PALEOCEANOGRAPHIC HISTORY OF THE SEYMOUR-BELIZE INLET COMPLEX, BRITISH COLUMBIA, CANADA, THROUGH THE LAST 1100 YEARS BASED ON FORAMINIFERAL DATA

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Abstract

Foraminiferal and thecamoebian faunas from the Seymour-Belize Inlet Complex (SBIC), a fjord network situated in the mainland coast of British Columbia, were studied to asses climatic cycles and trends impacting the area through the ~ AD 900 – AD 2002 interval. Through cluster analysis, ordination methods, and the use of foraminiferal-based transfer functions, a period of weak estuarine circulation due to diminished precipitation, with feeble, infrequent incursions of ocean water into the basin was recognized to have impacted the area during the Medieval Warm Episode (MWE), which occurred here between ~ AD 900 and 1495. Conversely, in the years between AD 1574 and 1943, a very strong estuarine circulation developed, with frequent renewals of the bottom waters by cold, oxygenated ocean currents enhanced by a strong precipitation pattern. This period is concomitant with the onset of the Little Ice Age (LIA) in western Canada. A reversal towards weaker estuarine flow has happened since AD 1943. A detailed taxonomy of the foraminiferal fauna of the area is also presented, which includes the description of *Eggerella belizensis* n. sp.

Acknowledgements

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A mis padres.

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1. Introduction

Coastal mainland British Columbia is a geographically complex, vast area, characterized by a mountainous terrain punctuated by numerous fjords that reach far inland. The Seymour-Belize Inlet Complex (SBIC) is one of these fjord systems. The SBIC is the target of an ongoing multidisciplinary project that is mandated to assess climate cycles and trends through the Holocene. Assessing paleoceanographic changes based on variation in foraminiferal faunas over time is an important component of this research. Unfortunately, there is very little baseline foraminiferal distributional data available for this region that can be used to interpret Holocene foraminiferal faunas (e.g., Guilbault et al., 1997; Guilbault et al., 2003; Jonasson and Patterson, 1992; Patterson, 1993; Patterson and Cameron, 1991a; Patterson and Cameron, 1991b; Schafer et al., 1989; Vázquez Riveiros et al., 2006). Thus the primary purpose of the research presented here is to:

1) document and characterize the modern distribution of foraminiferal faunas from the SBIC;

2) use this data to develop a training set to interpret the observed foraminiferal faunas recovered from a freeze core that was collected near the mouth of the SBIC and deposited over the last ~ 1000 years; and

3) to provide baseline data that will be used by other researchers to interpret cores deposited through the Holocene in the SBIC.

2. Geographic setting

The SBIC is a network of long and deep steep-sided fjords on the central coast of mainland British Columbia (Figure 1), about 40 km northeast of Port Hardy, Vancouver Island. The complex lies between latitudes 50°50.2’ N and 51°10.6’ N, and longitudes 126° 30.2’ W and 127°40.5’ W, and opens to Queen Charlotte Sound in the Pacific Ocean via Slingby and Schooner Channels.

The main arms of the complex are the east-west trending Seymour and Belize inlets, which reach inland about 70 and 50 km respectively. Alison Sound is a smaller inlet that extends 20 km off the northern margin of Belize Inlet, in a northeasterly direction before turning towards the east. Small rivers and creeks provide freshwater to the heads of all inlets in the SBIC, with Belize Creek and Waamtx Creek in Belize Inlet, and Waump Creek in Alison Sound being amongst the most important streams. The freshwater input of these rivers, together with numerous waterfalls along the inlets, peaks during the snow-melt period that starts in May and plays an important role in circulation in the SBIC (Thomson, 1981).

3. Regional climate

The climate coastal British Columbia is mild, with winter temperatures typically remaining above the freezing point accompanied by frequent rains, and warm days and cool nights in summer (Hare and Thomas, 1979). Mean annual

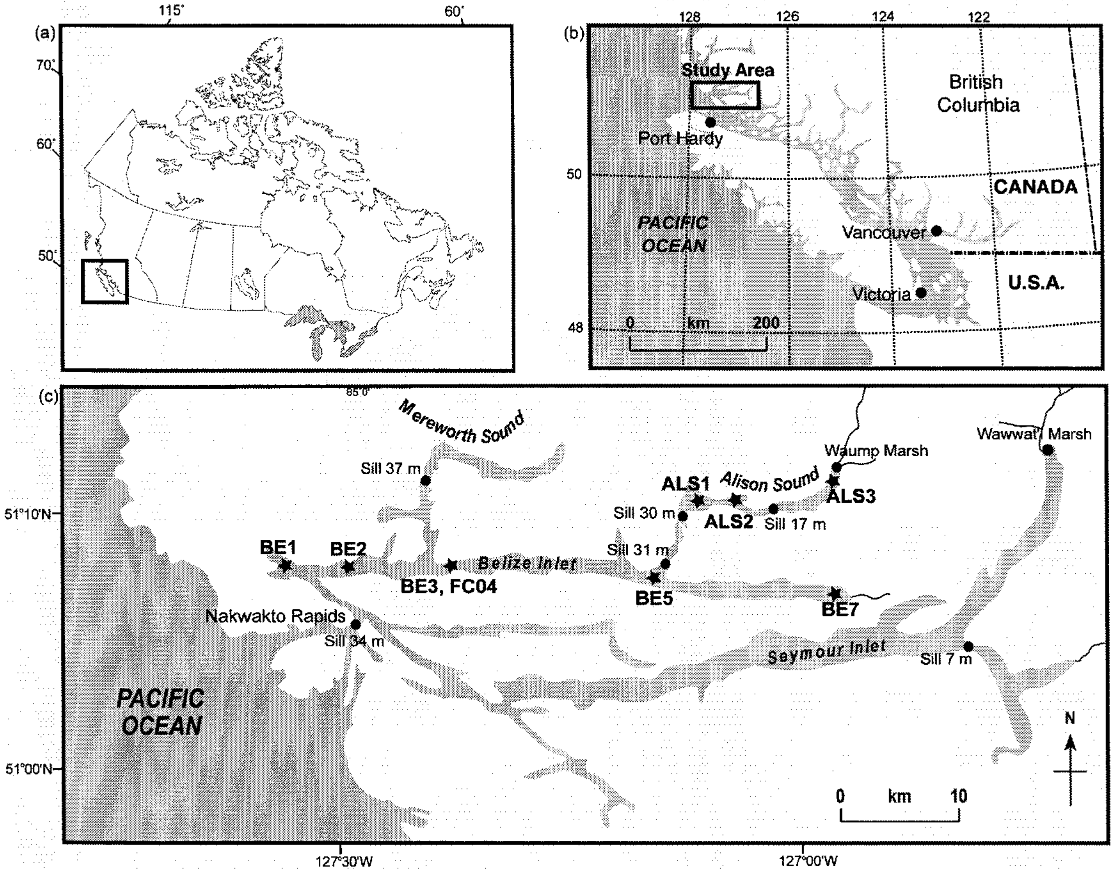


Figure 1: location of study area and sampling site. (a) Map of Canada. (b) Map of Vancouver Island and mainland coastal British Columbia. (c) Map of the Seymour-Belize Inlet Complex, with sampling sites marked with stars.

precipitation in the SBIC region is 3120 mm (range between 2009 mm and 3943 mm), with an average annual temperature of 9.1°C (range between 5.4° to 9.4°C) (Green and Klinka, 1994).

Weather systems are seasonally dominated by the counter-clockwise circulating winds that accompany the Aleutian Low (AL) in winter and the clockwise circulating winds that occur with the North Pacific High (NPH) in summer. The relative position of these pressure systems is in turn influenced by shifts in the positioning of the jet stream (Ware and Thomson, 2000), that is influenced by sunspot cycles (Harmeed and Lee, 2003). The mouth of the SBIC is situated at the northern border of the Coastal Upwelling Domain (CUD) (Ware and McFarlane, 1989), where from May through September the northwesterly winds of the NPH displace warm water from the surface, promoting the upwelling of cold, nutrient-rich deep water that greatly enhances productivity in the surface layers. However, because the SBIC is at the northern boundary of the domain and opens to Queen Charlotte Sound instead of the open ocean, the influence of upwelling within the SBIC is virtually nil as compared to more exposed inlets on the west coast of Vancouver Island (e.g., Patterson et al., 2004b). Another type of upwelling occurs when a deep current encounters an underwater ridge that deflects it towards the surface (Thomson, 1981). This localized effect can have a very important influence on circulation in fjord systems such as the SBIC, which have pronounced sills at their entrances.

The AL is also responsible for the frequency and intensity of winter storms that promote cold weather and precipitation at this time of the year (Beamish et al., 1999; Chang and Patterson, 2005; Miller et al., 1994). Storms that form in the ocean on the southern edge of the AL travel northeast towards southern BC and northern Washington. At the same time, storms that form in the Gulf of Alaska move southeastward towards the coast, due to the clockwise circulation of the Alaska Gyre. Therefore, the coast of BC receives the highest amount of precipitation when the AL dominates circulation patterns in the North Pacific (Cayan and Peterson, 1989; Trenberth and Hurrel, 1995). During the spring and summer, when the NPH moves northward and the AL dissipates, less precipitation and clear skies are the dominant features in the area (Chang and Patterson, 2005; Thomson, 1981). Although the position and strength of the AL is characterized by great interannual variability, there have been periods where a strong westward position dominated at longer time scales (Spooner et al., 2003). Cycles of 2, 11, 20 - 30, 50 - 70, 150 and 200 - 500 years have been observed in the region that may in part be accounted for by the varying influence of the AL and NPH (Chang and Patterson, 2005; Hu et al., 2003).

4. Oceanographic setting

Maximum depths within the SBIC are greater than 600 m in Seymour Inlet, ~ 300 m in Belize Sound, and 150 m in Alison Sound. Oxygen concentrations in the bottom waters of the SBIC range from high oxic in the main arms (more than 6 mL/L) to anoxic conditions in Alison Sound .

An important characteristic of these bathymetrically U-shaped basins is the presence of sills in most of them, formed by crushed rock and silt that were deposited as moraines by advancing glaciers. The sills reduce the input of oxygen-rich ocean water into the inlets, which together with a low-salinity wedge caused by riverine input at the surface, results in reduced mixing between surface and bottom waters, forming a stratified water column. It is also typical in these partially mixed estuaries to have the salinity of the surface layer increase down-inlet away from freshwater sources, and the salinity of bottom waters increasing slightly towards the head of the inlet (Pickard and Stanton, 1980; Thomson, 1981). The restricted circulation in these systems enhances the trapping of organic and inorganic material borne by runoff, making these environments effective nutrient traps. Disturbance at the sediment water interface is minimized due to the high residence time and slow circulation of the bottom water, thus creating an ideal setting for paleoenvironmental research.

The main sill at the mouth of the SBIC, the Nakwakto Rapids, is only 34 m deep and 300 m wide, and forms a major bottleneck during tidal cycles (Department of Energy, 1979) (Figure 1). During the ebb tide current flow through Nakwakto Rapids can reach velocities of 8 m/s, making it one of the strongest tidal currents in the world (Thomson, 1981). This tidal constriction at the Nakwakto Rapids is so restrictive that it is impossible for sea level with the SBIC to equalize with that of Queen Charlotte Sound during ebb tidal flow, resulting in a tidal range of more than 2 m in Queen Charlotte Sound and a maximum of only 1.3 m in the interior of the SBIC (Fisheries and Oceans, 2003).

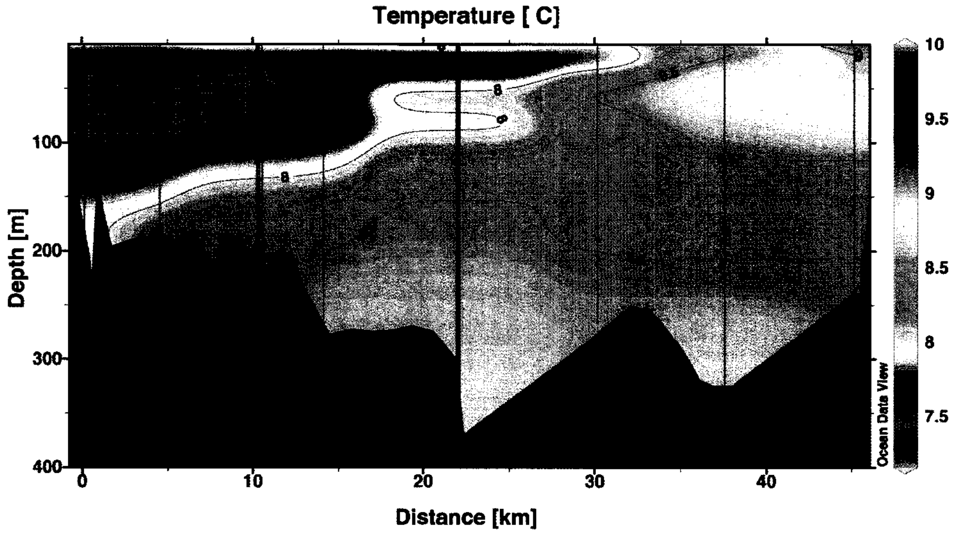
There are three sills in Alison Sound (Figure 1), which further restrict circulation into this inlet. The outermost one, located at the juncture of Alison Sound with Belize Inlet, is 31 m deep; the second, just inside the mouth of Alison Sound, is 30 m deep, while the last sill, located near the head of the inlet, is only 17 m deep.

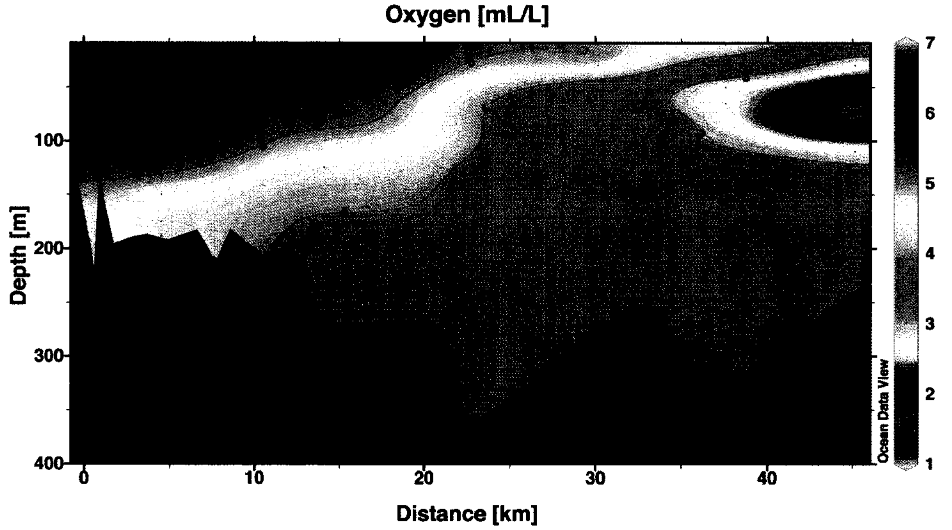
4.1 Belize Inlet

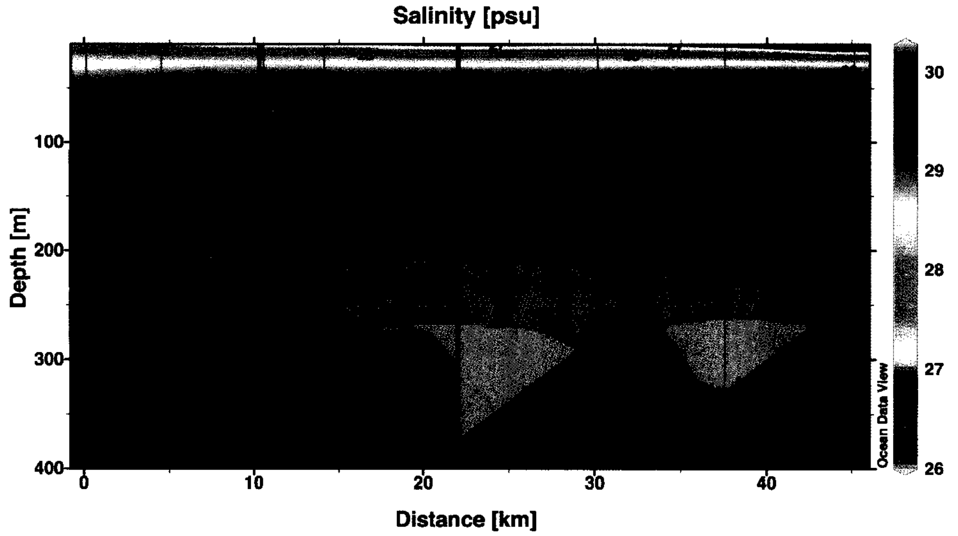
Belize Inlet is a low runoff fjord with an average fresh water discharge of 80 m^3/sec. The level of runoff through the year closely mirrors the seasonal coastal rainfall pattern, with values above average in the spring and winter months, and below average between July and September. The influence of stored runoff (glaciers, snow fields) is minimal in the SBIC (Pickard, 1961).

The penetration of cold oceanic waters into the SBIC is enhanced by the presence of strong estuarine circulation (Pickard, 1961; Thomson, 1981), that in this case is strongly influenced by the seasonal variability in local precipitation patterns. Rainfall acts as a source of low density water to the surface layer, stabilizing the stratification and increasing the horizontal flux of the river runoff as the freshwater moves towards the sea (e.g., Gibbs et al., 2000). The net motion of the surface layer in these environments is always directed towards the ocean as an immediate consequence of the discharge of freshwater into the heads of the inlets. This freshwater creates a low salinity surface layer, enhanced at the head and more diluted towards the mouth, that gains volume and velocity as it entrains saline water from below on its movement towards the sill. This unidirectional flow is superimposed on the tidal current, increasing the speed of the flood tide and decreasing that of the ebb (Pickard, 1961).

As a result of the outflow of surface layer, a subsurface inflow of oceanic waters must take place, in order to preserve the net volume of the inlet (Thomson, 1981). This influx of ocean waters was monitored in April 2002 by researchers aboard the CCGS *Vector* who noted a prominent plume characterized by colder


Temperature [C]


Oxygen [mL/L]


Salinity [psu]

temperatures and high dissolved oxygen concentration at the mouth of Belize Inlet (Figure 2). The density in the inlets is mainly determined by salinity (Pickard, 1961) so that the more saline, and hence denser, ocean water sinks to the bottom of the inlet effectively "renewing" the deep layer and hindering the development of anoxic conditions. Whether the cold, oxygenated ocean water fills the deep basin, displacing the old water, or is interlayered in the water column, depends on its density relative to the density of the waters of the SBIC (Gillibrand et al., 1996; Neumann et al., 1997). Judging from observations made in April 2002, the density difference between the two water masses was not high enough to promote a renewal through the entire water column, so the oceanic water can be seen as a layer at an average depth of 100 m (Figure 2).

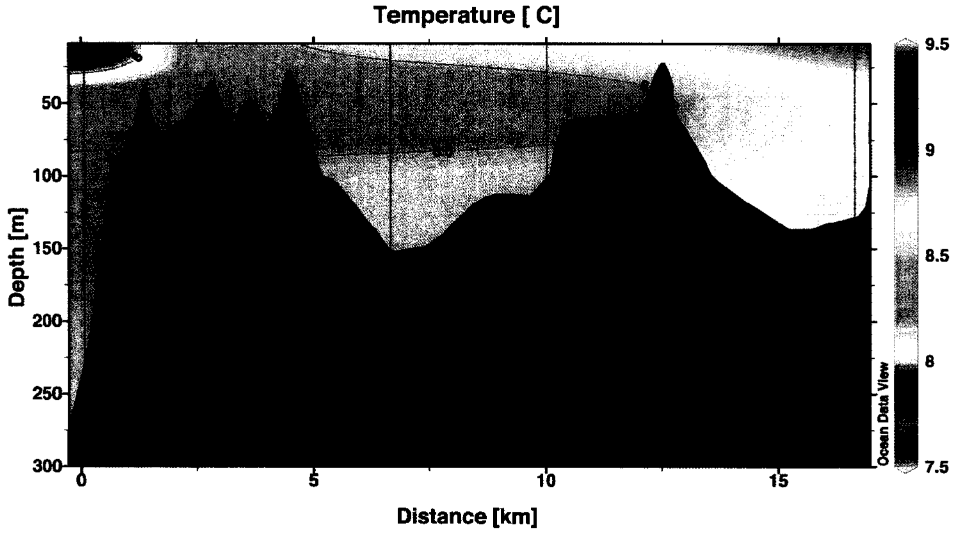
Time-series measurements carried out in other fjords systems, especially in Europe, have recognized a good correlation between the input of salty oceanic water and oxygen input below the halocline (Neumann et al., 1997). The frequency of deep water renewal in these fjords varies considerably, ranging from a few weeks up to several years (e.g., Gillibrand et al., 1996; Gustafsson and Nordberg, 2000; Lassen et al., 2004; Neumann et al., 1997).

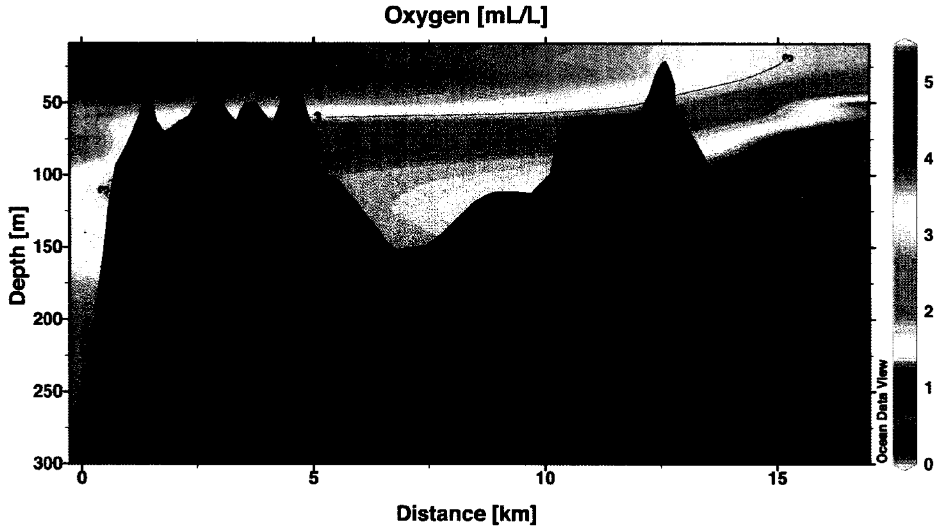
The brackish layer at the surface of Belize Inlet (Figure 2) has a minimum value of 26‰ close to the head of the inlet. This layer is restricted to the top 25 m of the water column, with deeper areas of the inlet being characterized by salinities of 30‰. Since the lower salinity surface layer is shallower than the sill depth (34 m) the flow of oceanic water into the fjord is constrained but not completely blocked, as is the case in many fjords elsewhere (e.g., scottish lochs; Gillibrand et al., 1996; Murray et al., 2003). Bottom oxygen concentrations in the inlet range between 3 and 4 mL/L.

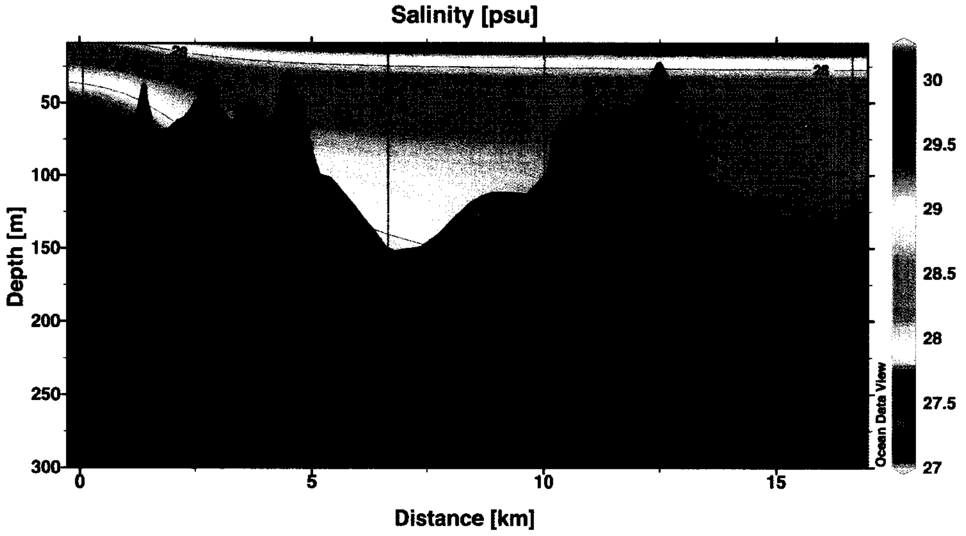
4.2 Alison Sound

Oceanographic conditions in Alison Sound, where circulation is more restricted, are quite different from those observed in Belize Inlet (Figures 1, 3). A low salinity surface plume (26.5‰ - 28‰) is present above a bottom water layer characterized by a constant salinity of 28.5‰. The reduced salinity levels at depth relative to those measured in Belize Inlet reflect the reduced oceanic influence within Alison Sound, although a small tongue of colder oceanic water was observed to penetrate a short distance into the sound in April 2002 (Figure 3). In contrast, temperature profiles measured in Alison Sound tend to be more homogeneous than those observed in Belize Inlet, which may in part be related to the shallower depth of the sound.

Oxygen concentration values in excess of 4 mL/L characterize the surface water mass of Alison Sound, which easily penetrates from Belize Inlet past both the first and second sills at the mouth of the sound. These sills impact the circulation of deeper water masses, though. Despite there being a lower salinity variation between surface and bottom waters in Alison Sound than observed in Belize Inlet, bottom water oxygen levels of < 2 mL/L prevail. At Station ALS3, which is beyond the third and shallowest sill in Alison Sound (17 m; Figure 1) circulation is further restricted, resulting in minimum oxygen values of 0.06 mL/L.


Temperature [C]


Oxygen [mL/L]


Salinity [psu]

5. Previous work

There has been extensive research on foraminifera as paleoecological proxies along the west coast of North America, although very few studies on the distribution of modern foraminifera have been carried out in coastal mainland British Columbia waters. The first published descriptive study on Recent foraminifera from off the coast of British Columbia was that of Cushman (1925), who described a few Recent species found in shallow waters in Queen Charlotte Sound. Cockbain (1963) described two main faunal divisions in Juan de Fuca and Georgia Straits, and linked those assemblages with the physical oceanography of the area. McCulloch (1977) described and illustrated the fauna found in several samples from Vancouver Harbor during her extensive taxonomic research of foraminifera from the Eastern Pacific. Jones and Ross (1979) related the seasonal distribution of foraminifera with different ecological factors in Samish Bay, Washington. A key descriptive study of foraminifera found in coastal British Columbia waters was the illustrated atlas of common benthic foraminifera produced by Patterson et al., (1998).

Several studies have focused on the continental shelf and on the Strait of Georgia in order to determine the Holocene climate history of the area (Guilbault et al., 1997; Guilbault et al., 2003; Mathewes et al., 1993; Patterson, 1993)

More relevant to this study has been the increase in foraminiferal-based paleoceanographic research on inlets and fjords, especially from Vancouver Island. Saanich Inlet, an anoxic fjord on the southeast coast of Vancouver Island has been extensively researched. Blais-Stevens and Patterson (1998) identified five foraminiferal biofacies in sediment-water interface samples that were mainly defined by water circulation within the fjord. Foraminifera were also used in Saanich Inlet to identify environmental changes in the last 14000 years from ODP sites 1033B and 1034B (Kumar and Patterson, 2005; Patterson and Kumar, 2002). In Effingham Inlet, on the southwest side of Vancouver Island, different foraminiferal associations were found to be controlled by varying levels of oxygen content in the bottom waters (Patterson et al., 2000). Knight and Bute Inlets, south of the SBIC, were the sites of the only previous study on foraminifera carried out along the coastal mainland (Schafer et al., 1989). These researchers recognized low-diversity arenaceous foraminifera assemblages at the head of both inlets that were replaced by calcareous assemblages near the mouths due to the increasing influence of marine water from the continental shelf (Schafer et al., 1989).

The only previous foraminiferal study carried out in the SBIC was an investigation of the distribution of foraminifera and thecamoebians in two marshes at the heads of Alison Sound and Belize Inlet (Vázquez Riveiros et al., 2006, submitted). However, there have been other recent studies in the SBIC using different micropaleontological proxies (diatoms, pollen) to quantify the nature of climate and sedimentary variability through the Holocene (Galloway, 2006; Patterson et al., 2006, submitted; Wigston, 2006).

6. Methods and materials

6.1. Sampling

Sampling took place during a research cruise to the SBIC by the CCGS *Vector* in April 2002. Eight sediment-water interface samples were collected using a Smith-

Mac grab sampler in Belize Inlet (BE1, BE2, BE3, BE5, BE7) and Alison Sound (ALS1, ALS2 and ALS3; Figure 1; Table 1). In addition, one 145 cm freeze core, FC04, was collected in Belize Inlet at a water depth of 274 m (Figure 1). Subsequent to collection, the grab samples were treated with alcohol as a preservative, stored in plastic vials, and shipped by air to Carleton University, where they were stored prior to processing in a cool room at +4°C.

The freeze core was stored in a freezer aboard the CCGS *Vector* until the vessel returned to port, at which point the core was transported to the Pacific Geoscience Centre (PGC) in Sidney, BC. At the PGC, the outer layer of the freeze core was removed *in situ* to reduce the risk of contamination. The core was then subdivided longitudinally into ~1 x 2 cm subsections using a band saw, and then subdivided laterally to facilitate handling and x-raying. One complete set of freeze core subsections was transported frozen to Carleton University for subsequent analysis, where they were kept at a constant temperature of –6°C. Water property data profiles of pressure, temperature and transmissivity were measured at each grab and freeze core station (with the exception of BE3), using a Sea-Bird model SBE-911Plus Conductivity, Temperature, Density (CTD) instrument. In addition, bottle samples were obtained through the water column throughout the entire SBIC network using a standard CTD array to collect water property data such as photosynthetically active radiation (PAR), salinity, dissolved oxygen, nitrate plus nitrite, silicate and phosphate. Samples for salinity analysis were analyzed on a Guildline model 8410 Portasal Salinometers, standardized with IAPSO standard seawater. Oxygen analysis was carried out using an automated Winkler titration system, following the procedures of

	DEPTH	**LATITUDE**	**LONGITUDE**
	(m)	*(°')*	*(°')*
BE1	225	51°7.79' N	127°34.19' W
BE2	190	51°7.94' N	127°30.38' W
BE3	290	51°7.78' N	127°21.95' W
BE5	276	51°7.10' N	127°8.82' W
BE7	245	51°6.50' N	126°55.72' W
ALS1	152	51°10.0 0' N	127°5.13' W
ALS2	135	51°10.16' N	126°2.48' W
ALS3	135	51°10.02' N	126°56.79' W
FC04	274	51°7.90' N	127°9.02' W

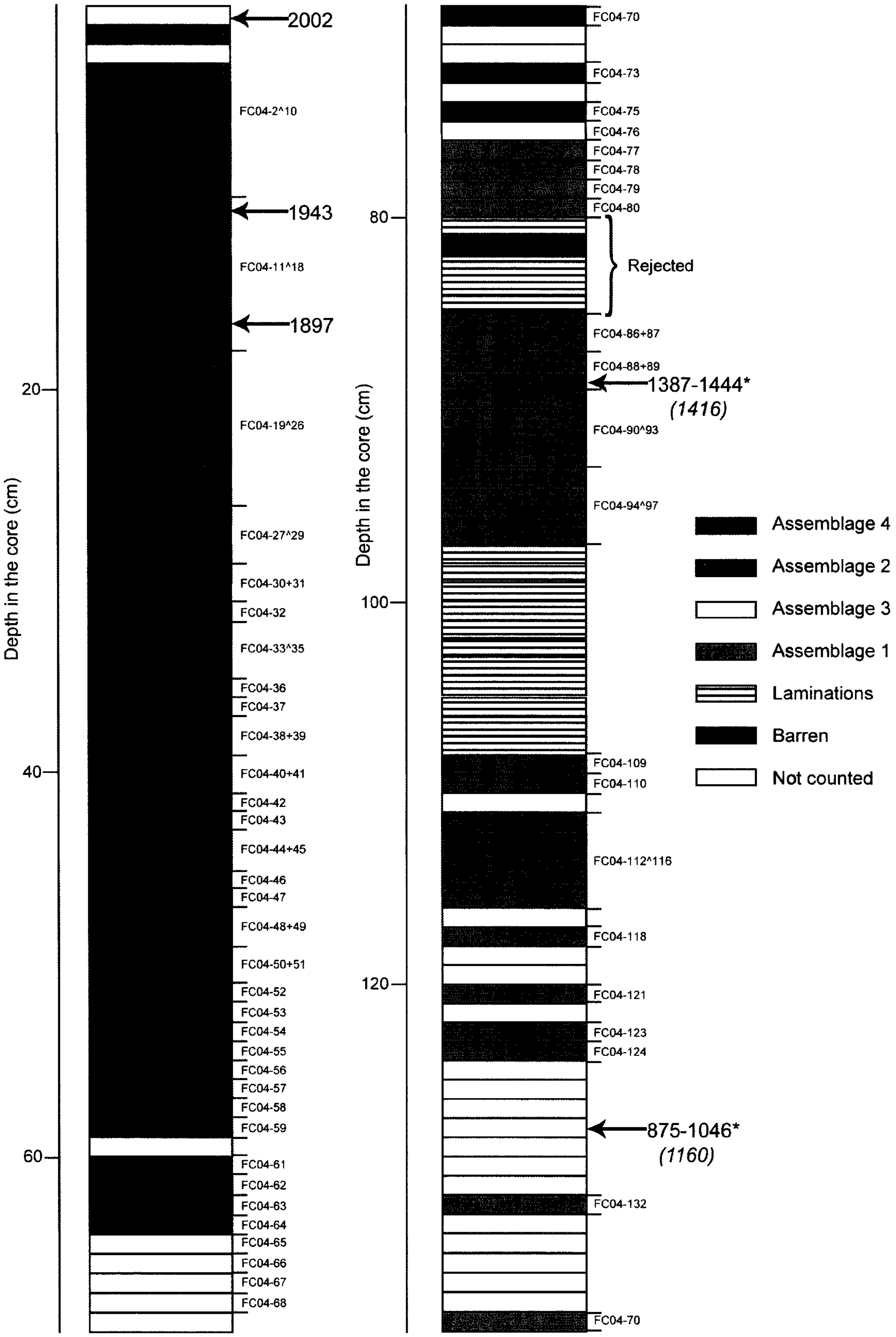
Table 1: water depth, latitude and longitude of sediment-water interface samples and freeze core FC04 used on this study.

Carpenter (1965). Nutrient samples were analyzed frozen with a Technicon AAII autoanalyzer, following the method described by Barwell-Clarke and Whitney (1996)

6.2. Laboratory analysis

Examination of the grab samples in 2004 revealed no discernable deterioration. Samples from Alison Sound, where dysoxic conditions prevailed, were characterized by a slight sulfurous smell, as well as darker color. Ten cm^3 aliquots were taken from each grab sample and wet sieved through a 63 μm screen to retain foraminifera and a 500 μm screen to remove coarse organic material. The samples were subsequently split into two fractions using a 125 μm screen, dried under low heat (50°C) in an oven and weighted. Splitting dry samples into fractions prior to quantitative analysis was done in order to avoid counting errors, as the focus of the microscope does not have to be continually changed (Schröder et al., 1987).

Freeze core FC04 was also taken out of the freezer in 2004 and inspected. As no visible disturbances were found on the surface, such as desiccation cracks or evidence of mold, it was deemed suitable for analysis. The freeze core was first X-rayed at the Altavista Animal Hospital so that any internal sedimentary structures or laminations could be detected. The sediments comprising the freeze core FC04 were very fine grained and soupy, and would have been impossible to recover using conventional coring methods. Two sections of the core, 80 - 85 cm, and 93 - 104 cm, were comprised of laminations that were clearly visible on the X-ray. The organic content of the core increased significantly below 75 cm, and was characterized by an increasing proportion of fecal pellets down core (Figure 4).


2002
1943
1897
FC04-2^10
FC04-11^18
FC04-19^26
FC04-27^29
FC04-30+31
FC04-32
FC04-33^35
FC04-36
FC04-37
FC04-38+39
FC04-40+41
FC04-42
FC04-43
FC04-44+45
FC04-46
FC04-47
FC04-48+49
FC04-50+51
FC04-52
FC04-53
FC04-54
FC04-55
FC04-56
FC04-57
FC04-58
FC04-59
FC04-61
FC04-62
FC04-63
FC04-64
FC04-65
FC04-66
FC04-67
FC04-68
20
40
60
Depth in the core (cm)
FC04-70
FC04-73
FC04-75
FC04-76
FC04-77
FC04-78
FC04-79
FC04-80
80
Rejected
FC04-86+87
FC04-88+89
1387-1444*
(1416)
FC04-90^93
FC04-94^97
100
FC04-109
FC04-110
FC04-112^116
FC04-118
120
FC04-121
FC04-123
FC04-124
875-1046*
(1160)
FC04-132
FC04-70
Depth in the core (cm)
Assemblage 4
Assemblage 2
Assemblage 3
Assemblage 1
Laminations
Barren
Not counted

Based on the results of the visual analysis of the X-rays, the 0 - 138 cm portion of the core was subdivided using a ceramic knife into 121, 1 cm thick samples for foraminiferal analysis. Ceramic knives are particularly useful for subdividing freeze cores, as the blade is extremely thin and sharp and permits the production of extremely thin slices when required. The 93 - 104 cm interval of the core was not subsampled as visual inspection of the X-ray revealed that it was comprised of fine laminations. Based on examination of similar sedimentary intervals in other cores from the area, it was assumed that this interval was deposited under anoxic conditions and would therefore be barren of foraminifera.

With the exception of small portions of 15 aliquot samples that were removed for ^{210}Pb dating (see below) all freeze core samples were subsequently sieved and processed using the same procedure as described above for the grab samples. These sediment-water interface grab and freeze core samples were quantitatively analyzed for foraminifera under an Olympus SZH10 stereo microscope. All foraminiferal specimens were picked and stored on gridded micropaleontological slides, and identified following the classification of Loeblich and Tappan (1987). Scanning electron photomicrographs were obtained using a JEOL 6400 Scanning Electron Microscope at the Carleton University Research Facility for Electron Microscopy (CURFEM). These digital images were converted into plates using Adobe © Photoshop 7.0 and Adobe © Illustrator 10.0.3 (Plates 1 to 15).

6.3. Chronology

The ^{210}Pb dating method is routinely used for the high resolution dating of marine sediments. Due to the short half-life of ^{210}Pb, it is limited to sediments deposited during the last 150 years (Appleby, 2001; Sorgente et al., 1999). However, as the method involves the dating of several samples over many centimeters of core, it is possible to determine sedimentation rates that may permit the estimation of ages in older sediments, particularly if corroborating ^{14}C dates are available down core, as was the case here. The fifteen subsamples removed for ^{210}Pb dating were weighed wet and then dried in the oven at 50°C without sieving. After reweighing of the dry residue, the samples were stored in inert vials and sent to MyCore Scientific Inc. (Dunrobin, ON) for measurement of ^{210}Pb using alpha ray spectroscopy. Two additional subsamples from FCO4 were submitted for accelerated mass spectrometry (AMS) ^{14}C analysis at IsoTrace Laboratory (Toronto, ON). The first sample from FC04, at 89 cm depth, was a wood fragment, while the second sample, at 128 cm, consisted of bulk sediment, as no other dateable wood or shell were available lower in the core.

6.4. Statistical analysis

One hundred and one samples, eight from surface grabs and 93 from the freeze core, were utilized in the statistical analysis of this study. All eight surface grab samples were found to contain foraminifera. Of the 121 samples obtained from core FC04, 97 samples presented foraminifera, and four were found to be barren. Of the 41 samples not quantified for foraminifera (out of the 138 cm of the core), seven were utilized in chronostratigraphic dating, leaving no residue suitable for micropaleontological analysis. An additional eleven samples were comprised of laminated sediments deposited under anoxic conditions and were not processed, as examination of some laminated sediments from elsewhere in this core revealed laminated horizons to be either barren or to contain statistically insignificant foraminiferal populations. The remaining 23 samples not quantified were from portions of the core where there was very little stratigraphic change in the foraminiferal content. As little variability in faunal makeup occurred here, assemblage continuity was interpolated from adjacent samples.

Many samples were found to have low foraminiferal abundances, so an important first step was to determine which samples contained statistically significant populations. The probable error (pe) for each of the samples was calculated using the following formula:

$$pe = 1.96\left(\frac{s}{\sqrt{X_i}}\right)$$

where s is the standard deviation of the population counts and X_i is the number of counts at each sample i. A sample was judged to have a statistically significant population if the total counts for each sample were greater than the probable error. Fifty-seven samples were found to have statistically significant population, although 44 other samples, all from FC04 and representing more than 43% of the total, were rejected. To reduce the rate of sample rejection, and since the primary purpose of this study was to determine the major faunal changes down core and compare them with the different assemblages present in surface samples, the combination of adjacent samples was deemed to be a better solution than the rejection of such a significant portion of freeze core samples.

A first attempt at merging contiguous samples, with the subsequent calculation of pe, resulted in 17 samples being rejected as not statistically significant. Visual inspection of the faunal makeup of these samples revealed that most of them contained low numbers of specimens of well-defined assemblages and that none of them was stratigraphically close to any major faunal shifts. Therefore, it was deemed that a second pass at amalgamating adjacent samples should be carried out to minimize the loss of information due to the discarding of samples. In the end only one group of five samples was not utilized in the statistical analysis (Figure 4).

In these samples, 100 benthic foraminiferal species, four planktic foraminiferal species and ten freshwater thecamoebian species were identified. The relative fractional abundance (F_i) of each species was calculated for each sample as follows:

$$F_i = \frac{C_i}{N_i}$$

where C_i is the species count and N_i is the total of all the species count for that sample. Using this information, the standard error (S_{xi}) at the 95% confidence level (Patterson and Fishbein, 1989) associated with each species was calculated using the following formula:

$$S_{xi} = 1.96\sqrt{\frac{F_i(1-F_i)}{N_i}}$$

If the calculated standard error was greater than the fractional abundance for a particular species in all samples then that species was not included in successive multivariate analysis. Subsequently, 67 species were rejected from further consideration because they did not have statistically significant numbers in any samples. This number included four planktic foraminiferal species and seven species of thecamoebians. Since all of the planktic foraminifera and thecamoebians were considered allochtonous, it was deemed that their presence or absence might provide some information on transport mechanisms in the area. The different planktic species were therefore grouped together under the generic heading "planktic species", and the ten species of thecamoebians were similarly grouped under "thecamoebian species". A recalculation of fractional abundances and standard errors resulted in 51 species, including the groupings of "planktic species" and "thecamoebian species", being present in statistically significant numbers (Appendix A).

The Shannon-Weaver diversity index (SDI) was used to assess environmental stability based on the proportion and diversity of species found at each sample station within the marshes. This index was calculated using the Shannon and Weaver (1949) formula:

$$SDI = -\sum_{1}^{S}\left(\frac{F_i}{N_i}\right)\times \ln\left(\frac{F_i}{N_i}\right)$$

where S is equal to the species richness of the sample. The SDI in natural environments normally ranges between 1 and 3.5, with high values corresponding to stable environments, and low values indicating stressed conditions (Sageman and Bina, 1997).

6.4.1. Cluster analysis

Once the reduced number of statistically significant samples and species were determined, cluster analysis was carried out on the resulting matrix. Cluster analysis is a commonly used multivariate analytical technique in foraminiferal research; it classifies entities (samples or species) into "naturally occurring" groups, and quantifies the relation between groups (Parker and Arnold, 1999). R-mode and Q-mode cluster analyses were carried out on the reduced dataset using SPSS 11 for Mac OS X (SPSS, 2005). Q-mode cluster analysis was used to group samples with significantly similar variables (i.e., species), using a proximity matrix with Ward's minimum variance method measured as Square Euclidean Distances (Fishbein and Patterson, 1993). R-mode analysis was carried out using the same methodology to determine which species were most closely related to others, and thus best characterized a particular assemblage.

6.4.2. Ordination

Ordination methods represent species distributions related to gradients of environmental change. If data for environmental variables affecting the population are known, a constrained ordination analysis is used, where the variability of the population is represented with respect to the environmental variables measured. If no measured environmental data are accessible, unconstrained analysis will show any variation within the species data along axes that represent gradients of environmental change. The determination of which variables correlate best with the axes is left to the researcher. The results are normally displayed in an ordination diagram that shows the axes of the environmental gradients, and the positions of samples and species relative to them.

For this study, a dataset comprised of the surface grab samples and the environmental variables measured for them (depth, temperature, salinity, oxygen content, nitrate + nitrite, silicate and phosphate) was available, although for sample BE3 only the water depth was measured. In order not to lose the valuable information that the species composition of this sample provided, the values for the other variables were imputed by building a multiple regression model, using the samples with no missing values as predictors (Leps and Smilauer, 2003). The procedure was utilized for sample ALS3 as well and its missing values for nitrate + nitrite, silicate and phosphate. The synthetic predictors developed for these two samples were derived from other samples from the same inlet, to minimize dispersion of the data (Table 2).

Ordination analysis commenced with a dataset containing the fractional abundances of statistically significant species for the surface samples, and the environmental variables dataset, using the computer program CANONO 4 (ter Braak and Smilauer, 1998a). The parameter "Depth" was chosen to be interpreted as a covariable, so the ordination diagram showed the relationship between the response variables (species) and environmental variables after eliminating the effect of depth on the sample composition (partial correspondence analysis) (ter Braak and Prentice, 1988).

In order to determine if the response of the species to the environmental variables is unimodal or linear, a preliminary test run was done, selecting Detrended

Sample	**Temperature**	**Salinity**	**Oxygen**	**Nitrate + Nitrite**	**Silicate**	**Phosphate**
	(°C)	*(psu)*	*(mL/L)*	*(μmol/L)*	*(μmol/L)*	*(μmol/L)*
BE1	7.84	30.05	4.95	20.9	44.0	2.20
BE2	8.38	30.16	4.16	23.0	46.1	2.51
BE3	8.57*	30.23*	3.70*	22.5*	51.0*	2.43*
BE5	8.61	30.23	3.71	23.0	51.8	2.45
BE7	8.52	30.21	3.74	22.3	46.7	2.52
ALS1	8.55	28.83	1.67	23.3	61.9	3.23
ALS2	8.56	28.80	1.72	23.6	61.2	3.24
ALS3	8.76	28.52	0.06	23.6*	61.2*	3.24*

Table 2: values of environmental variables measured at the sediment-water interface samples. The values marked with * represent values imputed with linear regression using the values for the rest of the stations in the same inlet.

Correspondence Analysis (DCA) on all the response and predictor variables, with depth as a covariable. The gradient length on the first axis showed a value of 4.089, indicating a large beta diversity in community composition along the individual independent gradients. Use of a linear method would not have been appropriate for the present analysis, since too many species deviate from the assumed model of linear response to the variable (Leps and Smilauer, 2003). The unimodal response method assumes that the species has an optimum on the environmental gradient, with a symmetric bell-shaped response around it. Therefore, the chosen method of analysis was partial Canonical Correspondence Analysis (constrained unimodal ordination with covariables).

A problem arose when the table of Variance Inflation Factors of the environment variables on the DCA log was considered. These factors are related to the (partial) multiple correlation between one environmental variable an the others in the analysis, and all values were extremely high, indicating that the variables were almost perfectly correlated with each other. They therefore do not provide a unique contribution to the regression equation (ter Braak and Smilauer, 1998b). In order to ascertain the influence that the environmental variables have on each other, the correlations between them were calculated with SPSS 11 for Mac OS X (SPSS, 2005), using a two-tailed bivariate correlation with Pearson's coefficient. The result showed that there was a high degree of correlation between several of the variables (Table 3). "Temperature", "oxygen" and "silicate" were the variables subsequently chosen to be retained in the analysis, even though there was a degree of correlation between oxygen and silicate. Partial Canonical Correspondence Analysis was then

		DEPTH	TEMP	SALIN	OXY	NITR	SILICAT	PHOSPH
DEPTH	Pearson Correlation	1	-0.18	0.889**	0.741*	-0.55	-0.681	-0.844**
	Sig. (2-tailed)	.	0.67	0.003	0.036	0.158	0.063	0.008
	N	8	8	8	8	8	8	8
TEMP	Pearson Correlation	-0.18	1	-0.406	-0.693	0.866**	0.655	0.604
	Sig. (2-tailed)	0.67	.	0.318	0.057	0.005	0.078	0.113
	N	8	8	8	8	8	8	8
SALIN	Pearson Correlation	0.889**	-0.406	1	0.928**	-0.633	-0.908**	-0.951**
	Sig. (2-tailed)	0.003	0.318	.	0.001	0.092	0.002	0
	N	8	8	8	8	8	8	8
OXY	Pearson Correlation	0.741*	-0.693	0.928**	1	-0.781*	-0.926**	-0.942**
	Sig. (2-tailed)	0.036	0.057	0.001	.	0.022	0.001	0
	N	8	8	8	8	8	8	8
NITR	Pearson Correlation	-0.55	0.866**	-0.633	-0.781*	1	0.793*	0.805*
	Sig. (2-tailed)	0.158	0.005	0.092	0.022	.	0.019	0.016
	N	8	8	8	8	8	8	8
SILICAT	Pearson Correlation	-0.681	0.655	-0.908**	-0.926**	0.793*	1	0.947
	Sig. (2-tailed)	0.063	0.078	0.002	0.001	0.019	.	0
	N	8	8	8	8	8	8	8
PHOSPH	Pearson Correlation	-0.844**	0.604	-0.951**	-0.942**	0.805*	0.947**	1
	Sig. (2-tailed)	0.008	0.113	0	0	0.016	0	.
	N	8	8	8	8	8	8	8

Table 3: values for the Pearson correlation coefficient for the environmental variables. **: Correlation is significant at the 0.01 level (2-tailed).*: Correlation is significant at the 0.05 level (2-tailed).

applied to the dataset composed of fractional abundances of statistically significant species from the surface samples, and the environmental variables “temperature”, “oxygen” and “silicate”, with “depth” as a covariable.

6.4.3. Transfer function

Recent developments in quantitative paleoenvironmental reconstruction employing transfer functions have permitted the reconstruction of past values for a suite of environmental variables. The development of transfer functions has generally focused on diatoms and their utility as indicators of hydrochemical characteristics (e.g. Birks et al., 1990; Campeau et al., 1999; Gasse et al., 1995), though they have been applied as well with foraminifera to determine past sea levels (e.g., Edwards and Horton, 2000; Gehrels, 2000; Patterson et al., 2004a).

The use of microfossils in paleoenvironmental reconstruction is based on the assumption that the modern relation between indicator species and environmental variables of interest has not changed through time. In this way, by quantifying the present distribution of indicators (foraminifera in this case) with respect to the target variables, their distribution in paleoenvironments can be used as a proxy for former environmental conditions, given that the fossil assemblages have analogues in the surface fauna.

This is a two-step process. First, the response of modern foraminifera with respect to environmental variables is modeled with regression analysis. The resultant coupled assemblage-variable data constitutes a training set. Secondly, the modeled responses are used to infer past conditions from the composition of fossil foraminifera assemblages through calibration. The set of mathematical equations that achieve this calibration is the transfer function.

To estimate the error of the transfer function, cross-validation is performed on the datasets. However, due to the very small size of the training set used on this study (only eight samples), the software was not able to perform the validation; therefore, the reconstructions of past environmental data values are shown here without error estimates.

In this study, transfer functions were derived using the computer program C2 (Juggins, 2005). The program calculates the transfer function using two methods: weighted averaging (WA) and weighted averaging with tolerance downweighting (WA (Tol)). Both techniques are suitable for species that display an unimodal response to the environmental variables in question (Birks et al., 1990), as shown by the CCA results to be the case in the present study. WA (Tol) is a modification of WA where species with narrow ranges are given more weight, because they have a better indicator value.

The statistical parameters produced by C2 are the apparent root mean square error (RMSE), a coefficient of determination (r^2), and values for average and maximum bias. The RMSE is a measure of the predictive accuracy of the model (Wallach and Goffinet, 1989), which is the average square difference between observed values and values predicted by the model. The maximum bias is the largest difference between mean observed and predicted values along the environmental gradient in question. Both WA and WA(Tol) analyses were performed on the data set, with classical and inverse deshrinking. Deshrinking is necessary in WA reconstructions because the averages are taken twice, once in regression and once in calibration, which results in shrinkage of the range of inferred environmental values (Birks et al., 1990).

The modern data set is the same one used in the ordination analysis, and the dataset used to calibrate the function comprises the fractional abundances of statistically significant species found in core FC04, as shown in the cluster analysis methodology.

7. Results

7.1 Chronology

The ^{210}Pb dates were calculated using the constant rate of supply (CRS) method, which assumes that the rate of supply of ^{210}Pb to the sediments is constant, regardless of changes in the sedimentation rate (Table 4). The calculated value for the sedimentation rate with this method was 1.52 mm/yr.

The radiocarbon dates obtained were the average of two separate analyses, and were corrected for $^{13}C/^{12}C$ isotope fractionation. They were calibrated using the radiocarbon calibration program CALIB, version 5.0.1 for Mac OS X, with the Intcal.04 calibration data set (Reimer et al., 2004). CALIB makes the conversion from radiocarbon age to calibrated calendar years by calculating the probability distribution of the samples' true age (Stuiver et al., 2005). The dates are reported as calendar years AD (cal yr AD), and as the median probability of the 95.5% (2σ) confidence interval (Table 5). No marine reservoir effect was applied to the bulk sediment

Sample	**Depth**	**^{210}Pb**	**Precision 1 std**	**Age**	**STD in date**
	(cm)	*(Bq/g)*	*(%)*	*(year AD)*	*(years)*
FC04-1	1	0.204	4.9	2002	0.0
FC04-2	2			2001	
FC04-3	3	0.127	5.0	2000	0.7
FC04-4	4			1999	
FC04-5	5	0.214	5.6	1995	1.3
FC04-6	6			1990	
FC04-7	7	0.145	6.2	1979	6.5

FC04-8	8			1972	
FC04-9	9	0.125	3.8	1964	12.3
FC04-10	10			1956	
FC04-11	11	0.083	3.9	1943	37.0
FC04-12	12			1932	
FC04-16	16	0.078	5.7	1897	76.2
FC04-20	20	0.045	5.4		
FC04-23	23	0.051	8.9		
FC04-28	28	0.039	8.9		
FC04-31	31	0.051	7.5		
FC04-35	35	0.076	6.9		
FC04-40	40	0.033	5.7		
FC04-42	42	0.018	8.0		
FC04-81	81	0.027	9.0		

Table 4: results of the ^{210}Pb analysis, showing the ages at different depths on the top section of FC04, and their standard deviation. The sedimentation rate calculated from these dates is 1.52 mm/yr.

sample derived date, since there are no studies in the variations of reservoir effects in enclosed fjords such as the SBIC. Even though areas of strong upwelling such as the east coast of Vancouver Island tend to have strong marine reservoir effects (up to 1200 years, Hutchinson et al., 2004), values for estuaries are very much affected by the freshwater inflow, especially at boundaries between different ocean circulation regimes, such as the SBIC (Ingram and Southon, 1996).

An age-depth model based on calibrated radiocarbon dates was constructed using linear interpolation, since this method has been demonstrated to provide the best performance when the number of dates is low (Telford et al., 2004). A depth of 0 cm was included in the linear regression as the year AD 2002, a value corroborated by the ^{210}Pb dating. The fact that the first radiocarbon date (FC04-89) was chosen from a depth where there is a change in sediment lithology strengthens the validity of the model (Telford et al., 2004). The sedimentation rate was calculated from the slope of the regression curve, giving a result of 1.24 mm/yr, in close agreement with the ^{210}Pb data (Figure 5).

Sample name	Lab number	Depth	Sample type	Radiocarbon age	Calibrated Calendar Date	Median Probability Date	error 2sigma
		(cm)		*(yr BP)*	*(cal yr AD)*	*(yr AD)*	*(yr)*
FC04-89	TO-12566	89	Wood	530 ± 40	1387-1444	1415	28
FC04-128	TO-12567	128	Sediment	1060 ± 50	875-1046	960	85

Table 5: radiocarbon ages and calibrated ages (years AD) for the two radiocarbon samples sent to Isotrace Lab. The calibration was done using the program CALIB v. 5.0.1., with the calibration dataset Intcal.04. The calibrated results are reported at the 95.5% (2σ) confidence interval. The median probability ages are rounded to the nearest year.

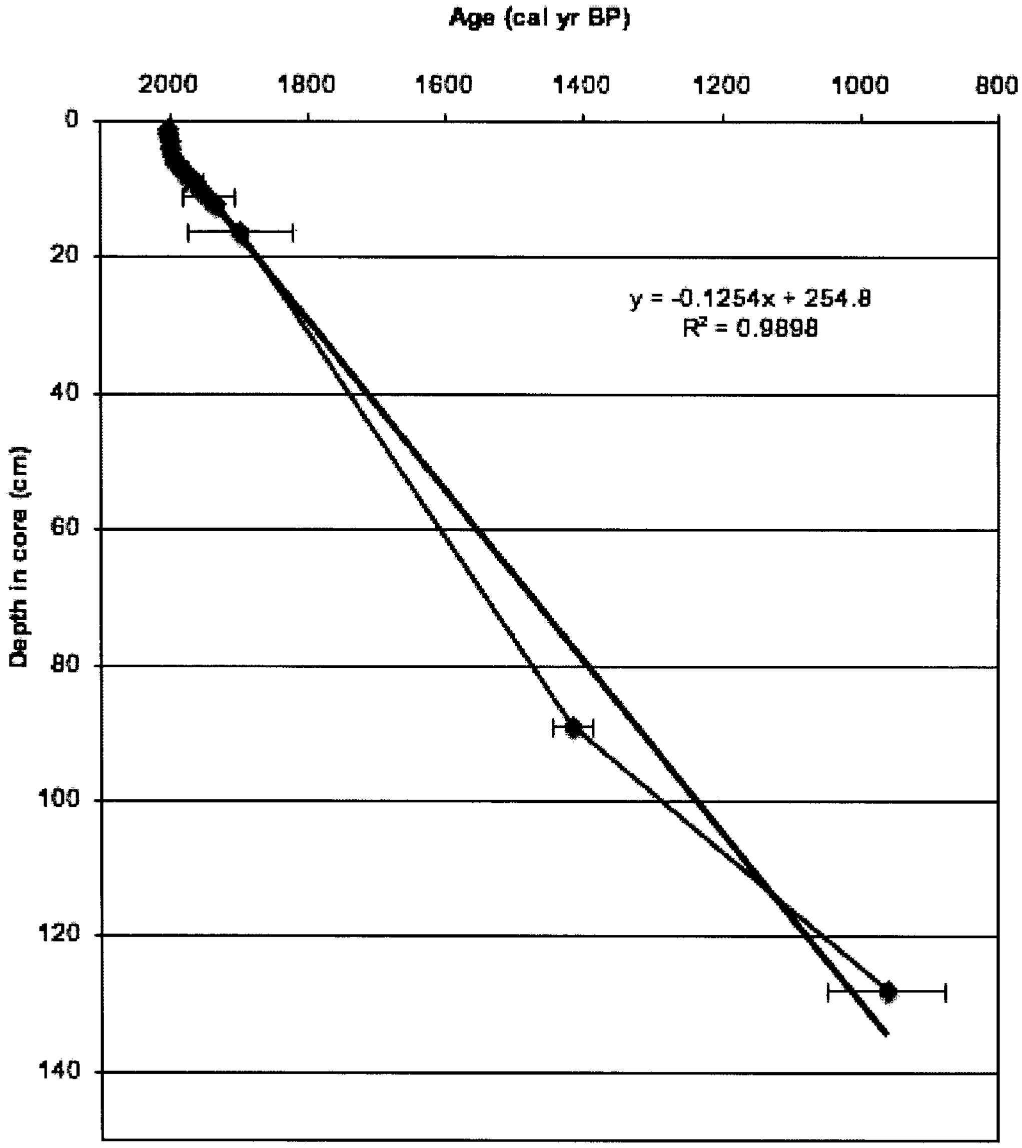


Figure 5: age-depth model for calibrated radiocarbon dates. The sediment accumulation rate derived from the slope of the linear regression line is 1.242 mm/yr. Horizontal error bars represent the range of ages defined by the probability distribution of the samples' true age.

7.2 Environmental variables

The data for different environmental variables were kindly provided by Dr. R.E. Thomson and C. Wright from the Institute of Ocean Sciences (Sydney, BC), and they were plotted for both Belize Inlet (Figure 2) and Alison Sound (Figure 3) using Ocean Data View, version 3.0.4 for Mac OS X (Schlitzer, 2004).

The profiles for Belize Inlet (Figure 2) show a marked wedge of ocean water entering the inlet, with temperature values lower than 8°C and a high oxygen content (more than 5 mL/L). Towards the head of the inlet, an oxygen minimum zone at mid-depth can be observed, with the lowest values of the profile (1 mL/L). This minimum appears to be an intermittent feature in low runoff fjords of the coast of British Columbia. It was first supposed that high oxygen demand in the surface water depleted the oxygen in the lower water column, but a steady flow of dense oxygenated water sinks to the bottom and replenishes the values there (Pickard and Stanton, 1980). Recent surveys indicate that the oxygen minimum zone may be the result of water leaking from a salt water marsh at the head of Belize Inlet and settling in at that density layer (Cindy W. Right, written communication, 2006). Oxygen values in the deeper portions of the inlet do not fall below ~ 3 mL/L.

The salinity profile displays a low-salinity wedge in the surface water (less than 30 m deep), strengthened towards the head of the inlet. Salinity at depth remains fairly constant, with average values of 30‰. This profile is consistent with the input of freshwater from rivers and creeks up the fjord.

In Alison Sound (Figure 3), temperature values were relatively constant. Only towards station ALS3 was an increase from 8.5°C to 9°C observed, probably reflecting the shallower depth of the inlet. Oxygen concentration, however, is lower when compared with Belize Sound, undergoing a sharp gradient from surface to bottom waters. Minimum values close to 0 mL/L appear at depth at the head of the inlet, whereas input of oxygenated water (> 3 mL/L) coming from Belize Inlet is manifest at stations ALS1 and ALS2. The low salinity wedge is also present in Alison Sound, although the overall salinity values are lower than those in Belize Inlet, with a maximum of 29‰.

7.3 Cluster analysis

The results of cluster analysis show a clear partition of the samples into four different assemblages, some of which are represented in both core and surface samples (Figure 6). The stratigraphic order of the assemblages is represented in Figure 4. The value of the SDI for all the assemblages remained between 1.41 and 1.84, indicating a moderately stable environment.

7.3.1. Assemblage 1

The first assemblage defined comprises 19 samples and includes samples FC04-77 to FC04-138 in the core (the basal portion) as well as samples ALS1 and ALS3. It is dominated by *Eggerella advena* (Cushman, 1922), with an average occurrence of 29.7% (range 15.7% - 47.15%), and *Eggerella belizensis* n. sp., with an average of 24.3% (range 0.0% - 34.78%). Another important species is *Cribrostomoides* cf. *subglobosum* (Cushman, 1910a) (average 9.0%, range 0.0% - 23.9%), with more than 15% of the total assemblage in five samples. *Recurvoides turbinatus* (Brady, 1881) is present in 17 of the 19 samples, ranging between 5.7%

and 23.3% (average of 11.0%). *Spiroplectammina biformis* (Parker and Jones, 1865) is significantly represented as well, comprising a total of 7.1% of the population on average (range between 0.0% - 22.4%). Other important species are *Cribrostomoides jeffreysii* (Williamson, 1858) (average of 1.0%, range 0.0% - 11.0%) and *Ammodiscus gullmarensis* Höglund (1948) (average of 1.5%, range 0.0% - 8.1%).

Thecamoebians are present in 50% of the samples, with an average abundance of 5.7%, and ranging between 1.0% and 26.5%. Planktic foraminiferal species appear in a lone sample, making up 1.9% of the counts in that sample (0.1% of the total assemblage).

Other agglutinated foraminiferal species present in lone samples are *Portatrochammina bipolaris* (Brönnimann and Whittaker, 1980), *Cribrostomoides crassimargo* (Norman, 1892), *Miliammina fusca* (Brady and Robertson, 1870), *Cribrostomoides sp. A*, *Trochammina globigeriniformis* (Parker and Jones, 1865), *Trochammina nana* (Brady, 1881), and the calcareous species *Stainforthia feylingi* Knudsen and Seidenkrantz, 1994.

All the samples in this assemblage are dominated by agglutinated foraminiferal species, with the exception of sample FC04-77, that presents a few planktonic specimens, and sample FC04-138, where *S. feylingi* appears, contributing to 4.8% of that sample. The SDI has a value of 1.49.

7.3.2. Assemblage 2

This assemblage is comprised of 29 samples collected from FC04, at 11 cm to 64 cm core depth. The most representative species in this group is *Buccella frigida*

(Cushman, 1922), which appears in every sample, with an average concentration of 27.3% (range 52.3% - 6.3%). The second most abundant species is *Cribroelphidium excavatum* (Terquem, 1876) forma *'magna'* (Miller et al., 1982), which comprises 21.6% of the population, ranging between 44.1% and 6.7%. *Cribroelphidium excavatum* forma *'clavata'* (Cushman, 1930) follows closely, with an average abundance of 15.0% (range 0.0% - 27.9%). *Nonionellina labradorica* (Dawson, 1860) is significantly represented as well, forming 9.5% of the population on average, reaching up to 36.8% in some depths.

Another abundant species is *Cribroelphidium foraminosum* (Cushman, 1939), which ranges between 0.0% and 11.6% (average of 3.0%). *Cribroelphidium excavatum* forma *'excavata'* (Terquem, 1876), also a member of the *C. excavatum* family, is present in eight of the samples of this assemblage; its total average is 1.9% (range 0.0% - 9.2%). *Cassidulina crassa* d'Orbigny, 1939 is an important indicator species in this assemblage, with an average of 2.0%, reaching a maximum of 16.2%. *Buccella tenerrima* (Bandy, 1950) represents 1.2% of the assemblage (range 0.0% - 7.4%).

A proportion of 0.8% of the assemblage is made up of *Epistominella vitrea* Parker, 1953 (range 0.0% - 6.3%). Other species that represent less than 1% of the population in this assemblage include *Lobatula fletcheri* (Galloway and Wissler, 1927) (average 0.5%; range 0.0% - 3.7%), *Cribroelphidium excavatum* forma *'selseyensis'* (Heron-Allen and Earland, 1911) (average 0.4%; range 0.0% - 9.1%), *Neouvigerina* cf. *proboscidea* (Schwager, 1866) (average 0.4%; range 0.0% - 7.4%), *Lobatula mckannai* (Galloway and Wissler, 1927) (average 0.3%; range 0.0% -

8.5%), *Bolivina minuta* Natland, 1938 (average 0.3%; range 0.0% - 6.3%), *Euuvigerina peregrina* (Cushman, 1923) (average 0.2%; range 0.0% - 2.4%), undifferentiated variants of *C. excavatum* (average 0.1%; range 0.0% - 4.0%), *Buccella inusitata* Andersen, 1952 (average 0.1%; range 0.0% - 3.0%), *Elphidiella hannai* Cushman and Grant, 1927 (average 0.1%; range 0.0% - 4.4%), and *S. feylingi* (average 0.1%; range 0.0%-2.6%).

All the species of this assemblage are calcareous benthic foraminifera.

7.3.3. Assemblage 3

This assemblage comprises only five samples from FC04, at core depths 65 to 68 cm (both inclusive) and 76 cm. It is a mixed assemblage, where agglutinated foraminifera make up on average 13% of the population.

The distinctiveness of the assemblage lies with the very high numbers of *S. feylingi*, which incorporates almost half of the population on average (49.3%; range 40.6% - 57.0%). The following most abundant species is *Haplophragmoides bradyi* (Brady, 1887), with an average of 10.4% (range 8.2% - 15.7%). *C. excavatum 'clavata'* represents 9.9% of the assemblage, with values between 4.3 and 14.3% in different samples. Other members of the *C. excavatum* family, such as *C. excavatum 'magna'* (average 2.6%; range 0.0% - 4.6%) and *C. excavatum 'excavatum'* (average 2.2%; range 0.0% - 5.5%), make up almost 5% of the population when factored together. *B. frigida* represents a close 4.9% (range 1.2% - 7.2%), while *C. crassa* follows closely with an average of 4.7% (range 2.1% - 6.8%). *N. labradorica* accounts for 3.2% of the population (range 0.0% - 5.6%). Both *E. vitrea* and *B.*

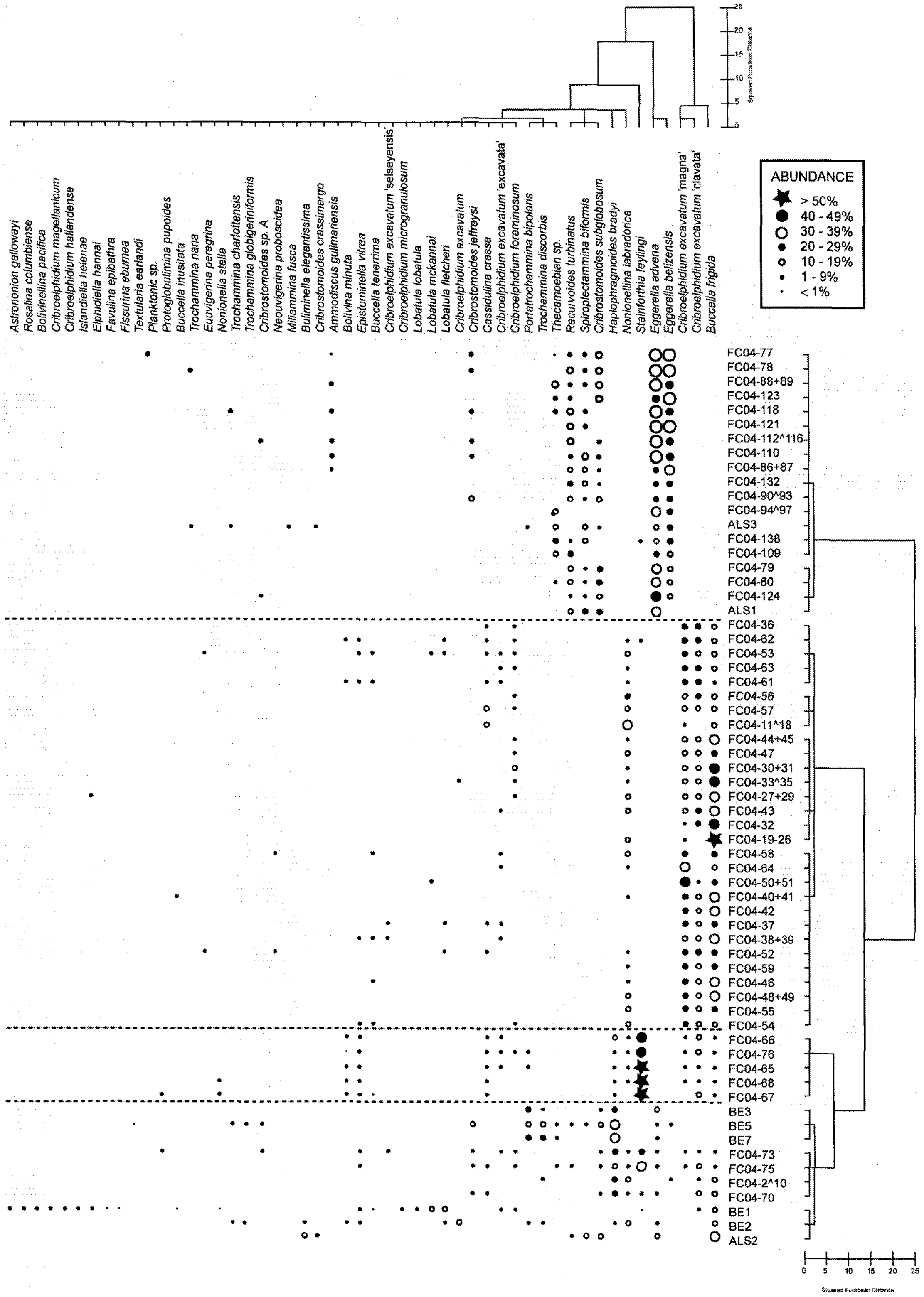


Figure 6: Q-mode vs. R-mode cluster diagram for FC04 and surface samples, with fractional abundances of the species indicated by symbols.

minuta are present in all the samples of this assemblage, with averages of 2.2% and 1.6% respectively (ranges of 1.5% - 2.7% and 1.0% - 2.0%). More scarcely abundant species are *Nonionella stella* (Cushman and Moyer, 1930) (average 1.4%; range 0.0% - 5.8%), *C. foraminosum* (average 0.9%; range 0.0% - 4.7%), *P. bipolaris* (average 0.5%; range 0.0% - 1.2%), *Protoglobulimina pupoides* (d'Orbigny, 1846) (average 0.3%; range 0.0% - 1.3%) and *B. tenerrima* (average 0.2%; range 0.0% - 0.9%).

7.3.4. Assemblage 4

Assemblage 4 groups together surface samples from Belize Inlet, as well as sample ALS2, and from FC04, the 2 to 10 cm, and 70 to 75 cm intervals.

This assemblage has the most diverse fauna of all assemblages (SDI = 1.84), with *H. bradyi* and *B. frigida* being the dominant species (average 18.8%; range 0.0% - 37.6%, and average 10.5%; range 0.0% - 33.2% respectively).

Other important contributors to the fauna of this assemblage are *S. feylingi* (average 6.4%; range 0.0 – 32.2%) and *E. advena* (average 5.6%; range 0.0 – 15.0%). *P. bipolaris* and *Trochammina discorbis* Earland, 1934 reach similar numbers, both with averages of 5.5% each (ranges of 0.0 – 20.5% and 0.0 – 23.9% respectively). *N. labradorica* has an average abundance of 4.1%, ranging between 0.0 and 17.5%. Four percent of the assemblage is made of *C.* cf. *subglobosum* individuals (range 0.0 – 14.2%), and 3.7% of *C. excavatum 'clavata'* (range 0.0 – 11.8%). The only other species that surpasses 2% of the total population is *C. jeffreysii* (average 2.3%; range 0.0 – 14.2%); *L. fletcheri* is on the borderline (average 2.0%; range 0.0 – 10.6%). Five species range between 1% and 2% of the total counts: *C. excavatum* (1.8%), *R.*

turbinatus (1.4%), *Buliminella elegantissima* (d'Orbigny, 1839) (1.4%), *L. mckannai* (1.2%) and *S. biformis* (1.2%). Thecamoebians form 1.2% of this assemblage (range 0.0 – 8.5%).

There are 28 other species with average values of less than 1% of the total population (see Appendix A).

The percentage of agglutinated foraminifera averages 58% in this assemblage; it varies, however, between samples with 100% of agglutinated species to samples with 100% of calcareous foraminifera.

7.4 Ordination

The chosen axes of environmental variability explain 74.4% of the total variance in the species data (total inertia, 2.294, Table 6). The first axis is the most important one, explaining 41% of the variance, with an eigenvalue of 0.741. This axis is very well correlated with the environmental data (r = 0.978). The second axis, characterized by a smaller eigenvalue (0.36), explains an additional 19.9% of the variance, and is also strongly correlated (r = 0.947). These correlations suggest that the data set is governed by these two dominant gradients (Leps and Smilauer, 2003). The difference between the total variation explained by the axis and the total inertia of the dataset (2.294 – 1.807) is explained by the covariables of the analysis, in this case depth, whose effect is removed from the other variables.

The percentage variance explained by the axes of the ordination analysis are very close to those explained by the axes of the unconstrained DCA (e.g., 41 in comparison with 43.3); the species-environment correlation is only slightly higher.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues :	0.741	0.36	0.244	0.21	2.294
Species-environment correlations :	0.978	0.947	0.98	0	
Cumulative percentage variance					
of species data :	41	60.9	74.4	86	
of species-environment relation:	55.1	81.8	100	0	
Sum of all unconstrained eigenvalues					1.807
Sum of all canonical eigenvalues					1.344

Table 6: values for the Canonical Correspondence Analysis (CCA) of the surface samples

This suggests that the measured environmental variables are the ones responsible for the variation in species composition.

The position of the environmental variable vectors in relation to the axes summarizes the relative weight of each variable in determining each axis (Figure 7). From the triplot, it can be observed that temperature is highly negatively correlated with the first axis, whereas oxygen and silicate are both correlated with axis 1 and axis 2, oxygen positively and silicate negatively. Hence, the diagram can be divided in two ways. In the first one, the left side of the diagram shows an affinity for higher temperatures, but when values move towards the right side, the optimum temperature values for the species diminish. With regards to oxygen and silicate, the upper right quadrant is populated with species with an affinity to high oxygen concentrations and low silicate values; the opposite is true for the lower left quadrant. If the vectors of the environmental variables are extended, and perpendicular lines linking them with the species scores drawn, it is possible to infer a qualitative position of the optimum for that species regarding that particular variable. The fact that there are several species occupying the same point on the triplot (Ihellen, Cexex, Cmicrogr, Lmckan, Llobat) indicates that their relative abundances are judged identical by the method in different samples.

The relative position of samples and species indicates the tendency of some of the species to occur in certain samples. From the figure, it can be seen that the agglutinated foraminifera and thecamoebians occur in settings of higher temperature relative to the mean (samples from Alison Sound and BE3, BE5 and BE7). Most of the calcareous foraminifera appear to prefer colder temperatures. As well, species

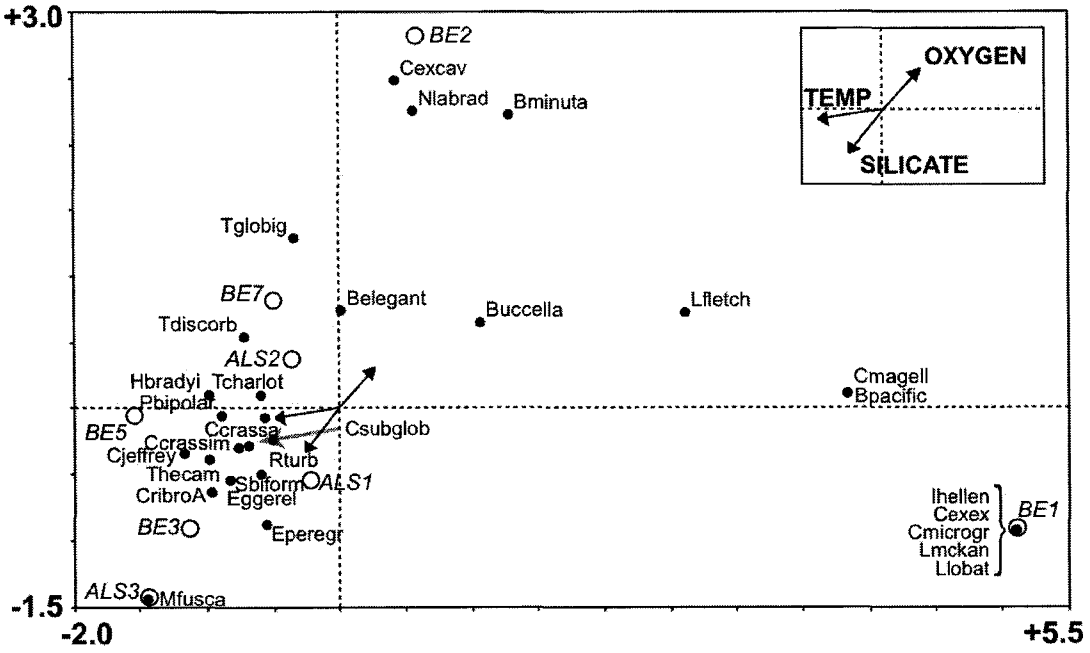


Figure 7: CCA triplot, representing the relation between the faunal distribution in the SBIC and temperature, oxygen and silicate. Filled circles represent species; open circles represent samples.

such as *E. advena*, *C. crassimargo*, *C. subglobosum*, *S. biformis*, *M. fusca*, *E. peregrina* and thecamoebians are abundant in low-oxygen high-silicate environments; the opposite is true for *Buccella* sp., *N. labradorica*, members of the *Cribroelphidium* and *Lobatula* groups and *B. elegantissima*, that thrive in relatively higher oxygen settings.

7.5 Transfer function

WA regression was used to describe the response of species (optima and range) as a function, first of oxygen and secondly of temperature.

Table 7 shows the values of RMSE, r^2 and maximum bias for both functions using the four different models described above. Inversion deshrinking gives better results for both the RMSE and r^2 for the two models. With respect to the model type, however, WA with tolerance downweighting performs better for oxygen, while temperature is best represented by WA.

The reconstructions for oxygen and temperature in core FC04 are shown in Figure 8, along with the stratigraphic values of key foraminiferal species. They can be correlated with the groups of samples as estimated by cluster analysis.

From the bottom of the core (depth of 138 cm) to a depth of 77 cm, the oxygen concentration seems to have been much lower than today, with a fairly constant average of ~1.0 mL/L. The predicted values for water temperature, on the other hand, are slightly higher (8.6°) than at present. This zonation corresponds with a complete dominance of agglutinated foraminifera, such as *C.* cf. *subglobosum*, *Eggerella* sp., *R. turbinatus* and *S. biformis* (Assemblage 1). Thecamoebians are very

Oxygen			
	RMSE	r^2	Max. bias
WA (Inv)	0.4225	0.9239	0.7529
WA (Cla)	0.4396	0.9239	0.7769
WATOL (Inv)	0.2553	0.9722	0.5120
WATOL (Cla)	0.2589	0.9722	0.4436

Temperature			
	RMSE	r^2	Max. bias
WA (Inv)	0.0532	0.9578	0.0842
WA (Cla)	0.0544	0.9578	0.0753
WATOL (Inv)	0.0663	0.9346	0.1360
WATOL (Cla)	0.0685	0.9346	0.1255

Table 7: performance of the two regression models, WA and WA(Tol), with classical (Cla) and inversion (Inv) deshrinking, for the oxygen and temperature reconstructions of the foraminiferal fossil set of FC04. Values in mL/L and °C, respectively.

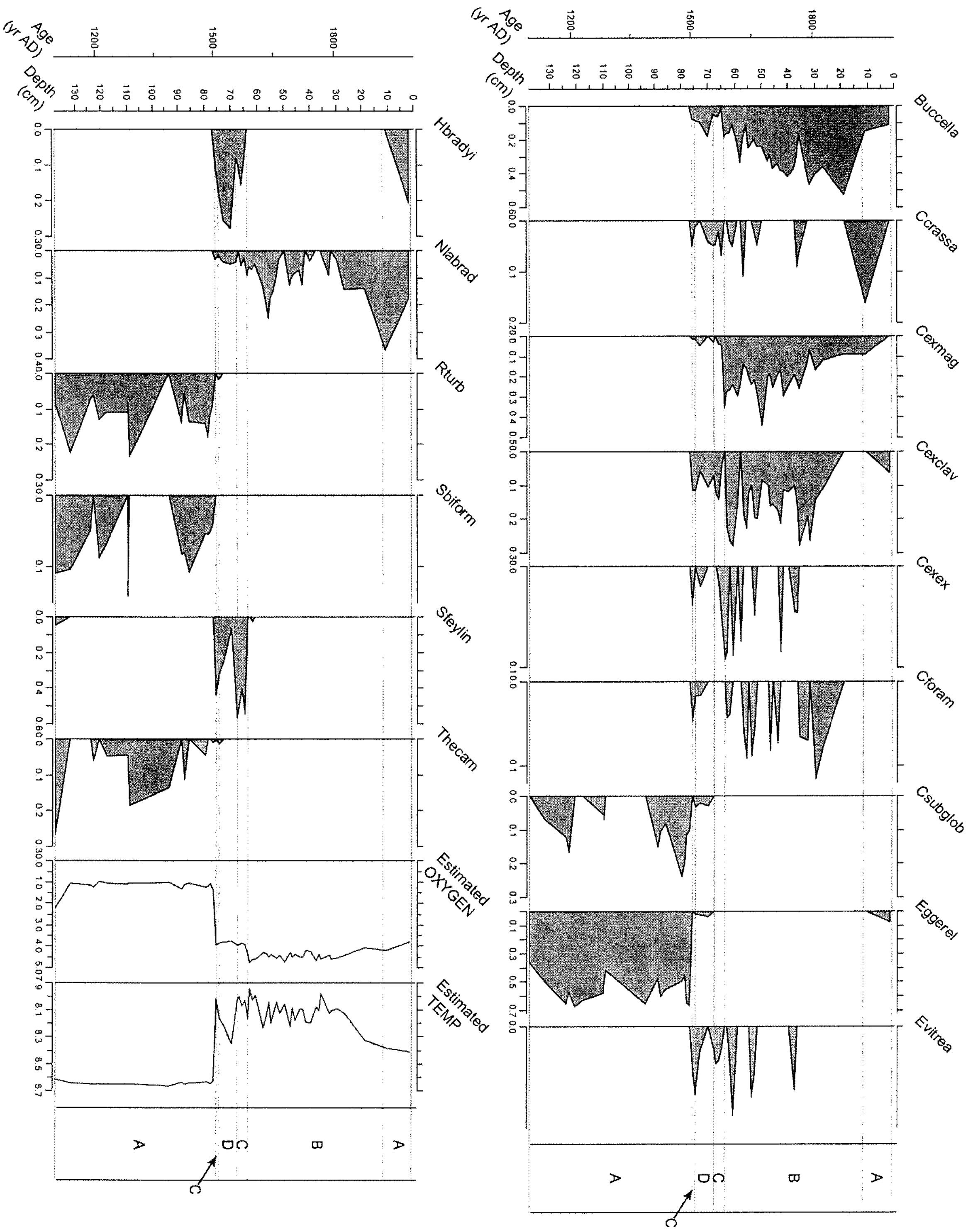
abundant, and a marginal occurrence of *S. feylingi* can be observed at the base of the core.

At a depth of 77 cm, a drastic change takes place. Oxygen concentration values increase significantly to ~4 mL/L, while temperatures drop around 0.6°. This depth corresponds to Assemblage 3. High abundances of *S. feylingi* are observed, and calcareous species begin to appear.

At cm. 74, the species' proportions change to those of Assemblage 4 and abundances of *S. feylingi*, although still high, become reduced with respect to Assemblage 3, and *H. bradyi* plays a dominant role. A smaller increase in temperature is noticeable, though oxygen values do not change significantly. The lack of change in temperature and oxygen concentration values with regard to the previous one is probably a reflection of the absence of surface analogues for Assemblage 3 (Figure 5). *Stainforthia feylingi*, the dominant species, does not appear as profusely anywhere in the surface samples. The closest assemblage is that of cluster 4, which includes smaller abundances of *S. feylingi*, so the values of temperature and oxygen for zone D mirror those of zone C (Figure 8).

The faunal composition changes again to Assemblage 3 at 68 cm: temperatures decrease, and oxygen seems to undergo a slight increase.

At cm. 64, oxygen values rise to almost 5 mL/L. Temperatures remain around 8.1°, though the trend seems to be quite noisy. The fauna changes completely to that of Assemblage 2, with complete dominance of calcareous species.


Age (yr AD)
1200
1500
1800
Depth (cm)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Hbradyi
Nlabrad
Rturb
Sbiform
Sfeylin
Thecam
Estimated OXYGEN
Estimated TEMP
Buccella
Ccrassa
Cexmag
Cexclav
Cexex
Cforam
Csubglob
Eggerel
Evitrea
A
B
C
D
C

At 11 cm, both temperature and oxygen values tend towards those of zone A. In fact, the dominant species in the top of the core are the same as those in the bottom (Assemblage 1)

8. Discussion

8.1. Modern Distribution of Foraminifera in the SBIC

The distribution of foraminiferal assemblages in both Belize Inlet and Alison Sound follow a common trend in many other higher latitude estuarine environments. In these environments, low diversity agglutinated faunas typically dominate deep-water, brackish areas where dysoxic conditions often prevail, and a higher diversity calcareous fauna is more common in areas where there is more open marine influence (Sen Gupta, 1999).

All foraminiferal assemblages found in the modern sediment-water interface samples from Belize Inlet correspond to Assemblage 4, the most faunally diverse assemblage observed in this study. This result is not unexpected, as salinity (30‰) and oxygen concentrations (~ 3 mL/L) (Figure 2) observed in the bottom waters of Belize Inlet most closely approach salinity and oxygen concentration values found in stable open shelf environments (Alve, 1995; Alve, 2000; Schafer et al., 1989; Sen Gupta, 1999). The high abundance of *Buccella* species and *C. excavatum,* particularly in samples BE1 and BE2, also clearly indicates the open shelf nature of the present day Belize Inlet. *Buccella frigida* has been observed to be a characteristic species of the open shelf in coastal British Columbia in cool, near shore environments with close to normal salinities (Patterson, 1993; Patterson et al., 2000). Similarly, *C. excavatum* is found in shallow waters of both polar and temperate seas where it appears in cold, normal salinity marine waters (Husum and Hald, 2004; Patterson, 1993; Patterson and Kumar, 2002; Sen Gupta, 1999).

The most abundant species toward the head of Belize Inlet (samples BE3, BE5 and BE7) is *H. bradyi.* This generalist species normally prefers cool muddy environments containing low concentrations of organic matter in waters that are deeper than 50 m (Klitgaard-Kristensen and Buhl-Mortensen, 1999; Murray, 1973). Although *H. bradyi* is well adapted to dysoxic conditions (Sen Gupta and Machain-Castillo, 1993) the measured oxygen values (3 mL/L at the time of collection) and the presence of other foraminiferal species that prefer more oxygenated environments, indicates that bottom water oxygen conditions in this part of Belize Inlet consistently remain high enough to maintain the observed fauna (Figure 2). The much lower bottom water oxygen concentration found at both stations ALS1 and ALS3 in Alison Sound is indicated by the presence of foraminiferal faunal Assemblage 1, which is characterized by very low species diversity and is comprised entirely of agglutinated forms. In the ordination triplot diagram (Figure 7) agglutinated species group together in the lowermost left quadrant. The foraminiferal training set developed from the analysis of water property data indicates that any samples and species plotting in this quadrant are tolerant of low oxygen conditions. Conditions at Station ALS3, where an oxygen concentration of 0.06 mL/L prevailed, and which plots on the farther corner of this quadrant, typify the environmental significance of this faunal distribution.

Eggerella advena, the dominant species observed in Assemblage 1, is a generalist, tolerant of brackish water conditions and often found in environments contaminated by organic matter where oxygen concentrations are frequently low (Blais-Stevens and Patterson, 1998). *Eggerella advena* is morphologically very similar to *Eggerella scabra* (Williamson, 1858), a common species in fjords and inner shelves of Northern Europe (Alve and Nagy, 1986). *Eggerella scabra* is another generalist that seems to have no specific substrate preference, tolerates highly variable organic matter content, and can thrive under very low oxygen concentrations, but the species is most common in environments where salinity ranges from 29-35‰ (Alve and Nagy, 1986). Another common species found in the Assemblage 1 samples from Alison Sound is *Cribrostomoides jeffreysii*, a species typical of artic waters at depths of between 60 - 360 m (Alves Martins and Ruivo Dragão Gomes, 2004). This species is also tolerant of dysoxic environments (< 0.1 mL/L), as so is *S. biformis* (< 0.5 mL/L; Sen Gupta and Machain-Castillo, 1993)

The foraminiferal fauna found at Station ALS 2 in Alison Sound is also comprised primarily of agglutinated species. However, it groups together with samples that comprise Assemblage 4 (Figure 5), due to the higher proportion of *B. frigida* present. The shallower water depth of this sample station, coupled with the highest bottom water oxygen concentrations (1.72 mL/L) recorded in Alison Sound, account for this mixed assemblage. Bottom water temperatures also play an important role in controlling the distribution of foraminifera in Belize Inlet and Alison Sound. The foraminiferal training set developed from the analysis of water property data indicates that any samples plotting in the right quadrant of the ordination triplot diagram (e.g. samples BE1 and BE2 and the dominant calcareous species found in Belize Inlet; *Buccella* sp., *C. excavatum* group, *N. labradorica*, *Lobatula* group, *I.*

helenae) can be closely correlated with cooler water masses (Figure 7). In contrast, samples from stations BE3, BE5, BE6, BE7, ALS1, ALS2 and ALS3, where bottom water temperatures were measured in 2002 to be above 8.5°C (Figures 2 and 3) clustered in the left quadrant of the ordination triplot diagram.

8.2. Paleoceanographic Changes in Belize Inlet (~ AD 900 – AD 2002)

Utilization of the training set developed based on the surface distribution of foraminifera in Belize Inlet and Alison Sound permitted a high-resolution determination of paleoceanographic change in freeze core FC04 from Belize Inlet. Of particular note was a dramatic and sudden shift from dysoxic/anoxic conditions to well-oxygenated conditions at ~ AD 1495 (77 cm core depth). There has been a steady decline in the level of oxygen in bottom waters through the last century, as dysoxic conditions seem to be slowly redeveloping in the open areas of Belize Inlet.

Several lines of evidence indicate that anoxic and dysoxic conditions prevailed during deposition of the basal portion of FC04 (138 - 77 cm core depth) that was deposited between ~ AD 900 and AD 1495. The presence of intervals of laminated sediments through portions of the basal section of FC04 indicates the existence of sustained anoxic bottom water conditions, where there would have been few if any intrusions of cold, high oxygen level oceanic water taking place. Similar occurrences of laminated sediments has been documented in many fjord environments where there is little exchange with open oceanic waters, resulting in dysoxic to fully anoxic bottom water conditions (e.g., Effingham Inlet, Vancouver Island, Chang and Patterson, 2005; Havstens and Koljö Fjord, Sweden, Gustafsson and Nordberg, 2002; Saanich Inlet, Vancouver Island, Nederbragt and Thurow, 2001; Patterson et al., 2004b; Frederick Sound, SBIC, Wigston, 2006). The presence of these generally non-fossiliferous laminations, coupled with the low diversity, low-oxygen tolerant species of the assemblage found in the more homogeneous sections of this part of the core (Assemblage 1), suggest little exchange with oceanic waters. Results of the transfer function analysis also indicate that oxygen concentration levels were never above ~ 1 mL/L during deposition of this entire unit, except at the base of the core (Figure 8).

There are two possible hypotheses that may explain the presence of anoxic/dysoxic conditions in the bottom waters of Belize Inlet during this interval. First, upwelling may have been suppressed in the area, in which case, the density of ocean waters would have been too similar to the water masses found within the SBIC to favor circulation exchange. However, at present upwelling conditions prevail in the open water areas outside the SBIC and do not penetrate past the restricted entrance at Nakwakto Rapids, where very strong seaward currents dominate (Thomson, 1981). As the bottom waters in the more open areas of the SBIC are currently well oxygenated, this hypothesis is negated. A second possible explanation hinges on the hypothesis that estuarine flow was severely reduced during deposition of the lower unit. This scenario would unfold if precipitation in the area became reduced, resulting in the low salinity layer that forms within the surface waters at present to become poorly developed. This more homogenous water mass would have a reduced tendency to flow toward the open ocean, which in turn would result in a reduction of return flow at depth of denser and well oxygenated subsurface water over the sill at

Nakwakto Rapids. This reduced flow into the SBIC would have quickly resulted in the development of stagnant bottom-water conditions and a concomitant decrease in oxygen levels, which would have given an ecological advantage to opportunistic foraminiferal species tolerant of low-oxygen concentration (e.g., *E. advena*, *S. biformis* or *Cribrostomoides* sp.) Even if full anoxic conditions dominated bottom water conditions for a significant part of the year, some foraminifera are known to be able to survive with only infrequent exposure to oxygenated water (Alve, 2000; Bernhard and Sen Gupta, 2000; Sen Gupta and Machain-Castillo, 1993). The abundance of fecal pellets is very high below 77 cm in the core, indicating conditions of high productivity in the surface waters, which may also have contributed to the development of reduced oxygen levels at depth. Weak estuarine circulation and high levels of productivity are consistent with a warm, low precipitation climatic regime.

The result of the application of the foraminifera training set derived transfer function to samples from FC04 indicates that the estimated paleo-oxygen concentrations and paleo-temperature values were quite stable through the agglutinated foraminifera dominated 138 - 77 cm portion of the core (Figure 8). Paleo-oxygen concentration values estimated for this portion of the core ranged from a high of ~ 2.2 mL/L for the lowermost sample, gradually decreasing to ~ 1 mL/L up core. Speculation as to whether this lowermost sampled horizon represents the final phase of a previous interval when elevated oxygen concentrations existed that was not penetrated by FC04 is entirely conjectural. The estimated paleo-temperature values remained at a uniform ~ 8.6°C through the entire interval of the core below 77 cm, supporting the hypothesis that there was little input of oceanic water during this phase.

The foraminiferal fauna in FCO4 changed significantly in the 76 - 65 cm (AD 1495 to AD 1574) core interval, from a fauna dominated by agglutinated taxa to a calcareous dominated assemblage, albeit comprised primarily of taxa most commonly found under dysoxic conditions. This faunal transition was concomitant with a transfer function derived estimate of oxygen concentration that jumped from 1 mL/L in the unit below to 4 mL/L, and a water temperatures decline from 8.6°C to 8.0°C. This interval is primarily comprised of Assemblage 3, which is dominated by *S. feylingi*, frequently making up more than 50% of the fauna. The estimated oxygen concentration value of 4 mL/L for this interval may be too high though. As discussed below, most species found in Assemblage 3 are dysoxic tolerant generalists, suggesting that the oxygen concentration may have in reality been lower in this interval. A major difficulty for the interpretation of this interval using the transfer function was that there was no close modern analogue with similar abundances of *S. feylingi* in the surface samples examined. For any paleoenvironmental analysis involving a transfer function, the accuracy of paleo-estimates is directly related to the presence of analogues in the training set; the wider the environmental range of samples utilized, the greater the predictive power of the function (Birks et al., 1990; Edwards et al., 2004; Gasse et al., 1995). For the same reason, the validity of the estimated drop in temperature to 8.0°C is similarly suspect.

As discussed above, the occurrence of *S. feylingi* has been correlated with low-oxygen environments, appearing even under fully anoxic conditions (Patterson et al., 2000; Patterson and Kumar, 2002). Patterson et al., (2000) observed a *Stainforthia* dominated assemblage under fully anoxic (with H_2S) conditions in Effingham Inlet. Based on this evidence they concluded that even the most isolated basins of that fjord were periodically oxygenated. This hypothesis was later corroborated when long-term monitoring of physical water property data was carried out in Effingham Inlet (Chang and Patterson, 2005; Patterson et al., 2004b). *Stainforthia fusiformis* (Williamson, 1858), a species closely related to *S. feylingi*, is a typical dweller in fjords of Norway, where it frequently appears as the first recolonizer in formerly anoxic areas (Alve, 1995; Alve, 2000; Alves Martins and Ruivo Dragão Gomes, 2004; Sen Gupta and Machain-Castillo, 1993). This species has also been found to thrive during periods of high primary productivity, which contribute to the organic content of the sediment (Alve, 2000). Other species dominant in this portion of the FC04 core included *H. bradyi* and *N. labradorica*, which have become adapted to dysoxic conditions due to their infaunal habitat (Sen Gupta and Machain-Castillo, 1993). Research has indicated that *N. labradorica* has accomplished this adaptation through the sequestration of algal chloroplasts in its cytoplasm, though the exact mechanism is unknown (Guilbault et al., 2003). *Epistominella vitrea* is also common in this core interval and it too has previously been reported as living in dysoxic environments in Swedish fjords (Gustafsson and Nordberg, 2000), although it is also abundant in outer neritic zones along the Pacific and Atlantic coasts where high sedimentation rates prevail (Alves Martins and Ruivo Dragão Gomes, 2004; Patterson, 1993). The overwhelming dominance of *S. feylingi* and other dysoxia tolerant species indicates that although the environment at the time of deposition was dysoxic, oxygen concentrations were higher than in the lower unit of the core. The dramatic increase in the proportion of calcareous species, particularly *S. feylingi* at the lowermost 76 cm horizon of this interval probably represents, as has been observed elsewhere (e.g., Alve, 1995), a pioneering stage colonization event as the previously stressed very low oxygen environment (~ 1 mL/L) received a prolonged injection of more oxygenated waters and rapidly became habitable for a calcareous foraminiferal assemblage. Another contributing factor to the explosive development of a calcareous fauna at the 76 cm horizon may have been related to an increase in organic matter in the substrate. The closely related *S. fusiformis* has been observed in Norwegian fjords to double its population in a short period of time following an increase in the input of organic matter and can grow to adult size in less than a month (Gustafsson and Nordberg, 2000). Thus, in addition to the opportunistic colonization of a new ecospace, the sudden abundance peak of *S. feylingi* may therefore also in part be related to the climatological change that was going on at that time as the atmospheric conditions shifted from a dryer to higher precipitation regime. During the transition, conditions may have been optimal for phytoplankton blooms in the surface waters that would have in turn increased the rain of organic material to the bottom of the inlet.

The interval of the core from 75 - 70 cm is characterized by the transition from an Assemblage 3 to Assemblage 4 dominated fauna. Although high concentrations of *S. feylingi* are still present in this assemblage, *H. bradyi* is also important. Species of *Haplophragmoides* are common in muddy shelf environments on both Atlantic and Pacific Ocean coasts (Murray, 1991). The diversity of foraminiferal species increases through this zone and may indicate that the faunal succession that was initiated with the first calcareous assemblages at 76 cm is reaching a climax phase of an ecological succession as bottom water conditions in the inlet changed. A transition back to a more *S. feylingi* dominated assemblage from 69 - 64 cm in the core indicates that bottom-water circulation patterns during the ~ 80 year span of this transitional phase were unstable with intervals of dysoxic and low oxic conditions prevailing.

The foraminiferal faunas found in the interval of FC04 from 64 - 11 cm (AD 1574 - AD 1943) are typical of higher oxygenation and colder temperature regimes. The introduction of well oxygenated water at depth was probably triggered by an increase in precipitation within the SBIC catchment area, which is the main variable that influences the extent of the brackish layer within a low run off inlet such as Belize Inlet (Pickard, 1961). Any increase in freshwater input results in development of a thicker brackish surface layer, which, on its way to the sea, entrains a higher amount of deeper saline water that gains velocity towards the mouth of the inlet (R. Thomson, written communication, 2006). The outflow of a large volume of low salinity surface water through the mouth of the SBIC at Nakwakto Rapids results in a return flow over the sill of cold, well oxygenated oceanic water from Queen Charlotte Sound in the subsurface layer. As long as precipitation levels remain high, estuarine flow is enhanced, which keeps oxygen levels in the bottom waters of Belize Inlet high, promoting the development of a diverse and primarily calcareous foraminiferal assemblage. The transfer function reconstruction of oxygen concentrations and average temperature through this interval are ~ 4.5 mL/L, and 8.1°C respectively, which are very similar to conditions in adjacent Queen Charlotte Sound (Thomson, 1981).

The most dominant species, *B. frigida* and *C. excavatum* are species typical in normal open marine cool-water conditions. The range of *C. excavatum* forma *clavata* is restricted to a high northern latitude belt in both the Pacific and Atlantic Oceans (Sen Gupta, 1999). *Nonionella labradorica*, present in most samples of this assemblage, has been recorded in sediments from Drammensfjord (Norway) associated with normal saline deep water conditions (Alve, 1991; Gustafsson and Nordberg, 2002). Although, as mentioned before, this species is well adapted to dysoxic conditions because of its ability to use opportunistically the increased organic loads generally associated with dysoxia, it is present in oxic environments as well, although its numbers are often reduced due to competition with other species (Sen Gupta and Machain-Castillo, 1993). Species of *Lobatula* are also found through this section. These epifaunal suspension feeders are most abundant in environments with good circulation, as the increased oxygen concentrations estimated for this interval suggest (Polyak et al., 2002).

Many foraminiferal specimens recovered from samples through this section were highly etched, to the point of being unrecognizable in many instances, suggesting that dissolution may be a taphonomic biasing factor through this interval of the core. Dissolution of calcareous tests is a process enhanced by macrofaunal reworking of the sediments, which prevents $CaCO_3$ saturation of the porewaters (Green et al., 1993). The etched foraminiferal specimens therefore provide further corroborative evidence that a healthy benthos had developed at this site following the increase in levels of oxygenation of the bottom water.

There is an increase in the proportion of agglutinated foraminifera in FC04 in sediments deposited after AD 1943 (11 - 2 cm), suggesting that estuarine circulation began to break down again, with a return to conditions as existed in the inlet in the mid-16th century, but not as weak, at least as of yet, to conditions that existed prior to AD 1495 (Figure 8). The foraminiferal transfer function indicates that since AD 1943 there has been a decrease in oxygen concentration from above 4 mL/L to slightly below, and an increase in temperature of ~ 0.1°C (Figure 8).

A trend similar to that observed in FC04 has been documented in cores from the Skagerrak Basin, NE North Sea (Alve, 1991; Alve, 1996). In that basin there are periodic shifts between agglutinated and calcareous foraminiferal faunas that have been interpreted to reflect varying bottom water oxygenation conditions brought on by infrequent deep water renewal and increased organic matter in the basin.

Thecamoebian Distribution in FC04

The relatively high abundance of freshwater thecamoebian tests, which are only found in the basal 138 - 77 cm interval of the base of the core deposited prior to AD 1495 is difficult to explain. Since thecamoebians are freshwater organisms that cannot survive in salinities higher than 5‰ (Scott et al., 2001), the whole fauna was transported to the basin from soil and freshwater habitats on the margins of the fjord by runoff. The intuitive assumption would be that intervals characterized by higher numbers of thecamoebians would correspond with periods of higher precipitation, conditions that did not exist during deposition of the basal unit of the core. More thecamoebians probably do get washed into the inlet during intervals when precipitation is higher (e.g., the post-77 cm interval of FC04). However, due to the high velocity of the low salinity surface waters above the pycnocline, they are most likely flushed out of the basin before they have time to settle to the bottom. This hypothesis is based on the observation that the distance that a particle will be carried in a surface water mass will depend on the time that the particle remains in suspension; the faster the velocity of the surface layer, the longer the particles will remain in suspension (Syvitski, 1989). This process has previously been documented in Sandsfjord, Norway, during an analysis of the impact of freshwater runoff on physical oceanography and plankton distribution. Kaartvedt and Svendsen (1990) found that when freshwater runoff increased, due to controlled discharge from a hydroelectric plant at the head of the fjord, the phytoplankton of the upper layers was flushed seawards. Therefore, the absence of freshwater thecamoebians on the SBIC during periods of high estuarine circulation and high precipitation is explained here as the result of them being flushed out of the basin by the high velocity of the surface layer.

8.3. Paleoclimatic Interpretation

Changes over time in the position of the respective centers of action (COA; Patterson et al., 2004b) of the AL and NPH strongly influence atmosphere/ocean circulation patterns in the North Pacific region, which in turn affect the amount of rainfall and ultimately streamflow occurring in coastal BC (Cayan and Peterson, 1989; Trenberth and Hurrel, 1995). Changes in the COA and strength of the AL and NPH may therefore provide a good explanation for the climatic variability observed in the SBIC through the last ~ 1100 years. During an interval when the AL was weakened, or when the NPH was stronger, there would have been a diminished estuarine circulation, resulting in a reduced exchange with more open ocean waters, as occurred in the SBIC during the ~ AD 900 – AD 1495 interval. This interval correlates well with the Medieval Warm Episode (MWE). In contrast, periods of a stronger or more persistent AL, accompanied by an increase in precipitation over coastal BC, would have enhanced estuarine circulation within the SBIC, as occurred beginning at AD 1495.

This period of strengthened AL influence that impacted the SBIC between AD 1495 and AD 1943 correlates well with the Little Ice Age (LIA), which has been described as occurring between AD 1500 and 1850 in western Canada (Bradley and Jones, 1995). Though the determination of the initiation of the LIA is controversial, and seems to vary locally, there is a general agreement that the period between the 15th and late 19th century was cooler and/or wetter than at present in most areas of British Columbia. Clague et al., (2004) observed that glaciers from the region were at their greatest extent of the last 3000 years, and perhaps the last 10000 years, during the LIA, and recognized evidence of a gradual climatic amelioration commencing in the 20th century. A second study that utilized varve thickness as a proxy for precipitation in Saanich Inlet, Vancouver Island, also correlated a period of increased precipitation after AD 1450 with the LIA, which ties in with the SBIC record (Nederbragt and Thurow, 2001).

Analysis of an oxygen isotope record from lacustrine carbonates at Jelly Bean Lake in the Yukon Territory also records similar climatic transitions, although the events there began a little later (*ca.* AD 1700) and terminated slightly earlier (*ca.* AD 1900) than observed in the SBIC and other areas to the south (Anderson et al., 2005). The authors correlated the observed sharp transition at *ca.* AD 1700 in the Jelly Bean Lake record with an initial eastward shift of the COA of the AL, which caused precipitation in the area to increase. When the COA of the AL eventually shifted westward again at *ca.* AD 1900, the amount of precipitation decreased in the area, marking the "end of the LIA".

At the hemispheric scale, there are many similar paleoclimatic proxy records of increased/decreased precipitation through the last millennium that were also influenced by changes in atmosphere-ocean circulation, which can be correlated with both the MWE and the LIA. For example, in the eastern Barents Sea region, there was an extended period of glacial retreat that has been linked to the comparatively mild climate that characterized the MWE in the Northern Hemisphere prior to AD 1400 (Polyak et al., 2004). The subsequent expansion of these glaciers during the LIA was the result of increased precipitation, which in turn originated with an intensification of the Icelandic Low (Polyak et al., 2004). In another study, Lassen et al., (2004) carried out a high-resolution stratigraphic analysis of foraminifera deposited during the last millennium in Igaliku Fjord, South Greenland, which revealed several distinct climatic episodes. Of particular relevance to the present study in the SBIC, where MWE warmer and drier conditions prevailed from ~ AD 900 to AD 1495, Lassen et al., (2004) found evidence of a period of MWE correlated climatic warming and increased vertical mixing in the water column that occurred from AD 885 to AD 1235. The transition at Igaliku Fjord from this warm period to the LIA occurred in two steps, with conditions warming slightly by AD 1520 before a subsequent maximum cooling took place (Lassen et al., 2004). The results from the SBIC provide further evidence that the MWE and the LIA were at least hemispheric phenomena, although the timing of initiation and termination seems to vary.

Although the present record is too short to indicate climatic fluctuations on a centennial scale, it is possible that the period between 1574 and 1943 corresponds to a well documented ~ 500 years solar cycle. This cycle between lower and higher solar irradiance levels have been correlated with wetter/drier conditions and an intensified/weakened AL (Patterson et al., 2004b). The cycle is prevalent in the Northern Hemisphere (Hu et al., 2003), and it broadly matches the LIA and Medieval Warm Period in the North Atlantic (Bond et al., 2001).

9. Conclusions

High resolution analysis of Recent and fossil foraminifera from the SBIC has provided evidence of the both the MWE and LIA. The presence of these global climate phenomena in coastal BC seems to have been controlled in large part by the relative strength, and long-term migration of the COA's of both the NPH and AL. Reduced precipitation in the SBIC catchment during the MWE from ~AD 900 – AD 1495 resulted in weakened estuarine circulation and the development of dysoxic and anoxic conditions in the bottom waters as indicated by the low diversity agglutinated foraminiferal fauna characterizing this interval. There was a major increase in precipitation in the SBIC area after AD 1495 as the COA of the AL migrated eastward. This change in atmospheric – ocean circulation is marked in the core by a transitional interval that terminates by AD 1574. Conditions during this ~ 80 year transitional interval varied though as there were not only episodes when cold, well oxygenated water entered the fjord but episodes when anoxia prevailed as well. Strong estuarine circulation permanently prevailed in the SBIC after AD 1574 as reflected by almost the diverse calcareous foraminiferal fauna in the core. Estuarine circulation seems to be weakening in the post AD 1943 interval suggesting a possible future return to conditions that prevailed during the MWE, although precipitation levels and bottom water oxygen levels are not as low yet in the SBIC as they were during the 10th – 15th centuries.

The present study shows the potential of high resolution foraminiferal research in the development of accurate climate chronologies. Cluster analysis proves to be a resourceful qualitative tool in the description of assemblages, and ordination methods are useful to determine the environmental factors affecting those assemblages. The use of transfer functions has great potential, both as a validation of previously defined clusters and as a quantitative instrument to estimate past values of environmental variables.

10. Systematic paleontology

Suprageneric classification follows that of Loeblich and Tappan (1987). Illustrated specimens are housed in the Department of Earth Sciences, Carleton University, Ottawa, Ontario.

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Hérouard, 1896

Superfamily ASTRORHIZACEA Brady, 1881

Family SACCAMMINIDAE Brady, 1884

Subfamily SACCAMMININAE Brady, 1884

Genus *Saccammina* Carpenter, 1869

Saccammina atlantica (Cushman, 1944)

Proteonina atlantica CUSHMAN, 1944, p. 5, Pl. 1, fig. 4.

Saccammina atlantica (Cushman, 1944). RODRIGUES, 1980, p. 69, Pl. 3-1, fig. 11.

Saccammina cf. *atlantica* (Cushman, 1944). BLAIS, 1995, p. 92, Pl. 2.3, fig. 4.

Description: test free, single elongate, oval or pyriform chamber; wall agglutinated, fairly coarse; aperture very small, at tapered end of chamber; no distinct neck, but gradually contracted toward apertural end; circular in section.

Saccammina sphaerica Sars, 1872

Saccammina sphaerica SARS, 1872, p. 250, figure in Carpenter, 1875, p. 532, fig. 272; HÖGLUND, 1947, p. 50, Pl. 3, fig. 7; SCHRÖDER, 1986, p. 37, Pl. 10, fig. 4; JONASSON, 1994, p. 47, Pl. 2, fig. 5.

Description: test free, single globular chamber, spherical or pyriform; wall agglutinated, fine, smooth; aperture rounded, may be nearly flush or on short neck; inner organic wall layer modified in living specimens to an oral apparatus or entosolenian tube around opening.

Superfamily AMMODISCACEA Reuss, 1862

Family AMMODISCIDAE Reuss, 1862

Subfamily AMMOVOLUMMININAE Chernykh, 1967

Genus *Ammodiscus* Reuss, 1862

Ammodiscus gullmarensis Höglund, 1948

Plate 1, figure 1

Ammodiscus planus HÖGLUND, 1947, p. 123, Pl. 8, fig. 2,3,8; Pl. 28, fig, 17,18.

Ammodiscus gullmarensis HÖGLUND, 1948, p. 45.

Description: test free, small, flattened but tending to irregular coiling in last whorls; wall arenaceous with fairly large amount of cement; 7 to 9 whorls; sutures distinct, proloculum central and subspherical.

Superfamily RZEHAKINACEA Cushman, 1933

Family RZEHAKINIDAE Cushman, 1933

Genus *Miliammina* Heron-Allen and Earland, 1930

Miliammina fusca (Bradyi, 1870)

Quinqueloculina fusca BRADY, in BRADY and ROBERTSON, 1870, p. 286, pl. 11, fig. 2.

Miliammina fusca (Brady, 1870) MURRAY, 1971, p. 21, Pl. 3, fig. 1-6; PATTERSON, 1990, p. 240, pl. 1, fig. 4.

Description: test elongate ovate; narrow chambers one-half coil in length, quinqueloculine arrangement; wall thick, very finely agglutinated; aperture at end of chamber, large and conspicuous, equal in size to transverse section of chamber.

Superfamily HORMOSINACEA Haeckel, 1894

Family HORMOSINIDAE Haeckel, 1894

Subfamily REOPHACINAE Cushman, 1910

Genus *Reophax* de Montfort, 1808

Reophax catella Höglund, 1947

Plate 4, figure 3

Reophax catella HÖGLUND, 1947, p. 97, fig. 77,78; ALVE, 1990, p. 693, Pl. 1, fig. 16, 18.

Leptohalysis catella (Höglund, 1947). BLAIS, 1995, p. 91, Pl. 2-1, fig. 6.

Description: test free, elongate, slender, tapering, circular in section; wall agglutinated, thin; numerous (up to 20) chambers, increasing in size, arranged in straight line or slightly curved; chambers short and broad, height equaling or slightly exceeding the breadth, chamber sides convex, slightly converging upward, contact surface between chambers broad; aperture a simple rounded opening at top of chamber.

Reophax gracilis (Kiaer, 1900)

Nodulina gracilis KIAER, 1900, p. 24, fig. 1,2.

Reophax gracilis (Kiaer, 1900). ALVE, 1990, p. 693, Pl. 1, fig. 17.

Description: test free, elongate, composed of about 19 loosely sutured segments, at the outset short and wide, becoming elongated and pointed towards top, with almost horizontally sectioned basal parts; wall agglutinated, smooth.

Remarks: *R. gracilis* is differentiated of *R. catella* and *R. scottii* by basal part of its chambers, which look almost horizontally sectioned.

Reophax scottii Chaster, 1892

Reophax scottii CHASTER, 1892, p. 57, Pl.1, fig. 1; MURRAY, 1971, p. 17, Pl. 1, fig. 6-8; ALVE, 1990, p. 693, Pl. 1, fig. 19.

Description: test free, elongate, narrow; wall agglutinated, very delicate, transparent, flexible when moist; 10-20 chambers arranged in a line, gradually increasing in size; chambers somewhat pyriform, abruptly truncated below; aperture small.

Superfamily LITUOLACEA de Blainville, 1827

Family HAPLOPHRAGMOIDIDAE Maync, 1952

Genus *Cribrostomoides* Cushman, 1910

Cribrostomoides crassimargo (Norman, 1892)

Plate 1, figure 2

Haplophragmium crassimargo NORMAN, 1892, p. 17, Pl. 7-8.

Labrospira crassimargo (Norman, 1892). HÖGLUND, 1947, p. 141, Pl, 11, fig. 1.

Alveolophragmium crassimargo (Norman, 1892). LOEBLICH and TAPPAN, 1953, p. 29, Pl. 3, fig. 1-3.

Cribrostomoides crassimargo (Norman, 1892). TODD and LOW, 1967, p. 15, Pl. 1, fig. 24.

Description: test free, planispiral, partially involute; wall agglutinated, thick, coarse, with large sand grains, sometimes of orange color; 2 to 4 whorls, 8 to 10 chambers in last whorl; sutures straight, slightly depressed; umbilicus depressed; periphery rounded, lobulate; aperture interio-aereal, forming an oblong, curved slit, upper and lower lip well developed

Cribrostomoides jeffreysii (Williamson, 1858)

Plate 1, figures 4a-c

Nonionina jeffreysii WILLIAMSON, 1858, p. 34, Pl. 3, fig. 72,73.

Alveolophragmium jeffreysii Williamson, 1858. LOEBLICH and TAPPAN, 1953, p. 31, Pl. 3, fig. 4-7.

Cribrostomoides jeffreysii (Williamson, 1858). MURRAY, 1971, p. 23, Pl. 4, fig. 1-5.

Description: test free, planispiral, almost involute, compressed laterally; wall finely agglutinated, yellow to brown; 6 to 8 chambers in last whorl, with triangular shape; periphery rounded, slightly lobulate; sutures depressed and radial; aperture a lipped slit near base of apertural face.

Cribrostomoides cf. *subglobosum* (Cushman, 1910a)

Plate 1, figures 5a-b

Haplophragmoides subglobosum CUSHMAN, 1910, p. 105, fig. 162-164.

Labrospira subglobosa (Cushman, 1910). HÖGLUND, 1947, p. 144, Pl. 11, fig. 2.

Cribrostomoides subglobosus (Cushman, 1910). SCHRÖDER, 1986, p. 48, Pl. 17, fig. 15, 16; JONASSON, 1994, p. 53, Pl. 5, fig. 8.

Cribrostomoides subglobosum (Cushman, 1910a). POAG, 1981, p. 57, Pl. 11, fig. 2.

Description: test free, planispiral, involute, depressed at the umbilicus; wall agglutinated, somewhat roughened but variable; chambers broad and low, usually 4 to 8 in last whorl, making test as whole subglobular; aperture interio-aereal, forming oblong, very narrow curved slit immediately above of inner margin of apertural face, with well developed lips.

Remarks: although *C. subglobosum* is reported to be of a bigger size than the specimens present on the SBIC (J. P. Guilbault, oral communication, 2006), the general shape of these specimens agrees well with the description of *C. subglobosum*. However, the apertural face in most specimens was covered by debris, making impossible to recognize the shape of the aperture. They are therefore named as *C.* cf. *subglobosum*, until a better designation is found.

Cribrostomoides wiesneri (Parr, 1950)

Plate 2, figures 1a-c

Labrospira wiesneri PARR, 1950, p. 272, Pl. 4, fig. 25, 26.

Cribrostomoides wiesneri (Parr, 1950). SCHRÖDER, 1986, p. 48, Pl. 17, fig. 10, 12; POAG, 1981, p. 57, Pl. 9, fig. 1.

Description: test free, planispiral, not completely involute; wall agglutinated, fine, with excess of yellow to reddish brown cement, smooth; umbilical region depressed, with chambers of earlier whorls visible; about 3 whorls; periphery slightly lobulate; 7 to 9 chambers in last whorl; sutures distinct, slightly depressed; aperture a short narrow slit slightly above base of apertural face.

Cribrostomoides sp. A

Plate 1, figures 3a, 3b

Description: test free, planispiral, involute, depressed at the umbilicus; wall agglutinated, somewhat roughened but variable; chambers broad and low, usually 5 to 7 in last whorl; last chamber much inflated and wider, protruding strongly on both sides on apertural view, rest of the chambers more compressed; periphery rounded; aperture interio-aereal, forming a curved slit immediately above of inner margin of apertural face.

Remarks: this species resembles *C. subglobosum*, but the width of the last chamber, very prominent in all specimens, sets it apart.

Genus *Haplophragmoides* Cushman, 1910

Haplophragmoides bradyi (Brady, 1887)

Plate 1, figures 6a-c

Trochammina robertsoni BRADY, 1887, p. 893, Pl, 20, fig. 4.

Trochammina bradyi ROBERTSON, 1891, p. 388.

Haplophragmoides bradyi (Brady, 1887). HÖGLUND, 1947, p. 134, Pl. 10, fig. 1; MURRAY, 1971, p. 24, Pl, 5, fig. 1,2; SCHRÖDER, 1986, p. 46, Pl. 17, fig. 8.

Description: test free, planispiral, partly evolute, discoidal or compressed, nearly symmetrical bilaterally; wall agglutinated, very fine, brown, very smooth; 5 chambers in outer whorl, somewhat inflated; sutures distinct, depressed; aperture interiomarginal, lipped.

Superfamily HAPLOPHRAGMIACEA Eimer and Fickert, 1899

Family AMMOSPHAEROIDINIDAE Cushman, 1927

Subfamily RECURVOIDINAE Alekseychik-Mitskevich, 1973

Genus *Recurvoides* Earland, 1934

Recurvoides turbinatus (Brady, 1881)

Plate 1, figures 7a, b

Lituola (Haplophragmium) turbinatum BRADY, 1881, p. 50, Pl. 35, fig. 9.

Recurvoides turbinatus (Brady, 1881). LOEBLICH and TAPPAN, 1953, p. 27, Pl. 2, fig. 11; RODRIGUES, 1980, p. 66, Pl. 3-3, fig. 8; JONASSON, 1994, p. 58, Pl. 7, fig. 2.

Description: test free, streptospiral, involute on one side and evolute on the other; wall agglutinated, somewhat roughened but variable; chambers not inflated but somewhat irregular in shape; periphery rounded; aperture an elongated aereal slit set at an angle on periphery.

Superfamily SPIROPLECTAMMINACEA Cushman, 1927

Family SPIROPLECTAMMINIDAE Cushman, 1927

Subfamily SPIROPLECTAMMININAE Cushman, 1927

Genus *Spiroplectammina* Cushman, 1927

Spiroplectammina biformis (Parker and Jones, 1865)

Plate 4, figures 6a-c

Textularia agglutinans d'Orbigny var. *biformis* PARKER and JONES, 1865, p. 370, Pl. 15, fig. 23, 24.

Spiroplectammina biformis (Parker and Jones, 1865). HÖGLUND, 1947, p. 163, Pl. 12, fig. 1; LOEBLICH and TAPPAN, 1953, p. 34, Pl. 4, fig. 1-6; SCHRÖDER, 1986, p. 51, Pl. 21, fig. 14.

Description: test free, elongate, narrow, ovoid in section, margins broadly rounded, sides nearly parallel; wall agglutinated, solid; large early planispiral coil of few chambers followed by biserially arranged chambers, coil commonly of greater breadth than first few parts of biserial chambers; chambers very slightly inflated; sutures somewhat indistinct, only slightly depressed; aperture a low arch at inner margin of final chamber.

Superfamily TROCHAMMINACEA Schwager, 1877

Family TROCHAMMINIDAE Schwager, 1877

Subfamily TROCHAMMININAE Schwager, 1877

Genus *Portatrochammina* Echols, 1971

Portatrochammina bipolaris Brönnimann and Whittaker, 1980

Plate 2, figures 3a-c

Portatrochammina bipolaris BRÖNNIMANN and WHITTAKER, 1980, pp. 181, 183, fig. 15, 16, 18, 19, 20-31.

Description: test free, trochospiral; wall agglutinated, imperforate; about 14 chambers, 6 to 8 chambers in the final whorl, increasing rapidly in size; shallow umbilicus covered by flap from each successive chamber; elongate-ovate in outline, final portion somewhat lobulate; compressed, almost flat spirally, concave umbilically; periphery rounded to sub-acute; final chamber characteristically flat on spiral side and strongly convex on umbilical side; radial sutures straight to sinuous on umbilical side and slightly curved on spiral side; color dark brow grading into light brown; aperture begins as low interiomarginal opening near periphery, extends as slit around umbilical flap.

Genus *Trochammina* Parker and Jones, 1859

Trochammina charlottensis Cushman, 1925

Plate 2, figures 4a-c

Trochammina charlottensis CUSHMAN, 1925, p. 39, Pl. 6, fig. 4a, b.

Trochammina charlottensis CUSHMAN, 1925. BLAIS, 1995, p. 92, Pl. 2-3, fig. 1; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 4, Pl. 26, fig. 5,6.

Description: test free, compressed, very flat trochospiral; wall coarsely agglutinated, opaque; sutures radiate and depressed, especially on the umbilical side; all chambers visible on spiral side, last 6 chambers visible on the umbilical side; aperture a low interiomarginal arch opening into the open umbilicus.

Remarks: this species is easily distinguishable by the very big, inflated last chamber.

Trochammina discorbis Earland, 1934

Plate 2, figures 6a-c; Plate 3, figure 4

Trochammina discorbis EARLAND, 1934, p. 104, Pl. 3, fig. 28-31; BLAIS, 1995, p. 93, Pl. 2-3, fig. 7, 8.

Description: test free, minute, trochospiral; wall agglutinated, very fine with much cement; surface smooth but not very highly polished; 3 or 4 whorls visible on spiral side, 4 or 5 chambers from final whorl visible on dorsal side; dorsal side highly convex, umbilical side nearly flat but with deeply sunk umbilicus; sutures recurved on dorsal side, straight on ventral; periphery subacute; aperture small slit on inner edge of final chamber on ventral side.

Trochammina globigeriniformis (Parker and Jones, 1865)

Plate 3, figures 7a, b

Lituola nautiloidea var. *globigeriniformis* PARKER and JONES, 1865, p. 40.7, Pl. 15, fig. 46,47.

Trochammina cf. *globigeriniformis* (Parker and Jones, 1865). SCHRÖDER, 1986, p. 52, Pl. 19, fig. 5-8.

Description: test free, trochospiral, varying from depressed to slightly conical; wall medium to coarsely arenaceous with finer grained matrix; 2 or 3 whorls; chambers rapidly increasing in size; periphery rounded; aperture simple at inner margin on umbilical side of last chamber opening into narrow umbilicus.

Trochammina grisea Earland, 1934

Trochammina grisea EARLAND, 1934, p. 100, Pl. 3, fig. 35-37.

Description: test free, large, trochospiral; wall agglutinated, fine, smooth, unpolished; 3 whorls with 6 chambers each on dorsal side, only 6 last chambers visible on umbilical side, very slightly inflated; dorsal side flattened, umbilical side deeply depressed at umbilicus; sutures on dorsal side straight and distinct, slightly depressed, sutures more depressed on umbilical side; periphery round, slightly lobulate at last few chambers; aperture a narrow slit on inner apertural face of last chamber.

Trochammina inflata (Montagu, 1808)

Plate 2, figures 2a, b

Nautilus inflatus MONTAGU, 1808, p. 81, Pl. 18, fig. 3

Trochammina inflata (Montagu, 1808). MURRAY, 1971, p. 35, Pl. 10, fig. 3-6; PATTERSON, 1990, p. 241, Pl. 1, fig. 8-10.

Description: test free, trochospiral; wall very finely arenaceous, very smoothly finished; 2 or 3 whorls, with 4 to 5 chambers in last whorl; chambers extremely inflated; periphery rounded; sutures distinct but only slightly depressed, nearly radial; aperture a narrow slit on ventral side, at base of last-formed chamber.

Trochammina nana (Brady, 1881)

Plate 2, figures 5a, b

Haplophragmium nana BRADY, 1881, p. 50; BRADY, 1884, p. 311, pl. 35, fig. 6-8; *Trochammina nana* (Brady, 1881). LOEBLICH and TAPPAN, 1953, p. 50, Pl. 8, fig. 5; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 4, Pl. 1, fig. 1-3.

Description: test free, trochospiral, with spiral side almost flattened and umbilical side more convex; wall agglutinated, opaque, of medium-size grains, with some larger clear quartz grains, quite smooth; lobulate periphery; two-and-one-half whorls, all chambers visible on spiral side, only final 6 or 7 visible on umbilical side; chambers somewhat inflated; sutures distinct, nearly straight and radiate ventrally, curving backwards to periphery on dorsal side; aperture low interiomarginal arch extending into very open umbilicus.

Trochammina nitida Brady, 1881

Plate 3, figures 1a, b

Trochammina nitida BRADY, 1881, p. 52, figure in Brady, 1884, Pl. 41, fig. 5, 6; SNYDER, HALE and KONTROVITZ, 1990, p. 277, Pl. 7, fig. 3.

Description: test free, low trochospiral, compressed; wall agglutinated, thin and fragile; 2 or 3 whorls on dorsal side, final whorl with 9 chambers, increasing rapidly in size as added; dorsal side flat, umbilical side convex, somewhat excavated at umbilicus; periphery rounded, slightly depressed at sutures; aperture a curved or angled slit, beginning at base of apertural face in equatorial position and curving openly upward onto umbilical side of chamber.

Trochammina ochracea (Williamson, 1858)

Plate 3, figures 3a-c

Rotalina ochracea WILLIAMSON, 1858, p. 55, Pl. 5, fig. 113.

Lepidodeuterammina ochracea (Williamson, 1858). LOEBLICH and TAPPAN, 1987, Pl. 135, fig. 10-14.

Trochammina ochracea (Williamson, 1858). MURRAY, 1971, p. 37, Pl. 11, fig. 1-5; ALVES MARTINS and RUIVO DRAGÃO GOMES, 2004, p. 29, fig. 2.12.

Description: test free, trochospiral, depressed; wall agglutinated; two-and-one-half whorls in dorsal side, with 8 or 9 chambers each, filled with dark organic matter on umbilical side; slightly convex on dorsal side, correspondingly concave on ventral side; periphery round, very slightly lobulate at last chambers; sutures sometimes raised, arcuate, flexuous and very prominent; aperture a peripheral interiomarginal arch, secondary umbilical apertures at umbilical inflated portions of chambers.

Trochammina pacifica Cushman, 1925

Plate 3, figures 5a-d

Trochammina pacifica CUSHMAN, 1925, p. 39, Pl.6, fig. 3; PATTERSON, 1990, p. 240, Pl. 1, fig. 5-7; SNYDER, HALE and KONTROVITZ, 1990, p. 273, Pl. 5, fig. 1; BLAIS, 1995, p. 93, Pl. 2.2, fig. 7-8.

Description: test free, trochospiral; wall coarsely arenaceous, smoothly finished; 2 or 3 whorls, with 4 to 5 chambers in last whorl; chambers extremely inflated; periphery rounded; sutures distinct but only slightly depressed, nearly radial; aperture a narrow slit on ventral side, at base of last-formed chamber.

Trochammina rotaliformis Heron-Allen and Earland, 1911

Plate 3, figures 6a, b

Trochammina rotaliformis HERON-ALLEN and EARLAND, 1911, p. 309; LOEBLICH and TAPPAN, 1953, p. 51, Pl. 8, fig. 6-9; MURRAY, 1971, p. 39, Pl. 12, fig. 1-5; BLAIS, 1995, p. 93, Pl. 2-3, fig. 1-3.

Description: test free, trochospiral; wall agglutinated, imperforate; 20 elongated chambers arranged in 3 whorls on dorsal side, 5 chambers broadly triangular on umbilical side; strongly convex on dorsal side, shallow-concave on umbilical side;

periphery rounded, slightly lobulate; sutures not well defined, more depressed on umbilical side; umbilical depression start-shaped, open and deep with 5 arms; primary aperture interiomarginal extraumbilical, secondary posterior aperture umbilical-sutural.

Trochammina squamata Jones and Parker, 1860

Plate 3, figures 2a, b

Trochammina squamata JONES and PARKER, 1860, fig. in HEDLEY, HURDLE and BURDETT, 1964, p. 422, fig. 1, p. 424, fig. 1-3.

Trochammina astrifica Rhumbler, 1938. HÖGLUND, 1947, p. 206, Pl. 15, fig. 2.

Trochammina squamata Jones and Parker, 1860. SNYDER, HALE and KONTROVITZ, 1990, p. 279, Pl. 8, fig. 1.

Description: test free, small, low trochoidal, excavated on umbilical side; wall finely arenaceous, with occasional larger grains, smoothly finished; periphery angular in outline, slightly lobulate; chambers not inflated, lunate shaped; 2 whorls visible on spiral side; sutures distinct, apparently flush with surface of test, visible on spiral side as dark brown curved backwards lines; aperture a narrow slit at inner margin of umbilical side of last chamber.

Superfamily VERNEULINACEA Cushman, 1911

Family VERNEULINIDAE Cushman, 1911

Subfamily VERNEULININAE Cushman, 1911

Genus *Gaudryina* d'Orbigny, 1939

Gaudryina arenaria Galloway and Wissler

Plate 4, figure 1

Gaudryina arenaria GALLOWAY and WISSLER, 1927, p. 68, Pl. 11, fig. 5; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 5, Pl. 1, fig. 6,7.

Description: test free, elongate, of equal with for much of the test length, tapers to base; wall agglutinated, finely perforate, opaque, surface roughened; chambers initially triserial and triangular in cross-section, then become biserial and slightly inflated; sutures indistinct in triserial section, become depressed in biserial portion; aperture arched at base of final chamber.

Superfamily TEXTULARIACEA Ehrenberg, 1838

Family EGGERELLIDAE Cushman, 1937

Subfamily EGGERELLINAE Cushman, 1937

Genus *Eggerella* Cushman, 1935

Eggerella advena (Cushman, 1922)

Plate 4, figures 4a-d

Verneuilina advena CUSHMAN, 1922, p.141.

Eggerella advena (Cushman, 1922). LOEBLICH and TAPPAN, 1953, p. 36, Pl. 3, fig. 8-10; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 5, Pl. 28, fig. 6.

Description: test free, elongate, sharply tapering, early portion with 4 to 5 chambers in a whorl, later portion triserial; wall finely agglutinated with occasional larger grains; chambers numerous, low and broad in early portion, increase in relative height as added, those of final whorl approximately equal in height and breadth; sutures distinct and depressed; aperture small, central, low arch at base of final chamber.

Eggerella belizensis n. sp.

Plate 4, figures 5a-d

Eggerella advena (Cushman, 1922). RESIG, 1963, p. 125, fig. 2.

Diagnosis: a species of *Eggerella* with triangular cross-section and inflated last chambers.

Description: test free, elongate, sharply tapering, early portion with 4 to 5 chambers in a whorl, later portion triserial, triangular in cross-section; wall finely agglutinated with occasional larger grains; normally 4 to 5 whorls; chambers numerous, low and broad in early portion, increasing slowly in relative height as added, normally three chambers in final whorl, very inflated and extending outwards of the axis of the test, giving the test a triangular outline in apertural view and an almost flat apertural face; sides straight, except for sutures, increasing at 25° from the axis; sutures distinct and depressed; aperture small, central, low arch at base of final chamber, sometimes with a narrow lip.

Etymology: from Belize Inlet, British Columbia, Canada, and *–ensis*, denoting place, locality.

Types and occurrences: holotype collected from freeze core FC04, collected from Belize Inlet in the Seymour-Belize Inlet Complex, in the coast of British Columbia, 51°7.90'N, 127°9.02'W, at a depth of 274 m.

Remarks: *Eggerella belizensis* appears together with *E. advena* (Cushman), although the latter is easily differentiated by the tapering of the final chambers and the more elongated test, as well as by the last chambers being equal in height and width, while the ones of *E. belizensis* are more inflated and shorter. The test of *E. advena* is narrower, with a smaller angle with respect to the longitudinal axis. *Eggerella belizensis* is most similar to *Eggerella scabra* (Williamson, 1858), a species known from European waters; however, it is differentiated by the more elongated test shape and globular chambers of the latter. *Eggerella belizensis* has been described from the shelf of Washington State as a short morphotype of *Eggerella advena* present in deep waters (Resig, 1963). Harmon (1972) described, but did not illustrate, two morphotypes of *E. advena*, one of which seems to correspond with *E. belizensis*. Members of *E. belizensis* and *E. advena* found within the SBIC have the same size, indicating that *E. belizensis* is not a juvenile form.

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily TEXTULARIINAE Ehrenberg, 1838

Genus *Textularia* Defrance, 1824

Textularia earlandi Parker, 1952

Plate 4, figures 2a, b

Textularia earlandi PARKER, 1952, new name for *Textularia tenuissima* Earland, 1933, p. 95, Pl. 3, fig. 21-40; MURRAY, 1971, p. 33, Pl. 9, fig. 1-5; BLAIS, 1995, p. 92, Pl. 2-2, fig. 1

Description: test minute, very elongate, biserial, straight or slightly curved, oval in section, tapering very gradually to the oral, thickest portion; wall agglutinated, thin, smooth, with little sign of cement; periphery straight in first half of test, then slightly lobulate, rounded throughout; chambers very numerous, distinct, regularly increasing in size and thickness, finally becoming slightly inflated; sutures distinct, depressed; aperture an interiomarginal arch, distinct.

Suborder MILIOLINA Delage and Hérouard, 1896

Superfamily CORNUSPIRACEA Schultze, 1854

Family HAUERINIDAE Schwager, 1876

Subfamily HAUERININAE Schwager, 1876

Genus *Quinqueloculina* d'Orbigny, 1926

Quinqueloculina sp.

Description: test ovate in outline; wall calcareous, imperforate, porcelanous; aperture ovate, flush with surface; chambers quinqueloculine, one-half coil in length, five chambers visible from exterior.

Remarks: the specimens were too badly preserved to identify to species level.

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus *Dentalina* Risso, 1826

Dentalina ittai Loeblich and Tappan, 1953

Plate 5, figures 1a, b

Dentalina ittai LOEBLICH and TAPPAN, 1953, p. 56, Pl. 10, fig. 10-12; RODRIGUES, 1980, p. 150, Pl. 3-7, fig. 6.

Description: test free, narrow, elongate, arcuate; 2 to 6 elliptical chambers, nearly equal in diameter, slightly overlapping; sutures distinct, constricted, straight; wall calcareous, finely perforate, translucent, so that neck and aperture of earlier chambers may be seen through wall of following chamber, surface smooth and unornamented; aperture radiate, terminal and central in position, very slightly produced.

Suborder LAGENINA Delage and Hérouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family LAGENIDAE Reuss, 1862

Genus *Hyalinonetrion* Patterson and Richardson, 1988

Hyalinonetrion dentaliforme (Bagg, 1912)

Plate 5, figure 10

Lagena dentaliformis BAGG, 1912, p. 45, Pl. 13, fig. 1,2.

Hyalinonetrion dentaliforme (Bagg, 1912). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 8, Pl. 2, fig. 9.

Description: test free, large, elongate, circular in cross-section, tapers at ends; wall calcareous, hyaline, smooth, finely perforate, although pores do not penetrate outer wall; aperture small and circular with phialine lip.

Genus *Lagena* Walker and Jacob, 1798

Lagena laevis (Montagu, 1803)

Plate 5, figures 3a, b

Vermiculum leave MONTAGU, 1803, p. 524.

Lagena laevis (Montagu, 1803). LOEBLICH and TAPPAN, 1953, p. 61, Pl. 11, fig. 5-8; MURRAY, 1971, p. 83, Pl. 32, fig. 6, 7.

Description: test free, unilocular, flask-shaped, somewhat elongate, widest slightly below midportion of test, base rounded; wall calcareous, hyaline,, finely perforate, surface smooth except occasionally very slightly and finely hispid at base, but without distinct spines; upper portion of test tapering gradually to very elongate and slender neck; rounded aperture at top of neck.

Lagena meridionalis Wiesner, 1931

Plate 5, figures 4a, b

Lagena gracilis var. *meridionalis* Wiesner, 1931, p. 117, Pl. 18, fig. 211

Lagena meridionalis Wiesner, 1931. TODD and LOW, 1967, p. 24, Pl. 3, fig. 21.

Description: test free, unilocular, minute, flask-shaped, wider near rounded base, tapering into long, slender neck; wall calcareous, hyaline, finely perforate, surface ornamented with longitudinal costae, of which every second one is shorter, stopping at the base of the neck, the long costae extend onto neck; aperture simple, terminal, rounded.

Lagena parri Loeblich and Tappan, 1953

Lagena laevis (Montagu) var. *baggi* CUSHMAN and GRAY, 1946, p. 18, Pl. 3, fig. 26, 27.

Lagena parri LOEBLICH and TAPPAN, 1953, p. 64, Pl. 11, fig. 11-13.

Description: test free, unilocular, flask-shaped to ovate, widest in lower half of test, with single distinct basal spine; long, very slender neck; wall calcareous, hyaline, finely perforate, smooth; aperture terminal at top of delicate neck.

Lagena semilineata Wright, 1886

Plate 5, figures 5a, b

Lagena semilineata WRIGHT, 1886, p. 320, Pl. 26, fig. 7; LOEBLICH and TAPPAN, 1953, p. 65, Pl. 11, fig. 14-22.

Description: test free, unilocular, flask-shaped, widest near apiculate base, somewhat tapered at upper portion and grading into very long, slender, delicate neck; wall calcareous, hyaline, finely perforate, upper one-half to two-thirds of test is smooth, lower portion ornamented with fine costae, which double in number by intercalation a short distance from the base, in occasional specimens intercalary costae do not develop; delicate basal spine of about one-half the diameter of neck, sometimes broken; neck long, slender, length about two-thirds of chamber; aperture terminal at end of neck, surrounded by slight lip.

Genus *Procerolagena* Puri, 1953

Procerolagena cf. *amphora* (Reuss, 1862)

Plate 5, figures 9a, b

Lagena amphora REUSS, 1862, p. 330, Pl. 4, fig. 57; TODD and LOW, 1967, p. 23.

Description: test free, unilocular, big, amphora-shaped, elongate, tapering into long, slender neck; wall calcareous, hyaline, finely perforate, surface ornamented with thick, longitudinal, plate-like costae that extend onto neck; aperture simple, terminal, rounded, with phialine lip.

Procerolagena gracilis (Williamson, 1848)

Plate 5, figure 7

Lagena gracilis WILLIAMSON, 1848, p. 13, Pl. 1, fig. 5

Procerolagena gracilis (Williamson, 1848). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 9, Pl. 6, fig. 1.

Description: test free, unilocular, elongate, circular in cross-section, widest near midpoint; wall calcareous, hyaline; 16 to 20 discontinuous and occasionally anastomosing longitudinal costae that extend from base to neck, in some specimens costae unite to form an elongate process in aboral region; neck narrow and elongate, comprises less than one-half of test length; aperture small and circular with phialine lip.

Procerolagena mollis (Cushman, 1944)

Plate 5, figure 6

Lagena gracillima (Seguenza) var. *mollis* CUSHMAN, 1944, p. 21, Pl. 3, fig. 3.

Lagena mollis (Cushman, 1944). LOEBLICH and TAPPAN, 1953, p. 63, Pl. 11, fig. 25-27.

Description: test free, unilocular, elongate-fusiform, with basal spine and extremely long and slender neck at opposite end, sides nearly parallel over central portion of test; wall calcareous, hyaline, finely perforate, ornamented with numerous very fine longitudinal ribs which die out at beginning of neck; aperture terminal, surrounded by flared lip, at end of long, slender and smooth neck.

Procerolagena wiesneri (Parr, 1950)

Plate 5, figure 9

Lagena striata (Montagu) var. *wiesneri* PARR, 1950, p. 301.

Procerolagena wiesneri (Parr, 1950). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 10, Pl. 5, fig. 5,6.

Description: test free, unilocular, subglobular, broadest near midpoint; wall calcareous, hyaline, surface smooth, finely perforated between costae; on average 28 delicate costae extending from base, every sixth terminates at aperture, 3 intervening costae terminate at base of neck, separated by 2 costae of intermediate length which terminate halfway up to neck; no tendency for costae to form an elongate aboral process; aperture round with a phialine lip.

Genus *Pygmaeoseistron* Patterson and Richardson, 1988

Pygmaeoseistron hispidulum (Cushman, 1913)

Plate 5, figures 2a, b

Lagena hispidula CUSHMAN, 1913, p. 14, Pl. 5, fig. 2,3.

Pygmaeoseistron hispidulum (Cushman, 1913). PATTERSON and RICHARDSON, 1988, p. 243, 245, fig. 7-10; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 10, Pl. 6, fig. 2,3.

Description: test free, unilocular, elongate, circular in section; wall calcareous, translucent, surface coarse, imperforate; aperture small, circular, with phialine lip, terminal on narrow neck.

Family ELLIPSOLAGENIDAE Silvestri, 1923

Subfamily OOLININAE Loeblich and Tappan, 1961

Genus *Favulina* Patterson and Richardson, 1988

Favulina epibathra Patterson and Richardson, 1988

Plate 6, figures 1a-c

Favulina epibathra PATTERSON and RICHARDSON, 1988, p. 250, fig. 30, 31.

Description: test free, unilocular, subspherical; wall calcareous, hyaline; surface ornamented with 8 to 10 high, stout longitudinal costae, and discontinuous transverse costae, about one-half the height of longidudinal costae, so pattern on test is rectangular; longitudinal costae bifurcate near apex of text to form a single row of hexagonal reticulations; aperture small, round, with phialine lip, may have entosolenian tube.

Favulina melo (d'Orbigny, 1839)

Plate 6, figures 2a, b

Oolina melo D'ORBIGNY, 1839, p. 20, Pl. 5, fig. 9; LOEBLICH and TAPPAN, 1953, p. 71, Pl. 12, fig. 8-15; MURRAY, 1971, p. 93, Pl. 37, fig. 4-6.

Favulina melo (d'Orbigny, 1839). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 11, Pl. 6, fig. 6-9.

Description: test free, unilocular, globular, circular in section; wall calcareous, hyaline, fine perforations do not penetrate outer wall; 9 to 14 longitudinal costae extend from base to aperture; numerous downward curved cross struts unite longitudinal costae giving squamiform appearance to test surface; aperture small and circular, phialine lip; entosolenian tube short and straight.

Genus *Homalohedra* Patterson and Richardson, 1987

Homalohedra apiopleura (Loeblich and Tappan, 1953)

Plate 6, figures 3a-c

Lagena apiopleura LOEBLICH and TAPPAN, 1953, p. 59, Pl. 10, fig. 14, 15.

Homalohedra apiopleura (Loeblich and Tappan, 1953). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 11, Pl. 28, fig. 4,5.

Description: test free, unilocular, rare twins occur, ovate to pyriform, circular in section, base rounded; wall calcareous, hyaline, finely perforate, translucent; 14 longitudinal costae merge to 7 on upper part of test; collar terminates at base of apertural neck, surface smooth or may have costae with slight bifurcations; aperture small, circular, at end of short smooth neck.

Homalohedra borealis (Loeblich and Tappan, 1954)

Plate 6, figures 4a-c

Oolina costata (Williamson, 1858). LOEBLICH and TAPPAN, 1953, p. 68, Pl. 13, fig. 4-6, new name for *Entosolenia costata* Williamson, 1858, p. 9, Pl. 1, fig. 18.

Homalohedra borealis (Loeblich and Tappan, 1954). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 11, Pl. 7, fig. 1,2.

Description: test free, unilocular, globular, circular in section; wall calcareous, hyaline, finely perforate but pores do not penetrate outer surface; 11 to 17 narrow longitudinal ribs extend from circular basal ring and grade into smooth area surrounding aperture; aperture terminal and circular with slightly produced rim; entosolenian tube short and straight.

Homalohedra guntheri (Earland, 1934)

Plate 6, figures 5a, b, 6a-c

Lagena guntheri EARLAND, 1934, p. 151, Pl. 6, fig. 53, 54.

Homalohedra guntheri (Earland, 1934). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 11, Pl. 28, fig. 1,2.

Description: test free, unilocular, pyriform, broadest near midpoint, circular in section; wall calcareous, translucent, imperforate; 6 to 9 longitudinal costae extend from basal ring, then bifurcate and rejoin forming hexagonal pits encircling upper part of test; aperture terminal, small, and round; entosolenian tube short and straight.

Remarks: there is a variation in the number of costae present in this species, going from 9 to 14.

Subfamily ELLIPSOLAGENINAE Silvestri, 1923

Genus *Fissurina* Reuss, 1850

Fissurina cucurbitasema Loeblich and Tappan, 1953

Plate 7, figures 3a-c

Fissurina cucurbitasema LOEBLICH and TAPPAN, 1953, p. 76, Pl. 14, fig. 10, 11.

Description: test free, unilocular, ovate, depressed in cross section, with seed-like outline, occasionally very slightly produced at the base; wall calcareous, translucent, finely perforate, with thin marginal keel, surface smooth; aperture terminal, ovate, with slight lip, entosolenian tube extending about one-half the length of the test.

Fissurina eburnea (Buchner, 1940)

Plate 7, figures 1a, b, 9

Lagena eburnea BUCHNER, 1940, p. 458, Pl. 9, fig. 146, 147.

Fissurina eburnea (Buchner, 1940). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 12, Pl. 8, fig. 3,4.

Description: test free, unilocular, compressed, circular in side view; marginal carina completely encircling test; wall calcareous, hyaline, smooth, finely perforate; aperture circular at centre of fissurine opening; entosolenian tube short and straight.

Fissurina lucida (Williamson, 1848)

Plate 7, figure 2a, b

Fissurina lucida (Williamson, 1848). LOEBLICH and TAPPAN, 1953, p. 76, Pl. 14, fig. 4; MURRAY, 1971, p. 97, Pl. 39, fig. 1-3; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 12, Pl. 8, fig. 5,6.

Description: test free, unilocular, slightly elongated, compressed in section; wall calcareous, hyaline, smooth; broad horseshoe-shaped white band follows the margin except in the upper part of test; test entirely encircled by broad and thick marginal carina; aperture slightly produced, fissurine and very elongate, within marginal carina; entosolenian tube short and straight.

Fissurina quadrata (Williamson, 1858)

Plate 7, figure 6

Entosolenia marginata (Montagu) var. *quadrata* WILLIAMSON, 1858, p. 11, Pl. 1, fig, 27, 28.

Fissurina quadrata (Williamson, 1858). LOEBLICH and TAPPAN, 1994, p. 90, Pl. 155, fig. 1-6

Description: test free, unilocular, compressed in section, with the shape of a parallelogram; wall calcareous, hyaline, smooth; test encircled by thin marginal carina; aperture slightly produced, fissurine and very elongate, within marginal carina; entosolenian tube short and straight.

Fissurina vitreola (Buchner, 1940)

Lagena vitreola BUCHNER, 1940, p. 477, Pl. 13, fig. 256-258.

Fissurina vitreola (Buchner, 1940). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 12, Pl. 9, fig. 1-5.

Description: test free, unilocular, oval in side view, compressed; wall calcareous, hyaline, smooth, fine pores do not penetrate outer wall; 2 while longitudinal bands near margins, may be connected at base forming horseshoe-shaped structure; aperture an elongate fissurine slit on slight extension of test; entosolenian tube short and straight.

Genus *Palliolatella* Patterson and Richardson, 1987

Palliolatella frangens Buchner, 1940

Plate 7, figure 4

Lagena frangens BUCHNER, 1940, p. 504, Pl. 19, fig. 407-409.

Palliolatella frangens (Buchner, 1940). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 12, Pl. 10, fig. 3,4.

Description: test free, unilocular, oblong, compressed in cross-section; wall calcareous, hyaline, smooth, finely perforate; wide marginal carina completely encircles test forming a very slight recurved lip around the aperture; 2 high, thin longitudinal costae nearly encircle each test face; aperture a fissurine slit, entosolenian tube attached to one wall and terminating half way down test wall.

Palliolatella immemora Patterson, 1990

Plate 7, figures 5a-c

Lagena neglecta BUCHNER, 1940, p. 503, Pl. 19, fig. 405 (not *Lagena neglecta* Buchner, 1940, p. 463, Pl. 11, fig. 173-178).

Palliolatella immemora PATTERSON, 1990, p. 686, fig. 5; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 13, Pl. 10, fig. 1,2.

Description: test free, unilocular, compressed, oblong in side view; wall calcareous, hyaline, smooth, finely perforate; thin marginal carina completely encircles test, becomes much wider on short neck; outer margin of carina also thickens on neck, forms recurved area around aperture; aperture small and circular within narrow fissurine slit; entosolenian tube attached to one wall and terminates near test base.

Subfamily PARAFISSURININAE Jones, 1984

Genus *Parafissurina* Parr, 1947

Parafissurina semicarinata (Buchner, 1940)

Parafissurina lateralis (Cushman) forma *semicarinata* BUCHNER, 1940, p. 520, Pl. 23, fig. 493-494.

Parafissurina semicarinata (Buchner, 1940). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 13, Pl. 10, fig. 5-8.

Description: test free, unilocular, oblong, compressed in section; wall calcareous, hyaline, smooth, finely perforate; narrow lateral carina encircles test; aperture arched; subterminal slit at one side of test with overhanging hood-like extension of opposite wall; entosolenian tube attached to overhanging wall and terminates halfway down test.

Family GLANDULINIDAE Reuss, 1860

Subfamily GLANDULININAE Reuss, 1860

Genus *Laryngosigma* Loeblich and Tappan, 1953

Laryngosigma trilocularis (Bagg, 1912)

Plate 7, figures 7a, b

Polymorphina trilocularis BAGG, 1912, p. 75, Pl. 20, fig. 15-18.

Laryngosigma trilocularis (Bagg, 1912). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 13, Pl. 12, fig. 7,8.

Description: test free, elongate, compressed; wall calcareous, hyaline, smooth, finely perforate; chambers 3 to 4 pairs, high, narrow, biserial, added slightly less than 180° apart, form a sigmoid series; aperture terminal and radiate; entosolenian tube short and straight.

Suborder GLOBIGERININA Delage and Hérouard, 1896

Superfamily GLOBOROTALIACEA Cushman, 1927

Family CANDEINIDAE Cushman, 1927

Subfamily GLOBIGERINITINAE Bermúdez, 1961

Genus *Globigerinita* Brönnimann, 1951

Globigerinita uvula (Ehrenberg, 1861)

Plate 15, figures 1a, b

Pylodexia uvula EHRENBERG, 1861, pp. 276, 277, 308.

Globigerinita uvula (Ehrenberg, 1861). SAITO, THOMPSON and BREGER, 1981, p. 81, Pl. 24.2, fig. 3.

Description: test free, very small, high trochospiral; 3 or 4 whorls with 15 to 20 chambers, 3 or 4 chambers in last whorl; chambers spherical, increasing slowly in size as added, much embracing; sutures distinct; wall calcareous, fragile, translucent, very smooth, finely perforate, non-spinose, slightly pustulate near aperture; aperture interiomarginal, umbilical, a small, low arch.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Subfamily GLOBIGERININAE Carpenter, Parker and Jones, 1862

Genus *Globigerina* d'Orbigny, 1826

Globigerina bulloides d'Orbigny, 1826

Plate 15, figures 2a, b

Globigerina bulloides D'ORBIGNY, 1826, p. 277; MURRAY, 1971, p. 211, Pl. 87, fig. 1-5; SAITO, THOMPSON and BREGER, 1981, p. 40, Pl. 7.1, fig. 1.

Description: test free, size variable, low to medium trochospiral, well lobulate; 2 to two-and-one-half whorls with 8 to 10 chambers, 3 to 5 globular chambers in the last whorl; chambers spherical to slightly ovoid, well separated, size increasing slowly; sutures deep; wall calcareous, uniformly and densely perforated, spines simple and with circular cross-sections; aperture umbilical, interiomarginal, a high, symmetrical arch occasionally with thin rim-like lip.

Globigerina quinqueloba Natland, 1938

Plate 15, figures 3a, b

Globigerina quinqueloba NATLAND, 1938, p. 149, Pl. 6, fig. 7; MURRAY, 1971, p. 217, Pl. 90, fig. 1-5; SAITO, THOMPSON and BREGER, 1981, p. 48, Pl. 10, fig. 1.

Description: test free, small, low trochospiral; two-and-one-half whorls with 15 chambers, 5 chambers in final whorl; chambers subglobular, slightly flattened radially, final chamber of mature specimens typically partially or completely covers umbilicus like a bulla; sutures distinct, slightly incised; wall calcareous, thick, finely perforated, hispid, spinose; aperture umbilical-extraumbilical, interiomarginal, frequently obscured by final chamber with its rim-like basal lip.

Genus *Globigerinoides* Cushman, 1927

Globigerinoides cyclostomus (Galloway and Wissler, 1927)

Plate 15, figures 4a, b

Globigerina cyclostoma GALLOWAY and WISSLER, 1927, p. 42, Pl. 7, fig. 8, 9.

Globigerinoides cyclostomus (Galloway and Wissler, 1927). SAITO, THOMPSON and BREGER, 1981, p. 60, Pl. 15, fig. 2.

Description: test free, small, low to medium trochospiral; 3 whorls with 11 chambers, 3 chambers on final whorl; chambers subspherical to ovoid, increasing moderately in size but closely packed giving the test a rectangular outline; wall calcareous, coarsely perforated, spinose; spines simple rounded cross sections, in simple raised bases;

primary aperture umbilical, small oval opening, secondary aperture(s) on spiral side at intersection of spiral and intercameral sutures.

Suborder ROTALIINA Delage and Hérouard, 1896

Superfamily BOLIVINACEA Glaessner, 1937

Family BOLIVINIDAE Glaessner, 1937

Genus *Bolivina* d'Orbigny, 1839

Bolivina decussata Brady, 1881

Plate 8, figures 1a, b

Bulimina (Bolivina) decussata BRADY, 1881, p. 58, fig. in Brady, 1884, p. 423, Pl. 53, fig. 12, 13.

Bolivina decussata Brady, 1881. PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 14, Pl. 11, fig. 5,6.

Description: test free, elongate, very compressed, of nearly equal thickness throughout; wall calcareous, translucent, finely perforate although perforations commonly obscured by coarse reticulations formed by secondary calcification; chambers 8 to 10 pairs, rapidly expand from subacute initial end; sutures distinct, slightly curved at about 45° to longitudinal axis; aperture loop shaped at top of final formed chamber, with internal toothplate attached to one side.

Bolivina minuta Natland, 1938

Plate 8, figures 2a, b

Bolivina minuta NATLAND, 1938, p. 146, Pl. 5, fig. 10.

Description: test free, very compressed, sides nearly parallel, periphery angled, flattened, forming a slightly concave side; wall calcareous, thin, finely perforated; 8

to 10 pairs of chambers biserially arranged, rapidly increasing in size; sutures distinct, curved, quite oblique; aperture a loop-shaped opening in top of last chamber.

Genus *Bolivinellina* Saidova, 1975

Bolivinellina pacifica (Cushman and McCulloch, 1942)

Plate 8, figures 4a, b

Bolivina acerosa Cushman var. *pacifica* CUSHMAN and MCCULLOCH, 1942, p. 185, Pl. 21, fig. 2, 3.

Bolivinellina pacifica (Cushman and McCulloch, 1942). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 14, Pl. 13, fig. 1,2.

Description: test free, elongate, compressed, broadest near aperture and tapers to base; wall calcareous, hyaline, smooth, finely perforate; chambers 10 to 13 pairs, biserially arranged, slightly inflated and wider than high, gradually increase in size as added; sutures slightly curved and depressed, about 60° to longitudinal axis; aperture lipped, loop-shaped at base of final formed chamber, with internal toothplate attached to one side.

Superfamily CASSIDULINACEA d'Orbigny, 1939

Family CASSIDULINIDAE d'Orbigny, 1939

Subfamily CASSIDULININAE d'Orbigny, 1939

Genus *Cassidulina* d'Orbigny, 1826

Cassidulina crassa d'Orbigny, 1839

Plate 8, figures 6a-d

Cassidulina crassa D'ORBIGNY, 1839, p. 56, Pl. 7, fig. 18-20.

Cassidulina crassa d'Orbigny, 1839. ALVES MARTINS and RUIVO DRAGÃO GOMES, 2004, p. 118, fig. 2.67.

Description: test free, circular to oval, biconvex; periphery slightly rounded; chambers slightly inflated, last chamber rectangular to trapezoidal; sutures slightly depressed; wall calcareous, delicate, translucent, shiny, finely perforated; aperture a simple slit in the middle of a central, triangular depression of the basal suture of the last chamber, partially closed by an apertural plate.

Remarks: *C. crassa* differs from *C. reniforme* NØrvang in the more globular test, slightly inflated chambers and depressed sutures.

Genus *Islandiella* NØrvang, 1959

Islandiella helenae Feyling-Hanssen and Buzas, 1976

Plate 8, figures 5a-c

Islandiella helenae FEYLING-HANSSEN and BUZAS, 1976, p. 155, fig. 1-4; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 15, Pl. 31, fig. 1-3.

Description: test free, biconvex with a sub acutely thickened peripheral margin, lenticular; wall calcareous, perforate, translucent to hyaline, very distinctly radial when viewed in polarized light; about 5 pairs of chambers in the final whorl, biserially arranged, evolutely coiled so that the previous whorls are seen through the thick, clear shell material of the umbilical region, chambers felly bean-shaped, oriented at 45° to umbilicus giving them the appearance of leaning into side of previous chamber; sutures distinct, thickened, flush with the surface, outlining the chambers; aperture a broad short slit paralleling the periphery and with a free apertural tongue projecting out of it.

Superfamily TURRILINACEA Cushman, 1927

Family STAINFORTHIIDAE Reiss, 1963

Genus *Stainforthia* Hofker, 1956

Stainforthia feylingi Knudsen and Seidenkrantz, 1994

Plate 8, figures 3a-c

Stainforthia feylingi KNUDSEN and SEIDENKRANTZ, 1994, Pl. 1, fig. 1-32; Pl. 2, fig. 1-6, 8; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 16, Pl. 14, fig. 5,6.

Description: test free, elongate, streamlined, fusiform, compressed and ovate in cross-section, broadest often near the middle; wall calcareous, hyaline, smooth, finely perforate; chambers slightly inflated, approximately 7 to 11 pairs, triserially arranged in early stages, later biserial and often slightly twisted; sutures depressed and slightly curved at 45° to 50° to longitudinal axis; aperture depressed and loop-shaped at base of final chamber, with narrow incurved lip at one side and broad toothplate at opposite side bending under lip and partially closing opening; toothplate with serrated free folded portion, lower portion attached to preceding chamber wall.

Superfamily BULIMINACEA Jones, 1875

Family BULIMINIDAE Jones, 1875

Genus *Protoglobulimina* Hofker, 1951

Protoglobulimina pupoides (d'Orbigny, 1846)

Plate 9, figures 1a-c

Bulimina pupoides D'ORBIGNY, 1846, p. 185, Pl. 11, fig. 11, 12.

Protoglobulimina pupoides (d'Orbigny, 1846). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 17, Pl. 17, fig. 7,8.

Description: test free, elongate, broadest near base, almost circular in cross-section; wall calcareous, hyaline, smooth, finely perforate; chambers inflated, much higher than wide and strongly overlapping, triserially arranged, in 2 or 3 whorls; sutures depressed; aperture elongate, extends up from base of final chamber; successive chambers connected by an internal toothplate; toothplate final tip can be seen in aperture.

Family BULIMINELLA Cushman, 1911

Genus *Buliminella* Cushman, 1911

Buliminella elegantissima (d'Orbigny, 1839)

Plate 9, figures 2a-d

Bulimina elegantissima D'ORBIGNY, 1839, p. 51, Pl. 7, fig. 13, 14.

Buliminella elegantissima (d'Orbigny, 1839). MURRAY, 1971, p. 105, Pl. 42, fig. 1-4; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 17, Pl. 16, fig. 6,7.

Description: test free, elongate, with a high and close spiral formed by numerous high narrow chambers in 3 to 4 whorls; wall calcareous, hyaline, smooth, finely perforate; aperture loop-shaped with internal toothplate connecting aperture with foramen of previous chamber.

Subfamily UVIGERININAE Haeckel, 1894

Genus *Euuvigerina* Thalmann, 1952

Euuvigerina aculeata (d'Orbigny, 1846)

Plate 9, figures 3a-c

Uvigerina aculeata D'ORBIGNY, 1846, p. 191, Pl. 11, fig. 27, 28.

Euuvigerina aculeata (d'Orbigny, 1846). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 17, Pl. 16, fig. 1-3.

Description: test free, elongated, rounded in section; wall calcareous, hyaline, surface finely perforate and covered with numerous cone-shaped spines occasionally uniting to form discontinuous rib-like elements; 4 to 5 whorls of inflated, triserially arranged chambers become cuneate in later whorls; aperture small and circular within a phialine lip at top of tubular neck; toothplate a narrow twisted ribbon extending from the aperture to fasten against the previous foramen.

Euuvigerina peregrina (Cushman, 1923)

Plate 9, figures 5a-d

Uvigerina peregrina CUSHMAN, 1923, p. 166, Pl. 42, fig. 7-10; MURRAY, 1971, p. 121, Pl. 50, fig. 1-7;

Euuvigerina peregrina (Cushman, 1923). ALVES MARTINS and RUIVO DRAGÃO GOMES, 2004, p. 162, fig. 2.93, 2.94.

Description: test free, elongate, triserial to biserial in last chambers; chambers numerous, distinct, inflated; sutures depressed; wall calcareous, perforate, surface with numerous longitudinal costae, generally discontinous, disrupted by sutures; space between costae presents little pustules; aperture terminal, rounded, on tubular neck, bordered with phialine lip, narrow ribbon like and twisted toothplate extends within from aperture to fasten against previous foramen.

Genus *Neouvigerina* Thalmann, 1952

Neouvigerina cf. *proboscidea* (Schwager, 1866)

Uvigerina proboscidea SCHWAGER, 1866, p. 250, Pl. 7, fig. 96.

Neouvigerina proboscidea (Schwager, 1866). NARAYAN, BARNES and JOHNS, 2005, p. 137, Pl. 5., fig. 20, 21.

Description: test small to medium, stout, one-and-one-and-a-half times as long as wide; 3 to 4 whorls; chambers in early portion triserially arranged, small, closely packed, later portion biserial, much inflated, globular; periphery lobulate; sutures distinct, depressed; wall calcareous, finely perforate, ornamented with numerous fine papillae, appearing slightly spinose or granular; aperture terminal, rounded, at end of elongate, papilliose neck with phialine lip.

Remarks: the ornamentation in these specimens is much damaged, making it difficult to ascribe them with certainty to this species. However, the overall shape and fainted papillae seem to belong to *N. proboscidea.*

Subfamily ANGULOGERININAE Galloway, 1933

Genus *Angulogerina* Cushman, 1927

Angulogerina fluens Todd, 1947

Plate 9, figures 4a, b

Angulogerina fluens TODD, 1947, in CUSHMAN and MCCULLOCH, 1948, p. 288, Pl. 36, fig. 1; LOEBLICH and TAPPAN, 1953, p. 112, Pl. 20, fig. 10-12; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 18, Pl. 16, fig. 4,5.

Description: test free, elongate, trigonal in cross-section, angles subrounded and carinate; wall calcareous, hyaline, smooth except numerous discontinuous longitudinal costae cross suture lines and extend from base to aperture; chambers arranged in 4 to 5 whorls, initially triserial, become cuneate; sutures depressed and curved; aperture terminal, reniform, produced on very short neck and bordered by pronounced lip; internal toothplate extends from foramen to foramen, externally visible as narrow projection in aperture.

Superfamily DISCORBACEA Ehrenberg, 1838

Family ROSALINIDAE Reiss, 1963

Genus *Gavelinopsis* Hofker, 1951

Gavelinopsis campanulata (Galloway and Wissler, 1927)

Plate 10, figures 1a-c

Globorotalia campanulata GALLOWAY and WISSLER, 1927, p. 58, Pl. 9, fig. 14.

Gavelinopsis campanulata (Galloway and Wissler, 1927). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 18, Pl. 18, fig. 5-7.

Description: test free, plano-convex; wall calcareous, hyaline, smooth; all chambers visible on convex spiral side, only final 6 to 7 of final whorl visible on ventral side; sutures smooth and radiating on spiral side, depressed and slightly curved on ventral side, radiating from open umbilicus with central umbilical plug, often invisible, partially filling gap; aperture an interiomarginal extra umbilical arch with secondary sutural openings at margins of previous chambers.

Genus *Rosalina* d'Orbigny, 1926

Rosalina columbiensis (Cushman, 1925)

Plate 10, figures 2a-c

Discorbis columbiensis CUSHMAN, 1925, p. 43, Pl. 6, fig. 13.

Rosalina columbiensis (Cushman, 1925). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 18, Pl. 19, fig. 1-3.

Description: test free or attached, plano-convex, trochospiral; wall calcareous, hyaline, smooth, finely perforate; chambers irregular in shape and gradually increase in size as added, all visible on spiral side, and only 6 to 7 visible on final whorl around open umbilicus on partially evolute umbilical side; sutures depressed and slightly curved; aperture an interiomarginal arch at base of final chamber, near periphery on umbilical side extending into umbilicus; planktic-stage specimens have large subglobular float chamber completely covering umbilical side.

Superfamily DISCORBINELLACEA Sigal, 1952

Family PSEUDOPARRELLIDAE Voloshinova, 1952

Subfamily PSEUDOPARRELLINAE Voloshinova, 1952

Genus *Epistominella* Husezima and Maruhasi, 1944

Epistominella vitrea Parker, 1953

Plate 10, figures 3a-c

Epistominella vitrea PARKER, 1953, in PARKER, PHLEGER and PEIRSON, 1953, p. 9, Pl. 4, fig. 34-36, 40, 41; MURRAY, 1971, p. 131 Pl. 54, fig. 1-6; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 19, Pl. 20, fig. 3-5.

Description: test free, trochospiral, biconvex, periphery rounded, and slightly lobulate; wall calcareous, hyaline, smooth, finely perforate; test spiral side with all 3 whorls and chambers visible and sutures straight, depressed, and oblique; only final 6 chambers visible on umbilical side with sutures radial and depressed; aperture narrow lipped slit oriented slightly oblique to peripheral margin.

Superfamily PLANORBULINACEA Schwager, 1877

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus *Lobatula* Fleming, 1828

Lobatula fletcheri (Galloway and Wissler, 1927)

Plate 10, figures 4a-c

Cibicides fletcheri GALLOWAY and WISSLER, 1927, p. 64, Pl. 10, fig. 8, 9.

Lobatula fletcheri (Galloway and Wissler, 1927). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 19, Pl. 19, fig. 4-6.

Description: test free, plano-convex, trochospiral with spiral side flattened and umbilical side rounded and convex; wall calcareous, translucent, smooth, coarsely perforate on spiral side; 8 to 9 slightly inflated chambers visible on concave umbilical side; all chambers visible on spiral side with a well developed umbilical boss; sutures slightly curved and depressed; aperture low interiomarginal lipped, may extend along spiral suture on spiral side.

Lobatula lobatula (Walker and Jacob, 1784)

Plate 10, figures 5a-d

Nautilus lobatulus WALKER and JACOB, 1784, p. 20, Pl. 3, fig. 71.

Cibicides lobatulus (Walker and Jacob, 1784). MURRAY, 1971, p. 175, Pl. 73, fig. 1-7.

Lobatula lobatula (Walker and Jacob, 1784). LOEBLICH and TAPPAN, 1987, p. 168, Pl. 637, fig. 10-13; VILLANUEVA GUIMERANS and CERVERA CURRADO, 1999, p. 186, fig. 2.3; ALVES MARTINS and RUIVO DRAGÃO GOMES, 2004, p. 211, fig. 2.126.

Description: test trochospiral, ovate; wall calcareous, coarsely perforate or lacking pores on umbilical side, on spiral side with pores of intermediate size and uniformly distributed; spiral side flat or irregular, umbilical side convex; chambers inflated, 7 or 8 in final whorl, gradually increasing in size as added; periphery acute, carinate; sutures on spiral side slightly raised and imperforate, depressed and slightly backwards on umbilical side; aperture interiomarginal, extraumbilical-equatorial, bordered by protruding rim continuing into spiral supplementary aperture, open in last 1 to 3 chambers.

Lobatula mckannai (Galloway and Wissler, 1927)

Plate 11, figures 1a-c

Cibicides mckannai GALLOWAY and WISSLER, 1927, p. 65, Pl. 10, fig. 5-6.

Lobatula mckannai (Galloway and Wissler, 1927). PATTERSON and KUMAR, 2002, p. 121, Pl. 1, fig. 5; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 19, Pl. 19, fig. 7-9.

Description: test free, plano-convex, trochospiral with flattened spiral side and high convex umbilical side; wall calcareous, translucent, coarsely perforate, especially on umbilical side where has roughened appearance; only final 9 slightly inflated chambers of umbilical side visible; all chambers visible on spiral side; sutures slightly depressed and radiate; aperture low interiomarginal lipped slit which may extend back several chambers on spiral side.

Subfamily STICHOCIBICIDINAE Saidova, 1981

Genus *Dyocibicides* Cushman and Valentine, 1930

Dyocibicides biserialis Cushman and Valentine, 1930

Plate 11, figures 2a, b

Dyocibicides biserialis CUSHMAN and VALENTINE, 1930, p. 31, Pl. 10, fig. 1,2; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 20, Pl. 20, fig. 1,2.

Description: test attached, elongate, trochospiral, with attachment area on spiral side; wall calcareous, translucent, smooth, coarsely perforate; all chambers visible on flattened spiral side; only 7 to 8 slightly inflated chambers visible in final whorl of umbilical side, gradually increasing in size as added; later chambers uncoiled and irregularly biserial, increasing greatly in size as added; sutures depressed and curved; aperture terminal and lipped.

Superfamily NONIONACEA Schultze, 1854

Family NONIONIDAE Schultze, 1854

Subfamily NONIONINAE Schultze, 1854

Genus *Nonionella* Cushman, 1926

Nonionella digitata NØrvang, 1945

Plate 11, figure 5

Nonionella turgida (Williamson) var. *digitata* NØRVANG, 1945, p. 29, fig. 4.

Nonionella digitata NØrvang, 1945. PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 20, Pl. 21, fig. 1-3.

Description: test free, compressed, general outline elongate, elliptical, in low trochospiral coil, periphery rounded; wall calcareous, hyaline, smooth, finely perforate without pustules; spiral side partially evolute around umbonal boss with all chambers visible (about 10), rapidly increasing in size; sutures strongly depressed and slightly curved; umbilical side involute with only 5 to 6 chambers of final whorl visible, flap-like extensions of final chambers subdivided in finger-like projections that cross umbilical regions, obscuring it; aperture small interiomarginal and nearly equatorial arch, extending onto umbilical side.

Nonionella stella Cushman and Moyer, 1930

Plate 11, figures 3a-c

Nonionella miocenica Cushman var. *stella* CUSHMAN and MOYER, 1930, p. 56, Pl. 7, fig. 17.

Nonionella stella Cushman and Moyer, 1930. PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 20, Pl. 22, fig. 1-3.

Description: test free, trochospiral, slightly compressed; wall calcareous, translucent, smooth, finely perforate; 7 to 10 inflated low chambers rapidly increase in size as added; large umbilical flap extends from last chamber and covers umbilical region; all chambers visible on spiral side; aperture low arch extending somewhat onto umbilical side, at base of large flat apertural face.

Nonionella cf. *turgida* (Williamson, 1858)

Plate 11, figure 4

Rotalina turgida WILLIAMSON, 1858, p. 50, Pl. 9, fig. 95-97.

Nonionella turgida (Williamson, 1858). MURRAY, 1971, p. 193, Pl. 81, fig. 1-5.

Nonionella cf. *N. turgida* (Williamson, 1858). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 20, Pl. 23, fig. 8.

Description: test free, compressed, slightly elongated in low trochospiral coil, periphery rounded; all chambers visible on spiral side, partially evolute around umbonate boss; only 9 final chambers visible on umbilical side, extension of final chambers into umbilicus, partially obscuring it; sutures depressed and slightly curved on both sides; wall calcareous, hyaline, smooth, finely perforate; aperture low, interiomarginal, a nearly equatorial arch, extending slightly onto umbilical side.

Remarks: the few specimens recovered were broken in the last chamber, therefore the species is named *N.* cf. *turgida*.

Genus *Nonionellina* Voloshinova, 1958

Nonionellina labradorica (Dawson, 1860)

Plate 11, figures 7a-c

Nonionica scapha var. *labradorica* DAWSON, 1860, p. 191, fig. 4.

Nonion labradoricum (Dawson, 1860). LOEBLICH and TAPPAN, 1953, p. 86, Pl. 17, fig. 1, 2.

Nonionellina labradorica (Dawson, 1860). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 20, Pl. 23, fig. 1,2.

Description: test free, trochospiral in early stage, later nearly planispiral and involute, periphery rounded and slightly lobulate; wall calcareous, hyaline, smooth other than fine pustules clustered in sutural depression and filling umbilicus, finely perforate; 14 chambers visible on both umbilical and spiral sides; sutures strongly depressed and curved; aperture low arched slit at base of final chamber.

Genus *Pseudononion* Asano, 1936

Pseudononion basispinata (Cushman and Moyer, 1930)

Plate 11, figures 6a, b

Nonion pizarrensis Berry var. *basispinata* CUSHMAN and MOYER, 1930, p. 54, Pl. 7, fig. 18.

Pseudononion basispinata (Cushman and Moyer, 1930). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 21, Pl. 23, fig. 3-5.

Description: test free, asymmetric planispiral and involute, compressed; wall calcareous, hyaline, smooth, finely perforate; 10 to 16 slightly inflated low chambers rapidly increasing in size as added; sutures slightly depressed and curved, hispid material found in open umbilicus and along lower parts of sutures on one side, or with an umbilical knob on the other side; aperture narrow, interiomarginal with equatorial opening.

Subfamily ASTRONONIONINAE Saidova, 1981

Genus *Astrononion* Cushman, 1937

Astrononion gallowayi Loeblich and Tappan, 1953

Plate 12, figures 1a-c

Astrononion gallowayi LOEBLICH and TAPPAN, 1953, p. 90, Pl. 17, fig. 4-7; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 21, Pl. 23, fig. 6-7.

Description: test free, planispiral and involute, compressed, periphery rounded and lobulate; wall calcareous, hyaline, with medium sized perforations; 7 to 8 strongly inflated chambers of final whorl visible, increase gradually in size as added; wedge-shaped supplementary chambers surround umbilicus on each side, taper outward to suture about two-thirds the distance to periphery; sutures slightly curved and depressed; aperture low arch at base of final chamber extending on each side toward umbilicus with supplementary opening at outer posterior margin or each of the supplementary chambers.

Family TRICHOHYALIDAE Saidova, 1981

Genus *Buccella* Andersen, 1952

Buccella depressa Andersen, 1952

Plate 12, figures 2a, b

Buccella depressa ANDERSEN, 1952, p. 145, 146, fig. 7, 8; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 22, Pl. 24 fig. 1-3.

Description: test free, trochospiral, roughly biconvex, periphery rounded, lobulate; wall calcareous, hyaline, smooth except concentrations of fine pustules in umbilicus and in narrow bands along sutures, coarsely perforate; two-and-one-half whorls and all chambers visible on slightly convex spiral side; spiral side sutures slightly curved, oblique, and very slightly depressed; only highly inflated final 7 to 9 chambers of final whorl visible on umbilical side and gradually increase in size as added; umbilical side sutures slightly curved and radial; aperture interiomarginal with slit-like supplementary apertures found along posterior margins of chambers on umbilical side.

Buccella frigida (Cushman, 1922)

Plate 12, figures 3a-c

Pulvinulina frigida CUSHMAN, 1922, p. 144; LOEBLICH and TAPPAN, 1953, p. 115, Pl. 22, fig. 2, 3; MURRAY, 1971, p. 129, Pl. 53, fig. 1-5; REINHARDT, EASTON and PATTERSON, 1996, p. 41, fig. 3; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 22, Pl. 25 fig. 6-8.

Description: test free, trochospiral, plano-convex; wall calcareous, hyaline, smooth, finely perforate; all chambers visible on convex, spiral side; only 6 to 7 slightly inflated chambers gradually increase in size as added and visible on flattened umbilical side; sutures oblique on spiral side, slightly curved and radial and depressed on umbilical side; pustulose material most concentrated on the umbilicus partially obscures sutures; aperture interiomarginal with supplementary sutural apertures at posterior margin or each chamber.

Buccella hannai (Phleger and Parker, 1951), emend. Andersen, 1952

Plate 12, figures 4a-c

Eponides hannai PHLEGER and PARKER, 1951, p. 21, Pl. 10, fig. 11-14.

Buccella hannai (Phleger and Parker, 1951). ANDERSEN, 1952, p. 147, fig. 3

Description: test free, trochospiral, biconvex, ranging from specimens with equal convexity on both sides to extremely convex on dorsal side and flat on ventral side; wall calcareous, hyaline, smooth, finely perforate; 7 to 9 chambers, slightly inflated; three to three-and-one-half whorls; sutures curved, limbate on spiral side, depressed and radial on umbilical side; periphery distinctly lobulate, typically acute and limbate; pustulose material most concentrated on the umbilicus partially obscures sutures; aperture interiomarginal with supplementary sutural apertures at posterior margin or each chamber.

Buccella inusitata Andersen, 1952

Plate 12, figures 5a, b

Buccella inusitata ANDERSEN, 1952, p. 148, fig. 10a-c, 11a-c; LOEBLICH and TAPPAN, 1953, p. 116, Pl. 22, fig. 1.

Description: test free, trochospiral, dorsal and ventral sides equally biconvex in the microspheric form, ventral side nearly flat and dorsal side extremely convex in the megalospheric form; wall calcareous, hyaline, smooth, finely perforated; all chambers visible on convex, spiral side; only 7 to 9 slightly inflated chambers visible on flattened umbilical side; sutures slightly limbate, strongly oblique to the peripheral margin on dorsal side, depresses and radial on ventral side; umbilicus, sutures and basal margin of last chamber with thick coating of pustules; periphery acute and limbate, last 2 or 3 chambers usually lobate; sutural apertures at posterior margin or each chamber.

Buccella tenerrima (Bandy, 1950)

Plate 12, figures 6a-c

Rotalia tenerrima BANDY, 1950, p. 278, Pl. 42, fig. 3.

Buccella tenerrima (Bandy, 1950). REINHARDT, EASTON and PATTERSON, 1996, p. 41, fig. 3.

Description: test free, trochospiral, biconvex; wall calcareous, hyaline, smooth, finely perforated; periphery slightly lobulate, carinate; umbilicus pustulose; three-and-one-half whorls, 8 to 10 chambers in last whorl; dorsal sutures somewhat oblique and slightly curved, ventral sutures depressed, nearly radial; pustulose material covering umbilicus and sutures; aperture a series of pores at base of last septal face.

Superfamily ROTALIACEA Ehrenberg, 1839

Family ELPHIDIIDAE Galloway, 1933

Subfamily ELPHIDIINAE Galloway, 1933

Genus *Cribroelphidium* Cushman and Brönnimann, 1948

Cribroelphidium excavatum (Terquem, 1876)

Plate 13, figures 1-5

Polystomella excavata TERQUEM, 1876, p. 25, Pl. 2, fig. 2.

Elphidium excavatum (Terquem, 1876). MURRAY, 1971, p. 159, Pl. 66, fig. 1-7.

Cribroelphidium excavatum (Terquem, 1876). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 22, Pl. 25, fig. 4,5; Pl. 26, fig. 1,2.

Description: test free, planispiral, involute, biumbonate, periphery rounded; wall calcareous, thin, smooth except concentrations of pustules found along sutures, in umbilicus, and around aperture; fine circular pores less concentrated along septa and on apertural face; no pores in central extensions of chamber walls; usually 9 to 11 gradually enlarging chambers in last whorl; sutures depressed, backward-curved, usually closed before reaching the umbilical region, with single row of large sutural pores, and few 2 to 7 short sutural bridges which may not be visible in smaller specimens; aperture multiple interiomarginal.

Remarks: five different morphotypes of *C. excavatum* are differentiated, following the work of Miller et al., (1982). They are grouped on five formae: *C. excavatum* forma *excavata* (Terquem, 1876), *C. excavatum* forma *selseyensis* (Heron-Allen and Earland, 1911), *C. excavatum* forma *clavata* (Cushman, 1930), *C. excavatum* forma *lidoensis* (Cushman, 1936), and *C. excavatum* forma *magna* (Miller et al., 1982). For more information on the taxonomy and ecology of these formae, the reader is referred to Miller et al., 1982.

Cribroelphidium foraminosum (Cushman, 1927)

Plate 14, figures 1a-c

Elphidium hughesi var. *foraminosum* CUSHMAN, 1939, p. 49, Pl. 13, fig. 8.

Cribroelphidium foraminosum (Cushman, 1927). REINHARDT, EASTON and PATTERSON, 1996, p. 41, fig. 3; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 22, Pl. 24, fig. 6-8.

Description: test free, planispiral, involute, biumbonate, periphery rounded; wall calcareous, hyaline, smooth, coarsely perforate except on imperforate apertural face; 10 to 11 chambers of last whorl visible and gradually increase in size as added; sutures depressed, backward-curved, with single row of large oblong sutural pores separated by short sutural bridges; aperture multiple interiomarginal.

Cribroelphidium hallandense (Brotzen, 1943)

Plate 14, figures 3a-c

Elphidium hallandense BROTZEN, 1943, p. 268, fig. 109.

Cribroelphidium hallandense (Brotzen, 1943). PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 22, Pl. 25, fig. 1-3.

Description: test free, planispiral, involute, sides flat, periphery broadly rounded, slightly lobulate margin; wall calcareous, hyaline, smooth except bands of granular material found in umbilicus along sutures and near aperture; 7 to 9 slightly inflated and gradually enlarging chambers in final whorl; sutures slightly depressed and curved; aperture a low interiomarginal equatorial arch often obscured by granular material covering apertural face.

Cribroelphidium magellanicum (Heron-Allen and Earland, 1932)

Plate 14, figures 4a-c

Elphidium (Polystomella) magellanicum HERON-ALLEN and EARLAND, 1932, p. 440, Pl. 16, fig. 26-28.

Elphidium magellanicum (Heron-Allen and Earland, 1932). MURRAY, 1971, p. 163, Pl. 68, fig. 1-7; MURRAY, 2003, p. 21, fig. 7.9, 7.10.

Description: test free, planispiral, involute, biumbonate, compressed; 5 to 6 chambers in the last whorl; sutures backward curved and strongly depressed, chambers slightly inflated; periphery rounded, markedly lobulate; sutures filled with very finely granular matter, contrasting with glassy chambers; fossettes concealed under granules; aperture a series of interiomarginal pores.

Cribroelphidium microgranulosum (Galloway and Wissler, 1927)

Plate 14, figures 2a-c

Themeon decipiens GALLOWAY and WISSLER, 1927, p. 83, Pl. 12, fig. 15,16.

Cribroelphidium microgranulosum (Galloway and Wissler, 1927). PATTERSON, BRUNNER, CAPO and DAHL, 1990, p. 11, fig. 13; REINHARDT, EASTON and PATTERSON, 1996, p. 41, fig. 3.

Description: test free, planispiral, involute, biumbonate, compressed; 5 to 6 chambers in the last whorl; periphery very slightly lobulate; sutures slightly curved, slightly depressed and each provided with 8 to 10 small, indistinct, round pores; wall calcareous, granular, completely covered with pustulose material; aperture a very narrow curved slit.

Genus *Elphidiella* Cushman, 1936

Elphidiella hannai (Cushman and Grant, 1927)

Plate 14, figures 5a-c

Elphidium hannai CUSHMAN and GRANT, 1927, p. 77, Pl. 7, fig. 1

Elphidiella hannai (Cushman and Grant, 1927). REINHARDT, EASTON and PATTERSON, 1996, p. 41, fig. 3; PATTERSON, BURBIDGE and LUTERNAUER, 1998, p. 22, Pl. 26, fig. 3,4.

Description: test free, lenticular, planispiral, involute, bilaterally symmetrical, periphery rounded; wall calcareous, hyaline, smooth except concentration of granular material near aperture; 13 to 15 chambers of the last whorl visible and increase gradually in size as added; sutures distinct, thickened but not raised, slightly curved, bordered by double row of fine sutural pores that extend to smooth umbilical region; aperture a row of pores at base of apertural face of final formed chamber.

Subphylum SARCODINA Schmarda, 1871

Class RHIZOPODEA von Siebold, 1845

Subclass LOBOSA Carpenter, 1861

Order ARCELLINIDA Kent, 1880

Superfamily ARCELLACEA Ehrenberg, 1830

Family CENTROPYXIDIDAE Deflandre, 1953

Genus *Centropyxis* Stein, 1859

Centropyxis aculeata (Ehrenberg, 1832)

Strain '*aculeata*' Reinhardt, Dalby, Kumar and Patterson, 1998

Arcella aculeata EHRENBERG, 1832, p. 91.

Centropyxis aculeata (Ehrenberg, 1832). MEDIOLI and SCOTT, 1983, p. 39, fig. 11.7-11.16, Pl. 7, fig. 10-12, 18, 19.

Centropyxis aculeata (Ehrenberg, 1832) strain *aculeata* REINHARDT, DALBY, KUMAR and PATTERSON, 1998, Pl. 1, fig. 1.

Description: test depressed; in dorsal view, usually large and more or less circular; anterior slope large, with small (15° to 45°) anterior angle; posterior slope ill-defined, practically absent, fusing into fundus; fundus quite posterior; 1 to 8 spines in postero-lateral margin; wall basically organic, agglutinated, with siliceous particles completely covering the membrane; aperture subcentral, usually slightly anterior, invaginated.

Centropyxis constricta (Ehrenberg, 1843)

Strain '*constricta*' Reinhardt, Dalby, Kumar and Patterson, 1998

Plate 15, figure 9

Arcella constricta EHRENBERG, 1843, p. 410, Pl. 4, fig. 35, Pl. 5, fig. 1.

Centropyxis constricta (Ehrenberg, 1843). MEDIOLI and SCOTT, 1983, p. 41, fig. 12.7, 12.14, 12.16, 12.17, Pl. 7, fig. 1-4, 6-9.

Centropyxis constricta (Ehrenberg, 1843) strain *constricta* REINHARDT, DALBY, KUMAR and PATTERSON, 1998, Pl. 1, fig. 4.

Description: test much less depressed than in *C. aculeata*, usually elliptical on dorsal view, with profile usually raised posteriorly; large (40° to 65°) anterior angle; posterior angle well-defined; fundus raised in uppermost position; ventral side often small; 3 or less spines on fundus; wall agglutinated, completely covered with mineral particles of various nature; aperture antero-marginal, with variable degree of invagination.

Centropyxis constricta (Ehrenberg, 1843)

Strain '*aerophila*' Reinhardt, Dalby, Kumar and Patterson, 1998

Plate 15, figure 5

Centropyxis aerophila DEFLANDRE, 1929.

Centropyxis aerophila Deflandre, 1929. OGDEN and HEDLEY 1980, p. 48-49.

Centropyxis constricta (Ehrenberg, 1843). MEDIOLI and SCOTT, 1983, p. 41, fig. 12.6, 12.8-12.12, 12.15, 12.18-12.26, Pl. 7, fig. 5.

Cucurbitella [sic.] *constricta* REINHARDT, DALBY, KUMAR and PATTERSON 1998, Pl. 1, fig. 6.

Centropyxis constricta (Ehrenberg, 1843) strain *aerophila* KUMAR and DALBY, 1998, fig. 5.1.

Description: test much less depressed than in *C. aculeata*, usually elliptical on dorsal view, with profile usually raised posteriorly; large (40° to 65°) anterior angle; posterior angle well-defined; fundus raised in uppermost position; ventral side often small; spines absent; wall agglutinated, completely covered with mineral particles of various nature; aperture antero-marginal, with variable degree of invagination.

Genus *Cyclopyxis* Deflandre, 1929

Cyclopyxis kahli (Deflandre, 1929)

Plate 15, figure 10

Centropyxis kahli DEFLANDRE, 1929, p. 330

Cyclopyxis kahli (Deflandre, 1920). OGDEN and HEDLEY, 1980, p. 70-71, pl. 24, figs. a-e; ROE and PATTERSON, 2006, p. 29, Pl. 1, fig. 7, p. 33, Pl. 3, fig. 1-6.

Description: test plano-convex, radially symmetrical, hemispherical; wall agglutinated; aperture circular, large, centered.

Family HYALOSPHENIIDAE Schulze, 1877

Genus *Heleopera* Leidy, 1879

Heleopera sphagni (Leidy, 1874)

Plate 15, figures 11a, b

Difflugia sphagni LEIDY, 1874, p. 157

Heleopera picta LEIDY, 1879.

Heleopera sphagni (Leidy, 1879). MEDIOLI and SCOTT, 1983, p. 37-38, fig. 9, Pl. 6, figs. 15-18.

Description: test strongly compressed, ovoid; oral pole narrower in broadside view; test composed of siliceous idiosomes, substituted more or less extensively by xenosomes; aperture at narrow end of test, an elongated, narrow ellipse with acute commissures.

Genus *Nebela* (Leidy, 1874)

Nebela collaris (Ehrenberg, 1848)

Nebela collaris EHRENBERG, 1848; OGDEN and HEDLEY 1980, p. 94-95; KUMAR and DALBY, 1998, fig. 9.2.

Description: test strongly compressed, ovoid; oral pole narrower in broadside view; test composed of siliceous plates; collar showing at narrow end of test; aperture elongate, narrow, at end of collar.

Family DIFFLUGIDAE Stein, 1859

Genus *Difflugia* Leclerc in Lamarck, 1816

Difflugia oblonga Ehrenberg, 1832

Plate 15, figure 6

Difflugia oblonga EHRENBERG, 1832, p. 90; OGDEN and HEDLEY, 1980, p. 148, pl. 63, figs. a-c; HAMAN, 1982, p. 397, Pl. 3, Figs. 19-25; SCOTT and MEDIOLI, 1983, p. 818, fig. 6, Pl. 2, fig. 1-17.

Description: test variable in shape and size, pyriform, flask-shaped, rounded in cross-section; fundus rounded to subacute; neck subcylindrical, more or less long, gradually narrowed toward oral end; test agglutinated, made of sand particles, sometimes mixed with diatom frustules; aperture terminal, circular to slightly oval.

Difflugia protaeiformis Lamarck, 1816

Plate 15, figure 7

Difflugia protaeiformis LAMARCK, 1816, p. 95; KUMAR and DALBY, 1998, fig. 14.1, 15.1, 15.2.

Description: test pyriform, flask shaped, rounded in cross-section; fundus tapering, acuminate with one or more spines; oral end sometimes narrower; test agglutinated, fine to coarse grains; aperture terminal, circular.

Difflugia urceolata Carter, 1864

Plate 15, figure 8

Difflugia urceolata CARTER, 1864, p. 27, Pl. 1, fig. 7; MEDIOLI and SCOTT, 1983, p. 31, fig. 1-23, Pl. 4, fig. 1-4; KUMAR and DALBY, 1998, fig. 22.1, 22.2.

Description: test spheroid to acutely ovate, amphora-like to cauldron-like; fundus rounded to acuminate; neck short, terminating in evaginated, sometimes recurved or straight collar of variable shape and size; wall agglutinated, composed of sand grains of variable coarseness; aperture wide, circular, terminal.

Genus *Lagenodifflugia* Medioli and Scott, 1983

Lagenodifflugia vas (Leidy, 1874)

Difflugia vas LEIDY, 1874, p. 155.

Lagenodifflugia vas (Leidy, 1874). MEDIOLI and SCOTT 1983, p. 33, Pl. 2, figs. 18-23, 27, 28; REINHARDT, DALBY, KUMAR and PATTERSON 1998, Pl. 1, fig. 8.

Description: main part of test usually ovoid, with neck arising form its narrower extremity; wide fundus; neck usually slightly higher than wide, coniform, truncated at aperture and constriction; constriction between body and neck not always conspicuous, normally visible in wet specimens; wall agglutinated; aperture rounded, terminal.

11. Plates

The following plates 1 to 15 illustrate most of the foraminiferal and thecamoebian species found within the SBIC with scanning electron photomicrographs obtained using a JEOL 6400 Scanning Electron Microscope at the Carleton University Research Facility for Electron Microscopy (CURFEM). These digital images were converted into plates using Adobe © Photoshop 7.0 and Adobe © Illustrator 11 for Mac OS X.

Plate 1:

1.- *Ammodiscus gullmarensis* Höglund, from sample FC04-86, side view. **2.-** *Cribrostomoides crassimargo* (Norman), from sample FC04-90, side view showing lobulate periphery and coarse agglutination. **3.-** *Cribrostomoides* sp. A, from sample FC04-77; 3a, side view, showing rounded periphery and inflated last chamber; 3b, apertural view, showing inflated last chamber. **4.-** *Cribrostomoides jeffreysii* (Williamson), from sample BE5; 4a, side view, showing ovate periphery; 4b, apertural view, showing depressed test and typical aperture; 4c, apertural view from another specimen from sample BE7, showing leaf-like aperture. **5.-** *Cribrostomoides* cf. *subglobosum* (Cushman), from sample ALS2; 5a, side view showing rounded periphery; 5b, apertural view showing globular test and characteristic aperture. **6.-** *Haplophragmoides bradyi* (Brady), from sample BE3; 6a, side view showing very smooth test; 6b, apertural view showing characteristic interiomarginal aperture; 6c, side view of a more evolute specimen from sample BE5. **7.-** *Recurvoides turbinatus* (Brady), from sample ALS1; 7a, side view; 7b, apertural view showing asymmetry of test and angled aperture. All scales are 10 μm unless otherwise indicated.

PLATE 1

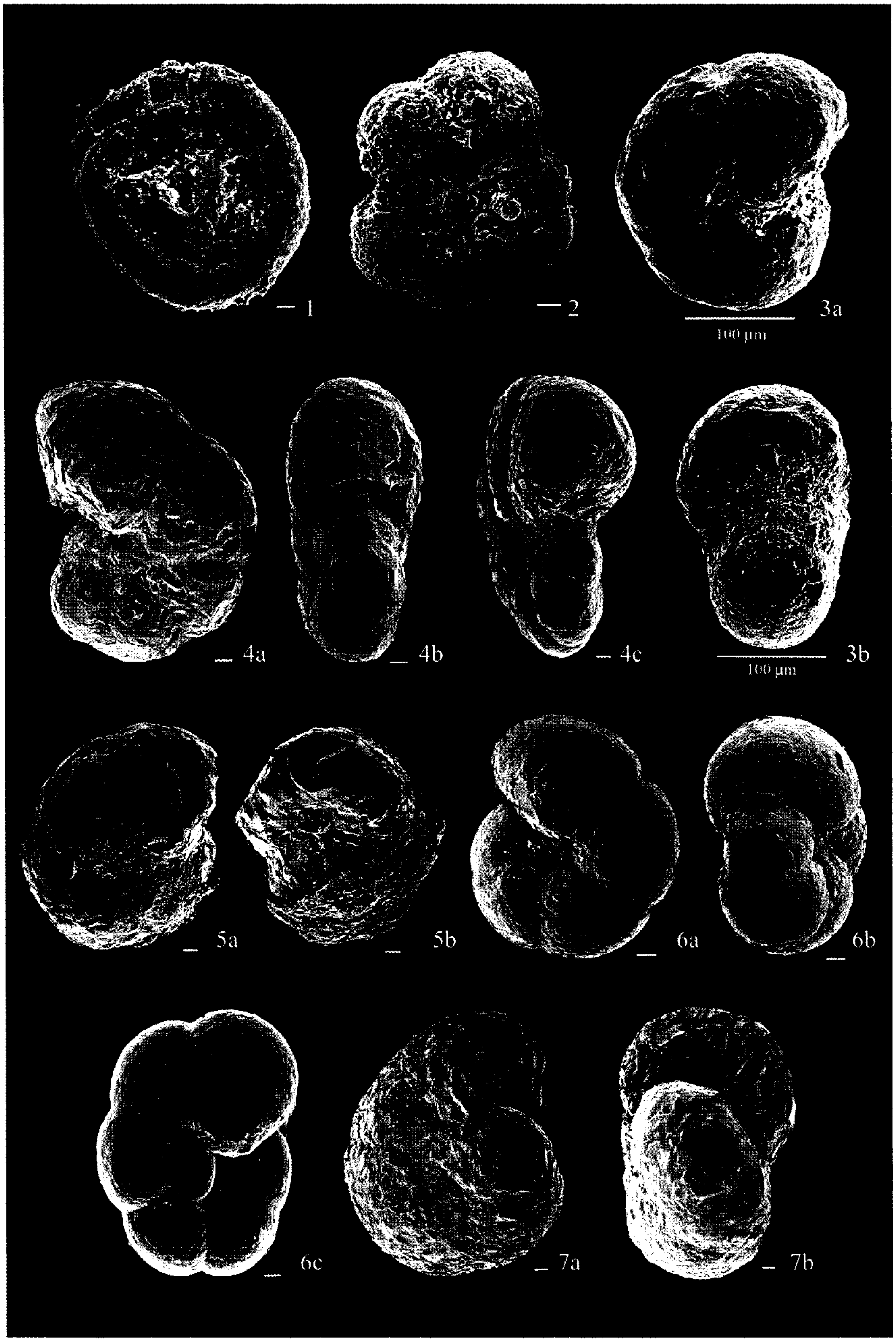


Plate 2:

1.- *Cribrostomoides wiesneri* (Parr); 1a, side view of specimen from sample FC04-99; 1b, side view of another specimen from sample FC04-99; 1c, apertural view of a third specimen from sample FC04-99. **2.-** *Trochammina inflata* (Montagu), from sample BE3; 2a, dorsal view; 2b, umbilical view. **3.-** *Portatrochammina bipolaris* Brönnimann and Whitaker, from sample BE7; 3a, dorsal view; 3b, umbilical view, showing characteristic umbilical flap; 3c, side view from another specimen from sample BE7. **4.-** *Trochammina charlottensis* Cushman, from sample BE5; 4a, dorsal view; 4b, umbilical view, showing characteristic very inflated last chamber; 4c, side view, from another specimen from sample ALS3, with first chamber broken. **5.-** *Trochammina nana* (Brady), from sample FC04-77; 5a, dorsal view; 5b, umbilical view, showing very deep umbilicus. **6.-** *Trochammina discorbis* Earland, from sample BE5; 6a, dorsal view; 6b, umbilical view; 6c, side view showing very high spiral. All scales are 10 μm unless otherwise indicated.

PLATE 2

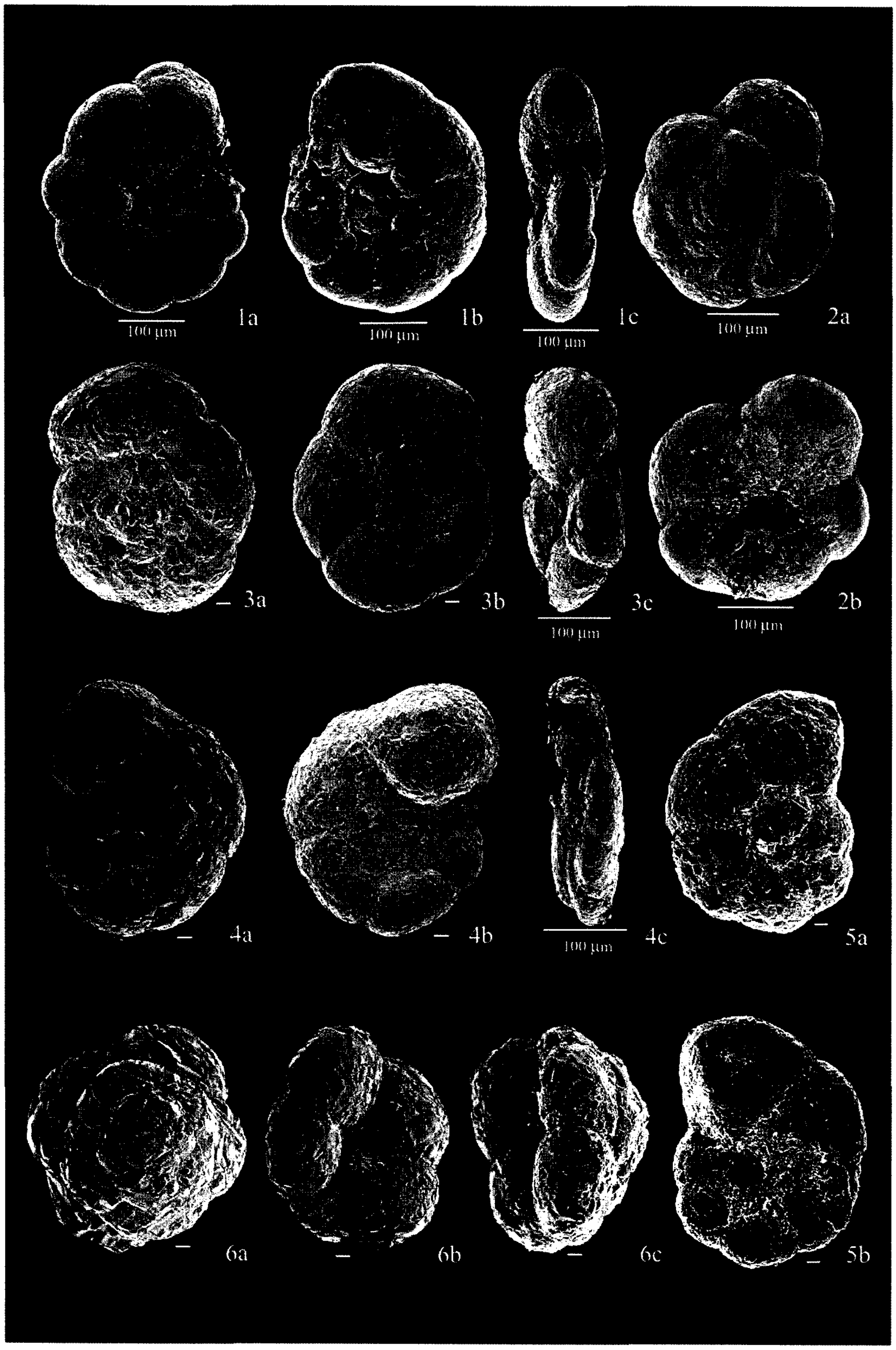

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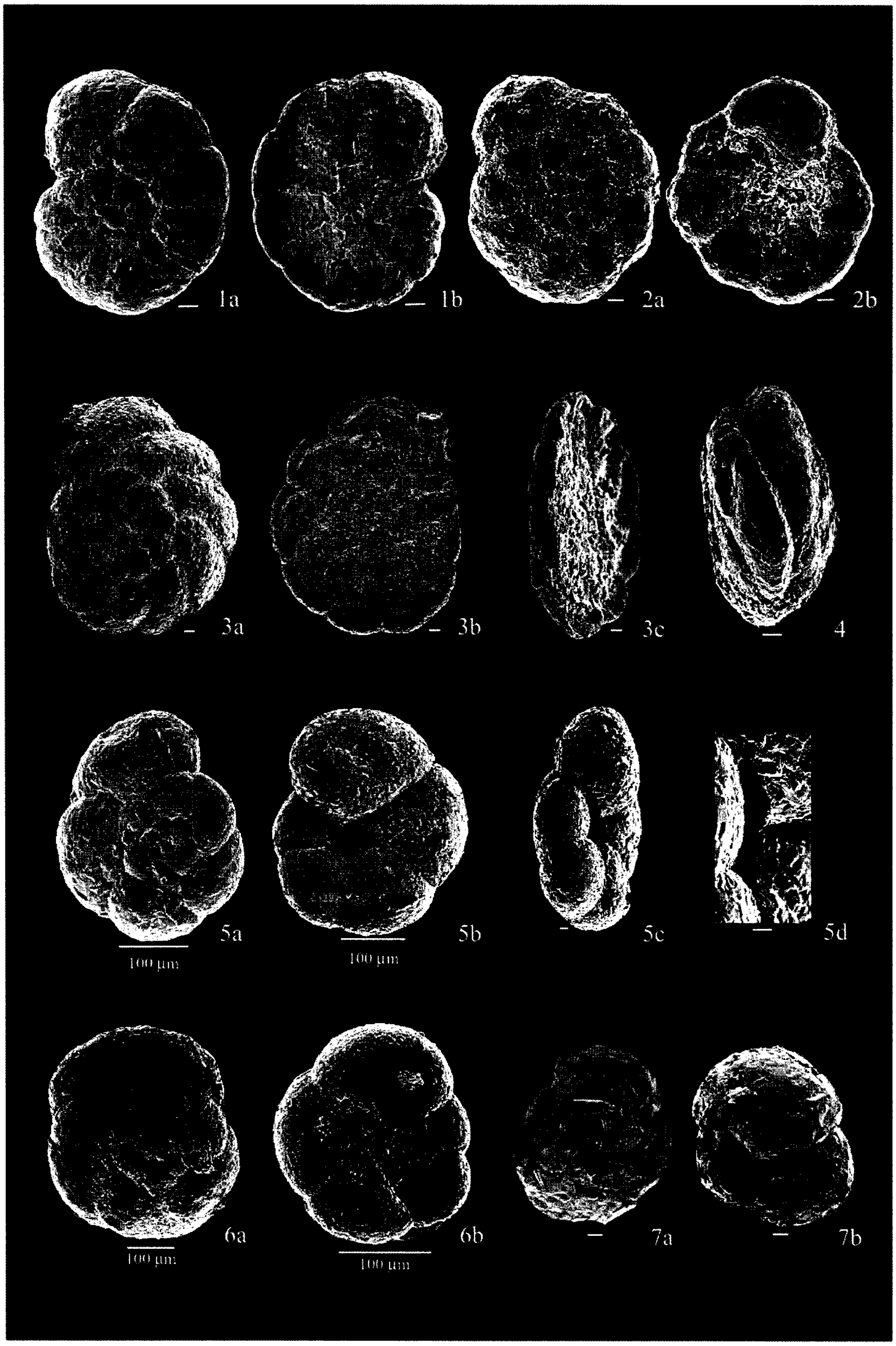
Plate 3:

1.- *Trochammina nitida* Brady, from sample BE7; 1a, dorsal view, showing very straight sutures; 1b, umbilical view. **2.-** *Trochammina squamata* Jones and Parker, from sample FC04-96; 2a, dorsal view; 2b, umbilical view. **3.-** *Trochammina ochracea* (Williamson), from sample ALS1; 3a, dorsal view; 3b, umbilical view, with umbilical region filled with organic matter; 3c, side view, showing depressed concave test. **4.-** Two forms of *T. discorbis* attached to each other, from sample FC04-79. **5.-** *Trochammina pacifica* Cushman, from sample BE5; 5a, dorsal view; 5b, umbilical view, showing inflated chambers; 5c, side view, showing aperture reaching the umbilicus; 5d, detail of aperture showing lip. **6.-** *Trochammina rotaliformis* Heron-Allen and Earland, both specimens from sample BE1; 6a, dorsal view; 6b, umbilical view, with debris partially obscuring star-shaped umbilicus. **7.-** *Trochammina* cf. *globigeriniformis* (Parker and Jones) from sample BE5; 7a, dorsal view of specimen with last chamber broken; 7b, umbilical view of another specimen. All scales are 10 μm unless otherwise indicated.

PLATE 3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7a
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Plate 4:

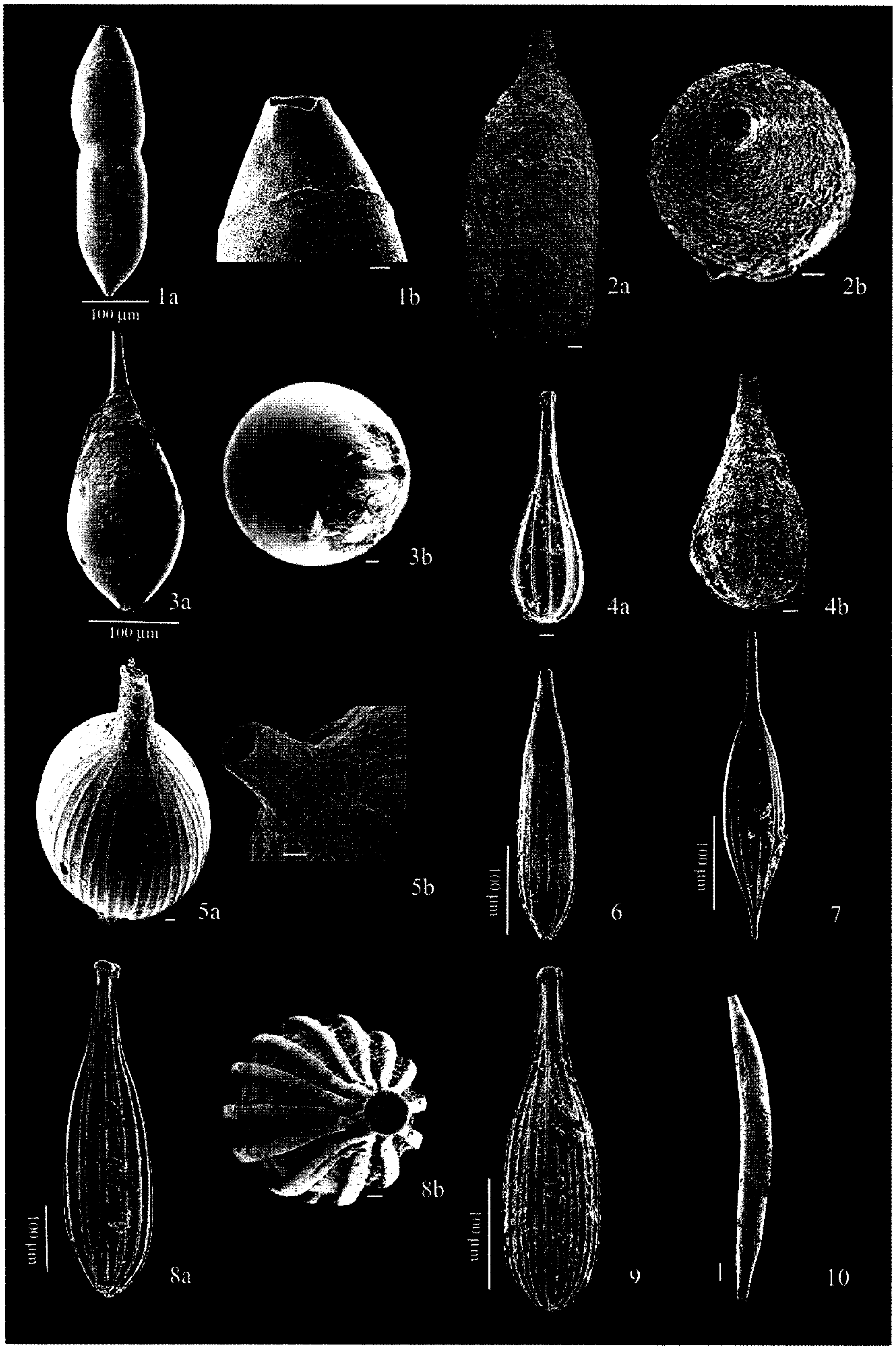
1.- *Gaudryina arenaria* Galloway and Wissler, from sample BE1, side view of eroded specimen. **2.-** *Textularia earlandi* Parker, from sample BE7; 2a, side view of broken specimen, with first chambers missing; 2b, apertural view, showing interiomarginal arch. **3.-** *Reophax catella* Höglund, from sample FC04-121, side view. **4.-** *Eggerella advena* Cushman, from sample ALS3; 4a, side view; 4b, apertural view; 4c, side view of second specimen, from sample ALS3; 4d, apertural view of specimen 4c. **5.-** *Eggerella belizensis*, n. sp., from sample ALS2; 5a, side view; 5b, apertural view; 5c, side view of a second specimen from sample ALS3; 5d, apertural view of specimen 5d. **6.-** *Spiroplectammina biformis* (Parker and Jones), from sample ALS1; 6a, side view of long specimen; 6b, side view of shorter specimen from sample BE1; 6c, apertural view of specimen 6b.

PLATE 4

Plate 5:

1.- *Dentalina ittai* Loeblich and Tappan, from sample BE1; 1a, side view; 1b, detail of apertural end. **2.-** *Pygmaeoseistron hispidulum* (Cushman), from sample BE3; 2a, side view of very corroded specimen; 2b, apertural view. **3.-** *Lagena laevis* (Montagu), from sample BE2; 3a, side view; 3b, apertural view. **4.-** *Lagena meridionalis* Wiesner, from sample FC04-68; 4a, side view of well preserved specimen; 4b, side view of very corroded specimen. **5.-** *Lagena semilineata* Wright, from sample BE1; 5a, side view; 5b, bottom view, showing hollow basal spine. **6.-** *Procerolagena mollis* Cushman, from sample FC04-66, side view. **7.-** *Procerolagena gracilis* (Williamson), from sample FC04-75, side view; **8.-** *Procerolagena* cf. *amphora* (Reuss), from sample BE1; 8a, side view; 8b, apertural view. **9.-** *Procerolagena wiesneri* (Parr), from sample BE1, side view. **10.-** *Hyalinonetrion dentaliforme* (Bagg), from sample BE1; side view. All scales are 10 μm unless otherwise indicated.

PLATE 5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8a
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Plate 6:

1.- *Favulina epibathra* Patterson and Richardson, from sample BE1; 1a, side view; 1b, apertural view; 1c, bottom view. **2.-** *Favulina melo* (d'Orbigny), from sample BE2; 2a, side view; 2b, apertural view. **3.-** *Homalohedra apiopleura* (Loeblich and Tappan), from sample BE1; 3a, side view; 3b, apertural view; 3c, bottom view. **4.-** *Homalohedra borealis* (Loeblich and Tappan), from sample BE1; 4a, side view; 4b, apertural view; 4c, bottom view. **5-6.-** *Homalohedra guntheri* (Earland), from sample BE1; 5a, side view of specimen showing few longitudinal costae; 5b, apertural view of specimen 5a; 6a, side view of specimen from sample FC04-38 showing more longitudinal costae; 6b, apertural view of specimen 6a; 6c, bottom view of specimen 6a. All scales are 10 μm unless otherwise indicated.

PLATE 6

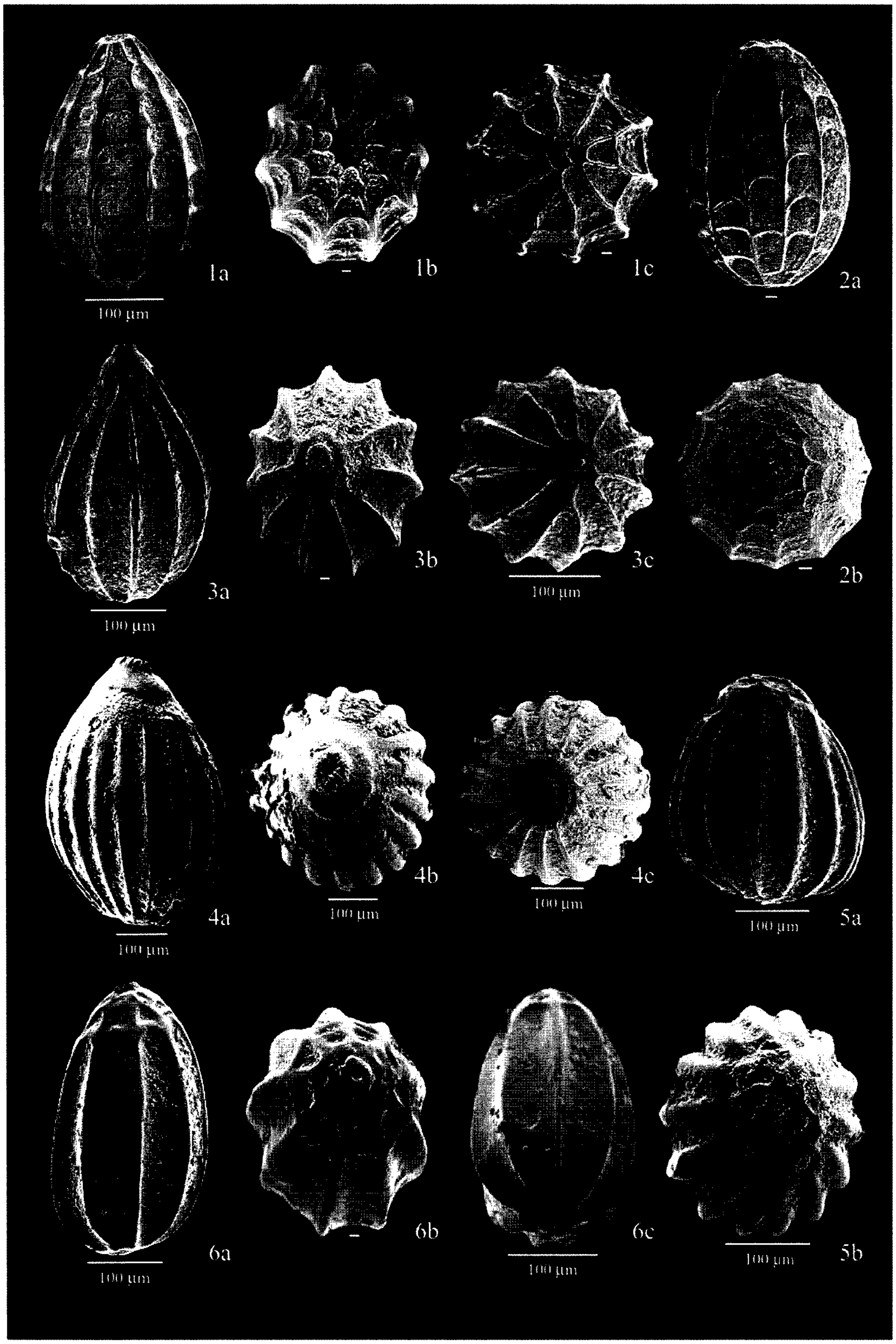
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Plate 7:

1.- *Fissurina eburnea* (Buchner), from sample BE1; 1a, side view; 1b, lateral view showing aperture. **2.-** *Fissurina lucida* (Williamson), from sample FC04-59; 2a, side view; 2b, apertural view. **3.-** *Fissurina cucurbitasema* Loeblich and Tappan; 3a, side view of specimen from sample FC04-65, showing thin marginal keel; 3b, apertural view of specimen from sample FC04-67; 3c, side view of specimen from sample FC04-76, showing seed-like shape. **4.-** *Palliolatella frangens* (Buchner), side view of specimen from sample BE1. **5.-** *Palliolatella immemora* Patterson, from sample BE1; 5a, side view; 5b, apertural view; 5c, detail of the aperture. **6.-** *Fissurina quadrata* Williamson, from sample BE1, side view. **7.-** *Laryngosigma trilocularis* (Bagg), pictures of two specimens from sample BE1; 7a, side view; 7b, apertural view showing radiate aperture. **8.-** *Fissurina eburnea* (Buchner), from sample BE1, apertural view of specimen with more globular test. All scales are 10 μm unless otherwise indicated.

PLATE 7

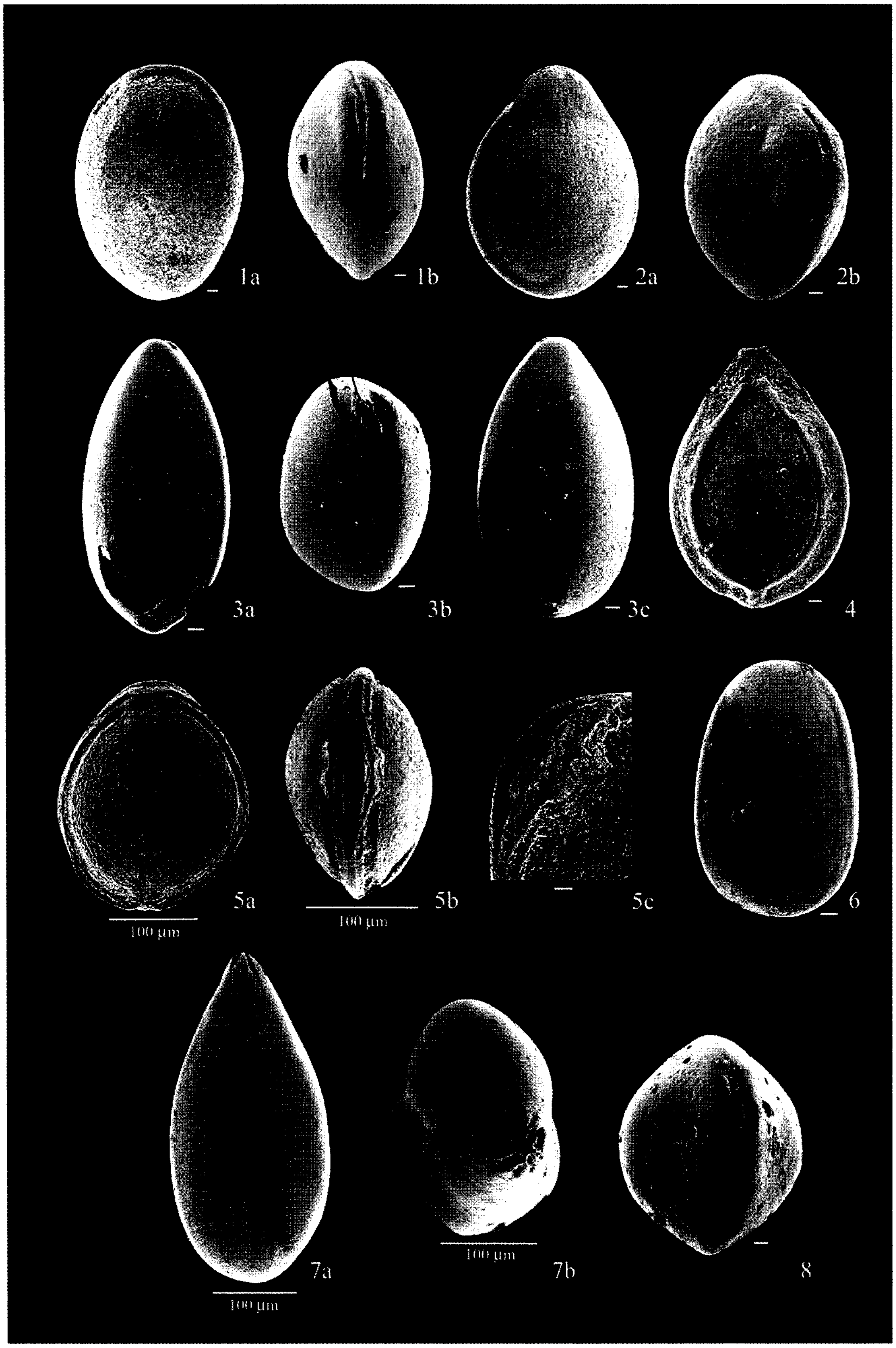

Plate 8:

1.- *Bolivina decussata* Brady, from sample BE1; 1a, side view showing roughened surface; 1b, apertural view. **2.-** *Bolivina minuta* Natland, from sample BE1; 2a, side view showing nearly parallel sides; 2b, apertural view. **3.-** *Stainforthia feylingi* Knudsen and Seidenkrantz, from sample BE1; 3a, side view showing smooth, finely perforated test; 3b, side view showing fusiform test; 3c, detail of aperture showing toothplate. **4.-** *Bolivinellina pacifica* (Cushman and McCulloch), from sample BE1; 4a, side view showing elongated test and biserial arrangement; 4b, apertural view, showing lip and internal toothplate. **5.-** *Islandiella helenae* Feyling-Hanssen and Buzas, from sample BE1; 5a, side view showing smooth test; 5b, view of the other side, showing position of aperture along periphery; 5c, apertural view showing biconvex test. **6.-** *Cassidulina crassa* d'Orbigny, from sample FC04-14; 6a, side view showing rectangular last chamber; 6b, view of the other side, showing slightly inflated chambers; 6c, detail of aperture; 6d, view of another specimen from sample BE3, showing rounded outline and depressed sutures, different from the more compressed test and flushed sutures of *C. reniforme*. All scales are 10 μm unless otherwise indicated.

PLATE 8


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Plate 9:

1.- *Protoglobulimina pupoides* (d'Orbigny), three specimens from sample FC04-76; 1a, side view showing strongly overlapping chambers; 1b, apertural view showing internal toothplate; 1c, basal view showing circular cross-section and triserial arrangement. **2.-** *Buliminella elegantissima* (d'Orbigny); 2a, side view of specimen from sample BE1, showing close spiral; 2b, side view of specimen from sample FC04-64, showing aperture obscured by debris; 2c, apertural view of specimen from sample FC04-63, showing internal toothplate; 2d, detail of aperture of specimen 2c. **3.-** *Euuvigerina aculeata* (d'Orbigny), from sample FC04-52; 3a, side view showing elongated shape; 3b, side view showing etched surface, spines uniting to form ribs at the base of test can be discerned; 3c, detail of tubular neck, showing remnants of cone-shaped spines at the base. **4.-** *Angulogerina fluens* Todd, from sample BE1; 4a, side view showing elongate test and longitudinal costae crossing the sutures; 4b, apertural view showing trigonal cross-section. **5.-** *Euuvigerina peregrina* (Cushman); 5a, side view of specimen from sample FC04-53 showing clear longitudinal costae; 5b, apertural view of specimen 5a showing rounded aperture on top of tubular neck; 5c, side view of specimen from sample FC04-55, showing etched surface; 5d, side view of specimen from sample FC04-52 showing less developed costae and well developed pustules between them. All scales are 100 μm unless otherwise indicated.

PLATE 9

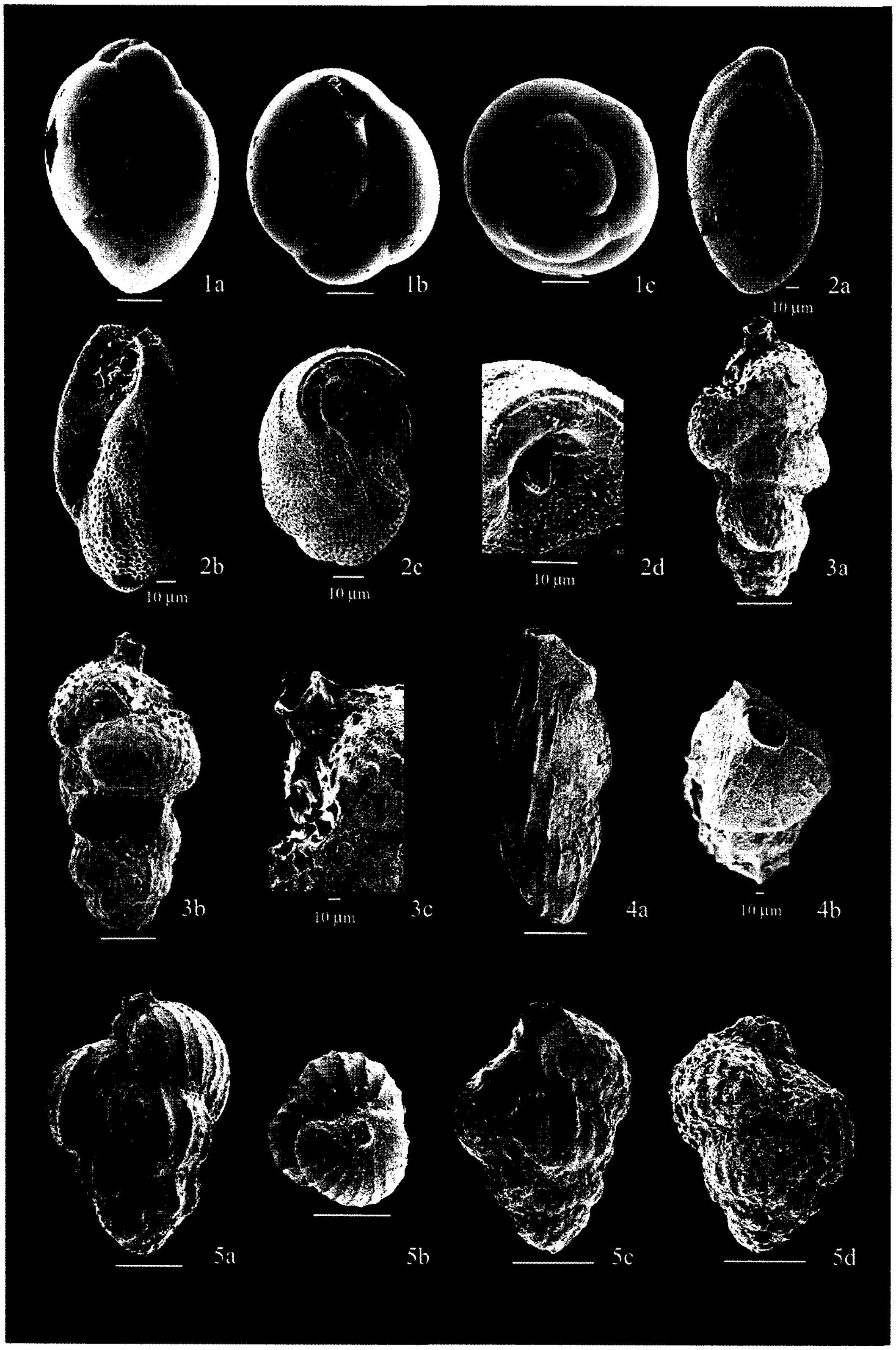
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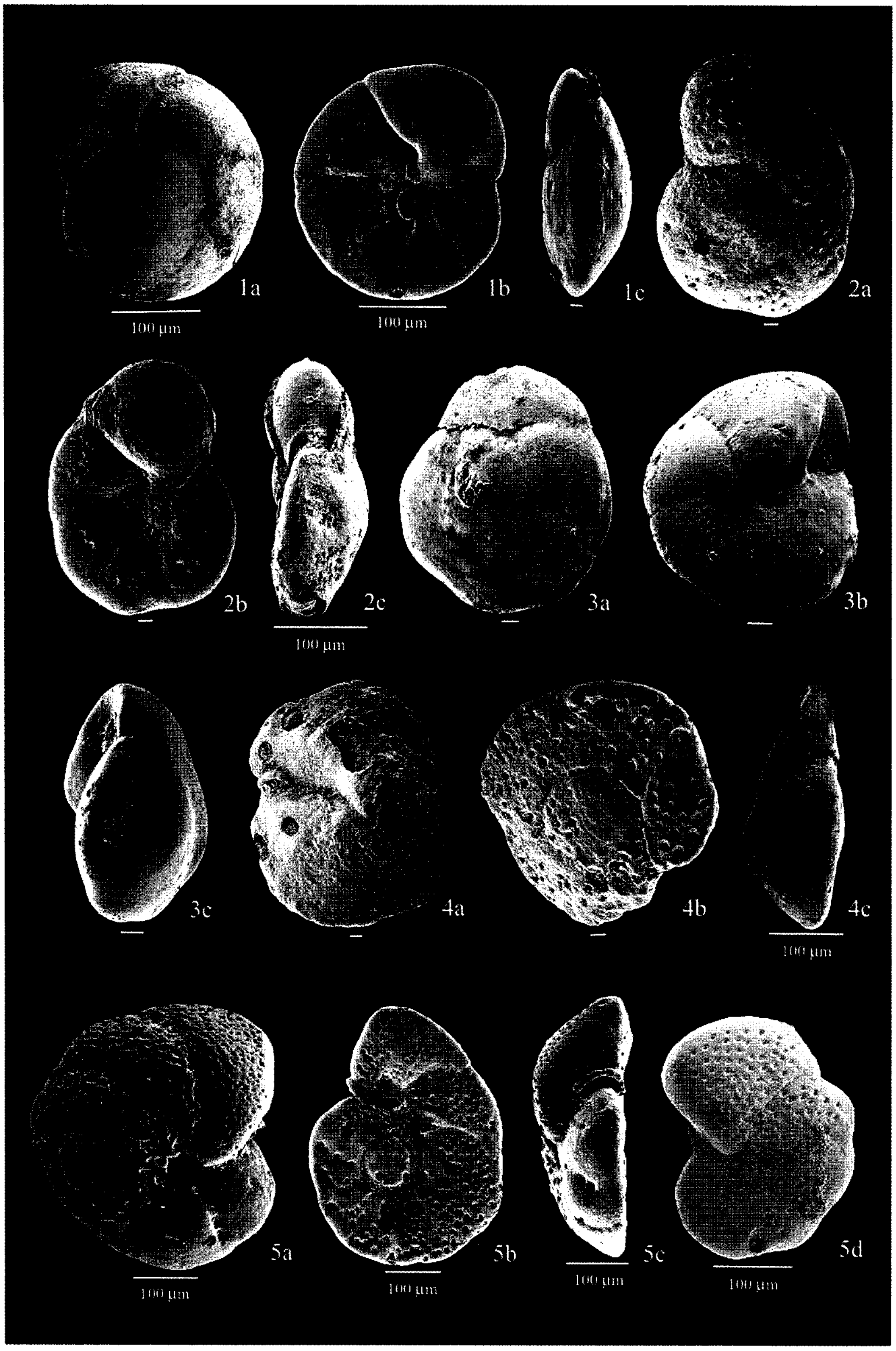
Plate 10:

1.- *Gavelinopsis campanulata* (Galloway and Wissler), from sample BE1; 1a, dorsal view; 1b, ventral view showing umbilical plug; 1c, side view showing more convex dorsal side. **2.-** *Rosalina columbiensis* (Cushman), from sample BE1; 2a, dorsal side showing coarse pores; 2b, ventral view showing aperture extending back along umbilicus; 2c, side view showing lipped marginal aperture. **3.-** *Epistominella vitrea* Parker, from sample BE2; 3a, dorsal side showing smooth test; 3b, ventral view showing radial sutures; 3c, side view. **4.-** *Lobatula fletcheri* (Galloway and Wissler), from sample BE1; 4a, dorsal view showing lipped aperture; 4b, ventral view showing coarse perforation; 4c, side view showing well developed umbilical view on spiral side. **5.-** *Lobatula lobatula* (Walker and Jacob), from sample BE1; 5a, dorsal view showing very coarse perforation; 5b, ventral view showing aperture extending on the last few chambers; 5c, side view showing lipped aperture; 5d, dorsal view of another specimen with a more ovate outline. All scales are 10 μm unless otherwise indicated.

PLATE 10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100 μm

Plate 11:

1.- *Lobatula mckannai* (Galloway and Wissler), from sample BE1; 1a, dorsal view; 1b, ventral view covered with debris; 1c, side view showing aperture. **2.-** *Dyocibicides biserialis* Cushman and Valentine, from sample BE1; 2a, dorsal view showing irregular outline; 2b, ventral view showing coarse perforation. **3.-** *Nonionella stella* Cushman and Moyer, from sample BE1; 3a, side view showing umbilical flap extending from broken last chamber and covering the umbilicus; 3b, view of other side; 3c, apertural view showing basal arcuate aperture. **4.-** *Nonionella* cf. *turgida* Williamson from sample BE1, side view. **5.-** *Nonionella digitata* Nørvang from sample FC04-76, side view with broken last chamber, showing finger-like projections over umbilicus. **6.-** *Pseudononion basispinata* (Cushman and Moyer) from sample BE2; 6a, side view showing hispid material in open umbilicus; 6b, apertural view showing compressed test. **7.-** *Nonionella labradorica* (Dawson) from sample BE1; 7a, side view; 7b, view of the other side showing pustules covering umbilicus; 7c, apertural view showing broad flat apertural face. All scales are 100 μm unless otherwise indicated.

PLATE 11

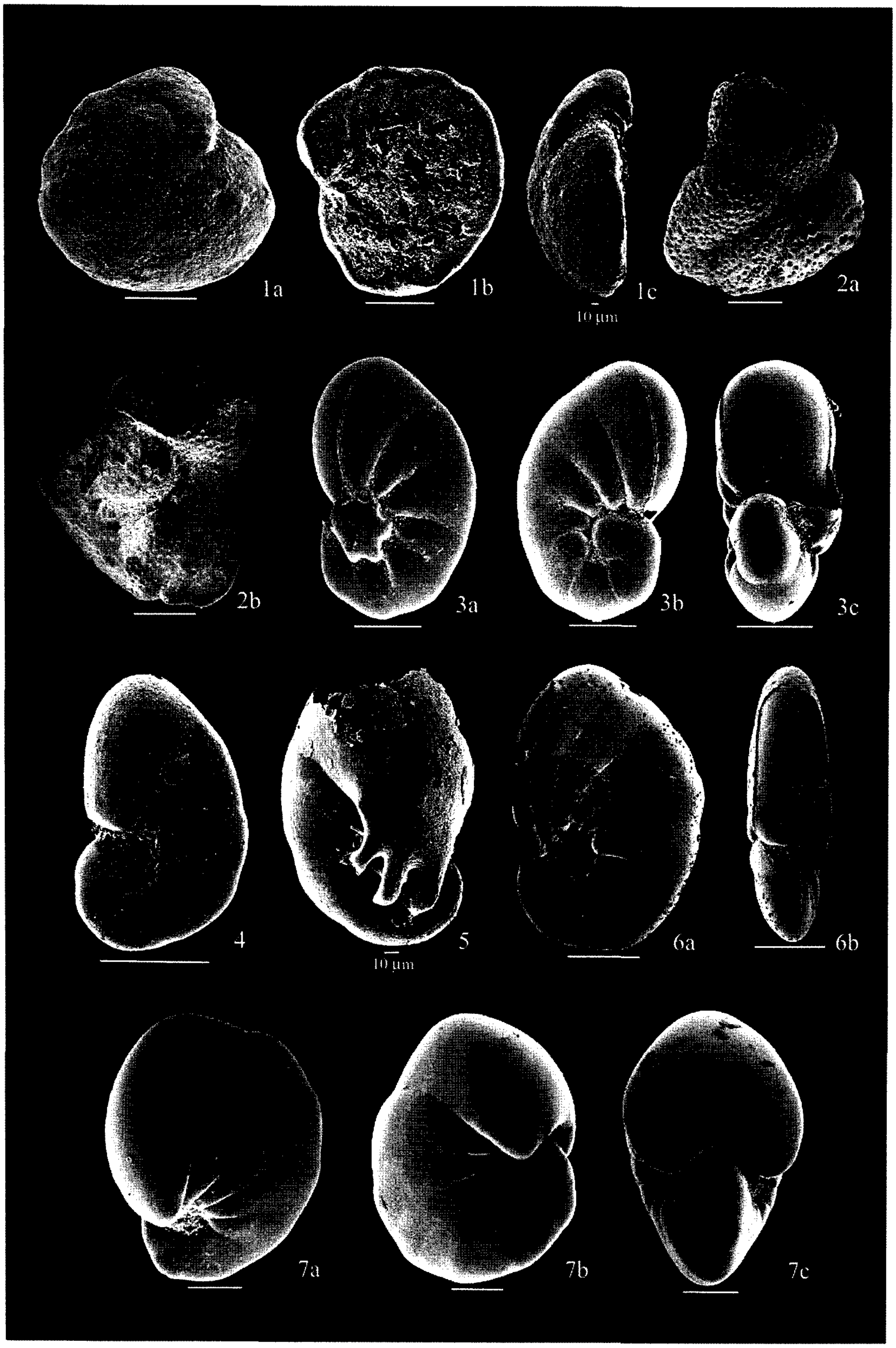
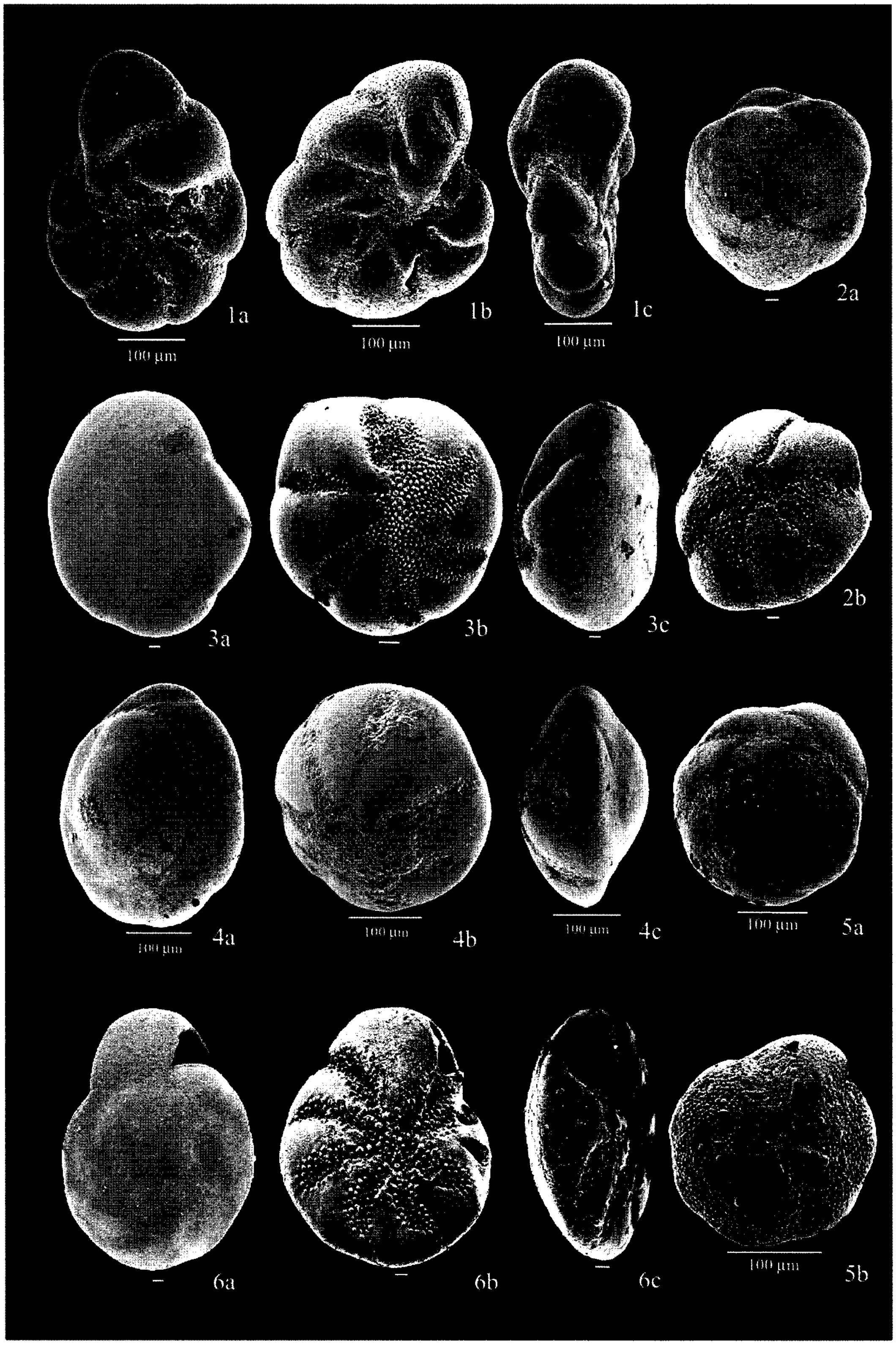


Plate 12:

1.- *Astrononion gallowayi* Loeblich and Tappan, from sample BE1; 1a, side view showing wedge-shaped supplementary chambers surrounding umbilicus; 1b, view of the other side showing supplementary apertures at the posterior margin of the supplementary chambers; 1c, apertural view. **2.-** *Buccella depressa* Andersen from sample FC04-39; 2a, dorsal view showing lobulate periphery; 2b, ventral view. **3.-** *Buccella frigida* (Cushman) from sample BE1; 3a, dorsal view showing smooth test; 3b, ventral view showing pustules along sutures; 3c, side view showing plano-convex test. **4.-** *Buccella hannai* (Phleger and Parker) from sample BE1; 4a, dorsal view; 4b, ventral view showing radial sutures; 4c, side view showing biconvex test and limbate periphery. **5.-** *Buccella inusitata* Andersen from sample BE1; 5a, dorsal view; 5b, ventral view showing thick pustulose coating. **6.-** *Buccella tenerrima* (Bandy) from sample BE1; 6a, dorsal view showing overgrown last chamber; 6b, ventral view showing 8 chambers; 6c, side view. All scales are 10 μm unless otherwise indicated.

PLATE 12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4a
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4b
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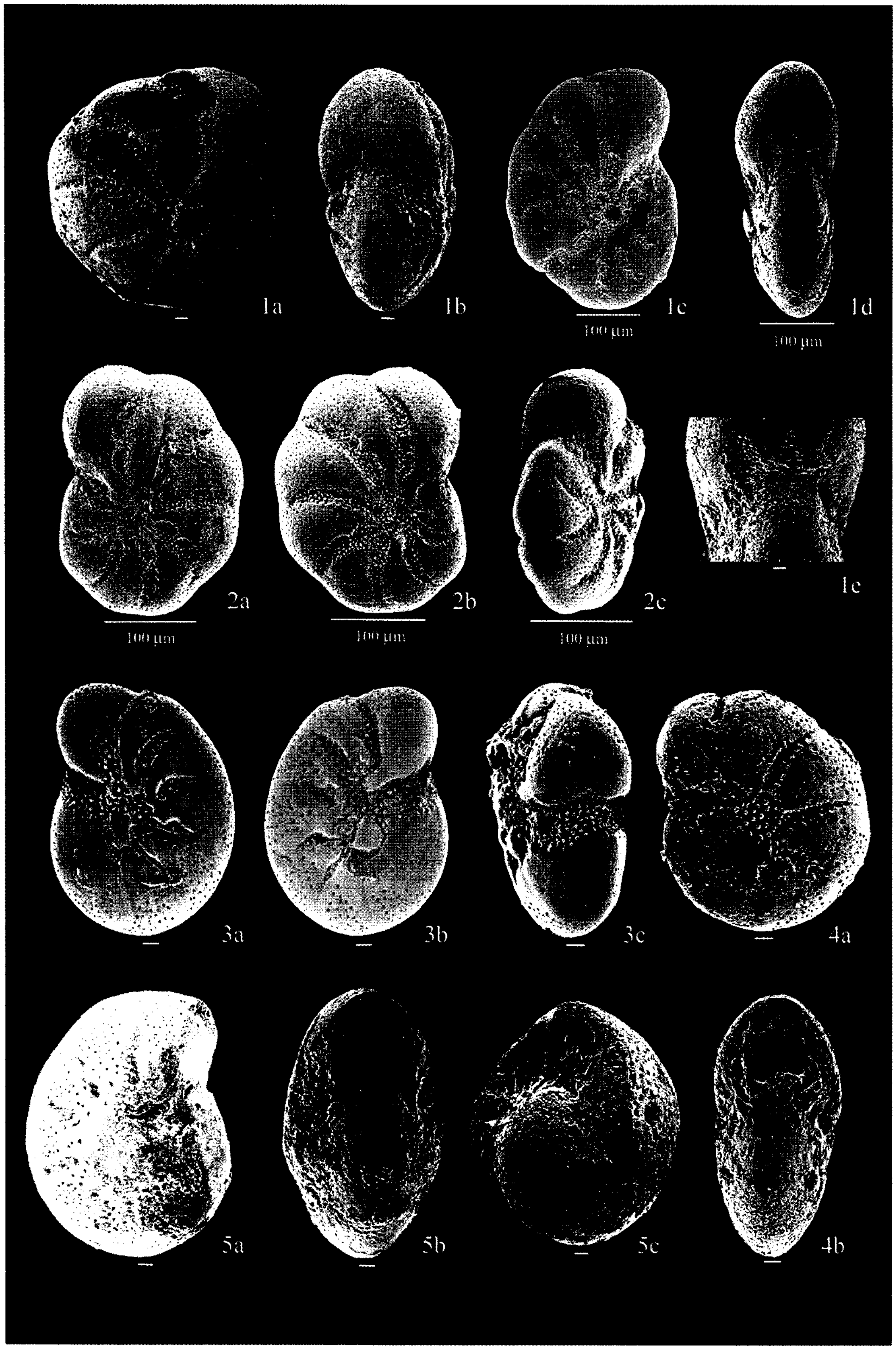
4c
100 µm
5a
100 µm
6a
6b
6c
100 µm
5b

Plate 13:

1.- *Cribroelphidium excavatum* forma *excavata* (Terquem); 1a, side view of specimen from sample BE5, showing straight sutures extending unconstricted to the umbilicus; 1b, apertural view of specimen 1a; 1c, side view of specimen from sample BE1; 1d, apertural view of specimen 1c; 1d, detail of aperture of specimen 1c, showing pustulose material arranged on triangular patterns on the apertural face. **2.-** *Cribroelphidium excavatum* forma *lidoensis* Cushman, from sample BE1; 2a, side view showing sutures curved backwards, broadening towards the umbilicus, filled with papillae; 2b, other side; 2c, apertural view. **3.-** *Cribroelphidium excavatum* forma *clavata* Cushman, from sample BE1; 3a, side view showing umbilical boss and backwards-curved sutures; 3b, view of the other side; 3c, apertural view. **4.-** *Cribroelphidium excavatum* forma *selseyensis* (Heron-Allen and Earland), from sample BE1; 4a, side view showing granular material filling the umbilicus; 4b, apertural view. **5.-** *Cribroelphidium excavatum* forma *magna* Miller, from sample FC04-62; 5a, side view showing large umbilicus filled with one knobby boss, and sutures constricted before reaching the umbilicus; 5b, apertural view showing strongly convex walls and raised umbilicus; 5c, view of another specimen from sample FC04-62, with very strongly convex walls that give it an almost circular cross-section. All scales are 10 μm unless otherwise indicated.

PLATE 13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1e
3a
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3c
4a
5a
5b
5c
4b

Plate 14:

1.- *Cribroelphidium foraminosum* (Cushman), from sample BE1; 1a, side view showing coarse perforation, sutural pores and sutural bridges; 1b, view of the other side; 1c, apertural view showing imperforate apertural face and multiple aperture. **2.-** *Cribroelphidium microgranulosum* (Galloway and Wissler), from sample BE1; 2a, side view showing round pores along sutures; 2b, view of other side showing wall completely covered with pustulose material; 2c, apertural view showing narrow curved aperture. **3.-** *Cribroelphidium hallandense* (Brotzen) from sample BE1; 3a, side view showing bands of pustulose material covering umbilicus and along sutures; 3b, view of the other side; 3c, apertural view. **4.-** *Cribroelphidium magellanicum* (Heron-Allen and Earland) from sample BE1; 4a, side view showing very lobulate periphery; 4b, view of the other side with last chamber broken; 4c, apertural view. **5.-** *Elphidiella hannai* (Cushman and Grant) from sample BE1; 5a, side view showing rounded periphery; 5b, view of the other side showing thickened flushed sutures with double row of fine pores; 5c, apertural view showing concentration of granular material. All scales are 100 µm.

PLATE 14

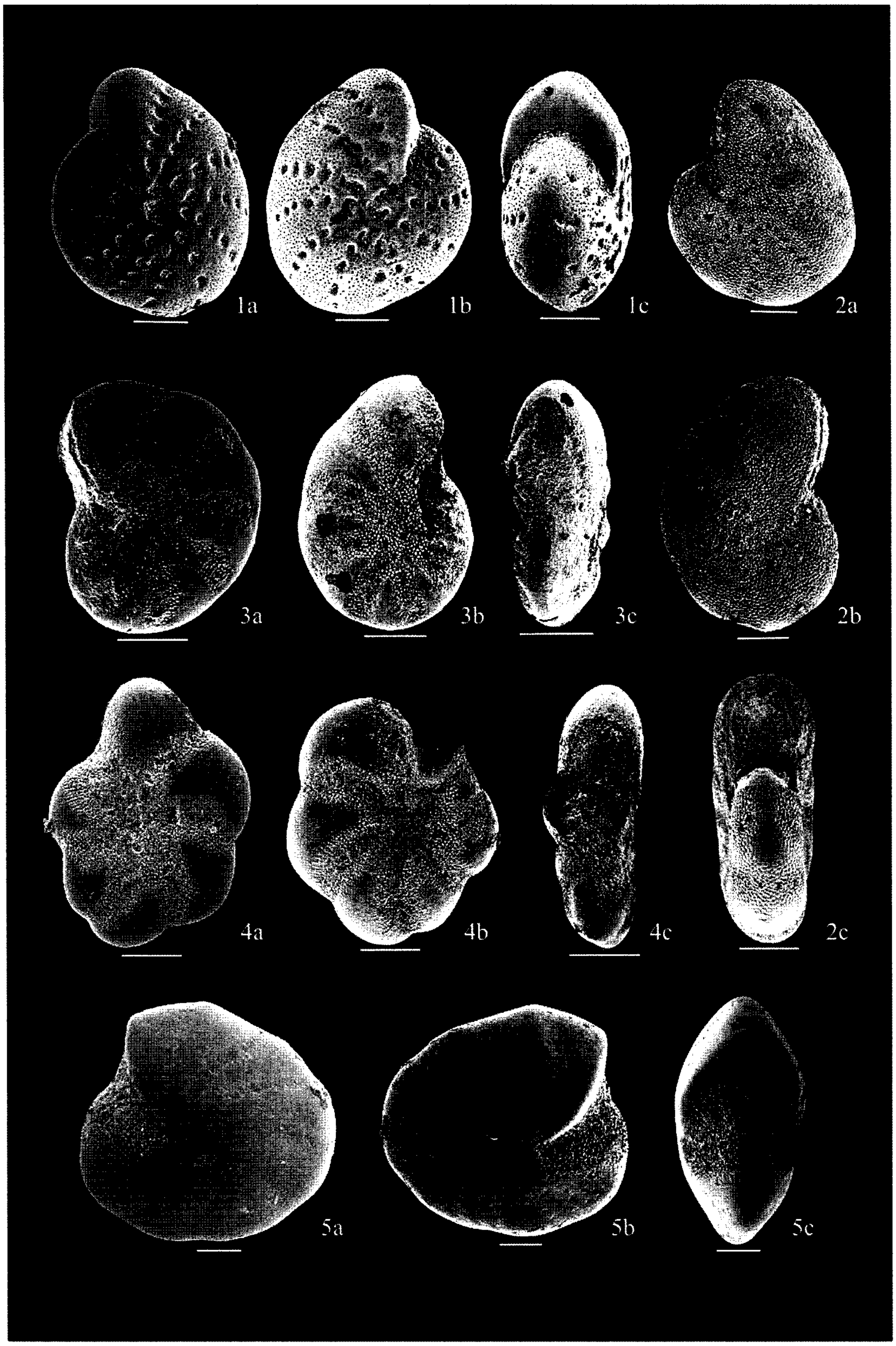
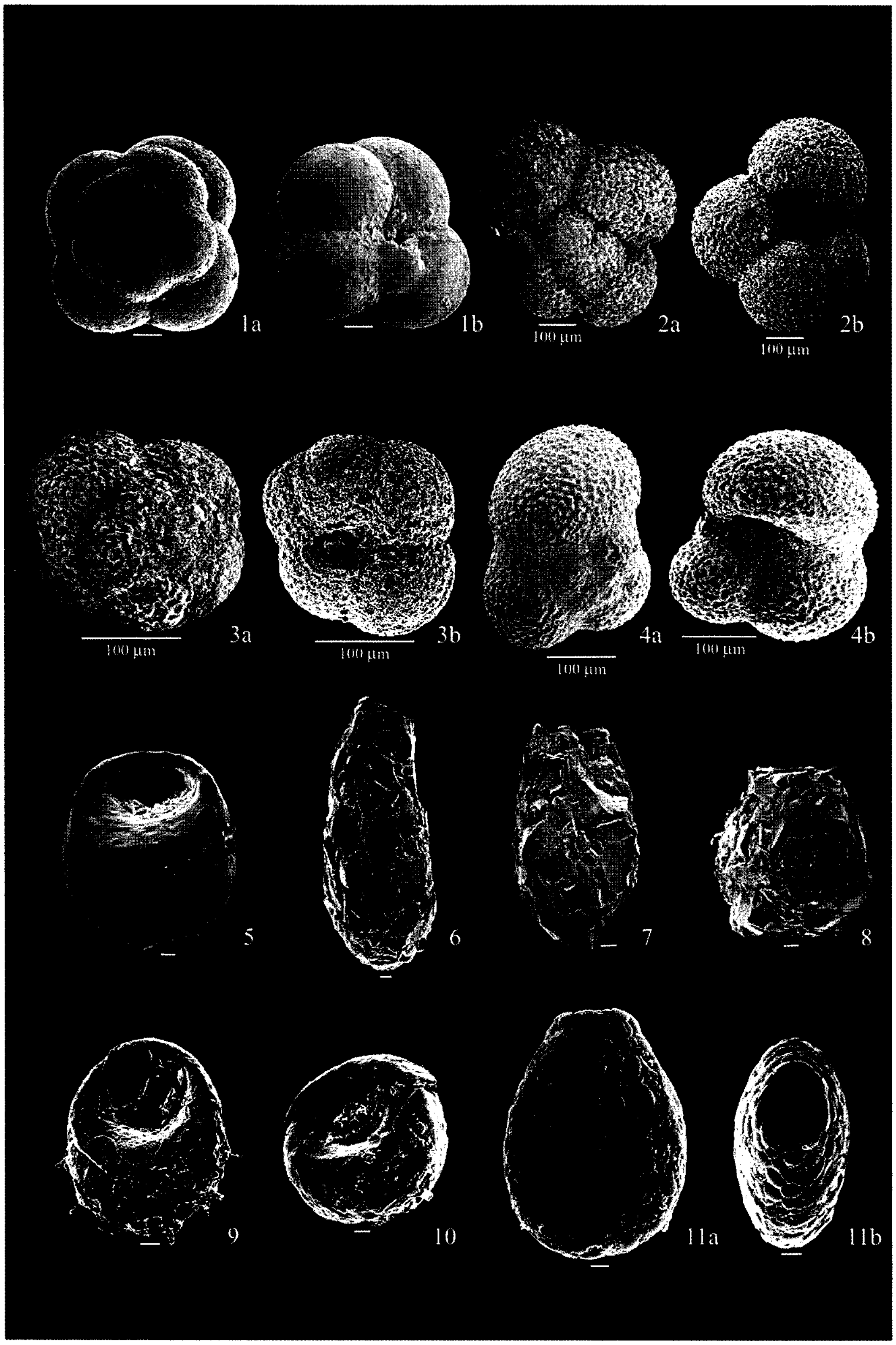


Plate 15:

1.- *Globigerinita uvula* (Ehrenberg), from sample FC04-64; 1a, dorsal view showing very smooth test; 1b, ventral view showing low-arched aperture. **2.-** *Globigerina bulloides* d'Orbigny from sample FC04-77; 2a, dorsal view showing globular chambers; 2b, ventral view showing high-arched aperture. **3.-** *Globigerina quinqueloba* Natland from sample FC04-77; 3a, dorsal view showing low trochospiral arrangement; 3b, ventral view showing lipped aperture. **4.-** *Globigerinoides cyclostomus* (Galloway and Wissler) from sample BE1; 4a, dorsal view showing ovoid chambers; 4b, ventral view showing rectangular test outline. **5.-** *Centropyxis constricta aerophila* Reinhardt et al., from sample ..., side view of specimen covered with organic material. **6.-** *Difflugia oblonga* Ehrenberg, from sample ..., side view showing pyriform test. **7.-** *Difflugia protaeiformis* Lamarck, from sample ..., side view showing spine in fundus. **8.-** *Difflugia urceolata* Carter, from sample ..., side view showing cauldron-like test. **9.-** *Centropyxis constricta constricta* Reinhardt et al., from sample FC04-110, showing spines in fundus. **10.-** *Cyclopyxis kahli* (Deflandre), from sample FC04-80, side view showing hemispherical test. **11.-** *Heleopera sphagni* (Leidy), from sample FC04-92; 11a, side view showing test entirely composed of idiosomes; 11b, apertural view showing compressed test and elliptical aperture. All scales are 10 μm unless otherwise indicated.

PLATE 15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3b
100 µm
4a
100 µm
4b
5
6
7
8
9
10
11a
11b

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APPENDIX A

Fractional abundance of all foraminiferal taxa from all samples. Species indicated with * represent the ones present in statistically significant numbers.

	BE1	BE2	BE3	BE5	BE7	ALS1	ALS2	ALS3	FCO4-2^10	FC04-11^18	FC04-19^26	FC04-27+29	FC04-30+31	FC04-32
Angulogerina fluens	0.01								0.05					
*Ammodiscus gullmarensis**														
*Astrononion gallowayi**	0.02													
Bolivina decussata	0.00	0.01												
*Bolivina minuta**	0.01	0.03									0.01			
*Bolivinellina pacifica**	0.03	0.01												
Botuloides pauciloculus	0.00													
*Buccella frigida**	0.12	0.14					0.33		0.11	0.15	0.53	0.36	0.40	0.47
Buccella hannai										0.01		0.03	0.01	
Buccella inusitata	0.01	0.01												
*Buccella tenerrima**	0.01													
Buccella depressa	0.00													
*Buliminella elegantissima**	0.01	0.03					0.12							
Cassidulina sp.														
*Cassidulina crassa**	0.00	0.02	0.05						0.05	0.16			0.02	0.05
*Cribroelphidium excavatum**		0.18	0.02								0.01			
*C. excavatum f. magna**										0.09	0.09	0.12	0.17	0.07
*C. excavatum f. clavata**	0.02			0.00					0.06	0.04		0.11	0.14	0.27
*C. excavatum f. excavata**	0.08										0.03		0.01	
*C. excavatum f. selseyensis**	0.00													
C. excavatum f. lidoensis	0.00													
*Cribroelphidium foraminosum**	0.01										0.01	0.08	0.12	0.05
*Cribroelphidium hallandense**	0.03													
*Cribroelphidium magellanicum**	0.03	0.01												
*Cribroelphidium microgranulosum**	0.07													
*Cribrostomoides sp. A**				0.02		0.02		0.01						
*Cribrostomoides crassimargo**							0.05	0.03						
*Cribrostomoides jeffreysii**	0.00		0.03	0.14	0.01	0.03		0.02			0.01			
*Cribrostomoides subglobosum**		0.01	0.07	0.11	0.01	0.21	0.14	0.03	0.02			0.01	0.01	
*Cribrostomoides wiesneri**														
Dyocibicides biserialis	0.01													
*Eggerella advena**	0.00	0.07	0.14	0.07	0.05	0.32	0.15	0.19	0.03	0.01	0.03	0.01		
*Eggerella whatever**				0.02				0.26	0.08		0.01			
*Elphidiella hannai**	0.03									0.01	0.01	0.04		
*Epistominella vitrea**	0.01	0.02							0.03	0.01		0.01	0.02	
Euuvigerina aculeata			0.02							0.03				
*Euuvigerina peregrina**	0.00		0.03	0.00					0.03	0.01		0.03	0.03	0.03
*Favulina epibathra**	0.01													
Favulina melo	0.00													
Fissurina cucurbitasema	0.00													
*Fissurina eburnea**	0.01													
Fissurina lucida														
Fissurina vitreola	0.00												0.01	
Gavelinopsis campanulata	0.00													
Gaudryina arenaria	0.00	0.01												
*Haplophragmoides brady**		0.02	0.27	0.30	0.38				0.21		0.01			
Homalohedra apiopleura	0.00													
Homalohedra borealis	0.00													
Homalohedra guntherii	0.01													
Hyalinonetrion dentaliforme	0.00													
Islandiella sp.	0.01													
*Islandiella helenae**	0.04													
Lagena sp.		0.01												
Lagena meridionalis														
Lagena laevis		0.01												
Lagena parri														
Lagena semilineata	0.00													
Laryngosigma trilocularis	0.01													
*Lobatula fletcheri**	0.11	0.10	0.02							0.01		0.01	0.01	0.03
*Lobatula lobatula**	0.07													
*Lobatula mckannai**	0.12								0.02	0.01	0.03			

	BE1	BE2	BE3	BE5	BE7	ALS1	ALS2	ALS3	FCO4-2^10	FC04-11^18	FC04-19^26	FC04-27+29	FC04-30+31	FC04-32
*Miliammina fusca**								0.09						
Miliammina sp.														
*Neouvigerina proboscidea**														
Nonionella digitata	0.00													
*Nonionella stella**	0.01								0.05					
Nonionella cf. turgida	0.00													
*Nonionellina labradorica**	0.01	0.13	0.02						0.17	0.37	0.14	0.14	0.04	0.02
Palliolatella fragens	0.00													
Palliolatella immemora	0.00													
Parafissurina semicarinata													0.01	
*Portatrochammina bipolaris**	0.00	0.03	0.20	0.11	0.21	0.03	0.00	0.04			0.01	0.01		
Procerolagena cf. amphora		0.01												
Procerolagena gracilis	0.00													
Procerolagena mollis	0.00													
Procerolagena wiesneri														
*Protoglobulimina pupoides**	0.01	0.01									0.01			
Pseudononion basispinata	0.00													
Pygmaeoseistron hispidulum			0.02											
Quinqueloculina sp.											0.03			
*Rosalina columbiensis**	0.02													
*Recurvoides turbinatus**				0.03		0.12	0.10	0.02			0.01	0.01	0.01	
Reophax catella														
Reophax cylindricus														
Reophax gracilis														
Reophax scottii														
Saccammina atlantica														
Saccammina sphaerica														
*Spiroplectammina biformis**		0.01	0.02	0.02	0.01	0.22	0.11	0.11						
*Stainforthia feylingi**	0.01	0.01											0.01	
*Textularia earlandi**				0.01	0.01									
Trochammina sp.		0.02												
*Trochammina charlottensis**	0.00	0.03		0.02	0.01	0.02		0.04	0.02					
*Trochammina discorbis**		0.06	0.08	0.11	0.24				0.06		0.01	0.01		
*Trochammina cf. globigeriniformis**		0.05	0.02	0.02										
Trochammina grisea														
Trochammina squamata														
*Trochammina nana**								0.02						
Trochammina nitida	0.00													
Trochammina ochracea	0.00	0.02		0.00										0.02
Trochammina pacifica	0.00							0.01	0.02	0.01				
Trochammina rotaliformis	0.01													
*Planktonic sp.**	0.01									0.04				
*Thecamoebians**		0.01		0.02	0.09	0.02		0.13						
Total Counts	528	193	59	577	117	98	226	161	63	68	78	91	112	60

	FC04-33^35	FC04-36	FC04-37	FC04-38+39	FC04-40+41	FC04-42	FC04-43	FC04-44+45	FC04-46	FC04-47	FC04-48+49	FC04-50+51	FC04-52	FC04-53
Angulogerina fluens														
*Ammodiscus gullmarensis**														
*Astrononion gallowayi**														
Bolivina decussata														
*Bolivina minuta**		0.02	0.02		0.01			0.01			0.01	0.02	0.02	0.01
*Bolivinellina pacifica**														
Botuloides pauciloculus														
*Buccella frigida**	0.42	0.16	0.29	0.30	0.39	0.39	0.38	0.34	0.31	0.29	0.33	0.24	0.24	0.16
Buccella hannai														
Buccella inusitata					0.03						0.01			
*Buccella tenerrima**				0.07		0.02			0.06				0.02	0.04
Buccella depressa				0.03										
*Buliminella elegantissima**														
Cassidulina sp.								0.03						
*Cassidulina crassa**		0.07	0.09	0.02	0.01					0.06	0.03	0.02	0.05	0.02
*Cribroelphidium excavatum**	0.04							0.01						
*C. excavatum f. magna**	0.13	0.26	0.23	0.19	0.25	0.30	0.17	0.19	0.26	0.18	0.20	0.44	0.29	0.22
*C. excavatum f. clavata**	0.19	0.28	0.17	0.10	0.12	0.11	0.21	0.18	0.16	0.16	0.10	0.08	0.20	0.20
*C. excavatum f. excavata**		0.03	0.05	0.05	0.01		0.09				0.03		0.01	0.05
*C. excavatum f. selseyensis**			0.04	0.09	0.01			0.03						
C. excavatum f. lidoensis														0.01
*Cribroelphidium foraminosum**	0.07	0.07			0.02	0.05		0.07	0.03	0.08			0.02	0.06
*Cribroelphidium hallandense**														
*Cribroelphidium magellanicum**														
*Cribroelphidium microgranulosum**														
*Cribrostomoides sp. A**														
*Cribrostomoides crassimargo**														
*Cribrostomoides jeffreysii**				0.01						0.02				
*Cribrostomoides subglobosum**					0.01			0.01			0.03			0.01
*Cribrostomoides wiesneri**														
Dyocibicides biserialis														
*Eggerella advena**														
*Eggerella whatever**														
*Elphidiella hannai**					0.02					0.02				
*Epistominella vitrea**	0.01	0.02		0.05		0.07			0.03	0.04	0.03	0.03	0.01	0.04
Euuvigerina aculeata	0.01			0.01									0.01	
*Euuvigerina peregrina**	0.02	0.02	0.01	0.02	0.01							0.02	0.02	0.02
*Favulina epibathra**													0.01	
Favulina melo														
Fissurina cucurbitasema														
*Fissurina eburnea**														
Fissurina lucida														
Fissurina vitreola					0.01									
Gavelinopsis campanulata														
Gaudryina arenaria														
*Haplophragmoides brady**					0.01				0.03	0.02				
Homalohedra apiopleura														
Homalohedra borealis														
Homalohedra guntherii														
Hyalinonetrion dentaliforme														
Islandiella sp.														
*Islandiella helenae**														
Lagena sp.		0.02												
Lagena meridionalis		0.02												
Lagena laevis														
Lagena parri					0.01									
Lagena semilineata														
Laryngosigma trilocularis														
*Lobatula fletcheri**	0.01	0.02	0.04	0.02		0.02		0.01	0.01		0.03		0.04	0.04
*Lobatula lobatula**														
*Lobatula mckannai**				0.03							0.01	0.08		0.02

	FC04-33^35	FC04-36	FC04-37	FC04-38+39	FC04-40+41	FC04-42	FC04-43	FC04-44+45	FC04-46	FC04-47	FC04-48+49	FC04-50+51	FC04-52	FC04-53
*Miliammina fusca**														
Miliammina sp.														
*Neouvigerina proboscidea**							0.02						0.04	0.01
Nonionella digitata														
*Nonionella stella**			0.03								0.01			
Nonionella cf. turgida														
*Nonionellina labradorica**	0.09	0.03	0.02	0.03	0.04	0.05	0.13	0.07	0.09	0.10	0.13	0.05	0.04	0.11
Palliolatella fragens														
Palliolatella immemora	0.01													
Parafissurina semicarinata			0.01		0.01									0.00
*Portatrochammina bipolaris**												0.02		
Procerolagena cf. amphora														
Procerolagena gracilis														
Procerolagena mollis														
Procerolagena wiesneri														
*Protoglobulimina pupoides**														
Pseudononion basispinata														
Pygmaeoseistron hispidulum														
Quinqueloculina sp.					0.01									
*Rosalina columbiensis**														
*Recurvoides turbinatus**										0.02				
Reophax catella														
Reophax cylindricus														
Reophax gracilis														
Reophax scottii														
Saccammina atlantica														
Saccammina sphaerica														
*Spiroplectammina biformis**														
*Stainforthia feylingi**			0.01											
*Textularia earlandi**														
Trochammina sp.								0.03	0.01		0.01			
*Trochammina charlottensis**			0.01											
*Trochammina discorbis**									0.01		0.01			
*Trochammina cf. globigeriniformis**														
Trochammina grisea														
Trochammina squamata														
*Trochammina nana**					0.01									
Trochammina nitida														
Trochammina ochracea														
Trochammina pacifica											0.01			
Trochammina rotaliformis														
*Planktonic sp.**														
*Thecamoebians**														
Total Counts	100	61	109	110	134	44	47	68	70	49	70	59	165	224

	FC04-54	FC04-55	FC04-56	FC04-57	FC04-58	FC04-59	FC04-61	FC04-62	FC04-63	FC04-64	FC04-65	FC04-66	FC04-67	FC04-68
Angulogerina fluens														
*Ammodiscus gullmarensis**												0.00	0.00	
*Astrononion gallowayi**														
Bolivina decussata														
*Bolivina minuta**	0.03	0.08	0.02	0.02		0.01	0.06	0.03	0.03	0.02	0.01	0.02	0.02	0.02
*Bolivinellina pacifica**														
Botuloides pauciloculus											0.01			
*Buccella frigida**	0.18	0.25	0.11	0.19	0.26	0.23	0.06	0.16	0.16	0.18	0.01	0.06	0.05	0.05
Buccella hannai														
Buccella inusitata														
*Buccella tenerrima**	0.05	0.03	0.02		0.07	0.01	0.05	0.02	0.02	0.02			0.01	0.00
Buccella depressa														
*Buliminella elegantissima**									0.02	0.03				
Cassidulina sp.														
*Cassidulina crassa**	0.01	0.03	0.02	0.11	0.04	0.03	0.05	0.04	0.03	0.03	0.07	0.02	0.05	0.05
*Cribroelphidium excavatum**														
*C. excavatum f. magna**	0.24	0.20	0.16	0.14	0.24	0.30	0.24	0.26	0.28	0.35	0.05	0.04		0.03
*C. excavatum f. clavata**	0.10	0.13	0.23	0.19		0.15	0.28	0.26	0.22		0.04	0.14	0.13	0.07
*C. excavatum f. excavata**			0.02		0.07		0.09		0.09	0.09	0.06	0.02		0.00
*C. excavatum f. selseyensis**														
C. excavatum f. lidoensis								0.01	0.01	0.03	0.00			
*Cribroelphidium foraminosum**	0.09		0.09	0.06	0.04	0.01		0.04	0.04	0.02	0.01	0.01		0.01
*Cribroelphidium hallandense**														
*Cribroelphidium magellanicum**														
*Cribroelphidium microgranulosum**														
*Cribrostomoides sp. A**											0.00			
*Cribrostomoides crassimargo**												0.01		
*Cribrostomoides jeffreysii**														
*Cribrostomoides subglobosum**										0.02		0.01	0.01	0.00
*Cribrostomoides wiesneri**														
Dyocibicides biserialis														
*Eggerella advena**						0.02					0.00		0.00	0.00
*Eggerella whatever**														0.00
*Elphidiella hannai**								0.01						
*Epistominella vitrea**	0.05	0.03	0.07	0.05		0.01	0.06	0.03	0.03	0.03	0.02	0.02	0.03	0.02
Euuvigerina aculeata						0.02						0.00	0.00	
*Euuvigerina peregrina**	0.03	0.05		0.02	0.02	0.02		0.01	0.02	0.03				
*Favulina epibathra**														
Favulina melo														
Fissurina cucurbitasema											0.00		0.00	0.00
*Fissurina eburnea**														
Fissurina lucida					0.02	0.02							0.00	
Fissurina vitreola					0.02									
Gavelinopsis campanulata														
Gaudryina arenaria														
*Haplophragmoides brady**	0.01					0.02					0.10	0.16	0.10	0.08
Homalohedra apiopleura														
Homalohedra borealis														
Homalohedra guntherii														
Hyalinonetrion dentaliforme														
Islandiella sp.														
*Islandiella helenae**														
Lagena sp.														
Lagena meridionalis													0.00	0.00
Lagena laevis														
Lagena parri														
Lagena semilineata														
Laryngosigma trilocularis														
*Lobatula fletcheri**	0.04	0.05		0.02		0.02	0.01	0.03			0.00		0.00	0.01
*Lobatula lobatula**														
*Lobatula mckannai**											0.01			

	FC04-54	FC04-55	FC04-56	FC04-57	FC04-58	FC04-59	FC04-61	FC04-62	FC04-63	FC04-64	FC04-65	FC04-66	FC04-67	FC04-68
*Miliammina fusca**														
Miliammina sp.														
*Neouvigerina proboscidea**					0.07					0.02				
Nonionella digitata														
*Nonionella stella**											0.01		0.06	0.01
Nonionella cf. turgida														
*Nonionellina labradorica**	0.15	0.18	0.25	0.19	0.13	0.10	0.05	0.07	0.06	0.09	0.03	0.06		0.04
Palliolatella fragens														
Palliolatella immemora				0.02										
Parafissurina semicarinata														
*Portatrochammina bipolaris**											0.01		0.00	
Procerolagena cf. amphora				0.02										
Procerolagena gracilis														
Procerolagena mollis												0.00		
Procerolagena wiesneri						0.01								
*Protoglobulimina pupoides**									0.01		0.00		0.01	
Pseudononion basispinata														
Pygmaeoseistron hispidulum										0.02				
Quinqueloculina sp.														
*Rosalina columbiensis**	0.01				0.02									
*Recurvoides turbinatus**	0.01										0.01		0.01	0.00
Reophax catella														
Reophax cylindricus														
Reophax gracilis														
Reophax scottii														
Saccammina atlantica														
Saccammina sphaerica							0.01					0.00		
*Spiroplectammina biformis**											0.00	0.01		0.00
*Stainforthia feylingi**							0.03	0.03			0.54	0.41	0.50	0.57
*Textularia earlandi**												0.00	0.00	0.01
Trochammina sp.														
*Trochammina charlottensis**											0.01			
*Trochammina discorbis**												0.01	0.00	0.01
*Trochammina cf. globigeriniformis**														
Trochammina grisea														
Trochammina squamata														
*Trochammina nana**													0.00	
Trochammina nitida														
Trochammina ochracea														
Trochammina pacifica												0.00		
Trochammina rotaliformis														
*Planktonic sp.**										0.03				
*Thecamoebians**											0.00		0.00	
Total Counts	79	40	44	64	54	91	79	155	116	65	325	286	446	365

	FC04-70	FC04-73	FC04-75	FC04-76	FC04-77	FC04-78	FC04-79	FC04-80	FC04-86+87	FC04-88+89	FCOA-90^93	FC0A-94^97	FC04-109	FC04-110
Angulogerina fluens														
*Ammodiscus gullmarensis**		0.01	0.00	0.00	0.01	0.00		0.02	0.08	0.05				0.04
*Astrononion gallowayi**														
Bolivina decussata														
*Bolivina minuta**		0.00	0.01	0.01										
*Bolivinellina pacifica**				0.00										
Botuloides pauciloculus														
*Buccella frigida**	0.18	0.09	0.08	0.07										
Buccella hannai														
Buccella inusitata														
*Buccella tenerrima**				0.00										
Buccella depressa				0.00										
*Buliminella elegantissima**			0.00											
Cassidulina sp.														
*Cassidulina crassa**	0.04	0.00	0.01	0.05										
*Cribroelphidium excavatum**														
*C. excavatum f. magna**	0.01	0.05	0.01	0.01										
*C. excavatum f. clavata**	0.11	0.06	0.12	0.11										
*C. excavatum f. excavata**	0.01	0.02	0.01	0.04										
*C. excavatum f. selseyensis**	0.01	0.01												
C. excavatum f. lidoensis			0.00											
*Cribroelphidium foraminosum**	0.01	0.02	0.02	0.05										
*Cribroelphidium hallandense**				0.00										
*Cribroelphidium magellanicum**														
*Cribroelphidium microgranulosum**														
*Cribrostomoides sp. A**	0.02	0.03		0.00									0.07	0.02
*Cribrostomoides crassimargo**					0.00									
*Cribrostomoides jeffreysii**	0.05	0.01	0.02		0.03	0.01	0.03	0.01			0.11	0.05		0.01
*Cribrostomoides subglobosum**	0.03	0.02	0.03	0.00	0.10	0.11	0.20	0.24	0.08	0.10	0.15	0.02	0.05	0.07
*Cribrostomoides wiesneri**							0.01							0.03
Dyocibicides biserialis														
*Eggerella advena**	0.04	0.02	0.02	0.00	0.33	0.32	0.31	0.37	0.24	0.31	0.21	0.39	0.28	0.31
*Eggerella whatever**					0.33	0.33	0.15	0.12	0.31	0.30	0.27	0.27	0.14	0.22
*Elphidiella hannai**														
*Epistominella vitrea**	0.01	0.02	0.05	0.03										
Euuvigerina aculeata			0.01	0.00										
*Euuvigerina peregrina**	0.01	0.01												
*Favulina epibathra**														
Favulina melo														
Fissurina cucurbitasema				0.00										
*Fissurina eburnea**														
Fissurina lucida			0.00											
Fissurina vitreola														
Gavelinopsis campanulata														
Gaudryina arenaria					0.00									
*Haplophragmoides brady**	0.28	0.26	0.17	0.09							0.01			
Homalohedra apiopleura														
Homalohedra borealis														
Homalohedra guntherii														
Hyalinonetrion dentaliforme														
Islandiella sp.														
*Islandiella helenae**														
Lagena sp.														
Lagena meridionalis														
Lagena laevis														
Lagena parri														
Lagena semilineata														
Laryngosigma trilocularis														
*Lobatula fletcheri**		0.01		0.00										
*Lobatula lobatula**														
*Lobatula mckannai**	0.01			0.00										

	FC04-70	FC04-73	FC04-75	FC04-76	FC04-77	FC04-78	FC04-79	FC04-80	FC04-86+87	FC04-88+89	FCOA-90^93	FCOA-94^97	FC04-109	FC04-110
*Miliammina fusca**														
Miliammina sp.													0.02	
*Neouvigerina proboscidea**														
Nonionella digitata				0.00										
*Nonionella stella**	0.01	0.01		0.01										
Nonionella cf. turgida														
*Nonionellina labradorica**	0.05	0.04	0.02	0.03										
Palliolatella fragens														
Palliolatella immemora														
Parafissurina semicarinata														
*Portatrochammina bipolaris**	0.01	0.01		0.01	0.00	0.01	0.02							0.02
Procerolagena cf. amphora														
Procerolagena gracilis			0.00											
Procerolagena mollis														
Procerolagena wiesneri														
*Protoglobulimina pupoides**	0.01	0.02	0.00	0.00										
Pseudononion basispinata														
Pygmaeoseistron hispidulum			0.01	0.00										
Quinqueloculina sp.														
*Rosalina columbiensis**														
*Recurvoides turbinatus**	0.01	0.01	0.02		0.09	0.12	0.18	0.14	0.14	0.06	0.14	0.07	0.23	0.08
Reophax catella														
Reophax cylindricus														
Reophax gracilis														
Reophax scottii	0.01													
Saccammina atlantica							0.02							
Saccammina sphaerica														
*Spiroplectammina biformis**	0.01	0.00	0.00	0.00	0.04	0.05	0.05	0.05	0.11	0.08	0.08	0.05	0.02	0.14
*Stainforthia feylingi**	0.06	0.25	0.32	0.44										
*Textularia earlandi**		0.00	0.01											
Trochammina sp.														
*Trochammina charlottensis**		0.01		0.00		0.00			0.01					
*Trochammina discorbis**	0.01	0.01	0.01		0.00	0.00	0.02							
*Trochammina cf. globigeriniformis**					0.00									
Trochammina grisea														
Trochammina squamata												0.02		
*Trochammina nana**			0.00		0.01	0.02					0.01			0.02
Trochammina nitida														
Trochammina ochracea														
Trochammina pacifica	0.01		0.01	0.00	0.01	0.00	0.02							0.01
Trochammina rotaliformis														
*Planktonic sp.**			0.01		0.02									
*Thecamoebians**	0.01	0.00	0.01		0.01	0.01		0.04	0.03	0.11	0.01	0.14	0.19	0.05
Total Counts	140	290	289	512	416	272	110	113	74	88	73	44	43	114

	FC04-112^116	FC04-118	FC04-121	FC04-123	FC04-124	FC04-132	FC04-138
Angulogerina fluens							
*Ammodiscus gullmarensis**	0.08	0.03	0.04	0.03			
*Astrononion gallowayi**							
Bolivina decussata							
*Bolivina minuta**							
*Bolivinellina pacifica**							
Botuloides pauciloculus							
*Buccella frigida**							
Buccella hannai							
Buccella inusitata							
*Buccella tenerrima**							
Buccella depressa							
*Buliminella elegantissima**							
Cassidulina sp.							
*Cassidulina crassa**							
*Cribroelphidium excavatum**							
*C. excavatum f. magna**							
*C. excavatum f. clavata**							
*C. excavatum f. excavata**							
*C. excavatum f. selseyensis**							
C. excavatum f. lidoensis							
*Cribroelphidium foraminosum**							
*Cribroelphidium hallandense**							
*Cribroelphidium magellanicum**							
*Cribroelphidium microgranulosum**							
*Cribrostomoides sp. A**	0.07				0.03		
*Cribrostomoides crassimargo**		0.01	0.04	0.03	0.02	0.03	0.01
*Cribrostomoides jeffreysii**	0.02	0.03		0.02			0.04
*Cribrostomoides subglobosum**	0.05	0.01		0.17	0.12	0.07	0.02
*Cribrostomoides wiesneri**							
Dyocibicides biserialis							
*Eggerella advena**	0.31	0.35	0.33	0.24	0.47	0.22	0.16
*Eggerella whatever**	0.27	0.28	0.35	0.33	0.19	0.28	0.20
*Elphidiella hannai**							
*Epistominella vitrea**							
Euuvigerina aculeata							
*Euuvigerina peregrina**							
*Favulina epibathra**							
Favulina melo							
Fissurina cucurbitasema							
*Fissurina eburnea**							
Fissurina lucida							
Fissurina vitreola							
Gavelinopsis campanulata							
Gaudryina arenaria		0.01					
*Haplophragmoides brady**					0.01		0.01
Homalohedra apiopleura							
Homalohedra borealis							
Homalohedra guntherii							
Hyalinonetrion dentaliforme							
Islandiella sp.							
*Islandiella helenae**							
Lagena sp.							
Lagena meridionalis							
Lagena laevis							
Lagena parri							
Lagena semilineata							
Laryngosigma trilocularis							
*Lobatula fletcheri**							
*Lobatula lobatula**							
*Lobatula mckannai**							

	FC04-112^116	FC04-118	FC04-121	FC04-123	FC04-124	FC04-132	FC04-138
*Miliammina fusca**							
Miliammina sp.							
*Neouvigerina proboscidea**							
Nonionella digitata							
*Nonionella stella**							
Nonionella cf. turgida							
*Nonionellina labradorica**							
Palliolatella fragens							
Palliolatella immemora							
Parafissurina semicarinata							
*Portatrochammina bipolaris**		0.01			0.01	0.02	
Procerolagena cf. amphora							
Procerolagena gracilis							
Procerolagena mollis							
Procerolagena wiesneri							
*Protoglobulimina pupoides**							
Pseudononion basispinata							
Pygmaeoseistron hispidulum							
Quinqueloculina sp.							
*Rosalina columbiensis**							
*Recurvoides turbinatus**	0.11	0.11	0.13	0.06	0.07	0.22	0.08
Reophax catella							0.01
Reophax cylindricus							0.01
Reophax gracilis	0.02				0.02		
Reophax scottii							
Saccammina atlantica							
Saccammina sphaerica							
*Spiroplectammina biformis**		0.07	0.09	0.05	0.05	0.10	0.11
*Stainforthia feylingi**							0.05
*Textularia earlandi**							
Trochammina sp.		0.01					
*Trochammina charlottensis**		0.03	0.02	0.02			
*Trochammina discorbis**							
*Trochammina cf. globigeriniformis**							
Trochammina grisea							
Trochammina squamata							
*Trochammina nana**		0.01			0.02		0.02
Trochammina nitida							
Trochammina ochracea							
Trochammina pacifica	0.02	0.01					
Trochammina rotaliformis							
*Planktonic sp.**							
*Thecamoebians**	0.04	0.05		0.06		0.05	0.27
Total Counts	91	148	46	66	123	58	83

APPENDIX B

AMS radiocarbon dates from core FC04. The following are copies of the original reports supplied by Dr. Rolf Beukens of IsoTrace Laboratories (Toronto, ON).

ISOTRACE Laboratory
Accelerator Mass Spectrometry Facility
at the University of Toronto

From: Alice W. C. Leung
Business Officer

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Canada. M5S 1A7
Telephone (416) 978 2258

Email **alice.leung@utoronto.ca**

Fax (416) 978 4711

Send to: Prof. R. Timothy Patterson
Dept. of Earth Sciences
Carleton University

2569
FAX N°: 613-520-~~4490~~

Date:

Number of pages including this page.............. 7

IsoTrace Radiocarbon Laboratory

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Accelerator Mass Spectrometry Facility
at the University of Toronto

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Radiocarbon Analysis Report

January 26, 2006

Submitter: R.T.Patterson, Dept of Earth Sciences, Carleton Univ, Ottawa ON

These results are the average of 2 separate analyses (normal precision) and are corrected for natural and sputtering isotope fractionation, using the measured $^{13}C/^{12}C$ ratios. The sample ages are quoted as uncalibrated conventional radiocarbon dates in years before present (BP), using the Libby ^{14}C meanlife of 8033 years. The errors represent 68.3 % confidence limits.

Sample Identification	Description	Weight used (mg)	IsoTrace Lab number	Age (years BP)
* FC04.77	wood	15	TO-12566	530 ± 40
* FC04.J5	gyttja	4000	TO-12567	1060 ± 50
TL136	gyttja	3200	TO-12568	8740 ± 70
TL160	gyttja	745	TO-12569	8840 ± 60

I would like to hear your comments on these results. If these results are used in a publication, I would appreciate it if you could send me a reprint.

Dr. R. P. Beukens

ISOTRACE RADIOCARBON CALIBRATION REPORT

Output by calibration program C14CAL04

26-Jan-06

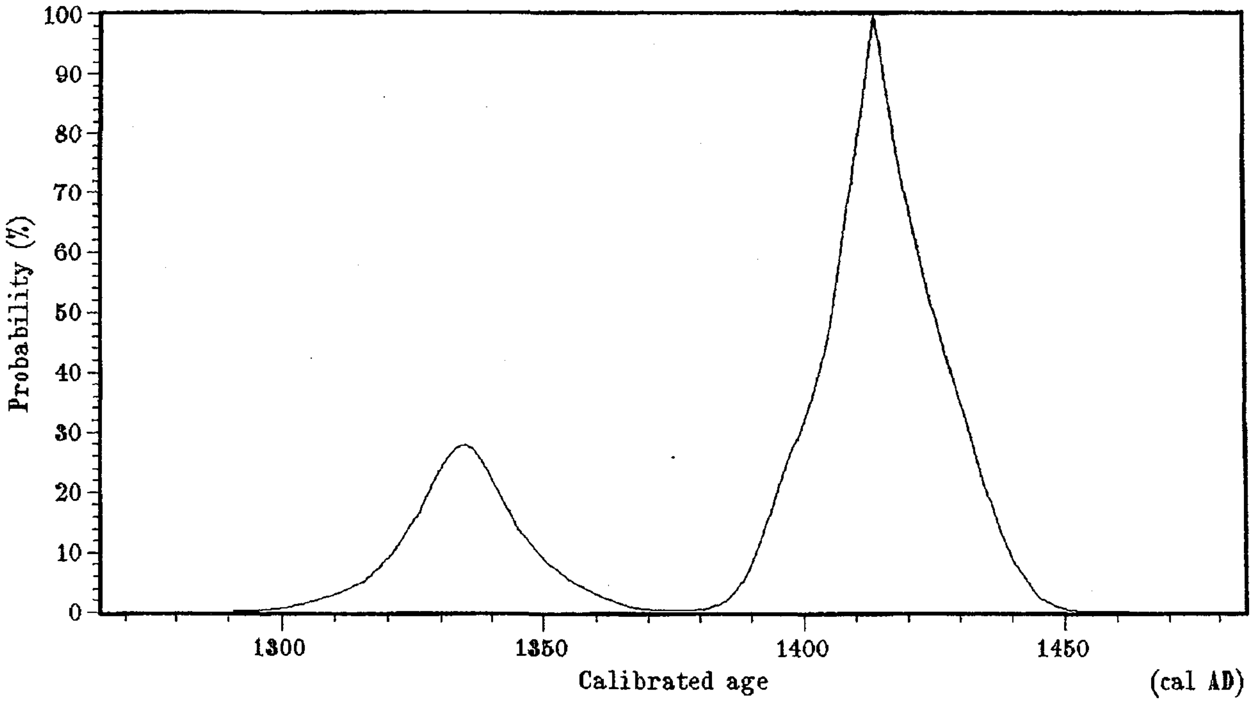
TO-12566 FC04.77 wood

Radiocarbon date : 530 ± 40 BP

All solutions, with a probability of 50% or greater for the calibrated age of this radiocarbon date, have been calculated from the dendro calibration data. The 68% and 95% confidence intervals, which are the 1σ and 2σ limits for a normal distribution, are also given. A probability of 100% means the radiocarbon date intersects the dendro calibration curve at this age.
All results are rounded to the nearest multiple of 5 years.

Probability	cal Age	68.3 % c.i.	95.5 % c.i.
100 %	1410 cal AD	1400 AD - 1430 AD	1385 AD - 1440 AD

Calibrated with the standard data set from:
INTCAL04 Terrestrial Radiocarbon Age Calibration, 0-26 cal kyr BP
P.J.Reimer et al.; Radiocarbon 46#3 (2004) p1029



ISOTRACE RADIOCARBON CALIBRATION REPORT

Output by calibration program C14CAL04

26-Jan-06

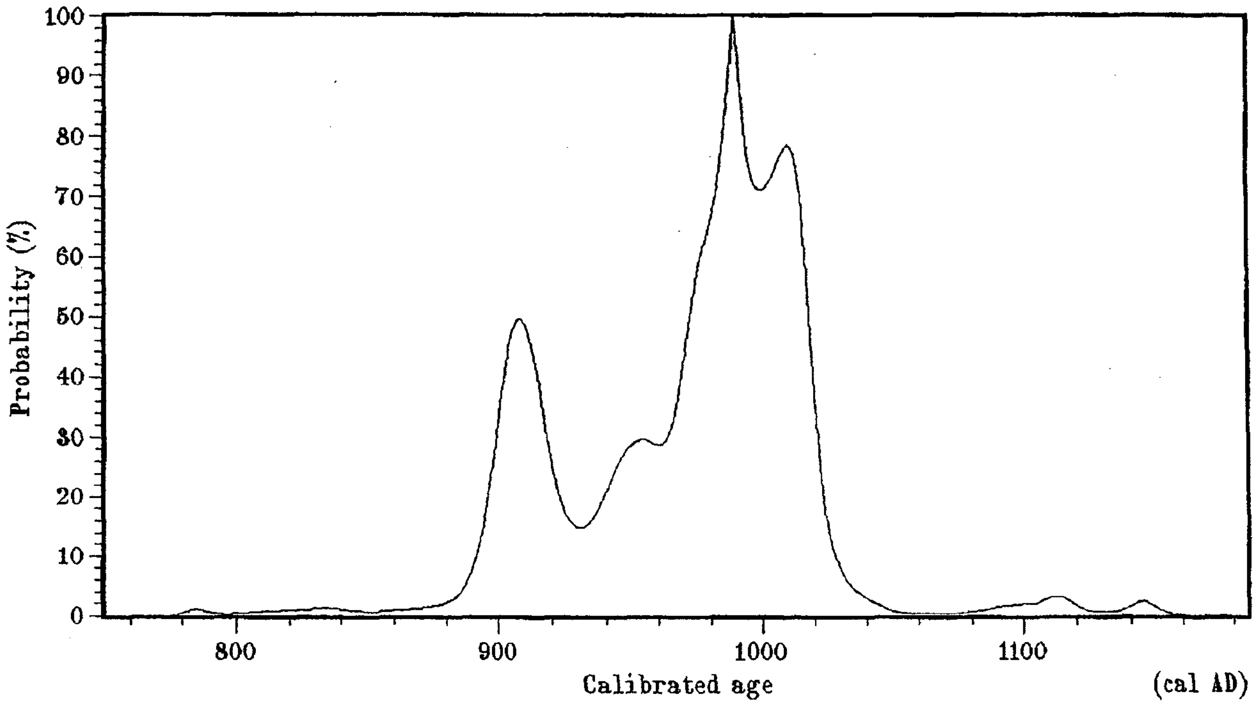
TO-12567 FC04.J5 gyttja

Radiocarbon date : 1060 ± 50 BP

All solutions, with a probability of 50% or greater for the calibrated age of this radiocarbon date, have been calculated from the dendro calibration data. The 68% and 95% confidence intervals, which are the 1σ and 2σ limits for a normal distribution, are also given. A probability of 100% means the radiocarbon date intersects the dendro calibration curve at this age.
All results are rounded to the nearest multiple of 5 years.

Probability	cal Age	68.3 % c.i.	95.5 % c.i.
100 %	990 cal AD	965 AD - 1020 AD	885 AD - 1035 AD

Calibrated with the standard data set from:
INTCAL04 Terrestrial Radiocarbon Age Calibration, 0-26 cal kyr BP
P.J.Reimer et al.; Radiocarbon 46#3 (2004) p1029



ISOTRACE RADIOCARBON CALIBRATION REPORT
Output by calibration program C14CAL04

26-Jan-06

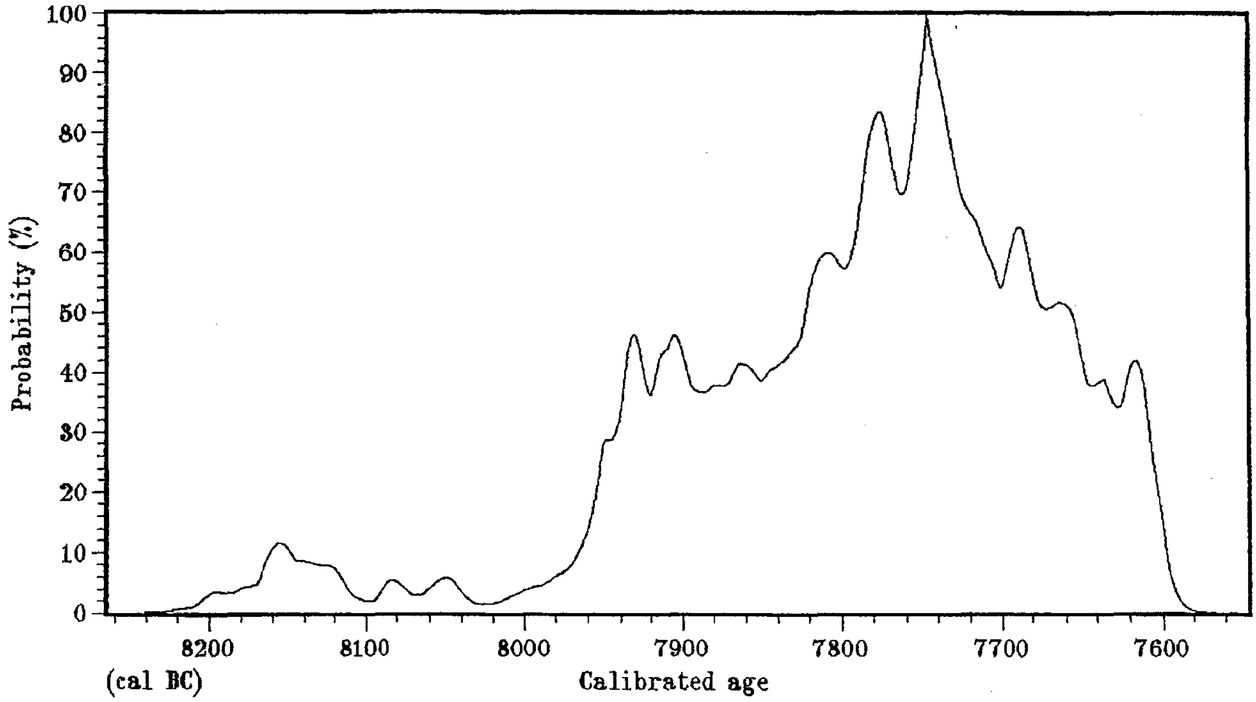
TO-12568 TL136 gyttja

Radiocarbon date : 8740 ± 70 BP

All solutions, with a probability of 50% or greater for the calibrated age of this radiocarbon date, have been calculated from the dendro calibration data. The 68% and 95% confidence intervals, which are the 1σ and 2σ limits for a normal distribution, are also given. A probability of 100% means the radiocarbon date intersects the dendro calibration curve at this age.
All results are rounded to the nearest multiple of 5 years.

Probability	cal Age	68.3 % c.i.	95.5 % c.i.
100 %	7745 cal BC	7940 BC - 7605 BC	7990 BC - 7590 BC

Calibrated with the standard data set from:
INTCAL04 Terrestrial Radiocarbon Age Calibration, 0-26 cal kyr BP
P.J.Reimer et al.; Radiocarbon 46#3 (2004) p1029



ISOTRACE RADIOCARBON CALIBRATION REPORT
Output by calibration program C14CAL04

26-Jan-06

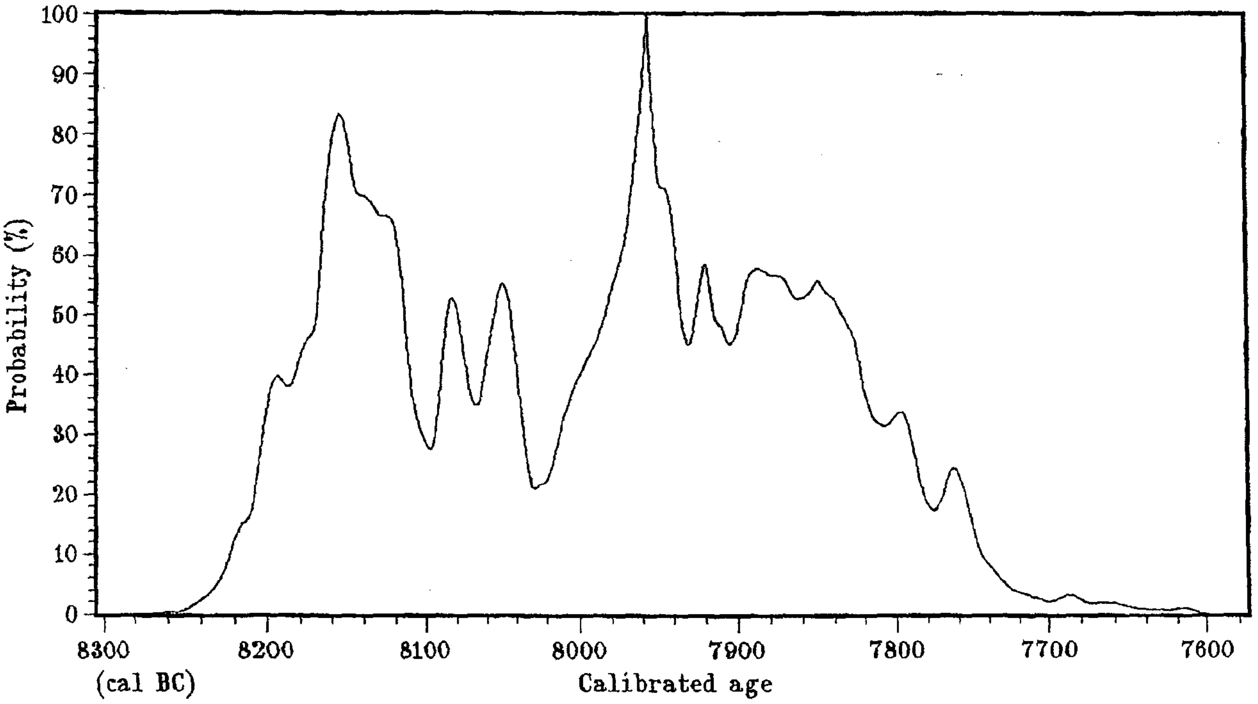
TO-12569 TL160 gyttja

Radiocarbon date : 8840 ± 60 BP

All solutions, with a probability of 50% or greater for the calibrated age of this radiocarbon date, have been calculated from the dendro calibration data. The 68% and 95% confidence intervals, which are the 1σ and 2σ limits for a normal distribution, are also given. A probability of 100% means the radiocarbon date intersects the dendro calibration curve at this age. All results are rounded to the nearest multiple of 5 years.

Probability	cal Age	68.3 % c.i.	95.5 % c.i.
83 %	8155 cal BC	8200 BC - 8100 BC	8230 BC - 7725 BC
55 %	8045 cal BC	8205 BC - 8030 BC	8230 BC - 7720 BC
100 %	7955 cal BC	8010 BC - 7810 BC	8230 BC - 7725 BC

Calibrated with the standard data set from:
INTCAL04 Terrestrial Radiocarbon Age Calibration, 0-26 cal kyr BP
P.J.Reimer et al.; Radiocarbon 46#3 (2004) p1029



ISOTRACE RADIOCARBON CALIBRATION SUMMARY
Output by calibration program C14CAL04
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26-Jan-06