seen in overdeepening of lowland areas, fjord-like features and tributary hanging valleys (King and Fader, 1986).

King and MacLean (1976) recognize three physiographic zones on the Scotian Shelf. There is an inner zone of rough topography that lies between Cape Sable and Saint Anne's Bank (including Chedabucto Bay) and extends to the 100 m contour. A central zone consists of isolated banks and intervening basins (LaHave and Emerald basins). An outer zone of shallow, wide and flat banks extends from Roseway Bank to Banquereau.

Recent acquision of high quality bathymetric data has allowed greater topographic resolution, and more detailed interpretations of the geomorphology and geologic evolution of the Scotian Shelf (Loncarevic et al., 1992, 1994). Stea et al. (1994) have studied the inner shelf in detail and divide it into five terrain zones. The northern part of the shelf (Sable Island Bank to the Laurentian Channel) has a complex topography with several belts of linear depressions reaching maximum depths of 360 m. A review of the possible origins of these features is given in Loncarevic et al. (1992).

Surficial Geology

King recognized and mapped (1970), and formally designated and described (1980), five surficial formations on the Scotian Shelf. These are well described and summarized in King and Fader (1986). The three formations that have formed largely in Holocene time are the LaHave Clay, the Sable Island Sand and Gravel and the Sambro Sand. The LaHave Clay is greyish brown, silty clay grading to clayey silt; derived by winnowing of glacial sediments on banks. The Sable Island Sand and Gravel is fine to coarse, well-sorted sand grading to subrounded and rounded gravels. Generally it is a 'clean' sand, derived from transgressive reworking, above 120 m to present depth. The Sambro Sand is silty sand grading locally to gravelly sand and well-sorted sand, deposited below the Late Pleistocene low stand of sea-level. This low-stand is believed to be -120 m for the outer banks (King and Fader, 1986; Fader, 1989; Amos and Miller, 1990) and -65 m for the inner shelf (Loncarevic et al., 1994; Stea et al., 1994).

Ocean Circulation

Surface water circulation off Nova Scotia is dominated by three main currents. The Labrador Current, from the north, has two elements. An Inner Labrador Current skirts the continental margin off Labrador, flows around Newfoundland and onto the shelf off Nova Scotia. One branch flows into the Gulf of St. Lawrence and enters the Scotian Shelf through the Cabot Strait between Nova Scotia and Newfoundland; it then flows southwest across the shelf as the Nova Scotian Current. The other branch flows southwest after rounding the Avalon Peninsula and flows southwest above the outer shelf. An offshore Outer Labrador Current diverges off the coast of Newfoundland and flows around the Grand Banks and across the (Scotian) shelf break and upper slope, parallel to the Nova Scotian Current. The Gulf Stream flows from the southwest to northeast to form the third water mass. Some of this warm, saline water mixes with the Outer Labrador Current and forms a major bottom water mass off Nova Scotia, the Slope Water (McLellan, 1957).

Five bottom water masses are recognized on the Scotian Shelf (Houghton et al., 1978), their distribution well documented in Williamson (1983, 1985) and Williamson et al. (1984). Four of these water masses encompass the present study area. Banquereau and Artimon Bank are affected by cold, relatively low salinity bottom waters originating fron the Inner Labrador Current, having travelled through Cabot Strait and the Gulf of St. Lawrence (water mass 1). The Slipper lies between Western Bank and Emerald Bank and lies on the boundary between water masses 3 and 4. Water mass 4 is warm, saline Slope Water; water mass 3 is formed by the mixing of water masses 1 and 4. Middle Bank is an area of mixing of water mass 1 with the warm saline Slope Water. Chedabucto Bay receives Inner Labrador Current surface waters, slightly warmer than the bottom waters of the same current (water mass 2).

CHEDABUCTO BAY

Sea-level studies

Over a 20 year period Scott, Medioli and co-workers carried out post-glacial sea-level / Holocene history studies throughout the coastal Maritimes (Scott, 1977; Scott and Medioli, 1978, 1979, 1980a, 1980b, 1982; Scott et al., 1981, 1987a, 1995a, 1995b; Scott and Greenburg, 1983; Miller et al., 1982a; Brown and Scott, 1993) synthesizing this data into a regional comparison (Scott et al., 1987b).

Quinlan and Beaumont (1981), based on the Peltier and Andrews (1976) model for the earth's response following deglaciation, place Chedabucto Bay within RSL zone B, substantially inside the former ice margin and subject to substantial elastic rebound as well as migration of the peripheral bulge. This area would have had substantial RSL fall with late RSL rise and would exhibit an abundance of raised marine features. Scott et al. (1987b, Figure 2) have constructed a sea level curve for the eastern shore of Nova Scotia, based on field observations (Scott, 1977; Scott and Medioli, 1982; Miller et al., 1982a; Scott et al., 1987b) and place the coast of Nova Scotia (including Chedabucto Bay) in zone C, just inside the former ice margin and and inside the crest of the peripheral bulge. This zone actually experienced an undetermined amount of RSL fall prior to 7.0 ka (Scott and Medioli, 1982) and RSL rise since that time. Scott and Medioli (1982) believe they have found a sea-level pivot point (based on marsh foraminifera) in a core taken in 25 m of water off Lunenburg, Nova Scotia, placing sea level at -27 m at 7.07 ka. The early RSL fall was smaller in amplitude than the subsequent RSL rise, as evidenced by the lack of emerged marine features along this portion of the Nova Scotia coast. Scott et al. (1987b) present a six step evolutionary model to account for the sedimentation pattern observed along the Eastern Shore of Nova Scotia. Holocene sedimentation in zone C was characterized by glacial scouring to bedrock and subsequent deposition of thin but widespread ground moraine, lodgement and ablation tills. The glacial sediment was reworked during the transgression and was preserved only as coastal deposits within the topographically low estuarine systems. Within these valley systems, the preserved sequence consists of Pleistocene till overlying Paleozoic bedrock with an uppermost unit of transgressive Holocene sediments deposited in estuarine and coastal barrier environments (Scott et al., 1987b).

The sea level curve for the eastern shore of Nova Scotia (Scott et al., 1987b, Figure 2) indicates a more rapid rise in sea-level from about 7-5.5 ka. More recently (Brown and Scott, 1993; Scott et al., 1995a, 1995b) have revised and commented on this rapid rise after observing a similar phenomena in South Carolina (Gayes et al., 1992; Scott et al., 1995a). This late mid-Holocene oscillation is ^{14}C dated (reported in sideral years) from 5.3-3.8 ka, about a 10 m rise in RSL over a 1500 year period (Scott et al., 1995b).

Forbes et al. (1991) and Stea et al. (1994) present regional overviews of the Quaternary evolution of the surficial sediments on the inner Scotian Shelf based on multi-beam bathymetry and detailed seismo-stratigraphic analysis and interpretation. From this study a new picture of sea-level fluctuations has emerged (Forbes et al., 1991; Stea et al., 1994). Forbes et al. (1991) infer a minimum low stand of 45-50 m below present day sea-level sometime between 13.0 and 11.0 ka. Previous to this, there was a high stand of relative sea-level during ice recession across the inner shelf. Stea et al. (1994) construct a sea-level curve for the inner shelf: RSL of higher than -60 m immediately after deglaciation, a -65 m lowstand between 11.65 and 11.25 ka, followed by a rapid rise of 1.5 to 2 m per century until ca. 11 ka.

Physiography and coastal evolution

Chedabucto Bay is a large, funnel shaped, eastward-opening embayment, extending from the estuary of Guysborough Harbour, at its head, out to water depths of 100 m or more (MacLean et al., 1977; Forbes et al., 1995). The inner shelf is very narrow in the south but is broader on the north side (Forbes et al.,1995, Figure 5), where it extends some 4 to 9 km offshore at about 38 m present water depth before dropping away more steeply into the deeper part of the basin (Forbes et al., 1995 Figure 6).

There is an early Holocene gravel foreland at 38 m present water depth (Forbes et al., 1995, Figure 5). This gravel foreland is believed to have been deposited at the low stand of sea-level; and to have originated as a result of large amounts of sediment entering the littoral zone as a result of erosion of glacial deposits (Shaw et al., 1993). Forbes et al. (1995) are of the opinion that this foreland's preservation is due to its size and partially protected location. This barrier was abandoned and overstepped; the mechanism is unclear and timing poorly constrained (Forbes et al., 1995). However, the abandonment and overstepping are probably related to accelerating sea-level rise. Shaw et al. (1995) estimates the age of this -38 m shoreline at about 9 + / - 1 ka. (This gravel foreland was sampled during Hudson Misson 94-032 with the large IKU sampling device and a vibrocorer).

Beaches and barriers along the present northern shore of Chedabucto Bay are fed from drumlin cliff sources. The drumlin orientation is oblique to the coast. Combined with general shore alignment, this results in a drift-aligned coast with strong longshore cell structure (Forbes et al., 1995).

Stea and Mott (1989) have found a diamicton overlying a peat bed at Collins Pond, along the north shore of Chedabucto Bay. The top of the peat bed has been radiocarbon dated at 11.8 + / - .1 ka (GSC - 4367); a thin organic seam within the diamicton has been radiocarbon dated at 10.9 + / - .1 ka (GSC - 4475). Stea and Mott (1989) observed strong fabrics parallel to the trend of other ice-flow landforms in the region; and that led them to conclude that glaciers were active in Nova Scotia durng the period from 10 - 11 ka, i.e. during Younger Dryas time.

Offshore of the gravel foreland Maclean et al. (1977) mapped material they referred to as glacial till, occurring in water depths as shallow as 70 m. Fader (1989) stated that this material is up to 29 m thick. Two possible mechanisms of preservation during transgression include: the protected bay location, or late glacial ice covering the till. Piper et al. (1986) have found a discontinuous till sheet offshore in shallow water, along the western shore of Nova Scotia, which they attribute to ice present in Late Wisconsinan time. Fader (1989) suggests that glacial ice a short distance offshore, during the Late Wisconsinan marine transgression, may account for the preservation of the till in Chedabucto Bay.

Surficial sediments

Single-channel high resolution seismic reflection profiling and sidescan sonar surveys reveal an extensive cover of Holocene mud in the upper part of the bay (landward of the lowstand shoreline) along the southern shoreline and in deeper water seaward of the lowstand shoreline; while the seabed of the northern shoreline (landward of the lowstand shoreline) is covered with an extensive veneer of gravel with small areas of bedrock, sand or mud and a band of coarse gravel close to the present shore (Shaw et al., 1995). The lowstand shoreline is marked by a linear pattern of gravel outcrop (Forbes et al., 1995). In profile, these gravels consist in places of large-scale clinoform structures, up to 15 m thick, interpreted as prograded barrier deposits built out over marine muds in deeper water and overlain by lagoonal or estuarine mud that accumulated in shallow water bodies impounded by the barrier (Forbes et al., 1995). Forbes et al. (1995) hypothesize that the Chedabucto Bay barrier developed as a dominantly drift-aligned spit or foreland and that relative sea-level was accelerating during the final phase of growth.

MICROPALEONTOLOGY

Scotian Shelf

(Note: all species names applied in this section are those used by their respective authors; in many instances they will be referred to by different names in this report. See Appendix A).

Until recently, it has been difficult to interpret the Quaternary foraminifera on the Scotian Shelf because little was known about modern assemblages living there today. Bartlett (1964) and Barbieri and Medioli (1969) carried out reconnaissance studies of total assemblages only on the inner and western portions of the shelf. Hamdan (1971) studied the ecology and distribution of foraminifera along a section of the shelf from Halifax to Emerald Basin. Williamson (1982, 1983, 1985) and Williamson et al. (1984) are credited with the first regional study of foraminifera which includes most of the continental margin off Nova Scotia. Medioli et al. (1986) completed a detailed distribution study of the foraminifera on Sable Island Bank around Sable Island with a dense sampling grid.

Williamson (1982, 1983, 1985) and Williamson et al. (1984) completed a comprehensive study of both living and total assemblages and correlated them to present day water masses. This modern data set provides both a baseline data set for further surficial studies and a data base to compare with fossil assemblages.

Williamson (1982, 1983, 1985) and Williamson et al. (1984) statistically recognized eight foraminiferal assemblages on the shelf. The distribution patterns are well illustrated and discussed in Wiiliamson et al. (1984, Figure 4) and Williamson (1985, Figure 3). The following synopsis is taken largely from Williamson et al. (1984) and Williamson (1985).

There are two principal shelf assemblages, which are also representative of living faunas, and can be correlated directly to temperature and salinity characteristics of the overlying waters. The most prevalent assemblage on the shelf is a totally agglutinated assemblage dominated by Adercotryma glomerata. Secondary in this assemblage are other agglutinated species Recurvoides turbinatus, Cribrostomoides crassimargo and Spiroplectammina biformis. This assemblage occurrs throughout the northeast area and is restricted to central and inner shelf regions (banks and basins). Its southern limit is bounded by the northern edge of Banquereau, Sable Island and Middle Bank. The occurrence of this assemblage is determined by water mass 1, the bottom waters of the Inner Labrador Current (0-4^{o} C, 32-33$^{o/oo}$). In the central basin area (Emerald and LaHave basins) a Globobulimina auriculata, Nonionellina labradorica assemblage occurrs. Secondary species are Bulimina aculeata and Bolivina subaenariensis. The species diversity is higher than for any other assemblage, the sediment type is LaHave Clay or Emerald Silt. The assemblage coincides strongly with the presence of water mass 4, the warmer, more saline water (8-12^{o} C, 35 $^{o/oo}$) formed by the mixing of the Outer Labrador Current and Slope Water. A transitional assemblage, agglutinated, dominated by Saccammina atlantica, lies between the Adercotryma and Globobulimina assemblages. Secondary species are Reophax scorpiurus and Cribrostomoides jeffreysii. Its distribution appears to reflect the variability of temperature and salinity conditions which in turn limit the distribution of the two principal assemblages. Substrate type is clays, silts and sands. A Cibicides lobatalus dominated assemblage shows widespread but patchy distribution throughout the shelf area. Occurring with C. lobatalus is an I. islandica assemblage. This assemblage occurs on parts of all the outer and central banks, and the inner shelf areas of of the Eastern Shore and St. Anne Bank. I. islandica occurs with C. lobatalus in these areas, and also along the inner shelf from Halifax to Cape Breton. The assemblage occurs preferentially on coarse substrates and appears to be temperature and salinity independent. Total numbers are very high, probably due to low sedimentation rates and winnowing by bottom currents. Along the shelf edge is a diverse Trifarina angulosa assemblage. Secondary species are Bolivina spathulata and Buccella frigida. The coinciding water mass is water mass 5, Deep Atlantic Water, not present anywhere on the shelf (or the present study area). In Chedabucto Bay and on the south side of Sable Island Bank is an exclusively agglutinated assemblage strongly dominated by Eggerella advena. Secondary species are Spiroplectammina biformis and Cribrostomoides crassimargo. Sediment type is muds, silts, or well sorted sands. In the Scotian Gulf area (between Emerald and LaHave Basins) and the southeastern portion of Emerald Basin is an Elphidium excavatum assemblage, not represented by live specimens. Secondary species are Bulimina aculeata, Fursenkoina fusiformis and Buccella frigida. Williamson (1983, 1985) and Williamson et al. (1984) interpret this assemblage as relict and due to post depositional transport.

Williamson's sampling intervals on Middle Bank and Banquereau were quite sparce (Williamson, 1983, 1985; Williamson et al., 1984). Only seven samples were collected from Middle Bank, and only the northwestern and northeastern portions of Banquereau were sampled. Williamson (1985, Figure 3) and Williamson et al. (1984, Figure 4) infer that the samples from Middle Bank were barren of foraminifera; some samples on Banquereau contained the A. glomerata assemblage, the C. lobatalus assemblage is present on the western flank and the central-most samples were barren.

Medioli et al. (1986) statistically recognized seven foraminiferal thanatotopes on Sable Island Bank, but only three thanatotopes are widespread. All seven thanatotopes are dominated by Eggerella advena. In thanatotope 2, the secondary species are Elphidum excavatum and Trochammina spp. In thanatope 1 the secondary species are other agglutinated forms Saccammina atlantica, Adercotryma glomerata and Cribrostomoides jeffreysii; and the calcareous species Globobulimina auriculata. In thanatotope 4 the secondary species are Quinqueloculina seminula and Fursenkoina fusiformis.

Chedabucto Bay

Extensive foraminiferal studies were carried out in Chedabucto Bay and the Strait of Canso in the early 1970's as part of a multidisciplinary study to determine the possible effects of causeway construction and subsequent industrialization of the area on the marine environment (Cole and Ferguson, 1975; Vilks et al., 1975).

Cole and Ferguson (1975) published an illustrated catalogue of foraminifera from both surface samples and cores in the Bay and Strait areas.

Vilks et al. (1975) reported on the surface distribution of foraminifera in the Strait of Canso. Using cluster analysis, six species groups were defined, four of these occurred south of the causeway. Three of the four were dominated by Eggerella advena. Cribrostomoides crassimargo, Spiroplectammina biformis and Recurvoides turbinatus are diagnostic species in three assemblages; Reophax arctica is diagnostic in two assemblages; and Reophax fusiformis, Ammotium cassis, Ammodiscus catinus and Elphidium incertum (=C. excavatum) are diagnostic of one assemblage each. Vilks et al. (1975) defined (the agglutinated species) C. crassimargo, S. biformis and R. turbinatus to be index species, occurring exclusively south of the causeway; and (the calcareous species) Protelphidium orbiculare, E. incertum and Ammonia beccarii diagnostic species occurring exclusively north of the causeway.

Schafer and Mudie (1980) looked at grab samples collected from nearby St. Georges' Bay, Gulf of St. Lawrence. They found Eggerella advena to be the dominant species in depths greater than 17 m and Ammonia beccarrii, Elphidium incertum / clavatum (=Elphidum excavatum) and Protelphidum orbiculare dominant in shallower depths.

Vilks et al. (1975) also looked at the foraminiferal content of a number of short cores take in the strait, though these were collected north of the causeway. Foraminiferal assemblages north of the causeway, influenced by Gulf waters, were strongly calcareous and quite different than the agglutinated surficial assemblages found south of the causeway.

SAMPLE NO.	SAMPLE TYPE	GEOGRAPHIC LOCATION	LATITUDE	LONGITUDE	WATER DEPTH (M)
1	IKU	The Slipper	43o43.8343' N	62o02.5580' W	87.0
2	IKU	The Slipper	43o42.2297' N	62o03.1393' W	83.7
4	IKU	The Slipper	43o40.5924' N	62o03.7022' W	84.7
6	IKU	The Slipper	43o38.9891' N	62o04.4751' W	83.0
8	VC-CC	Western Gully	43o33.2600' N	62o13.6135' W	83.6
9	IKU	Western Gully	43o33.3580' N	62o13.6243' W	83.2
10	IKU	Middle Bank	44o24.6660' N	60o36.7293' W	50.0
11	IKU	Middle Bank	44o24.5990' N	60o33.3824' W	45.0
12	IKU	Middle Bank	44o24.5345' N	60o33.3699' W	42.0
13	IKU	Middle Bank	44o24.5130' N	60o30.8974' W	31.0
14	VC-CC	Middle Bank	44o24.5248' N	60o30.9473' W	31.0
15	IKU	Middle Bank	44o28.2818' N	60o24.6697' W	40.0
16	IKU	Middle Bank	44o28.1215' N	60o20.9938' W	49.0
17	IKU	Middle Bank	44o28.1866' N	60o21.0292' W	52.0
18	IKU	Middle Bank	44o28.1464' N	60o20.3688' W	46.2
19	IKU	Middle Bank	44o28.1292' N	60o18.1494' W	54.5
20	IKU	Middle Bank	44o24.2381' N	60o15.3579' W	69.3
21	IKU	Middle Bank	44o24.2020' N	60o14.3164' W	70.5
22	IKU	Middle Bank	44o37.7971' N	60o31.5476' W	26.0
23	IKU	Middle Bank	44o29.4298' N	60o36.8757' W	42.0
24	IKU	Middle Bank	44o28.4233' N	60o29.8595' W	28.0
25	IKU	Middle Bank	44o32.7436' N	60o25.9728' W	27.0
26	IKU	Middle Bank	44.37.6616' N	60o23.3563' W	41.6
27	IKU	Banquereau	44o31.2963' N	59o35.5630' W	39.1
28	IKU	Banquereau	44o34.8210' N	59o34.3360' W	48.0
29	IKU	Banquereau	44o38.2090' N	59o27.9060' W	48.0
30	IKU	Banquereau	44o33.9310' N	59o19.5920' W	54.4
31	IKU	Banquereau	44o31.4740' N	59o13.1850' W	64.6
32	IKU	Banquereau	44o27.1850' N	57o55.9770' W	32.0
34	IKU	Banquereau	44o26.6380' N	58o06.3380' W	36.2
35	IKU	Banquereau	44o31.1320' N	57o51.9590' W	36.2
36	IKU	Banquereau	44o36.3130' N	57o46.9250' W	33.0
37	IKU	Banquereau	44o40.9700' N	57o39.9850' W	31.0
38	IKU	Banquereau	44o47.8980' N	57o35.0180' W	34.0
39	IKU	Banquereau	44o52.9920' N	57o38.9910' W	40.0
40	IKU	Artimon Bank	45o09.7300' N	58o03.9100' W	60.0
41	IKU	Artimon Bank	45o09.5807' N	58o03.9651' W	61.0
50	IKU	Chedabucto Bay	45o22.3690' N	61o23.3740' W	35.0
51	TWC	Chedabucto Bay	45o22.4272' N	61o22.5998' W	39.0
51	PC	Chedabucto Bay	45o22.4272' N	61o22.5998' W	39.0

Table 1: Sample numbers, geographic area, latitude and longitude and water depth for the samples studied.

METHODS

LABORATORY METHODS

Surface samples and core samples were processed differently.

Surface samples

Samples of approximately 50 cm^3 were placed in plastic vials and covered with a solution of sea water, formalin and $CaCl_2$ buffer (to balance the pH and prevent dissolution) and stored at G.S.C. (Atlantic) until processing. All samples were then washed with tap water through 500 and 63 micron stainless steel sieves. The procedure for staining with Sudan Black (see note below) was then carried out (Walker et al., 1974). Washed samples were then rinsed with alcohol and placed back in their vials. Stain was added to cover. Samples were shaken to distribute the stain throughout the sample, then placed in a 40° C water bath for at least 30 minutes. After the stain had set the samples were rewashed with tap water in a 63 micron sieve, then rinsed in an alcohol bath to remove all traces of excess stain. The rinsed residue was then washed back into its vial and dried in a 30 - 40° C oven. When dried, the foraminifera were then concentrated by adding the sample to a 10:4 solution of bromoform and acetone (Gibson and Walker, 1967), which separated the foraminfera by flotation. The separation took place in about one minute after which the float was washed into filter paper, rinsed with acetone and dried.

Core samples

Core samples (including the vibro-, trigger weight and piston core samples) were processed similarly to the surface samples, omitting the staining procedure. The vibrocore core catcher samples were preserved shipboard as per the surficial samples, but back in the laboratory they were washed with tap water and dried. The trigger weight and piston core were sampled in the laboratory; approximately 15 cm^3 samples were taken, some processed immediately, others stored for a few days at 4° C until processed.

ANALYTICAL METHODS AND IDENTIFICATION OF FORAMINIFERA

Those samples containing abundant foraminifera were dry split with a microsplitter. Between 200-400 Quaternary benthic specimens (when present) and the accompanying Quaternary planktonic foraminifera were subsequently identified and counted. No reworked (i.e.extinct Cretaceous or Tertiary species) foraminifera were observed.

A comment should be made here about the staining methods used to determine live specimens; and the differing opinions on the value of living / total foraminiferal studies.

In 1952, Walton introduced the method of staining modern foraminiferal samples with rose Bengal, to differentiate living from dead material. The advantage of using rose Bengal is that it is not acidic and therefore does not harm calcareous tests (Murray, 1982). However, many workers reported difficulties in staining with rose Bengal; a good review is given in Walker et al. (1974), also Douglas (1979) and Williamson, (1983). The main problems result from the staining of bacteria and other organic material in the chambers of a dead test, and the difficulties in recognizing stains in thick shelled calcareous species and agglutinated specimens (Williamson, 1983). Boltovskoy (1963) indicated that many empty foraminiferal tests were stained with rose Bengal; and also that rose Bengal often failed to penetrate the test. Gregory (1970) noted that the amount and subsequent colour of the dye taken up by even specimens of the same species can vary considerably; and commented on the subsequent subjectivity involved in determining living individuals. Green (1960) and Gregory (1970) also noted that broken and abraided specimens often take up stain, and that one can find specimens where isolated chambers are deeply stained in an individual otherwise filled with sediment. As a result of these difficulties, Walker et al. (1974) developed an alternate method, staining with Sudan Black B. Scott and Medioli (1980a, 1980c), Williamson (1983, 1985) and Williamson et al. (1984) prefer the rose Bengal method. Williamson (1983) states that there are difficulties involved in staining with Sudan Black; though he does not discuss or reference them.

As the expertise of Walker et al. (1974) was directly available, the Sudan Black method of staining was chosen for this study.

There are two main schools of thought about the usefulness, or more specifically, the application, of living / total foraminiferal populations. There is a large body of work published on seasonal variations of benthonic foraminifera. The vast majority of studies have been completed on material from nearshore and marginal marine environments (Scott and Medioli, 1980c; Douglas, 1979). Good reviews / examples are provided by Phleger (1960), Buzas (1965), Boltovskoy and Lena (1969), Murray (1973), Boltovskoy and Wright (1976) and Boltovskoy (1976).

Scott and Medioli (1980c) have carried out extensive studies of both living and total assemblages over a three year period, in a salt-marsh environment. Scott and Medioli (1980c) found highly variable (spatially and temporally) living populations and assemblages. However, Scott and Medioli (1980c) found that the total assemblages did not change significantly over the same time period because the total population integrates the small seasonal and spatial variations into a definable assemblage that reliably reflects prevailing marine conditions.

Murray (1982) disagrees with Scott and Medioli (1980c), and states that the use of the total assemblage is ill-founded. Murray (1982) advocates use of the living population. Dead assemblages can be influenced by post-mortem changes such as loss or gain through transport and loss through destruction by biological, physical or chemical means (Murray, 1982). Consequently dead assemblages may or may not be in equilibrium with the depositional environment in which they are found (Murray, 1982). The applicability of each approach is succinctly summerized by Conradsen (1993). If the approach is to determine environmental demands of species and assemblages the living only analysis of Murray (1982) should be applied. If the objective is to determine resulting fossil assemblages from prevailing recent marine conditions, the approach of Scott and Medioli (1980c) may best suit. The total assemblage cannot be applied uncritically. If the living and dead assemblages correlate well, suggesting no important post-mortem processes, the total assemblage may be applied (Conradsen, 1993).

Williamson (1983, 1985) and Williamson et al. (1984) found good correlation between living populations and total assemblages for seven of the eight species groups; only the E. excavatum assemblage was believed to be relict and non representative of present day conditions. Consequently, as the results of this study are in good agreement with Williamson's (1983) and Williamson et al.'s (1984) results, the living / total methods of Scott and Medioli (1980c) were applied.

The faunal reference list is given in Appendix A. Samples are curated at G.S.C. (Atlantic), B.I.O., Dartmouth.

For each sample, the (sample) number, (sample) depth, size of the (sample) split, number of foraminifera in each category (QB, QP) counted, relative species abundances for the QB species, and actual counts of QP specimens by species, are listed on Tables 2 (The Slipper), 3 (Western Gully), 4 (Middle Bank), 5 (Banquereau), 6 (Artimon Bank) and 7 (Chedabucto Bay).

OBSERVATIONS

SURFICIAL DISTRIBUTION

Five assemblages and six subassemblages based on living / total numbers are recognized in the surficial and vibrocore samples. Foraminiferal data is given on Tables: 2 (The Slipper), 3 (Western Gully), 4 (Middle Bank), 5 (Banquereau) and 6 (Artimon Bank).

Adercotryma glomerata - Atlantiella atlantica assemblage

An Adercotryma glomerata - Atlantiella atlantica assemblage is found in samples 2 and 4 from The Slipper. Co-dominant is Lagenammina atlantica. Secondary species are Islandiella algida, Cibicidoides subhaidingerii, Stainforthia fusiformis and Trifarina reussi.

Eggerella advena assemblage

An Eggerella advena assemblage (54-73% E. advena) is found occurring on portions of both Middle Bank and Banquereau; in samples 11, 12, 15 and 23 (Middle Bank) and sample 31(Banquereau).

Eggerella advena - Adercotryma glomerata subassemblage

An Eggerella advena - Adercotryma glomerata co-dominant subassemblage is found in Banquereau sample 29. The assemblage is only about 4% calcareous specimens.

Eggerella advena - Lobatula lobatalus subassemblage

An E. advena - L. lobatalus subassemblage is found in Middle Bank sample 10 and Banquereau samples 34 and 37. The total numbers are very low.

Eggerella advena - Atlantiella atlantica subassemblage

An Eggerella advena - Atlantiella atlantica subassemblage is found in sample 6 from The Slipper. Co-dominant is I. algida. Secondary species are Angulogerina angulosa and Cibicidoides pseudoungerianus.

Eggerella advena - Trochammina spp. - subassemblage

An E. advena - Trochammina spp. subassemblage is found in sample 1 from The Slipper and samples from Middle Bank (13, 22 and 25) and Banquereau (samples 30, 32, 35 and 36). The dominance of E. advena has dropped to 5-46%, and it is absent in sample 32.

In sample 1 there is 38.5% Portatrochammina advena, in sample 13 there is 28.5% Lepidodeuterammina plymouthensis and 21.5% Discorbis squamata; in sample 22 there is 17.5% L. ochracea and 23.5% Paratrochammina haynesi and 12% Epistominella spp.; and in sample 25 there is 11% L. ochracea, 16% D. squamata and 16% Eoeponidella pulchella.

On Banquereau there is 12.5% L. ochracea in sample 30; 27.5% L. ochracea, 55% Discorbis spp. and 18.5% E. pulchella in sample 32; 8% P. haynesi, 23.5% Discorbis spp. and 13.5% E. pulchella in sample 35; and 33% P. haynesi and 33% D. plana in sample 36.

THE SLIPPER				
SAMPLE NUMBER	1	2	4	6
TOTAL NOS. QUATERNARY BENTHICS (L/T)	15 / 56	15 / 81	56 / 160	10 / 37
NO. BENTHIC SPECIES (L/T)	10 / 19	9 / 19	22 / 30	6 / 17
SPLIT COUNTED	/	/	/	/
Adercotryma glomerata	/ 2.0	34.0 / 24.0	14.0 / 14.0	/ 5.5
Ammodiscus catinus	/ 2.0		/ X	10.0 / 8.5
Atlantiella atlantica		/ 12.5	14.5 / 14.0	10.0 / 13.5
Eggerella advena	/ 8.5	/ 5.0	1.5 / 2.5	20.0 / 13.5
Eggerella propinqua	12.5 / 8.5	/ 2.5	1.5 / 5.0	/ 8.5
Glomospira gordialis	6.5 / 2.0		4.0 / 2.0	
Hemispherammina bradyi			/ 1.5	
Lagenammina atlantica	/ 2.0	13.5 / 8.5	4.0 / 15.0	
Lepidodeuterammina plymouthensis			1.5 / X	
Lepidodeuterammina ochracea			1.5 / X	
Paratrochammina haynesi	/ 2.0			
Portatrochammina advena	26.5 / 38.5		/ X	
Recurvoides turbinatus				/ 2.5
Reophax arctica		/ 1.5		
Reophax fusiformis		/ 1.5		
Reophax scorpiurus	/ 2.0		/ 5.0	
Tolypammina vagens				/ 2.5
Veleroninoides crassimargo	/ 2.0			
Veleroninoides jeffreysii	12.5 / 3.5	/ 1.5	1.5 / X	/ 2.5
Angulogerina angulosa / fluens				10.0 / 2.5
Astrononion hamadaense		/ 3.5		
Buccella frigida			/ X	
Cassidulina reniforme			4.0 / 1.5	/ 2.5
Cibicidinella exorna			/ 1.5	/ 2.5
Cibicidoides pseudoungerianus	6.5 / 3.5		1.5 / 5.5	/ 2.5
Cibicidoides subhaidingerii		6.5 / 6.0	4.0 / 5.5	
Cornuspira planorbis	/ 2.0			
Cribroelphidium albiumbilicatum		/ 1.5		
Cribroelphidium excavatum			1.5 / 1.5	/ 2.5
Cribroelphidium subarcticum		/ 2.5		
Epistominella exigua			4.0 / 1.5	
Epistominella takayanagii		6.5 / 1.5		
Glabratella sp. 1			1.5 / X	
Haynesina orbiculare		6.5 / 1.5	/ X	
Islandiella algida	6.5 / 7.0	6.5 / 3.0	7.0 / 5.5	30.0 / 11.0
Islandiella helenae		/ 1.5	9.0 / 5.0	20.0 / 8.5
Lobatula lobatalus			4.0 / 1.5	/ 8.5
Melonis barleeanum			1.5 / X	
Paracassidulina neocarinata				/ 2.5
Quinqueloculina seminula			/ 1.5	
Stainforthia fusiformis	12.5 / 3.5	13.5 / 11.0	5.0 / 2.5	
Stainforthia rotundata	6.5 / 2.0	6.5 / 2.5	4.0 / 2.0	
Trifarina reussi	/ 7.0	6.5 / 8.5	9.0 / 6.0	
QUATERNARY PLANKTONICS				
TOTAL NO. SPECIMENS (L / T)	0 / 2	1 / 7	/	/
SPLIT COUNTED	/	/		
Neogloboquadrina pachyderma-left	0 / 2			
-right		0 / 6		
Globogerinita uvula		1 / 1		

Table 2: Foraminiferal data, The Slipper. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

WESTERN GULLY			VC -CC
SAMPLE NUMBER	9		8
TOTAL NOS. QUATERNARY BENTHICS (L/T)	36 / 83		33
NO. BENTHIC SPECIES (L/T)	17 / 24		13
SPLIT COUNTED	/		/
Adercotryma glomerata	2.5 / 3.5		
Ammodiscus catinus	8.5 / 6.0		
Atlantiella atlantica	5.0 / 9.0		
Eggerella advena	5.0 / 3.5		
Eggerella propinqua	/ 6.0		
Lagenammina atlantica	2.5 / 7.0		
Recurvoides turbinatus	2.5 / 2.5		
Textularia pseudogramen	8.5 / 9.0		
Veleroninoides jeffreysii	14.0 / 9.0		
Angulogerina angulosa / fluens	5.0 / 2.5		
Astrononion hamadaense	/ 1.5		
Cassidulina reniforme			6.0
Cibicidinella exorna	/ 3.5		
Cibicidoides pseudoungerianus	2.5 / 1.5		
Cibicidoides subhaidingerii	/ 2.5		6.0
Cribroelphidium albiumbilicatum			40.0
Cribroelphidium excavatum	/ 1.5		9.0
Discorbis squamata	2.5 / 1.5		
Epistominella exigua	8.5 / 5.0		
Guttulina lactea			3.0
Haynesina orbiculare	2.5 / 1.5		9.0
Islandiella algida	14.5 / 11.5		3.0
Islandiella norcrossi			3.0
Lobatula lobatalus			9.0
Quinqueloculina arctica			3.0
Quinqueloculina elongata			3.0
Quinqueloculina seminula	/ 1.5		3.0
Rotaliella chasteri			3.0
Stainforthia fusiformis	8.5 / 5.0		
Stainforthia rotundata	/ 1.5		
Trifarina hughesi	5.0 / 2.5		
QUATERNARY PLANKTONICS			
TOTAL NO. SPECIMENS (L / T)	0 / 11		7
SPLIT COUNTED	/		/
Globigerinoides ruber			1
Neogloboquadrina dutertrei			1
Neogloboquadrina pachyderma-left	0 / 3		4
-right	0 / 4		
Globogerinita uvula	0 / 1		1
Globorotalia inflata	0 / 3		

Table 3: Foraminiferal data, Western Gully. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

MIDDLE BANK								
SAMPLE NUMBER	10	11	12	13	15	16	17	18
TOTAL NOS. QUATERNARY BENTHICS (L/T)	3 / 10	9 / 127	10 / 32	5 / 14	3 / 37	320 / 538	1,448 / 2,584	3 / 15
NO. BENTHIC SPECIES (L/T)	2 / 7	3 / 18	3 / 10	3 / 16	2 / 11	13 / 17	15 / 23	2 / 8
SPLIT COUNTED	/	/	/	/	/	1 / 2	1 / 8	/
Adercotryma glomerata		/ 1.5			/ 3.0		/ X	
Ammodiscus catinus					33.0 / 3.0			
Atlantiella atlantica								
Eggerella advena	67.0 / 30.0	67.0 / 73.0	70.0 / 54.0	60.0 / 21.5	/ 59.0	23.0 / 16.0	7.5 / 7.5	67.0 / 20.0
Glomospira gordialis								
Hemispherammina bradyi	/ 10.0							
Lagenammina atlantica		/ 1.0			/ 5.0	/ X		
Lepidodeuterammina plymouthensis	/ 10.0	11.0 / 1.5						
Lepidodeuterammina ochracea		/ 1.0			/ 3.0			
Paratrochammina haynesi							X / 1.5	/ 7.0
Portatrochammina advena								
Recurvoides turbinatus		/ 1.0				1.0 / 1.5		
Reophax arctica								
Reophax pilulifer		/ 1.0						
Reophax scottii		/ 1.5						
Spiroplectammina biformis					/ 5.0		/ 1.0	
Textularia earlandi								
Textularia torquata								
Veleroninoides jeffreysii		/ 2.0					/ X	
Angulogerina angulosa / fluens							1.0 / X	
Astrononion hamadaense		/ 1.5				6.5 / 4.0	3.5 / 2.0	
Brizalina pseudopunctata								
Brizalina subaenariensis								
Buccella frigida						/ X	1.0 / X	/ 7.0
Buccella sp. 2							/ X	
Cassidulina reniforme	/ 10.0	/ 1.0	/ 9.5		/ 3.0	3.0 / 3.0	2.5 / 2.0	/ 7.0
Cibicidoides pseudoungerianus								
Cibicidoides subhaidingerii		/ 6.5	20.0 / 15.5		/ 8.0	34.5 / 37.0	42.0 / 34.5	
Cornuspira planorbis								
Cribroelphidium albiumbilicatum					/ 3.0	1.0 / 2.0	X / 1.5	
Cribroelphidium bartletti								
Cribroelphidium excavatum			/ 3.0	/ 7.0		X / X		
Cribroelphidium subarcticum						X / X		
Discorbinella subbertheloti								
Discorbis plana		/ 1.0					/ X	
Discorbis squamata			/ 3.0	20.0 / 21.5	67.0 / 5.0		/ X	
Eoeponidella pulchella		22.0 / 2.5	/ 3.0	/ 14.0			X / X	/ 7.0
Epistominella arctica								
Epistominella sandiegoensis								
Epistominella takayanagii								
Fissurina cucurbitasema								
Fissurina marginata								

Table 4: Foraminiferal data, Middle Bank. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

MIDDLE BANK								
SAMPLE NUMBER	10	11	12	13	15	16	17	18
Fissurina orbignyana							/ X	
Fissurina quadrata							/ X	
Fissurina semimarginata								
Fissurina serrata								
Fissurina stewartii								
Gavelinopsis praegeri								
Glabratella lauriei								
Glabratella wrightii							X / X	
Glabratella sp. 1								
Guttulina austriaca								
Guttulina lactea		/ 1.0	/ 3.0			X / X	X / 1.0	
Haynesina germanica								
Haynesina orbiculare		/ 1.0					X / X	
Islandiella algida					/ 3.0	2.0 / 5.0	5.0 / 5.5	
Islandiella helenae								/ 7.0
Lobatula lobatalus	/ 20.0	/ 1.0		/ 7.0		25.5 / 28.5	31.5 / 38.0	/ 33.0
Melonis barleeanum								
Nonionella auricula								
Nonionellina labradorica								
Oolina acuticostata						X / X		
Oolina apiculeata								
Oolina melo								
Oolina wiliamsoni								
Pateoris hauerinoides			10.0 / 3.0					
Patellina corrugata								
Pseudopolymorphina decora								
Pullenia osloensis								
Quinqueloculina seminula		/ 1.0	/ 3.0			/ X		33.0 / 12.0
Rosalina globularis	/ 10.0							
Scutuloris pyriformis	33.0 /10.0							
Stainforthia fusiformis								
Stainforthia rotundata			/ 3.0			X / X	1.5 / 1.5	
Trifarina hughesi								
Triloculina trihedra						/ X		
Ventrostoma fovigera								
QUATERNARY PLANKTONICS								
TOTAL NO. SPECIMENS (L / T)	1 / 2	0 / 20	0 / 8	0 / 4	1 / 1	2 / 6	40 / 152	0 / 1
SPLIT COUNTED	/	/	/	/	/	1 / 2	1 / 8	/
Globigerina bulloides		0 / 3	0 / 2					
Globigerina quinqueloba - right				0 / 1			0 / 8	
Neogloboquadrina dutertrei							0 / 8	
Neogloboquadrina pachyderma-left	0 / 1	0 / 2	0 / 4	0 / 1	1 / 1	1 / 3	24 / 80	
-right		0 / 9	0 / 2	0 / 1			0 / 8	0 / 1
Globogerinita uvula	1 / 1	0 / 6		0 / 1				
Globorotalia inflata							8 / 8	

Table 4: Foraminiferal data, Middle Bank. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

MIDDLE BANK										VC - CC
SAMPLE NUMBER	19	20	21	22	23	24	25	26		14
TOTAL NOS. QUATERNARY BENTHICS (L/T)	4,096 / 10,048	150 / 956	3 / 45	8 / 17	8 / 24	4 / 7	14 / 19	212 / 820		/
NO. BENTHIC SPECIES (L/T)	13 / 28	16 / 37	2 / 13	4 / 6	6 / 11	4 / 6	8 / 10	16 / 31		
SPLIT COUNTED	1 / 32	1 / 2	/	/	/	/	/	1 / 2		
Adercotryma glomerata	/ 3.5	5.0 / 5.0	/ 3.0				7.0 / 5.0	7.0 / 3.5		
Ammodiscus catinus					/ 4.0					
Atlantiella atlantica			/ 3.0				7.0 / 5.0			
Eggerella advena	6.0 / 7.5	6.0 / 8.0	67.0 / 20.0	50.0 / 41.0	37.5 / 60.0	25.0 / 14.5	22.0 / 16.0	10.0 / 9.0		
Glomospira gordialis				/ 6.0						
Hemispherammina bradyi										
Lagenammina atlantica		/ X	/ 3.0							
Lepidodeuterammina plymouthensis								/ X		
Lepidodeuterammina ochracea				12.5 / 17.5	12.5 / 4.0		14.0 / 11.0			
Paratrochammina haynesi				25.0 / 23.5				1.0 / X		
Portatrochammina advena		1.5 / 1.0								
Recurvoides turbinatus	1.5 / X							1.0 / X		
Reophax arctica						25.0 / 14.5		1.0 / X		
Reophax pilulifer										
Reophax scottii			/ 3.0							
Spiroplectammina biformis	1.5 / 1.0	2.5 / 1.0			/ 4.0			/ X		
Textularia earlandi		/ X								
Textularia torquata	/ X	/ X								
Veleroninoides jeffreysii	/ X	/ X	/ 3.0					1.0 / 1.0		
Angulogerina angulosa / fluens	1.5 / 1.5	6.5 / 3.5						1.0 / 1.0		
Astrononion hamadaense	/ 5.0	4.0 / 2.5						2.0 / 3.5		
Brizalina pseudopunctata	/ X	/ X								
Brizalina subaenariensis					/ 4.0					
Buccella frigida	/ 2.0	/ 1.0						1.0 / 1.0		
Buccella sp. 2										
Cassidulina reniforme	4.5 / 3.5	4.0 / 1.0					7.0 / 11.0	/ X		
Cibicidoides pseudoungerianus		/ 1.0	/ 6.0					1.0 / 1.5		
Cibicidoides subhaidingerii	43.5 / 34.0	24.0 / 19.5	33.0 / 24.0		12.5 / 4.0	25.0 / 14.5	7.0 / 10.0	32.0 / 32.5		
Cornuspira planorbis							/ 5.0			
Cribroelphidium albiumbilicatum		/ 3.5						1.0 / X		
Cribroelphidium bartletti								/ X		
Cribroelphidium excavatum		/ X								
Cribroelphidium subarcticum		/ X								
Discorbinella subbertheloti					/ 4.0			/ X		
Discorbis plana	/ X									
Discorbis squamata	/ X	4.0 / 1.0	/ 3.0			/ 14.5	22.0 / 16.0			
Eoeponidella pulchella	/ 2.0	/ 1.0			/ 4.0	25.0 / 27.5	14.0 / 16.0	/ X		
Epistominella arctica				12.5 / 6.0						
Epistominella sandiegoensis				/ 6.0						
Epistominella takayanagii	/ X									
Fissurina cucurbitasema	/ X									
Fissurina marginata	1.5 / X	/ X						1.0 / X		

Table 4: Foraminiferal data, Middle Bank. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

MIDDLE BANK										VC - CC
SAMPLE NUMBER	19	20	21	22	23	24	25	26		14
Fissurina orbignyana	4.5 / 1.0									
Fissurina quadrata										
Fissurina semimarginata		/ X								
Fissurina serrata	1.5 / X									
Fissurina stewartii								/ X		
Gavelinopsis praegeri							/ 5.0			
Glabratella lauriei	3.0 / X									
Glabratella wrightii										
Glabratella sp. 1								/ X		
Guttulina austriaca		/ X								
Guttulina lactea		/ X						/ X		
Haynesina germanica	/ X									
Haynesina orbiculare		/ X						/ X		
Islandiella algida	9.5 / 4.0	25.5 / 25.5			12.5 / 4.0			20.0 / 11.0		
Islandiella helenae			/ 3.0			/ 14.5				
Lobatula lobatalus	20.0 / 30.0	9.5 / 20.0	/ 29.0					19.0 /22.5		
Melonis barleeanum								/ X		
Nonionella auricula	/ X							/ X		
Nonionellina labradorica		/ X			12.5 / 4.0					
Oolina acuticostata		1.5 / X								
Oolina apiculeata		/ X								
Oolina melo		1.5 / X								
Oolina williamsoni		1.5 / X								
Pateoris hauerinoides										
Patellina corrugata								/ X		
Pseudopolymorphina decora		/ X	/ 3.0							
Pullenia osloensis	/ X									
Quinqueloculina seminula					12.5 / 4.0			/ X		
Rosalina globularis										
Scutuloris pyriformis		/ X								
Stainforthia fusiformis	/ 1.0	1.5 / X								
Stainforthia rotundata	1.5 / 1.0	1.5 / X						1.0 / 1.0		
Trifarina hughesi			/ 3.0							
Triloculina trihedra										
Ventrostoma fovigera								/ X		
QUATERNARY PLANKTONICS										
TOTAL NO. SPECIMENS (L / T)	96 / 768	0 / 22	0 / 1	/	/	0 / 1	0 / 1	2 / 34		
SPLIT COUNTED	1 / 32	/	/			/	/	1 / 2		
Globigerina bulloides	0 / 64						0 / 1			
Globigerina quinqueloba - right										
Neogloboquadrina dutertrei										
Neogloboquadrina pachyderma-left	32 / 384	0 / 14	0 / 1					0 / 18		
-right	64 / 288	0 / 8						2 / 8		
Globogerinita uvula	0 / 32					0 / 1		0 / 8		
Globorotalia inflata										

Table 4: Foraminiferal data, Middle Bank. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

BANQUEREAU												
SAMPLE NUMBER	27	28	29	30	31	32	34	35	36	37	38	39
TOTAL NOS. QUATERNARY BENTHICS (L/T)	54 / 76	9 / 38	132 / 201	41 / 55	37 / 48	8 / 11	1 / 3	16 / 39	2 / 3	3 / 19	14 / 53	/ 10
NO. BENTHIC SPECIES (L/T)	9 / 10	5 / 14	14 / 23	12 / 13	13 / 17	5 / 5	1 / 3	10 / 17	2 / 3	3 / 10	7 / 17	/ 5
SPLIT COUNTED	/	/	/	/	/	/	/	/	/	/	/	/
Adercotryma glomerata		/ 8.0	34.0 / 27.0	/ 2.0	6.5 / 4.0							
Ammodiscus catinus				/ 2.0								
Atlantiella atlantica	1.5 / 1.5		1.0 / X	5.0 / 7.0	3.0 / 2.0							
Eggerella advena	11.0 / 12.0	22.0 / 24.0	44.5 / 31.0	52.0 / 45.5	57.0 / 50.0		/ 33.0	/ 5.0	/ 34.0	/ 28.0	14.0 / 3.5	
Eggerella propinqua				9.5 / 7.0							7.0 / 1.5	
Glomospira gordialis			/ 1.0									
Hyperammina fragilis								/ 2.5				
Lagenammina atlantica			4.5 / 4.0		/ 2.0					34.0 / 5.0		
Lepiodeuterammina ochracea				12.0 / 12.5		25.0 / 27.5						
Lepidodeuterammina ochracea sinuosa			1.5 / 3.0									
Lepidodeuterammina plymouthensis			1.0 / 1.5					12.5 / 8.0	50.0 / 33.0			
Paratrochammina haynesi	4.0 / 2.5	/ 8.0										
Recurvoides turbinatus		/ 5.5	4.5 / 5.5					/ 2.5		/ 5.0		
Reophax arctica			1.0 / 3.0	2.5 / 2.0								
Reophax scorpiurus			1.0 / 1.0									
Reophax scottii			2.0 / 7.0									
Rhabdammina abyssorum										/ 5.0		
Silicosigmoilina groenlandica			/ X									
Spiroplectammina biformis		/ 2.0	/ X									
Spiroplectammina typica			/ 1.0									
Textularia torquata			1.0 / 1.0		3.0 / 2.0			/ 2.5				
Trochamminula lobata			1.0 / 2.5									
Trochamminopsis quadriloba			/ 1.0									
Veleroninoides crassimargo			3.0 / 6.0									
Veleroninoides jeffreysii				4.5 / 5.5	3.0 / 2.0		/ 33.0					
Astrononion hamadaense	1.5 / 2.5		/ X	2.5 / 2.0	/ 2.0			/ 2.5		/ 5.0	/ 9.0	
Buccella frigida			/ X								/ 5.5	
Buccella sp. 2											/ 1.5	
Bulimina aculeata / marginata	1.5 / 1.5											
Cassidulina reniforme		/ 2.0		2.5 / 2.0	3.0 / 2.0						/ 1.5	
Cibicidoides subhaidingerii	35.5 / 30.0	/ 2.0		4.5 / 5.5	3.0 / 16.0			/ 10.0		33.0 / 22.0	28.5 / 43.0	/ 50.0
Cornuspira involvens								/ 2.5				
Cornuspira planorbis		11.0 / 2.0										
Cribroelphidium albiumbilicatum					/ 2.0							
Cribroelphidium excavatum					/ 2.0						/ 1.5	
Cribroelphidium frigidum										33.0 / 5.0		/ 20.0

Table 5: Foraminiferal data, Banquereau. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

BANQUEREAU												
SAMPLE NUMBER	27	28	29	30	31	32	34	35	36	37	38	39
Discorbinella subbertheloti		/ 2.0										
Discorbis plana						37.5 / 27.5		12.5 / 5.0	50.0 / 33.0		/ 1.5	
Discorbis squamata		11.0 / 2.0		2.5 / 3.5		12.5 / 18.5		/ 18.5		/ 10.0	7.0 / 3.5	
Discorbis translucens		/ 2.0				12.5 / 9.0						
Discorbis tricamerata								/ 2.5			7.0 / 1.5	/ 10.0
Eoeponidella pulchella		34.0 / 29.0			/ 2.0	12.5 / 18.5		/ 13.5		/ 10.0	/ 1.5	/ 10.0
Epistominella takayanagii											/ 1.5	
Fissurina orbignyana											21.5 / 5.5	
Glabratella lauriei								12.5 / 5.0				
Glabratella wrightii	1.5 / 2.5											
Glabratella sp. 1								12.5 / 5.0				
Guttulina lactea			/ X					/ 2.5				
Haynesina germanica								/ 2.5				
Islandiella algida	/ 2.5				6.5 / 4.0						/ 1.5	
Islandiella helenae	1.5 / 1.5			2.5 / 3.5	3.0 / 2.0						14.0 / 7.5	
Lobatula lobatalus	41.0 / 43.5	/ 2.0	/ 1.5				/ 34.0			/ 5.0	/ 9.0	
Nonionella auricula					3.0 / 2.0							
Paracassidulina neocarinata					/ 2.0							/10.0
Scutuloris pyriformis		22.0 / 5.5						25.0 / 10.0				
Stainforthia fusiformis			/ X									
Stainforthia rotundata					3.0 / 2.0							
QUATERNARY PLANKTONICS												
TOTAL NO. SPECIMENS (L / T)	/	/	1 / 2	/	0 / 1	1 / 2	0 / 1	2 / 3	0 / 1	0 / 1	0 / 24	/
TOTAL NO. SPECIES (L / T)			1 / 1		0 / 1	1 / 2	0 / 1	2 / 2	0 / 1	0 / 1	0 / 1	
SPLIT COUNTED			/		/	/	/	/	/	/	/	
Globigerina bulloides						0 / 1	0 / 1	1 / 1				
Neogloboquadrina pachyderma-left			1 / 2						0 / 1	0 / 1	0 / 23	
-right					0 / 1	0 / 1					0 / 1	
Globogerinita uvula								1 / 2				

Table 5: Foraminiferal data, Banquereau. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

ARTIMON BANK		
SAMPLE NUMBER	40	41
TOTAL NOS. QUATERNARY BENTHICS (L/T)	1,344 /	4,736 /
	5,931	35,456
NO. BENTHIC SPECIES (L/T)	10 / 27	8 / 31
SPLIT COUNTED	3 / 64	1 / 128
Atlantiella atlantica		/ 1.0
Eggerella advena	3.0 / 3.0	2.5 / 1.0
Recurvoides turbinatus		2.5 / X
Spiroplectammina biformis		/ X
Astrononion hamadaense	11.0 / 10.5	3.0 / 6.0
Brizalina pseudopunctata		/ X
Buccella frigida	/ X	/ 1.5
Buccella tenerrima		2.5 / X
Buccella sp. 2		/ X
Cassidulina reniforme	4.0 / 3.0	2.5 / 1.5
Cibicidoides subhaidingerii	43.0 / 29.0	46.0 / 35.5
Cribroelphidium albiumbilicatum	/ 1.0	/ 1.0
Cribroelphidium asklundi	/ 1.0	/ X
Cribroelphidium excavatum	1.5 / X	/ X
Cribroelphidium frigidum		/ X
Discorbis squamata	/ X	
Fissurina marginata	/ X	/ X
Fissurina orbignyana	/ X	/ 1.0
Fissurina serrata	/ X	
Fissurina ventricosa	/ X	
Gavelinopsis praegeri		/ X
Glabratella lauriei	1.5 / 2.0	
Glabratella sp. 1	/ X	/ 1.5
Haynesina germanica	/ X	
Islandiella algida	/ 4.0	3.0 / 4.0
Islandiella helenae	1.5 / X	
Lobatula lobatalus	30.0 / 37.5	38.0 / 36.5
Miliolinella subrotunda	1.5 / 2.0	/ X
Oolina borealis		/ X
Oolina caudigera		/ X
Oolina melo	/ X	
Pyrgo williamsoni	3.0 / 1.0	
Quinqueloculina arctica		/ X
Quinqueloculina seminula	/ X	/ 1.0
Robertinoides charlottensis	/ X	/ 1.0
Rosalina globularis	/ X	
Rotaliella chasteri		/ 1.0
Scutuloris pyriformis		/ 1.0
Scutuloris tegminus	/ X	
Stainforthia rotundata		/ X
Triloculina trihedra	/ X	
QUATERNARY PLANKTONICS		
TOTAL NO. SPECIMENS (L / T)	21 / 1,067	128 / 6,656
SPLIT COUNTED	3 / 64	1 / 128
Globigerina bulloides		0 / 256
Globigerina quinqueloba-left		0 / 128
-right		0 / 128
Neogloboquadrina pachyderma -left	21 / 1,003	768 / 4,864
-right	0 / 21	0 / 256
Globogerinita uvula	0 / 43	128 / 1,024

Table 6: Foraminiferal data, Artimon Bank. Relative species abundances (living / total) for the benthic species; total numbers for the planktonic species. X < 1%.

Eoeponidella pulchella - Eggerella advena subassemblage

In Middle Bank sample 24 and Banquereau sample 28, the Trochammina spp. component is missing from the Eggerella advena - Trochammina spp. subassemblage; E. pulchella becomes the dominant species and E. advena drops to 14.5-24%. However, total numbers are very low.

Cibicidoides spp. assemblage

A Cibicidoides spp. (L. lobatalus and C. pseudoungerianus) assemblage is found on portions of Middle Bank, Banquereau and Artimon Bank; in samples 16, 17, 18, 19, 21 and 26 (Middle Bank); samples 27, 38 and 39 (Banquereau) and samples 40 and 41 (Artimon Bank). Secondary species on Middle Bank are A. glomerata, I. algida and S. rotundata.

Cibicidoides spp. - Islandiella algida subassemblage

In Middle Bank sample 20 the occurrence of I. algida increases to 25.5%; the remainder of the species are consistent with the Cibicidoides spp. assemblage.

Islandiella algida - agglutinated species assemblage

An Islandiella algida - agglutinated species assemblage is found in sample 9 from Western Gully. The dominant species is I. algida. Agglutinated species make up 55% of the assemblage; co-dominant are Atlantiella atlantica, Textularia pseudogramen and Veleroninoides jeffreysii. Calcareous species Epistominella exigua, Stainforthia spp. and Trifarina spp. are also present.

Cribroelphidium albiumbilicatum assemblage

Present in the vibrocore core catcher sample from station 8 in Western Gully is an Cribroelphidium albiumbilicatum (40%), entirely calcareous assemblage. Co-dominant are Cribroelphidium excavatum, Haynesina orbiculare, Lobatula lobatalus, and Quinqueloculina spp.

CHEDABUCTO BAY

Two benthonic foraminiferal assemblages (and 3 subassemblages of one of these assemblages) are recognized from the grab sample and cores from Chedabucto Bay. Foraminiferal data is given on Table 7. Downcore relative species abundances, benthic species, are illustrated graphically on Figure 1.

Eggerella advena - Lagenammina atlantica - Spiroplectammina biformis subassemblage

This assemblage occurs in the surface (grab) sample. There are high numbers of benthic specimens. It is almost entirely agglutinated species. Eggerella advena occurrs as < 30%, co-dominant are Lagenammina atlantica and Spiroplectammina biformis.

Eggerella advena - Spiroplectammina biformis - agglutinated species subassemblage

This assemblage occurs in the trigger weight core (0-22 cm, CC), the surface sample of the piston core (0-2 cm) and the base of the piston core (320-322 cm). The

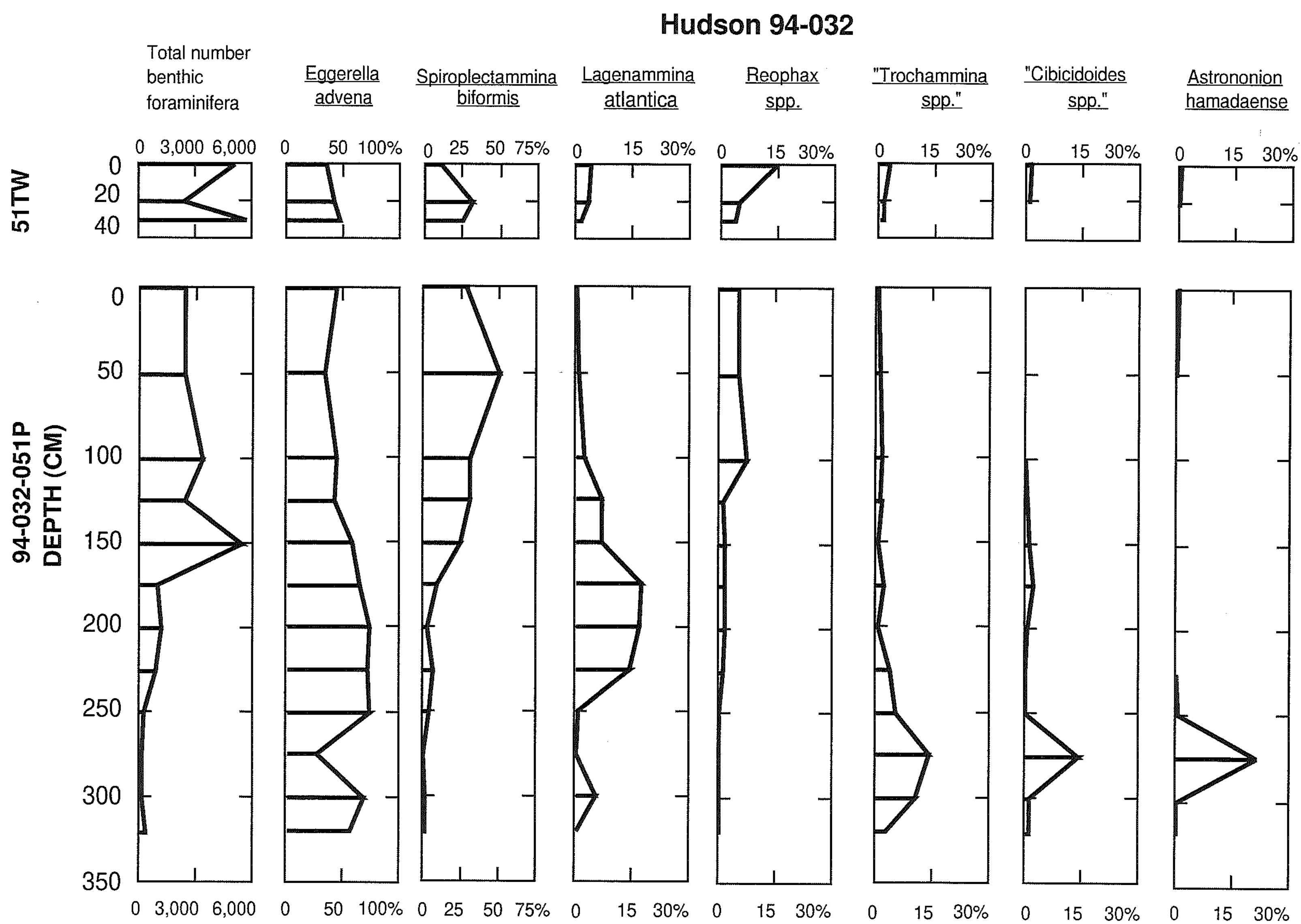

Figure 1: Foraminiferal abundances and percent occurrences of key QB species in cores 94-032-51TW and 51P, inner Chedabucto Bay. Genus names in quotation marks refer to species groups; species of closely related genera lumped into one group for graphical representation.

Hudson 94-032

CHEDABUCTO BAY	S-50	TWC	TWC	TWC	P	P	P	P	P	P	P	P	P	P	P	P
DEPTH (IN CORE - CM)	(0)	0-2	20-22	CC	0-2	50-52	100-102	125-127	150-152	175-177	200-202	225-227	250-252	275-277	300-302	320-322
TOTAL NOS. QUATERNARY BENTHICS	4,896	5,072	2,432	5,696	2,336	2,384	3,352	2,424	5,431	936	1,128	819	158	113	125	252
SPLIT COUNTED	1 / 16	1 / 16	1 / 8	1 / 16	1 / 8	1 / 8	1 / 8	1 / 8	7 / 128	1 / 2	1 / 4	3 / 8	/	/	/	/
Adercotryma glomerata	6.5	X		X			X									
Ammodiscus catinus		X			X											
Ammobaculites dilatatus		X														
Ammotium cassis	X	2.0	1.0	2.0		X	7.5	3.5	1.0	3.5	1.0	2.0				2.0
Ammotium salsum																X
Atlantiella atlantica	3.0	7.0	6.0	5.5	X			1.5	2.0	X		X		2.0		2.5
Eggerella advena	28.0	34.0	41.0	47.0	42.5	33.5	44.0	42.0	57.0	63.0	72.5	70.0	71.5	27.0	68.0	54.5
Hemispherammina bradyi		3.0	1.0	X	2.0	X	1.0	1.0			1.0					
Hyperammina fragilis	X															
Hyperammina friabilis	X															
Jadammina macrescens		X										X		1.5		1.0
Lepidodeuterammina ochracea		2.0	X	1.0			1.5		X	X		1.0		7.0		
Lepidodeuterammina plymouthensis				X				X		1.0			1.0	1.0	1.0	X
Miliammina fusca													X			
Paratrochammina haynesi			X		X			X		X	X	2.0	4.0		9.0	1.0
Psammospaera fusca		X							X							
Psammosphaera parva	1.0															
Recurvoides turbinatus	6.5	6.5	5.0	3.5	1.5		X		2.0	1.0		1.0	X	1.0	8.0	11.5
Reophax arctica	5.0	11.0	3.0	2.5	2.5	1.0			X	X	1.0	1.0				
Reophax dentaliniformis	2.5	X	X	X												
Reophax fusiformis		1.0	X		1.5	3.5	7.0				X					
Reophax scorpiurus	2.0	1.0	X	X				1.0	1.0							
Reophax scottii		1.0			1.0	X				1.0						
Rhabdammina abyssorum	X															
Saccammina atlantica	15.0	3.5	3.0	1.0		X	2.0	6.5	6.5	17.0	16.5	13.5	X		5.0	X
Spiroplectammina biformis	11.5	10.5	31.5	24.5	28.5	50.0	30.0	30.0	24.0	8.0	2.0	6.0	3.0		1.0	8.5
Textularia earlandi		1.0		X												
Textularia torquata	X	2.5	2.0	2.0	3.0	1.5	2.0	4.5	1.5	2.0	1.0	1.0		3.5		1.0
Trochammina inflata													15.0	4.5		
Veleroninoides crassimargo	9.0	4.0	1.0	3.0	3.0	X	X	1.0	X	1.0		1.0	X	6.0	6.0	14.0
Veleroninoides jeffreysii						1.0										
Angulogerina angulosa / fluens	X															
Astrononion hamadaense		X			X								X	21.5		
Buccella frigida	2.0	1.5	1.0	1.0	2.5	1.0	2.0	1.0	X	1.0	1.0		2.0			
Buccella hannai					1.0											
Buccella tenerrima	1.0															
Buccella sp. 2														2.5		
Cassidulina reniforme				X	X			1.0						2.5	1.0	1.0
Cibicidoides pseudoungerianus														1.0		
Cibicidoides subhaidingerii	1.0	X						X	1.0	2.0	X			12.5	1.0	1.0
Cribroelphidium albiumbilicatum			X	X				X								
Cribroelphidium bartletti											1.0					
Cribroelphidium excavatum	X	3.0	X	3.0	8.0	2.5	X	2.0		X	1.0	X				
Cribroelphidium frigidum								X								
Discorbinella subbertheloti														1.5		
Discorbis plana								X								

Table 7: Foraminiferal data from a site in inner Chedabucto Bay. Relative species abundances for the benthic species; total numbers for the planktonic species. X < 1%.

Hudson 94-032

CHEDABUCTO BAY	S-50		TWC	TWC	TWC		P	P	P	P	P	P	P	P	P	P	P	P
DEPTH (IN CORE - CM)	(0)		0-2	20-22	CC		0-2	50-52	100-102	125-127	150-152	175-177	200-202	225-227	250-252	275-277	300-302	320-322
Discorbis squamata											X							
Discorbis translucens																		
Eoeponidella pulchella									X									
Epistominella sandiegoensis					X													
Epistominella takayanagii				X			X		X				X					
Fissurina laevigata					X		X											
Fissurina ventricosa										X								
Glabratella lauriei																1.5		
Haynesina germanica												X						
Haynesina orbiculare					X		X	1.0	X	1.0		X				1.0		
Islandiella algida								X			X							
Islandiella helenae	2.0		1.0	X				X										
Lagena mollis							1.0											
Lagena substriata			X															
Lobatalus lobatalus												3.0						
Miliolinella subrotunda										X								
Nonionellina labradorica			X	X	X			2.0	1.0	1.0		X	1.0					X
Parafissurina tectulostoma			X															X
Patellina corrugata										X								
Pseudopolymorphina decora																		
Pullenia asloensis																		X
Quinqueloculina seminula										X								
Quinqueloculina stalkeri			2.0	X														
Stainforthia fusiformis																1.0		
Stainforthia rotundata								X				X				1.5		
QUATERNARY PLANKTONICS																		
TOTAL NO. SPECIMENS	16		/	/	/		/	/	/	/	201	/	/	/	/	23	1	1
SPLIT COUNTED	1 / 16										7 / 128					/	/	/
Globigerina bulloides																3		
Globigerina quinqueloba -left																		
-right																		
Neogloboquadrina pachyderma -left	16										201					9	1	
-right																5		
Globogerinita uvula																6		1
Globorotalia inflata																		

Table 7: Foraminiferal data from a site in inner Chedabucto Bay. Relative species abundances for the benthic species; total numbers for the planktonic species. X < 1%.

total numbers continue to be high, except for the base of the core sample. The assemblage is almost entirely agglutinated. The dominant species is Eggerella advena, the main secondary species is Spiroplectammina biformis. Consistently present are Atlantiella atlantica, Reophax spp. (up to five species present), Recurvoides turbinatus, and Veleroninoides crassimargo. At the base of the core Recurvoides turbinatus, Spiroplectammina biformis and Veleroninoides crassimargo are all co-dominant; and Reophax is absent.

Eggerella advena - Spiroplectammina biformis subassemblage

This assemblage occurs in the piston core from 50-150 cm. The total numbers are lower than seen previously, the assemblage continues to be almost entirely agglutinated. Eggerella advena ocurrs as 30-50% of the assemblage, Spiroplectammina biformis occurs as 30-60% of the assemblage. Together they form 70-80% of the assemblage.

Eggerella advena assemblage

This assemblage occurs from 150-275 cm and at the 300 cm level in the piston core. There is a marked drop in the total numbers; numbers are now low, < 200 specimens per sample. Eggerella advena becomes strongly dominant. The occurrence of Eggerella advena increases to 60-75%. There is a decrease in the occurrence of S. biformis to < 10%, and an increase in the occurrence of S. atlantica, to 10-30%. Trochammina inflata is present at 250 cm (15%).

Eggerella advena - Astrononion hamadaense - Cibicidoides spp.

At 275 cm, there is a marked change in the fauna. There is a further drop in total numbers to 113 specimens. The occurrence of Eggerella advena decreases to 27.5%, there is 4.5% Trochammina inflata and there is a large calcareous component to the fauna. The secondary species are Astrononion hamadaense (21.5%) and Cibicidoides spp. (13.5%). There are also other calcareous outer estuarine / shelf species present: Angulogerina angulosa, Cassidulina reniforme, Discorbinella subbertheloti, Glabratella lauriei, Haynesina orbiculare and Stainforthia spp. Planktonic specimens are also present.

DISCUSSION

Surficial distribution

Generally the results are consistent and in good agreement with those of Williamson (1982, 1983, 1985) and Williamson et al. (1984). The same assemblages that Williamson found have been found in areas not sampled or sparcely sampled by Williamson (1982, 1983, 1985) and Williamson et al. (1984). The distribution patterns of these assemblages are consistent with the distribution patterns delineated by Williamson (1982, 1983, 1985) and Williamson et al. (1984). Total numbers present are larger than those found by Williamson (1982, 1983, 1985) and Williamson et al. (1984). This is attributed to the 50 cm^3 sample size versus the 20 cm^3 sample size of Williamson (1983). This also accounts for the greater number of species present (apparent greater species diversity).

The living populations (and magnitudes of the total numbers) provide a means of determining the presence of relict sediments, areas of sediment accumulation, and areas of sediment transport and winnowing.

Generally, the total numbers present in the samples are quite low. These low numbers indicate that strong bottom currents are continuously sweeping across Middle Bank and Banquereau, preventing foraminifera (and sand size and smaller sediment particles) from accumulating. Exceptions to this are samples 17 and 19 from Middle Bank; and samples 40 and 41 from Artimon Bank.

No "reworked" foraminifera were found, i.e. foraminifera of Tertiary age or older, reworked from underlying older sediments. No assemblages were found that were not consistent with those defined by Williamson (1983, 1985) Williamson et al. (1984); therefore no faunas showing evidence that they are relict were found, or assemblages having undergone considerable transport (not in situ).

Two of the five surficial assemblages and five of the six subassemblages recognized are dominated by agglutinated foraminifera. The differences on which the subassemblages are defined are very subtle; many species are present in only one or two samples and the total numbers are very low; so the differentiation of these subassemblages may be within the ranges of spatial variability and may be statistically invalid. For the purposes of this discussion, the subassemblages will be included with the associated assemblage. Again, species names used are those of the author quoted (except where indicated), and not necessarily the same as those used in this report for the same species (see Appendix A).

Other workers have found that modern day Scotian Shelf assemblages contain agglutinated foraminifera, from minor occurrences to virtual dominance of agglutinated forms (Bartlett, 1964; Barbieri and Medioli, 1969; Williamson, 1983; Williamson et al., 1984; Medioli et al., 1986; Miller, in press). Sen Gupta and McMullen (1969) and Sen Gupta (1971) found assemblages that were mostly calcareous, with some agglutinated species, present on the Tail of the Bank, Grand Bank. On the Labrador Shelf, those areas under strong influence of the Inner Labrador Current contain surface assemblages that are strongly dominant to entirely agglutinated foramininfera, in particular species such as Spiroplectammina biformis, Adercotryma glomerata, Reophax spp., Trochammina spp., Textularia spp. and Recurvoides spp. (Vilks et al., 1982; Mudie et al., 1984; Scott et al., 1984). Those surface sediments under the influence of the Outer Labrador Current contain foraminiferal assemblages composed largely of calcareous species, usually dominated by C. lobatalus (=Lobatula lobatalus), I. islandica, (=I.

algida), I. helenae, N. auricula or N. labradorica (Vilks, 1980, Mudie et al., 1984; Scott et al., 1984; Vilks and Deonarine, 1988).

All species found here to be dominant or co-dominant were also found by Williamson to be dominant or co-dominant; though the assemblages as defined here intuitively may not exactly match those defined statistically by Williamson (1982, 1983, 1985) and Williamson et al. (1984). Essentially the major elements are the same. Williamson (1982, 1983, 1985) and Williamson et al. (1984) found all of these species present in both the living / total populations and concluded that all of the assemblages found here (in this study) are in equilibrium with the present environment.

Williamson (1982, 1983) and Williamson et al. (1984) found an Adercotryma assemblage distributed widespreadly throughout the northeast shelf area (here it was found in samples 2 and 4 on The Slipper, and in sample 29 on Banquereau) and statistically determined that it strongly correlates with temperature. Its distribution on banks, basins and nearshore areas varies considerably with depth and substrate type. Williamson (1983) and Williamson et al. (1984) report the temperature limits of the assembage to be 1.8° C to 3.0° C, with salininty varying from 31.3 o/oo to 33 o/oo. Rodrigues and Hooper (1982) reported the dominance of this species in the Gulf of St. Lawrence. Vilks (1969, 1980) and Vilks et al. (1982) have found this species in the Arctic and on the Labrador Shelf in waters with temperatures of 2-4° C and salinities of 31-34 o/oo. Leslie (1965) found it in Hudson Bay were the waters have comparable temperatures but lower salinities. Schafer and Cole (1978) found it in the Bay of Chaleur under conditions very similar to those found by Leslie (1965). However, it has also been found in more saline waters (34-35 o/oo) of the Newfoundland Slope (Schafer and Cole, 1982) and the Grand Banks (Sen Gupta, 1971).

Co-dominant in this assemblage is Saccammina atlantica (=Lagenammina atlantica of this report). Williamson (1983) and Williamson et al. (1984) statistically defined a distinct Saccammina atlantica assemblage. Secondary species are Reophax scorpiurus and Cribrostomoides jeffreysii (Veleroninoides jeffreysii, this report). This is an entirely agglutinated assemblage Williamson found peripheral to the northern basin boundaries and on the northwest flank of Middle Bank. Williamson (1983) and Williamson et al. (1984) found no correlation between this assemblage and specific environmental paprameters such as depth, salinity, temperature and substrate type. Williamson found these species to be minor components of another assemblage (Globobulimina assemblage), when the environmental limits of Globobulimina and the accompanying secondary species (N. labradorica, B. aculeata / marginata and I. helenae) are reached, Saccammina and its accompanying species seem to take over by default. Saccammina may appear dominant here because The Slipper represents an area of transition between other major assemblages. Williamson et al. (1984) also suggest that the presence of this assemblage may be due to intense temperature and salinty gradients. The Slipper is adjacent to the boundary between water masses 3 (mixing of water mass 1 and Slope Water) and 4 (warm Slope Water) which resullts in steep bottom water temperature (1.8-10° C) and salinity (32-35 o/oo) variations.

Williamson (1983) and Williamson et al. (1984) found an Eggerella advena assemblage dominant in the inner bays (Chedabucto, Gaberous, Mahone and St. Margarets) and on shallow bank areas around Sable Island. Medioli et al. (1986) also found it dominant around Sable Island. Here it was found on The Slipper (samples 1 and 6), on portions of Middle Bank (samples 11,12, 13, 15, 22, 23, 24 and 25) and Banquereau (samples 28, 30, 31, 32, 35 and 36). It must be remembered that Williamson sparcely sampled these two banks and found many of his smaller samples to be barren. Williamson (1983) and Williamson et al. (1984) found that this assemblage strongly correlates with depth and percent sand and correlates inversely with percent mud.

Scott et al. (1980) based on data from Scott et al. (1977) and Schafer and Cole (1978) have found Eggerella advena assemblages to be diagnostic of the open bay (outer estuary) of intertidal estuaries and the transitional zone of shallow subtidal (i.e. Miramichi, Scott et al., 1977) and deep subtidal (i.e. Bay of Chaleur, Schafer and Cole, 1978) estuaries. Mudie et al. (1984) found a 100% agglutinated fauna, domin-ated by Eggerella advena, in Makkovik Inlet. Mudie et al. (1984), using the transfer functions of Imbrie and Kipp (1971), found the dominant presence of E. advena strongly related to depth and temperature. An Eggerella advena assemblage has also been found in the Kattegat (between Denmark and Sweden) in shallow water depths (< 30 m) and variable temperature, salinity and current flow conditions (Conradsen, 1993).

An assemblage dominated by Cibicidoides spp. (including Lobatula lobatalus) was found in the remainder of the samples from Middle Bank (samples 16, 17, 18, 19, 21 and 26) and Banquereau (samples 27, 38 and 39) and Artimon Bank (samples 40 and 41). This corresponds to the Cibicides lobatalus assemblage of Williamson (1983) and Williamson et al. (1984). Here two species of this group are recognized, Lobatula lobatalus and Cibicidoides subhaidingerii. Williamson (1983) and Williamson et al. (1984) found this assemblage showing a widespread but patchy distribution throughout the shelf area, in particular along the western flank of Banquereau. Williamson (1983) and Williamson et al. (1984) found it strongly correlates to substrate type. It occurs predominantly on shallow, sandy or gravel banks. C. lobatalus has a widespread distribution world-wide and along the Canadian Continental margin. Rodrigues and Hooper (1982) have found it in similar conditions in the Gulf of St. Lawrence; Sen Gupta and McMullen (1969) and Sen Gupta (1971) found C. lobatalus (sensu lato) at 90% of the stations on the Tail of the Bank (Grand Bank) with a mean percent occurrence of 12.5%; Vilks (1980) and Vilks et. al. (1982) report it on the Labrador Shelf and Scott et al. (1984) report it from four study areas along the Canadian Margin.

Two samples were found (Banquereau samples 34 and 37) where Eggerella advena and Lobatula lobatalus were co-dominant.

Often co-occurring with the Cibicidoides group is Islandiella algida (I. islandica of Williamson, 1983; Williamson et al., 1984). It is found in this study co-occurring with Cibicidoides spp. on Middle Bank (sample 20). Williamson (1983) and Williamson et al. (1984) also found it forming its own assemblage entirely, on isolated outer banks and in shallow depressions. Here it appears to replace Cibicidoides spp. where the salinity is slightly higher and the substrate remains coarse. It is also present in the Western Gully (sample 9) accompanied by agglutinated species. Sen Gupta and McMullen (1969) and Sen Gupta (1971) found I. islandica (=I. algida) the most common species on the sandy areas of the Tail of the Bank (Grand Bank), Vilks et al. (1982) found it in the sandy gravelly muds on the Labrador Shelf.

In the vibrocore core catcher sample from station 8 in Western Gully, a Cribroelphidium albiumbilicatum assemblage was found. The secondary species are Lobatula lobatalus, Cribroelphidium excavatum, Haynesina orbiculare and Quinqueloculina spp. It is assumed that the sample is in situ, and the assemblage was not "formed" during vibrocoring. This assemblage is not known to occurr in surface samples of this area today. This sample contained no agglutinated foraminifera. The reason for this is not known at this time; i.e. were they ever present or are they (now) absent due to post-depositional diagenisis.

Miller (in press) found a high number, high diversity C. asklundi / C. albiumbilicatum - C. excavatum fauna (assemblage 3) in the Louisburg - BH4 borehole on Banquereau. Also present are Buccella spp., Cibicidoides spp., Cassidulina reniforme, Epistominella spp. Miller (1993) found this assemblage in all three of the 1990 drilled Sable Island Bank boreholes; and it probably correlates to assemblage 9A (E. excavatum - E. subarcticum [E. albiumbilicatum]) at the 24 m interval in the 1987 drilled Panuke borehole, Sable Island Bank (Miller, 1989b). This fauna is interpreted as present in a very shallow water / estuarine / quiet water (low wave energy) environment with hyposaline conditions.

An E. excavatum - E. bartletti / E. albiumbilicatum fauna (assemblage 4) was also found in Louisburg - BH4 and in Louisburg - BH5 boreholes (Miller, in press); and it occurred in all three 1990 boreholes (Miller, 1993). This fauna corresponds to assemblage 9 in the1987 Panuke borehole (Miller, 1989b). This fauna is interpreted as occur-ring in a cold outer estuarine / inner shelf environment.

The fact that an Cribroelphidium albiumbilicatum fauna was recognized in the Sable Island Bank and Banquereau boreholes is strong evidence that it is in situ in Western Gully.

Lutze (1965) reports the species is common in recent boreal shallow and brackish water faunas. E. albiumbilicatum (= C. albiumbilicatum) was originally described by Weiss (1954) from the interglacial Gardiners Clay, New York, where he describes them as common. Weiss (1954) interprets the environment of deposition as shallow, brackish water in a bay or lagoonal area protected by an offshore bar.

Knudsen (1978) found an E. albiumbilicatum (=C. albiumbilicatum) zone in Late Quaternary marine deposits in northern Denmark. This zone is characterized by high frequencies of E. albiumbilicatum (up to 60%). E. excavatum (=C. excavatum) is co-dominant and Cassidulina crassa (= C. reniforme) is also consistently present. Generally, this assemblage occurs in sandy sediments, probably indicative of shallower water, higher current velocity, rising temperatures and lower salinities than an C. excavatum assemblage. Radiocarbon dates of mollusc shells from sediments containing these faunas are latest Pleistocene (11,000-15,000). Knudsen (1978) correlates this fauna to the Bølling Interstadial. Knudsen (1978) believes these sediments may have been deposited in a deep valley formed (prior to the late-glacial transgression) either by the ice itself, or by meltwater streams during deglaciation.

Knudsen (1978, p. 25) noted both the difficulties in separating E. subarcticum (= C. subarcticum) and E. albiumbilicatum; and the presence of transitional forms. Knudsen (1977) had previously noted this phenomena. Knudsen (1978) suggests that they are some form of variants of one species; E. subarcticum representing the arctic form and E. albiumbilicatum the boreo-arctic and boreal form.

Chedabucto Bay - Environments of Deposition

Two benthonic foraminiferal assemblages (and three subassemblages of one of these assemblages) are recognized in the core from Chedabucto Bay. In all assemblages and subassemblages Eggerella advena is the dominant or co-dominant species. The differences in these assemblages are very slight, but these subltle changes directly indicate and reflect changes in environment, sea level and ocean circulation; and must be noted. A summary of the key species in each of these assemblages and subassemblages, with the interpreted environment and sea level (relative to present day) is given on Figure 2 (next page).

The upper three subassemblages (grab, TWC and P:0-150 cm) are all dominated by Eggerella advena. The percent occurrence of E. advena increases slightly downcore. The occurrence of Spiroplectammina biformis increases markedly downcore. The percent occurrences of Lagenammina atlantica, Recurvoides turbinatus, Reophax spp. and Veleroninoides crassimargo, are highest in the upper subassemblage and decreases downcore. These changes all indicate a shallowing of water depth downcore, or and increase in water depth up core. The surface assemblage (grab and TWC:0-2 cm) represents inner shelf conditions, with L. atlantica, C. crassimargo and R. turbinatus. The middle subassemblage (TWC:20 cm , -CC and P:0-2 cm), with the increase in E. advena, S. biformis and the peak of Reophax spp. represents not so much a change in depth but a change in water circulation; these are the species indicative of a transitional zone (between upper estuary and open bay) of a deep subtidal estuary (sensu Scott et al., 1980; Miller et al., 1982a). The bottom of these three subassemblages (P: 50-150), with lower diversity and increases in the percent occurrences of E. advena and S. biformis, probably indicates a shallowing of water depth and decreases in salinity and mixing with ocean waters.

Directly underlying these three subassemblages is the E. advena assemblage, indicating the shallowest water depth and minimum salinity. However, Schafer and Mudie (1980) have found that E. advena only stays dominant in inner bay environments, in water depths greater than 17 m. They found Ammonia beccarrii, Elphidium incertum / clavatum (=Cribroelphidum excavatum) and Protelphidum orbiculare (=Haynesina orbiculare) dominant in shallower depths.

At 250 cm there is also 15% Trochammina inflata present (E. advena remains dominant). Scott and Medioli (1980a) find T. inflata in the low marsh zone in Nova Scotia marshes, the low marsh zone straddles the mean low water mark. However, the other low marsh, middle marsh and high marsh species are not present in this sample or other core samples. These specimens may not be indigenous, they may have been transported. The presence of T. inflata may indicate even shallower water depths (than 17 m).

Immediately underlying the E. advena peak, at 275 cm., is an assemblage indicating quite different conditions. There is a strong calcareous component to the benthic fauna, as indicated by the co-dominance of A. hamadaense and L. lobatalus. This fauna could indicate a maximum in salinity, probably a coarser substrate, higher wave energy and an appreciable mixing of bay and ocean waters, as indicated by the presence of planktonic foraminifera. It is problematic, because in isolation it represents deeper water, increase in salinity and maximum ocean influence. It is comparable to assemblages found occurring today at Hibernia, Grand Bank (Miller, unpub. data), where water depths are 40-90 m, the substrate coarse and wave energy very high. The presence of these two calcareous species may be due to another factor, an increase in suspended particulate matter (SPM). Schafer and Cole (1986) have looked at the surficial distribution of foraminifera in a number of Baffin Island fjords. Five agglutinated species are dominant or co-dominant in most of the fjords: Textularia earlandi, Spiroplectammina biformis, Trochammina nana (Trochammina spp.), Reophax arctica and Adercortyma glomerata. In some areas, particularily inner shelf settings, the calcareous species Cassidulina reniforme and Cibicides lobatalus (=Lobatula lobatalus) become dominant. Schafer and Cole (1986) are of the opinion that these two calcareous species, particularily C. reniforme, can tolerate higher

iDEPTH IN CORE (cm)	KEY SPECIES	ENVIRONMENT	CHANGE IN SEA LEVEL
Grab	E. advena (25-34%) L. atlantica (3.5-15%) S. biformis (10.5-11.5%) V. crassimargo (4-9%)	inner shelf temperature decrease	present water depth 39 m
TWC: 0-2 P: 0-2	E. advena (41-47%) S. biformis (24.5-31.5%) R. turbinatus (1.5-5%) Reophax spp. (3.5-15%)	transitional- deep subtidal estuary temp. increasing salinity increasing	increasing
P: 50-150	E. advena (33.5-57%) S. biformis (24-50%)	upper estuary?	increasing
P: 175-225	E. advena (63-72.5%) L. atlantica (X-17%) S. biformis (2-8%)	upper estuary?	increasing
P: 250	E. advena (71.5%) Trochammina inflata (15%)	shallowest water (?) but at least 17 m shallow subtidal or or intertidal	increasing
		sea level pivot point?	
P: 275	E. advena (27%) Trochammina inflata (4.5%) A. hamadaense (21.5%) L. lobatalus (12.5)	washover? ?	decreasing
P:300-320	E. advena (54.5%) S. biformis (8.5%) V. crassimargo (14%) R. turbinatus (11.5)	transitional- deep subtidal estuary	decreasing

Figure 2: Key benthonic foraminiferal species, inferred environments and sea level movements, as interpreted from cores 94-032-51 TWC and P, from Chedabucto Bay.

concentrations of SPM than agglutinated species. Another explanation has been suggested (Shaw, 1995, pers. comm.) and that is that this site was very close to sea level at this time and the gravel foreland was subject to wave washover. However, if this was the case, the assemblage should contain other shallow water species.

The subassemblage at the base of the core is very similar to the second subassemblage present downcore, and represents a transitional environment of a deep subtidal estuary (Scott et al., 1980).

Chedabucto Bay - Regional setting, Holocene history

The core was retrieved from a water depth of 39 m, 1 m deeper than the interpreted low sea-level stand of -38 m (Forbes et al., 1995; Shaw et al., 1995) The core's position places it just inside (i.e. east) of the gravel foreland in the upper bay, on the north side of the former estuary mouth.

Two levels in this core have been radiocarbon dated (G.B.J. Fader, Pers. Comm., 1995). At the 274 cm level shell material has been dated (Laboratory Number Beta 80733, CAMS 18964) at 8430 +/- 50 YBP. Wood fragments taken from the 286 cm level have been dated (Laboratory Number 80734, CAMS 18965) at 8980 +/- 60 YBP. Utilizing these two data points, sedimentation rates have been extrapolated (Figure 3, next page). Combining this information with Figure 2 and the work of Forbes et al. (1991,1995), Shaw et al. (1993) and Shaw et al. (1995) the following history is inferred and a sea-level curve constructed (Figure 4).

At the base of the core is a transitional environment of a deep estuarine system. Based on extrapolation of the sedimentation rates, the age is estimated at 10 - 10.5 ka. This deposited would have formed immediately after Younger Dryas deglaciation (Stea and Mott, 1989). However, the foraminiferal assemblage does not indicate direct meltwater influence. The dominance of E. advena in the intervals 300 cm and 175-250 cm suggests water depths were between 17 and 25 m (Schafer and Mudie, 1980) when these sediements were deposited. The foraminiferal assemblage at 250 cm, with 15% T. inflata is the shallowest water assemblage sampled in the core, if it is assumed that the calcareous species are not in situ. All this information suggests that the interval 250 -275 cm represents the period of shallowest water deposition. The foraminifera indicate that there was probably a sea-level reversal, with sea level decreasing until this interval, then increasing after this interval in the core. Utilizing the sedimentation rate graph (Figure 3), the conditions estimated for 300 cm interval are 21 m water depth (mean between 17 and 25 m, Schafer and Mudie, 1980) and sea-level decreasing at about 9.6 ka. At 275 cm the water depth was still decreasing and sea level dropping (8.5 ka, from Figure 3). At 250 cm, E. advena is dominant, but T. inflata indicates shallow water, so a minimum depth is inferred (17 m). The sediments at 250 cm are estimated to have been deposited at about 7.5 ka. Based on the sea-level curve constructed from this information (Figure 4), the sea-level pivot point is about - 29 m (10 m water depth) at about 8.3 ka. This is not in agreement with Forbes et al. (1995), who place the lowstand at about -38 m at 9 ka. (The water depth at the core site would be approximately 1 m at 9 ka, at approximately 285 cm in the core).

After 8.3 ka, water depth and the volume of oceanic waters entering the bay increase, producing transitional estuarine, then deep estuarine, then the present day inner shelf conditions.

The sea level curve constructed here (for the last 6 ka) agrees well with those of Scott et al. (1987b, Figure 2), Forbes et al., (1991, Figure 10) and Shaw et al. (1993, Figure 2) for the inner Scotian Shelf. (The new sea-level curve of Scott et al., 1995b has not been included because it has been converted to sideral years. It is very similar to the Scott et al., 1987b, curve; when the conversion is not applied). Scott et al. (1987b) place the coast of Nova Scotia (including Chedabucto Bay) in zone C, just inside the former ice margin and inside the crest of the peripheral bulge. Scott et al.

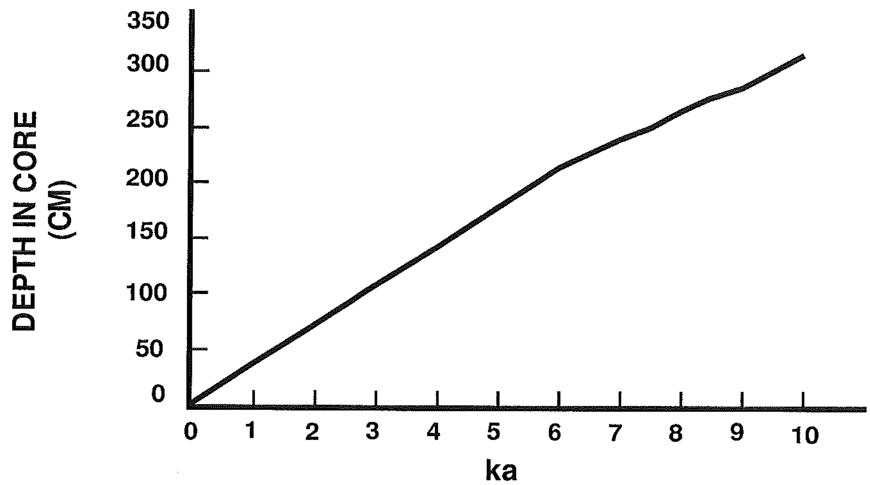

Figure 3: Sediment accumulation graph for cores 51TW & P, based on 2 ^{14}C ages cited in the text.

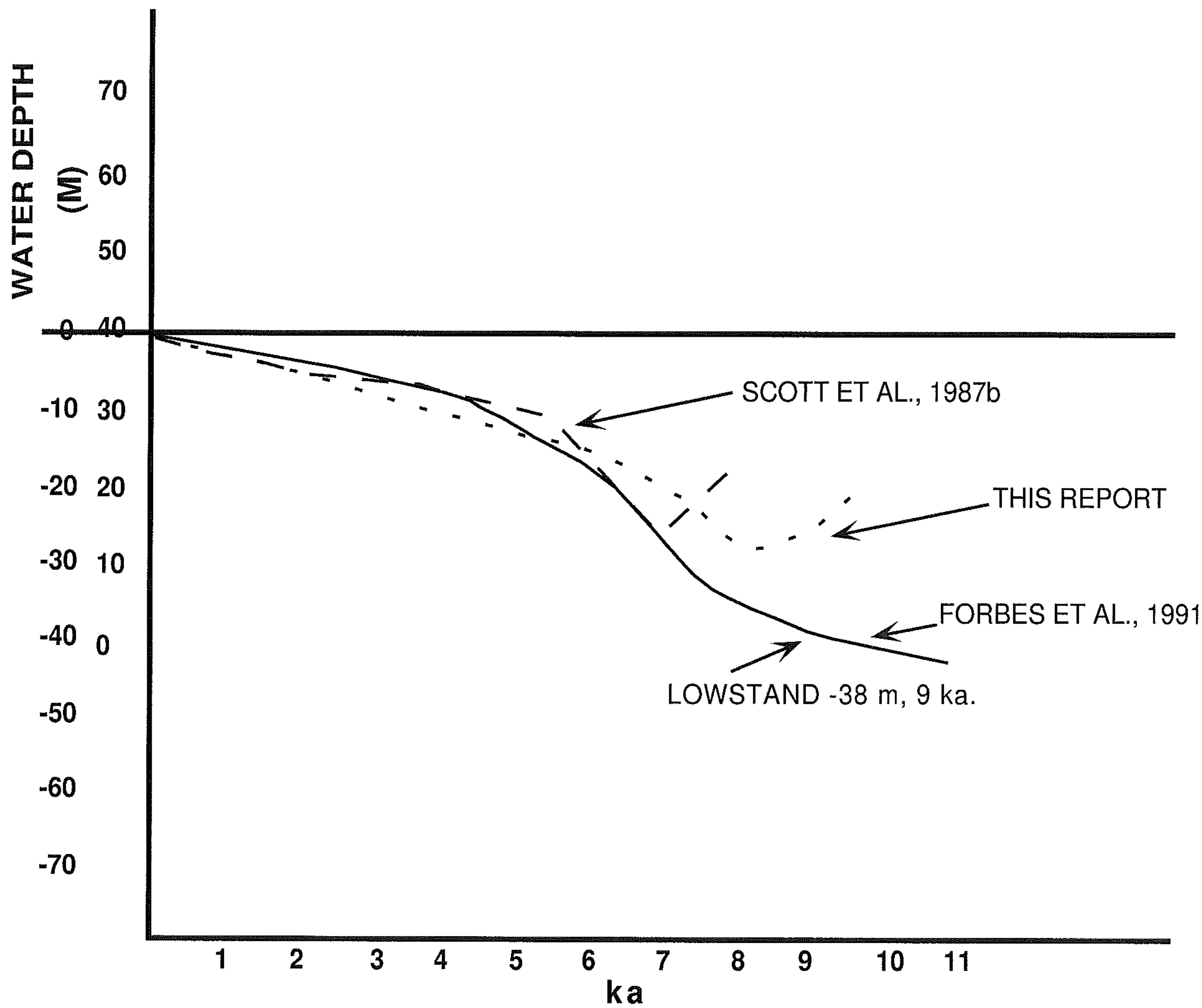

Figure 4: Sea-level curves for the inner Scotian Shelf: from Scott et al. (1987b), Forbes et al. (1991) and this report.

(1987b), based on field observations, found that this zone actually experienced an undetermined amount of RSL fall prior to 7.0 ka (Scott and Medioli, 1982) and RSL rise since that time. The early RSL fall was smaller in amplitude than the subsequent RSL rise, as evidenced by the lack of emerged marine features along this portion of the Nova Scotia coast. The foramini-fera in the core from Chedabucto Bay indicate that the same sequence of events occurred at this site. In Chedabucto Bay the shallowest water depths (the crest of the peripheral bulge passing through) are estimated to have occurred at approximately 8.3 ka, with a water depth of less than 17 m at the core site at this time. This time frame is later than that observed by Scott et al. (1987b), Shaw et al. (1993), Forbes et al. 1995) and Shaw et al. (1995). The sea level reversal or pivot point probably occurs in the core interval 250-275 cm, this core interval needs to be subsampled at close intervals in order to resolve this issue.

CONCLUSIONS

Thirty-five surface samples and two vibrocore samples from the outer bank regions of the Scotian Shelf (The Slipper, Western Gully, Middle Bank, Banquereau and Artimon Bank) have been analysed for benthonic and planktonic foraminifera. Five assemblages and six subassemblages based on living / total numbers are recognized. These assemblages (and subassemblages) are: an Adercotryma glomerata - Atlantiella atlantica assemblage, an Eggerella advena assemblage, an Eggerella advena - Adercotryma glomerata subassemblage, an Eggerella advena - Lobatula lobatalus subassemblage, an Eggerella advena - Atlantiella atlantica subassemblage, an Eggerella advena - Trochammina spp. - subassemblage, an Eoeponidella pulchella - Eggerella advena subassemblage, a Cibicidoides spp. assemblage, a Cibicidoides spp. - Islandiella algida subassemblage, an Islandiella algida - agglutinated species assemblage and a Cribroelphidium albiumbilicatum assembage (vibrocore sample only). The surficial assemblages are in good agreement with those defined by Williamson (1983, 1985) and Williamson et al. (1984) and the distribution of these assemblages is also consistent with the distribution patterns defined by Williamson (1983, 1985) and Williamson et al. (1984).

One surface sample, 3 triggerweight core samples and 12 piston core samples were analysed from one station site in Chedabucto Bay. Two benthonic foraminiferal assemblages (and 3 subassemblages of one of these assemblages) were recognized. These assemblages (and subassemblages) are: an Eggerella advena - Lagenammina atlantica - Spiroplectammina biformis subassemblage, an Eggerella advena - Spiroplectammina biformis - agglutinated species subassemblage, an Eggerella advena - Spiroplectammina biformis subassemblage, an Eggerella advena assemblage and an Eggerella advena - Astrononion hamadaense - Cibicidoides spp. subassemblage. The sequence in which these assembages (and subassemblages) occur downcore (or upcore) infer changes in water depth, salinity, degree of mixing with oceanic waters and sea level.

The interpretation of the environments of deposition, based on the foraminiferal content of the bottom 70 cm of the core, do not fully agree with the coastal observations; and surficial sediments and seismo-stratigraphic interpretation of the bay floor (Forbes et al., 1995; Shaw et al., 1995). For the period 6-10 ka, the foraminifera indicate deeper water depths, a higher and later sea-level low stand (-29 m at about 8.3 ka) than suggested by Forbes et al. (1995) and Shaw et al. (1995). The foraminifera also indicate that there may have been a period of RSL rise from 10.5 to 8.3 ka, similar to the sequence of events inferred by Scott and Medioli (1982) and Scott et al. (1987b) from a core collected off the southern shore of Nova Scotia.

For the period 0-6 ka the interpretation based on foraminifera, the inferred environments of deposition, water depths, and relative sea-level, are in good agreement with those of Scott et al. (1987b), Forbes et al. (1995) and Shaw et al. (1995). With these inferred changes in water depth, a relative sea level (RSL) curve is constructed for Chedabucto Bay.

The core interval 250-325 cm needs to be subsampled to try and further refine the estimated minimum water depth and find the sea-level reversal, or pivot point, if present.

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APPENDIX A

FAUNAL REFERENCE LIST

This is not a taxonomic report and lengthy synonymies will not be given here. However, it is important that an unambiguous concept of each species be conveyed to the reader; to that end the following references are given which contain an illustration and (in most cases) a synonymy of each species. Where the name of the species referred to is not the same as the one used in this report, the name in square brackets is the one used in the reference given.

The generic classification is in accordance with Loeblich and Tappan (1988), except for Cribrostomoides, emended and the implications for species now placed in Veleroninoides (Jones et al., 1993).

Species are listed alphabetically, first the agglutinated, then calcareous.

QUATERNARY BENTHONIC FORAMINIFERA

Adercotryma glomerata (Brady). VILKS, 1989, p. 530, pl. 21-I:16-17.
Ammodiscus catinus. HÖGLUND, 1947, p. 122-123, pl. 8:1-7.
Ammobaculites dilatatus Cushman and Brönnimann. TODD and BRÖNNIMANN, 1957, p. 23, pl. 2:4-5.
Ammotium cassis (Parker). MILLER ET AL.,1982a, p. 2362, pl. 1:7.
Ammotium salsum (Cushman and Brönnimann). SCOTT and MEDIOLI, 1980a, p. 35, pl. 1:11,13 (not 12).
Atlantiella atlantica (Parker). [Trochaminella atlantica Parker], VILKS ET AL., 1982, p. 226, pl. 1:11a-11b.
Veleroninoides crassimargo (Norman). [Cribrostomoides crassimargo (Norman)], VILKS, 1989, p. 530-531, pl. 21-I:18-19.
Veleroninoides jeffreysii (Williamson). [Cribrostomoides jeffreysii (Williamson)], VILKS, 1989, p. 531, pl. 21-I:20-21.
Eggerella advena Cushman. VILKS, 1989, p. 535-536, pl. 21-III:9-10.
Eggerella propinqua (Brady). KAMINSKI, 1983, p. 22, pl. 11:6.
Glomospira gordialis (Jones and Parker). BARKER, 1960, p. 78, pl. 38:7-9.
Hemisphaerammina bradyi Loeblich and Tappan. SCOTT AND MEDIOLI, 1980a, p. 40, pl. 1:4-5.
Hyperammina fragilis Höglund. COLE, 1981, p. 9-10, pl. 2:3.
Hyperammina friabilis Brady. KAMINSKI, 1983, p. 8, pl. 2:4.
Jadammina macrescens (Brady). [Trochammina macrescens Brady], SCOTT and MEDIOLI, 1980a, p. 44-45, pl. 3:1-8.
Lagenammina atlantica (Cushman). [Saccammina atlantica (Cushman)], VILKS, 1989, p. 527, pl. 21-I:6.
Lepidodeuterammina ochracea (Williamson). [Trochammina ochracea Williamson], VILKS, 1989, p. 535, pl. 21-III:4-6.
Lepidodeuterammina ochracea (Williamson) sinuosa (Brönnimann). BRÖNNIMANN and WHITTAKER, 1990, p. 116-117, pl. 2:9-12 (pls. 1 and 2 reversed).
Lepidodeuterammina plymouthensis. BRÖNNIMANN and WHITTAKER, 1990, p. 117, pl. 3:1-4.
Miliammina fusca (Brady). SCOTT and MEDIOLI, 1980a, p. 40, pl. 2:1-3.
Paratrochammina haynesi Atkinson. BRÖNNIMANN and WHITTAKER, 1990, p. 112, pl. 1:5-8 (pls. 1 and 2 reversed).

Portatrochammina advena (Cushman). [Trochammina advena Cushman], PARKER, 1952, p. 407, pl. 4:3a-b.
Psammosphaera fusca Schultze. COLE, 1981, p. 12, pl. 3:4.
Psammosphaera parva Flint. KAMINSKI, 1983, p. 9, pl. 3:3.
Recurvoides turbinatus (Brady). VILKS, 1989, p. 532, pl. 21-II:3.
Reophax arctica Brady. VILKS, 1989, p. 528, pl. 21-I:8.
Reophax dentaliniformis Brady. KAMINSKI, 1983, p. 15, pl. 6:9.
Reophax fusiformis (Williamson). SCHRÖDER, 1986, p. 44, pl. 15:9.
Rephax pilulifer Brady. SCHRÖDER, 1986, p. 45-46, pl. 15:1-5.
Reophax scorpiurus de Montfort. SCHRÖDER, 1986, p. 42, pl.14:1-5.
Reophax scotti Chaster. MILLER ET AL., 1982a, p. 2362, pl. 1:7.
Rhabdammina abyssorum Carpenter. KAMINSKI, 1983, p. 5-6, pl. 1:2.
Silicosigmoilina groenlandica (Cushman). VILKS, 1989, p. 530, pl. 21-I:14-15.
Spiroplectammina biformis (Parker and Jones). VILKS, 1989, p. 532, pl. 21-II:5-6.
Spiroplectammina typica Lacroix. PARKER, 1952, p. 403, pl. 3:3-8.
Textularia earlandi Parker. VILKS, 1989, p. 533, pl. 21-II:7.
Textularia pseudogramen Chapman and Parr. BARKER, 1960, p. 88, pl. 43:9-10.
Textularia torquata Parker. VILKS, 1989, p. 533, pl. 21-II:8-9.
Tolypammina vagens (Brady). SCHRÖDER, 1986, p. 39-40, pl.11:7-9.
Trochammina inflata (Montagu). VILKS, 1989, p. 534-535, pl. 21-II:16-17.
Trochamminopsis quadriloba (Höglund). [Trochammina quadriloba Höglund.] SCHRÖDER-ADAMS ET AL., 1990, p. 36, pl. 3:17; pl. 9:27-29.
Trochamminula lobata Cushman. [Trochammina lobata Cushman], PARKER, 1952, p. 408, pl. 4:7a-b.

Angulogerina angulosa / fluens. Angulogerina angulosa (Williamson), FEYLING-HANSSEN, 1964, p. 317-318, pl. 16:1-3; Angulogerina fluens Todd, FEYLING-HANSSEN, 1964, p. 318, pl. 16:4-5.
Astrononion hamadaense Asano. UJIIÉ ET AL., 1983, p. 61, pl. 9:10-11 (includes the junior synonym Astrononion gallowayi Loeblich and Tappan).
Brizalina pseudopunctata (Höglund). MILLER ET AL., 1982a, p. 2364, pl. 2:21.
Brizalina subaenariensis (Cushman). SCOTT, 1987, p. 327, pl. 1:11.
Buccella frigida (Cushman). MILLER ET AL., 1982a, p. 2364, pl. 3:9-10.
Buccella hannai [Eponides hannai]. PHLEGER and PARKER, 1951, p. 21, pl. 10: 11a-14b.
Buccella tenerrima Bandy. KNUDSEN, 1971, p. 254-255, pl. 8:15-17.
Bulimina aculeata / marginata d'Orbigny. POAG, 1981, p. 48-49, pl. 21:2; pl. 22:2.
Cassidulina reniforme Nørvang. FEYLING-HANSSEN, 1990b, p. 22, pl. 4:4-9.
Cibicidinella exorna (Phleger and Parker). [Planulina" exorna Phleger and Parker], MUROSKY and SNYDER, 1994, p. 164, pl. 2:21-22.
Cibicidoides pseudoungerianus (Cushman). [Cibicides pseudoungerianus Cushman], BARKER, 1960, p. 194, pl. 94:9a-c.
Cibicidoides subhaidingerii (Parr). [Cibicides subhaidingerii Parr], FUNNEL, 1989, p. 566, pl. 12.1:7-9.
Cribroelphidium albiumbilicatum (Weiss). [Elphidium albiumbilicatum (Weiss)], FEYLING-HANSSEN, 1980a, p. 179, pl. VI:13-14.
Cribroelphidium asklundi (Brotzen). [Elphidium asklundi Brotzen], FEYLING-HANSSEN, 1990b, p. 28, pl. 5:16-17.

Cribroelphidium bartletti (Cushman). [Elphidium bartletti Cushman], FEYLING-HANSSEN, 1980a, p. 179, pl. VI:17-18.
Cribroelphidium excavatum (Terquem). [Elphidium excavatum (Terquem) formae], MILLER ET AL., 1982b, p. 116-144, pls. 1-6.
Cribroelphidium frigidum (Cushman). [Cribrononion frigidum (Cushman)], SCOTT ET AL., 1980, p. 228, pl. 2:8.
Cribroelphidium subarcticum (Cushman). [Elphidium subarcticum Cushman], FEYLING-HANSSEN, 1980a, p. 179, pl. VI:11-12.
Cornuspira involvens (Reuss). [Cyclogyra involvens (Reuss)], SCHRÖDER-ADAMS ET AL., 1990, p. 24, pl. 6:1.
Cornuspira planorbis (Schultze). [Cyclogyra planorbis (Schultze)], SCHRÖDER-ADAMS ET AL., 1990, p. 24, pl. 6:2.
Discorbinella subbertheloti (Cushman). BARKER, 1960, p. 184, pl. 89:10.
Discorbis plana. HERON-ALLEN and EARLAND, 1932, p. 413, pl. 14:9-12.
Discorbis squamata. PARKER, 1952, p. 418, pl. 6:10-11.
Discorbis translucens. EARLAND, 1934, p. 181, pl. 8:20-22.
Discorbis tricamerata. HERON-ALLEN and EARLAND, 1932, p. 413-414, pl. 14:13-16.
Eoeponidella pulchella (Parker). VILKS, 1989, p. 540, pl. 21-IV:13-15.
Epistominella arctica Green. [Stetsonia horvathi Green], SCOTT, 1987, p. 328, pl. 2:1-2.
Epistominella exigua (Brady). SCOTT, 1987, p. 327, pl. 2:8-9.
Epistominella sandiegoensis. UCHIO, 1960, p. 68, pl. 9:6-7.
Epistominella takayanagii Iwasa. MILLER ET AL., 1982a, p. 2362, pl. 2:11-12.
Fissurina cucurbitasema Loeblich and Tappan. RODRIGUES and RICHARD, 1986, p. 20, pl. 3:8.
Fissurina laevigata (Reuss). RODRIGUES and RICHARD, 1986, p. 20, pl. 1:3.
Fissurina marginata (Walker and Boys). UJIIÉ ET AL., 1983, p. 56, pl. 3:3-8.
Fissurina orbignyana Seguenza. KNUDSEN, 1971, p. 230, pl. 6:8.
Fissurina quadrata (Williamson). BARKER, 1960, p. 122, pl. 59:3.
Fissurina semimarginata Reuss. LOEBLICH and TAPPAN, 1953, p. 78, pl. 14:3a-3b.
Fissurina serrata (Schlumberger). RODRIGUES and RICHARD, 1986, p. 20, pl. 3:15.
Fissurina stewartii (Wright). SCHNITKER, 1971, p. 200, pl. 4:16a-b.
Fissurina ventricosa (Wiesner). RODRIGUES and RICHARD, 1986, p. 20, pl. 3:14.
Gavelinopsis praegeri (Heron-Allen and Earland). HANSEN and REVETS, 1992, p. 177, pl. 6:1-3, 6, 7.
Glabratella sp. 1.
Glabratella sp. 2. [Glabratella wrightii (Brady)]. MILLER ET AL., 1982a, p. 2364, pl. 2:16-17.
Glabratella lauriei (Heron-Allen and Earland). SCHNITKER, 1971, p. 200, pl. 6:7a-c.
Glabratella wrightii (Brady). FEYLING-HANSSEN, 1990a, p. 104, pl. 2:6-8.
Guttulina austriaca d'Orbigny. FEYLING-HANSSEN, 1990b, p. 18, pl. 2:13-15.
Guttulina lactea Walker and Jacob. KNUDSEN, 1971, p. 214-215, pl. 5:14-18.
Haynesina germanica (Ehrenberg). SCHRÖDER-ADAMS ET AL., 1990, p.34, pl. 8:7-8.
Haynesina orbiculare (Brady). MILLER ET AL., 1982a, p.2362, pl. 2:7.
Islandiella algida (Cushman). MILLER ET AL., in press, pl. 1:1-5.
Islandiella helenae Feyling-Hanssen and Buzas. VILKS ET AL., 1982, p. 226, pl. 1:14.

Islandiella norcrossi (Cushman). VILKS, 1989, p. 538, pl. 21-IV:5-6.
Lagena mollis Cushman. LOEBLICH and TAPPAN, 1953, p. 63-64, pl. 11:25-27.
Lagena substriata (Williamson). UJIIÉ ET AL., 1983, p. 54, pl. 2:5.
Lobatula lobatalus (Walker and Jacob). [Cibicides lobatalus (Walker and Jacob)], FUNNEL, 1989, p. 566, pl. 12-1:4-6.
Melonis barleeanum (Williamson). [Nonion barleeanum (Williamson)], SCOTT and VILKS, 1991, p. 30, pl. 2:9; pl. 4:6-7.
Miliolinella circularis (Bornemann). POAG, 1981, p. 72, pl. 59:3; pl. 60:3a-b.
Miliolinella subrotunda (Montagu). FEYLING-HANSSEN, 1980b, p. 269-270, pl. 1:1-3.
Nonionella auricula (Heron-Allen and Earland). [Florilus auriculus (Heron-Allen and Earland)], SCHNITKER, 1971, p. 200, pl. 10:9.
Nonionellina labradorica (Dawson). VILKS, 1989, p. 545-546, pl. 21-IV:9-10.
Oolina acuticostata (Reuss). RODRIGUES and RICHARD, 1986, p. 21, pl. 1:7 (includes junior synonym Lagena apiopleura Loeblich and Tappan).
Oolina apiculata Reuss. BARKER, 1960, p. 116, pl. 56:15-16.
Oolina borealis Loeblich and Tappan. [Oolina costata (Williamson)], LOEBLICH and TAPPAN, 1953, p. 68, pl. 13: 4-6.
Oolina caudigera (Wiesner). LOEBLICH an TAPPAN, 1953, p. 67-68, pl. 13:1-3.
Oolina melo d'Orbigny. RODRIGUES and RICHARD, 1986, p. 20, pl. 1:6.
Oolina williamsoni (Alcock). RODRIGUES and RICHARD, 1986, p. 21, pl. 1:8.
Paracassidulina neocarinata Thalmann. SEIDENKRANTZ, 1995, p.155, pl. 1:10-11; pl. 4: 7; pl. 5:9-10.
Parafissurina himatiostoma. LOEBLICH and TAPPAN, 1953, p. 80, pl. 14, figs. 12-14.
Parafissurina tectulostoma Loeblich and Tappan. UJIIÉ ET AL., 1983, p. 57, pl.3:25-26.
Patellina corrugata (Williamson). SCHRÖDER-ADAMS ET AL., 1990, p. 34, pl. 6:3.
Pateoris hauerinoides (Rhumbler). SCOTT ET AL., 1980, p. 228-231, pl. 3:6-8.
Pseudopolymorphina decora (Reuss). FEYLING-HANSSEN, 1990b, p. 20, pl. 3:14-15.
Pullenia osloensis Feyling-Hanssen. FEYLING-HANSSEN, 1964, p. 334, pl. 18:5-6.
Pyrgo williamsoni (Silvestri). FEYLING-HANSSEN, 1990b, p. 16, pl. 2:15-18.
Quinqueloculina arctica Cushman. VILKS, 1989, p. 536, pl. 21-III:12-13.
Quinqueloculina elongata Natland. COLE, 1981, p. 50, pl. 8:7.
Quinqueloculina seminula (Linné). VILKS, 1989, p. 536, pl. 21-III:14.
Quinqueloculina stalkeri Loeblich and Tappan. FEYLING-HANSSEN, 1964, p. 252-253, pl. 4:13-18.
Rosalina globularis (d'Orbigny). SCHNITKER, 1971, p. 210, pl. 6:1a-c.
Robertinoides charlottensis (Cushman). SCOTT and VILKS, 1991, p. 32, pl. 4:16-17.
Rotaliella chasteri (Heron-Allen and Earland). [Glabratella arctica, *n. sp.]*, SCOTT and VILKS, 1991, p. 30, pl. 2:10-12.
Scutuloris pyriformis (Gudina). FEYLING-HANSSEN, 1990b, p. 16, pl. 2:1-6.
Scutuloris tegminus. LOEBLICH and TAPPAN, 1953, p. 41-42, pl. 5:10.
Stainforthia fusiformis (Williamson). KNUDSEN and SEIDENKRANTZ, 1994, p. 5-13, pl. 3:1-7, 16-17.
Stainforthia rotundata (Parr). UJIIÉ ET AL., 1983, p. 58, pl. 4:17-19.
Trifarina hughesi (Galloway and Wissler). RODRIGUES and RICHARD, 1986, p. 21, pl. 1:10.
Trifarina reussi Cushman. BARKER, 1960, p. 140, pl. 67:4-6.

Triloculina trihedra Loeblich and Tappan. VILKS, 1989, p. 537, pl. 21-III:15-16.
Ventrostoma fovigera Buchner. LOEBLICH and TAPPAN, 1988, p. 430, pl. 466:15-19.

QUATERNARY PLANKTONIC FORAMINIFERA

All references are to SAITO ET AL., 1981.
Globigerina bulloides (d'Orbigny), p. 40, pl. 7:1a-d.
Globigerina quinqueloba Natland (left and right coiled), p. 48, pl. 10.
Globigerinita glutinata (Egger), p. 17, pl. 22.
Globigerinita uvula (Natland), p. 81, pl. 24:3a-d.
Neogloboquadrina dutertrei (d'Orbigny), p. 111, pl. 36:1-2.
Neogloboquadrina pachyderma (Ehrenberg) (left and right coiled), p. 106-108, pl. 34.
Globorotalia inflata (d'Orbigny), p. 124, pl. 41:1a-d.
Globorotalia scitula (Brady), p. 137, pl. 46:2a-d.