LATE QUATERNARY BIOSTRATIGRAPHY OF TWO SHALLOW BOREHOLES, COMO P-21 AND PANUKE F-99 WELLSITES, SABLE ISLAND BANK

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ABSTRACT

Seventy-eight samples from two shallow geotechnical boreholes from the Como P-21 and Panuke F-99 wellsites on Sable Island Bank, Scotian Shelf have been analysed for Quaternary benthonic, Quaternary planktonic and reworked foraminifera. Seven distinct Quaternary benthic foraminiferal assemblages have been recognized in the Como borehole. These seven assemblages are: a low number Elphidium subarcticum assemblage; an Elphidium bartletti - (relict) Elphidium excavatum assemblage; a post glacial E. excavatum - E. subarcticum - I. helenae assemblage; a late glacial/immediate post glacial E. excavatum - C. reniforme assemblage; an E. excavatum - E. takayanagii - C. reniforme cold water shelf assemblage; an E. excavatum glacial assemblage and an E. excavatum - E. subarcticum - Glabratella wrightii bank assemblage. Twelve distinct assemblages are recognized in the Panuke borehole, they are: an E. barletti - E. subarcticum - E. advena surface fauna, "barren zone A", an E. excavatum - C. reniforme - E. takayanagii cold shelf fauna, an E. excavatum - C. reniforme - I. helenae immediate post glacial fauna, three late glacial faunas, E. excavatum - C. reniforme, E. excavatum - E. subarcticum and E. excavatum - C. reniforme, "barren zone B", alternating E. excavatum - B. frigida with E. excavatum - E. takayanagii low number cold shelf assemblage followed by the same sequence with higher numbers, an E. excavatum - C. reniforme - B. frigida - C. lobatalus bank/shelf fauna and an E. excavatum glacial fauna. The upper two assemblages in each borehole contain both modern and relict components, they have been reworked; and they lie above Regional Reflector R1, the acoustic reflector believed to represent the erosional surface at the base of the last marine transgression (Amos and Knoll, 1987). These upper two faunas in each hole occur within the Sable Island Sand and Gravel Formation. The underlying five assemblages at Como and the next six assemblages at Panuke occur within the Emerald Silt or its stratigraphic equivalent, of which the upper 2 m at Como and upper 10 m at Panuke appear to be above R1. The uppermost glacio-marine faunas (one at Como and two at Panuke) contain high numbers of reworked Cretaceous foraminifera interpreted as being eroded and transported by glacial ice, then redeposited with Quaternary sediments and foraminifera during the final deglaciation event.

In the Como borehole there are two faunas indicative of glacial activity/ice cover alternating with a cold shelf fauna and at the base a cold shelf/bank fauna.

In the Panuke borehole the six underlying faunas indicate glacial conditions. Immediately underlying these faunas is "barren zone B" which coincides with R2, the acoustic reflector believed to represent the mid-Wisconsinan low sea level stand. The next three faunas are indicative of cold shelf/bank conditions. The fauna at the base of the hole is a glacial fauna.

Local depositional environments, erosion, reworking and extensive subglacial channeling, result in varied foraminiferal assemblages and render difficult regional correlation between boreholes.

INTRODUCTION

The Scotian Shelf is characterized by central shelf basins and outer shelf banks. Studies of Quaternary paleo-oceanography have concentrated on basin sediments because of the complete glacial-post glacial sedimentary sequences they contain. By contrast, little has been done on the outer banks because they are areas of erosion and the coarser texture makes it difficult, if not impossible, to sample using conventional piston coring equipment. Consequently, very little is known of the Pleistocene stratigraphy of the outer shelf or the depositional environment these sediments represent.

The outer Scotian Shelf, particularily the area around Sable Island, has been an area of active petroleum exploration for the past 20 years. Geotechnical sampling of the top 100 m of sediment was common, but it was rarely analysed for stratigraphic characteristics. Scott et al. (1984), Ruffman et al. (1985) and Jacques, McClelland Geosciences inc. (1985) have studied late Quaternary sea level changes and Quaternary micropaleontology on Sable Island. A 152 m, continuously sampled drillhole, completed for Dalhousie University under a contract to Jacques, McClelland Geosciences inc. (1985) has been analysed stratigraphically (McLaren and Boyd, 1987; Boyd et al.,1988; Scott et al., 1988). Quantitative micropaleontological data from this hole, however, is not available, as the foraminifera were only analysed qualitatively (McLaren and Boyd, 1987; Boyd et al., 1988; Scott et al., 1988). The only quantitative information available at this time are two unpublished reports; one by Miller and Scott (1984) which describes the Quaternary micropaleontology of two shallow geotechnical boreholes at the Louisburg J-47 wellsite on central Banquereau and a second by Miller (1987b), which details the foraminifera found in the 46 m Cohasset A-52 wellsite borehole.

In 1987 Jacques, McClelland Geosciences inc. was contracted by Petro-Canada Ltd. to drill two boreholes at the Como P-21 (G057) and Panuke F-99 (G058) wellsites on Sable Island Bank to a depth of 36 m each and complete geotechnical tests. These sites are southwest of Sable Island (Figure 1); Como is 14 km west of the Cohasset site and 8 km northwest of Panuke. The Geological Survey of Canada was invited to

participate in the sampling program at both boreholes in order to help define the geological section. The Geological Survey then contracted Jacques, McClelland to drill an extension of the Panuke borehole from 36 to 61 m (G059) in an attempt to sample across a seismic disconformity thought to be Tertiary in age. The Geological Survey subsequently contracted Marine G.E.O.S. (Geological Exploration and Offshore Services; DSS Contract No. 23420-7-M516/01-0SC) to study the foraminifera from these two boreholes.

This report is a compilation and interpretation of the foraminiferal data from these two boreholes.

BOREHOLE LOCATION

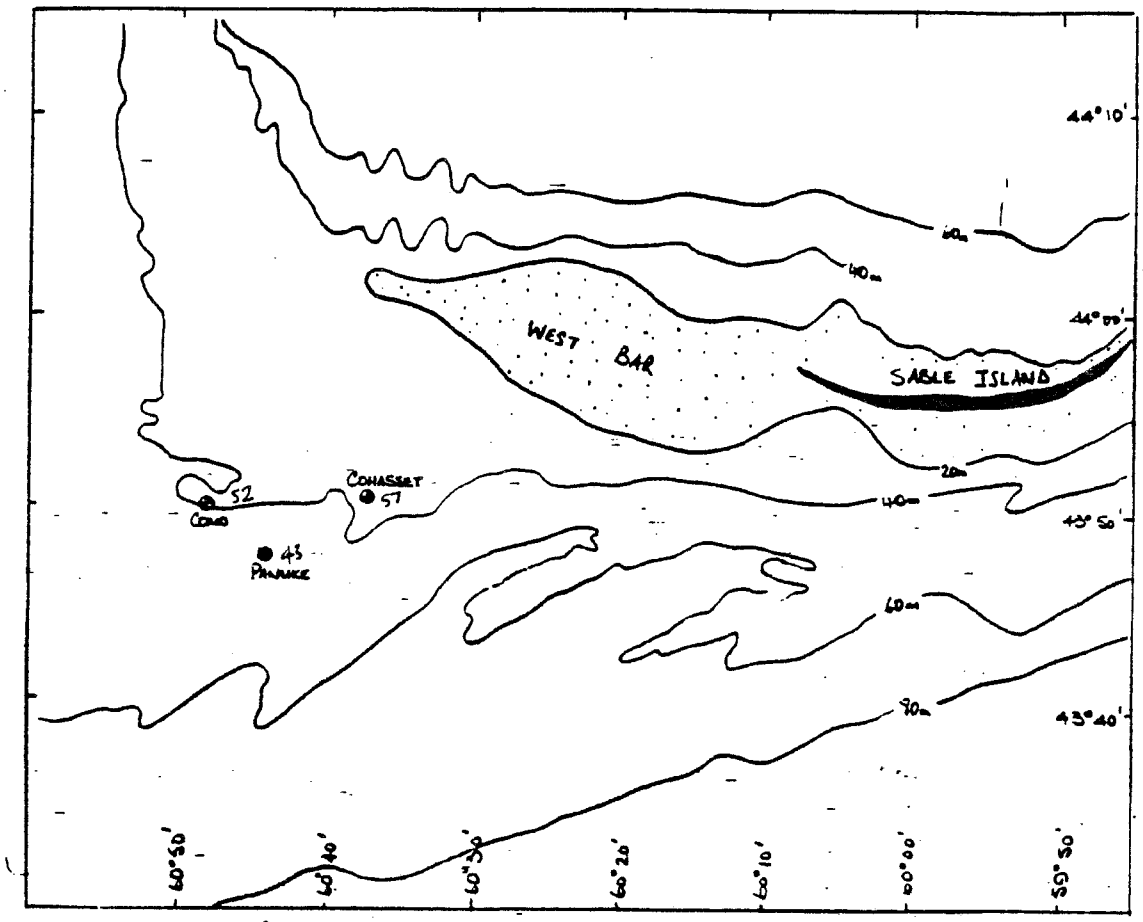

FIG. 1. LOCATION DIAGRAM

One boring was drilled at the Como P-21 wellsite (Figure 1, above from Amos, 1987), in 38.5 m of water to a depth of 36.15 m at 43^{o} 50' N, 60^{o} 48' W. The second boring was drilled at the Panuke F-99 wellsite in a water depth of 45 m at 43^{o}48' 27" N, 60^{o} 44' 35" W to a depth of 60.1 m.

PREVIOUS WORK

Pre-Quaternary Geology

The bedrock geology of the Scotian Shelf has been extensively studied, reported on and well summarized (King, 1980; King and Fader, 1986). Cretaceous rocks overlie Pennsylvanian and older rocks and form the bedrock beneath part of the Laurentian Channel and much of the shelf north of Sable Island (King and MacLean, 1976). Rocks of Cretaceous age have been dredged north of Sable Island and Sable Island Bank (King et al., 1970). Tertiary strata unconformably overlie the Cretaceous rock and forms the bedrock underlying the outer Scotian Shelf. These strata thicken seaward. MacLean and King (1971) include in this unit all material overlying the Cretaceous strata and underlying recognizable Pleistocene deposits; and this may include early Pleistocene material. Oligocene and Miocene material have been found outcropping in The Gully (Scotian Shelf) (Marlowe, 1965, 1969; Marlowe and Bartlett , 1968). There have been several cycles of erosion (some of which were subaerial) since deposition of the Cretaceous strata, particularily during the Late Cretaceous and Early Tertiary, causing deposition of Tertiary strata upon an eroded Cretaceous surface. Another period of subaerial erosion took place following deposition of Tertiary strata and prior to the onset of Pleistocene glaciation (MacLean and King, 1971). These erosional surfaces are a major controlling factor in the topography of the shelf today (MacLean and King, 1971).

Surficial Geology and Quaternary History

Little is known about the Quaternary cover on Sable Island Bank other than the sediments are composed of clean sand and gravel and underlain by a thick sequence of unconsolidated sediments of Late Tertiary /Pleistocene age (Berger et al., 1965). Numerous workers have attempted to survey the bank using acoustic methods (listed in Amos and Knoll, 1987); and these workers have proposed that the bank is underlain by a 200-300 m thick Quaternary section topped by a continuous layer of sand and gravel of Holocene age, formed by the reworking of glacial and glacio -

marine sediments. The sandy texture of the bank tops limits penetration by acoustic methods and by conventional coring techniques. Most Quaternary studies have been directed towards the basins, which contain complete post-glacial records well represented due to high sedimentation rates (Scott et al., 1984). The Quaternary sediments of Emerald Basin have been extensively studied (Vilks and Rashid, 1976; King, 1980; Mudie, 1980, 1982; Scott et al., 1984; King and Fader, 1986) though only the upper Quaternary stratigraphic sequence has been sampled. This basin sequence consists of: Scotian Shelf Drift (glacial till), the Emerald Silt (facies A and B, proglacial clayey sandy silt) and the LaHave Clay (Holocene silty clay, formed by winnowing of sediments on the banks and land areas). Seismic records of the bank sediments indicate a different stratigraphic sequence to that found in the basins. Results from five boreholes on Banquereau (Amos and Knoll, 1987) show a composite sequence consisting of Emerald Silt, overlain by a thick sequence of the Sable Island Sand and Gravel (a clean well sorted sand and gravel) that is in part a basal transgressive deposit (MacLean and King, 1971; King, 1980; King and Fader, 1986).

In some basin sequences and outcropping on the flanks of the banks is the Sambro Sand, a lateral equivalent of the Emerald Silt, composed of reworked deposits of Scotian Shelf Drift and Emerald Silt.

During the Pleistocene, the last glacial advance was fully developed by about 26,000 YBP and the extent of grounded ice is marked by an end moraine complex (King, 1980; King and Fader, 1986). The thickness, extent and duration of the floating ice in front of the ice sheet is not known, but this ice shelf was probably responsible for the deposition of most of the Emerald Silt. The ice receded and a minimum sea level stand was established about 15,000 YBP (Milliman and Emery, 1968) at 110-120 m below present sea level. (MacLean and King, 1971; King, 1980; King and Fader, 1986). Scott et al. (1983) have documented Holocene sea level rise on Sable Island and have evidence for a sea level at -21 m at approximately 8,000 YBP. Scott et al., (1988) have documented sea level rise of 78 m in the last 15,000 years, also on Sable Island.

Micropaleontology

Detailed previous work on the micropaleontology of the Quaternary sediments will be outlined in the discussion, as it becomes pertinent to

the comparison with the results of this study.

Until recently, it has been difficult to interpret the Quaternary foraminifera on the Scotian Shelf because little was known about modern assemblages living there today. Bartlett (1964) and Barbieri and Medioli (1969) have carried out reconnaissance studies of total assemblages only on the inner and western portions of the Shelf.

Williamson (1982, 1983) and Williamson et al. (1984) have completed a comprehensive study of both living and total assemblages on the entire shelf and have related living assemblages to present day water masses. This modern data set now provides a data base to compare with fossil assemblages.

Medioli et al. (1986) have studied the recent (surficial) distribution of foraminifera around Sable Island and on Sable Island Bank. The area west of the island, on the West Bar, is virtually barren of foraminifera, probably due to oceanographic conditions.

Very little work has been done on the Quaternary biostratigraphy in the numerous geotechnical boreholes drilled on the Scotian Shelf; that which has been done has remained the confidential property of the petroleum companies contracting the work. Two exceptions are reports completed by Miller and Scott (1984) and Miller (1987b) under contract to the G.S.C., examining the Quaternary and reworked foraminifera in two shallow boreholes at the Louisburg J-47 wellsite on central Banquereau and in the 46 m Cohasset A-52 wellsite, respectively. These works will be referred to in the discussion section of this report.

LABORATORY METHODS

Samples for biostratigraphic analysis were collected separately on site. Previously (i.e. Miller and Scott, 1984; Miller, 1987b) biostratigraphic analysis was carried out on samples that had already been subjected to any one or more of the following procedures: contamination with drilling mud, washing, mechanical sieving, grain size analysis and geotechnical testing. It had been observed in these samples that there was almost a complete absence of agglutinated foraminifera and that the calcareous tests showed the effects of mechanical working and abrasion. Separate samples for biostratigraphic analysis allowed the confirmation or elimination of geotechnical sampling methods as the cause of the absence of an agglutinated fauna and the mechanical wear and abrasion of the calcareous tests.

At the Como borehole 29 samples were collected (see Amos, 1987, or Table 1, this report for sample intervals). Thirty cubic cm (cc) samples were taken at the designated intervals, placed in plastic vials and covered with a solution of sea water and $CaCl_2$ buffer (to balance the pH and prevent dissolution) and stored at room temperature prior to processing. Twenty -nine 30 cc samples from the upper 36 m (see Amos, 1987, or Table 2, this report, for the intervals) at the Panuke borehole were collected and treated in the same manner. (Five cc was later removed from each of these Panuke samples and set aside for pollen analysis, before processing for foraminifera began). The bottom 24 m (the extension) of the Panuke borehole were not sampled on site. Fourteen Shelby tube cores were collected on site, well sealed with beeswax and stored at 4^{o} C until extruded and subsampled. Nineteen 25 cc samples were taken from these cores (separate 5 cc pollen samples were taken at the same time). These samples were stored in plastic vials at 4^{o} C until processed.

The samples stored in buffer and at room temperature were processed by wet sieving with 500 and 63 steel sieves. The samples stored at 4^{o}C were brought out and allowed to sit at room temperature for a few days after the addition of buffer and sea water was made. These were the processed using the same wet sieving methods. The 63-500 fraction was retained, air dried and the foraminifera concentrated by floatation twice with CCl_4 (Scott, 1987).

Foraminifera fell into three catagories: Quaternary benthic species (QB), Quaternary planktonic species (QP) and reworked (R). Those samples containing abundant foraminifera were dry split with a microsplitter. Between 200-400 Quaternary benthic specimens and the accompanying Quaternary planktonic and reworked specimens were subsequently counted.

Foraminiferal counts were made by spreading the float on a tray and examining it at 50x under the binocular microscope. Upon examination, it became apparent that in some samples the number of reworked specimens equalled or were greater than the number of Quaternary specimens. It was also noted early on that the number of reworked specimens varied greatly from sample to sample. Similar observations had been made in the Cohasset samples (Miller, 1987b). These Cretaceous species in the Cohasset materialwere identified in an attempt to locate the source rock. The distinct and easily recognizable species of Heterohelix, Gumbelitria and Praebulimina were identified first. Most of the other species have been tentatively identified and for the most part the same species were found in the Como and Panuke boreholes as were found at the Cohasset site. Gumbelitria cretacea and Heterohelix spp. are all restricted to the Maastrictian and based on this two major assumptions were made when identifying the remainder of the reworked material. One; that the remainder of the reworked material came from the same source rock as the specimens of Heterohelix, Gumbelitria and Praebulimina and are also Maastrictian in age. Two; there has only been one major cycle of reworking in each assemblage and therefore Maastrictian material was reworked directly into the Quaternary material. These assumptions may not hold and some of this reworked material may also be Tertiary or early Pleistocene in age.

Representative specimens of all species were placed on key slides. Samples and key slides are curated at A.G.C., B.I.O., Dartmouth.

OBSERVATIONS

The foraminifera in each sample were observed as falling into one of three catagories: Quaternary benthic species (QB), Quaternary planktonic species (QP) and reworked (Upper Cretaceous) species. Relative species abundance data for the Como borehole is given on Table 1. This data for the eight most common species, plus the total number of specimens in each of the three catagories in each sample and the number of QB species/sample are plotted on Figure 2. Relative species abundance data for the Panuke borehole is given on Tables 2 and 3. This data for the eight most common species, plus the total number of specimens in each of the three catagories in each sample and the number of QB species /sample are plotted on Figure 3.

Como Borehole

Seven distinct assemblages are recognized.

1. Low number Elphidium subarcticum assemblage. Samples 1 (0.20 m) to 6 (5.71 m) contain low numbers of foraminifera (20-140 specimens/ sample. There are too few specimens to show any statistically valid trends. However, the assemblage is dominated by Elphidium subarcticum (50.0 - 67.0%). E. excavatum (4.0 - 23.0%) and E. bartletti (0 - 30.0%) are also consistantly present. Specimens of these three species do not show as much reworking as do scattered specimens of Buccella frigida, Cassidulina reniforme, Islandiella helenae and Quinqueloculina spp. There are only scattered planktonic specimens (< 2/ sample), all Neogloboquadrina pachyderma left coiled or unidentified juveniles. There are no reworked specimens.

2. Elphidium bartletti - reworked Elphidium excavatum assemblage. Samples 7 (6.79 m) to 13 (12.84 m) contain a fauna dominated by E. bartletti (9.0 - 20.0%) and (probably) reworked specimens of E. excavatum (36.0 - 60.0 %); though some of these specimens may be indigenous. There is also the consistent presence of Eggerella advena (1.0 - 5.5 %)(only present in this fauna), Haynesina orbiculare (0.5 - 9.0%), Islandiella helenae (5.0 - 15.5 %), G. subglobosa (3.0 - 16.0 %) and Quinqueloculina seminula (1.0 - 4.5%). E. subarcticum is still present but in lower numbers (7.0 - 19.5 %). C. reniforme is almost absent (< 3.0

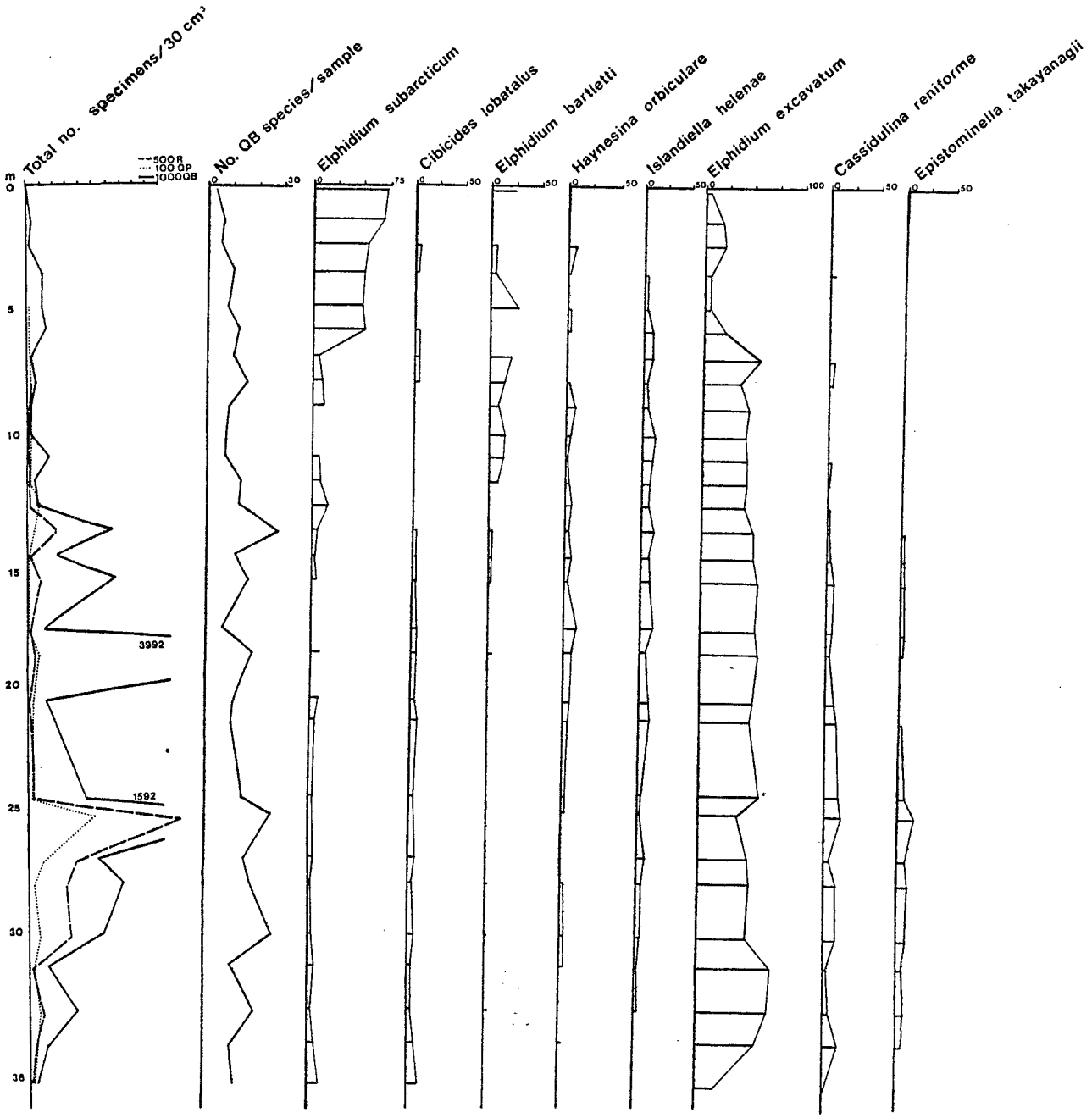

Figure 2: Como borehole. Percent occurrence data for the eight most common Quaternary benthic species plotted down hole. Horizontal bars are the actual values for the corresponding level.

SAMPLE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
DEPTH	0.2	1.36	2.34	3.52	4.83	5.71	6.79	7.82	8.86	10.02	10.92	11.91	12.8	13.8	14.9	15.88	17.8	18.69	20.7	21.6	24.58	25.39	27.1	28.12	30.29	31.4	33.2	34.58	36.2
TOTAL NO./30 cc	24	41	20	125	113	140	40	78	34	39	189	47	93	634	230	668	103	3992	179	215	496	1592	544	716	578	152	380	142	43
SPLIT COUNTED	/	/	/	/	/	/	/	/	/	/	/	/	/	1/2	/	1/2	/	1/8	/	3/4	3/4	1/4	1/8	1/2	1/2	/	/	/	/
QUATERNARY BENTHICS																													
Eggerella advena	4	7						1	5.5	2.5	3	2	1																
Trochammina lobata						0.5																							
Trochammina nitida																													2
Trochammina ochracea												2										X							
Amphicoryna separans											0.5																		
Astrononion gallowayi				1				1			0.5					X						X	X		X		0.5		
Bolivina skagerrakensis																				0.5			0.5						
Brizalina lanceolata																							1.5						
Brizalina subaenariensis																		X											
Buccella frigida		2.5		1.5	2	1.5	7.5	6.5			2.5	2	6	3	5	3.5	4		7.5	4	8	4	7.5	4.5	5.5	4.5	2	3.5	4.5
Bulimina aculeata							2.5						1	X		X		X	0.5		X	1		X					
Buliminella borealis																		X	0.5			4.5	2	1.5	2.5				
Cassidulina laevigata							5							X	5						0.5								
Cassidulina reniforme				1			5	1			3	2	3	3	6	9.5	6	4	7	12.5	14	18.5	8.5	17	14	2.5	7.5	15	2
Cibicides fletcheri													1																
Cibicides lobatalus			5	3		3	5	5			2	2	2	4.5	3.5	4	6.5	7.5	4	5	3.5	1.5	4	2	3	1.5	1	3	9
Cibicidoides corpulentus						0.5															X								
Cibicidoides floridanus														X															
Cibicidoides robertsonianus														X															
Cibicidoides umbonatus													1																
Cibicidoides wuellerstorfi																											X		
Discorbis squamata																						0.5	X				X		6.5
Ehrenbergina pacifica														X															
Elphidium bartletti	21		5	21.5	30		20	15.5	9	15.5	13	11		2	2	1		1.5						X	0.5		1.5		7
Elphidium excavatum	4	17	20	12	12.5	23	60	36	47	43.5	44.5	43	44	53.5	55.5	60.5	56.5	61.5	57.5	53	62	39.5	52	52	51	75.5	73.5	62	18.5
Elphidium groenlandicum														1															
Elphidium subarcticum	67	66	55	52	50	51.5	7.5	10	12		7	11	19.5	5.5	3.5	6.5		7	5	4	2.5	2	3.5	X	1	4.5	1.5	6.5	11.5
Eoeponidella pulchella				1		0.5		2.5					1									1		X			0.5		2
Epistominella exigua																						1			0.5				
Epistominella takayanagii								1			0.5			1.5	1	0.5	3	X		1.5	3.5	13.5	7.5	10.5	7	0.5	5	3	
Fissurina marginata																						X		X	X				
Fursenkoina fusiformis						1.5	2.5	2.5	5.5		0.5	4.5			2							1	2		0.5				
Gavelinopsis lobatalus																									X				
Glabratella crassa																X			0.5										
Glabratella wrightii					1											X		X		0.5	1	5.5	1	1	1.5	2.5	1	0.5	16
Globocassidulina subglobosa				1	1		5	7.5	3	13	16	2		3	2	0.5		1	0.5	0.5	X	X	2.5	1.5	0.5	0.5	X		
Globulina inaequalis		2.5																											
Guttulina lactea						0.5					0.5																		
Guttulina problema											0.5																		
Gyroidina orbicularis																						X							
Gyroidina quinqueloba														0.5															
Gyroidina soldanii																X									X				
Haynesina depressula																						X			X				
Haynesina orbiculare			10	1	1	5.5		1	9	5	0.5	2	6	5	10.5	4	15.5	10	8	5.5	0.5	1.5		1	3	4.5	2.5	3	
Hoeglundina elegans																									X			0.5	
Islandiella helenae	4			4	2	10	10	5	5.5	15.5	12	11	11	13.5	9	8.5	9	3.5	7	7	3	1.5	8	6	3	0.5	0.5		
Lenticulina convergens						0.5								X															
Lenticulina rotulata																X											X		
Melonis barleeanum																					0.5	X			0.5		1		
Miliolinella subrotunda																													7

Table 1: Foraminiferal data, Como borehole. Relative species abundance for the Quaternary benthic species; total numbers for the Quaternary planktonic and Reworked species. X < 0.5%.

SAMPLE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
QUAT. BENTHICS con't																													
Nonionella auricula																											X		
Nonionellina labradorica											0.5	2						X		0.5		0.5	X		X		X		
Oolina borealis																X		X											
Oolina globosa																								X					
Pullenia osloensis													1	X								X							
Pullenia subcarinata				1																									
Quinqueloculina elongata																						X			X				
Quinqueloculina seminula		2.5	5		1	2		1	3	2.5	4	4.5	3					X			X				X			1	11.5
Quinqueloculina stalkeri																								X		2	1		
Rectobolivina bifrons																									X				
Robertinoides charlottensis														X															
Rosalina globularis																									X		X		
Scutuloris tegminus																												0.5	
Stainforthia concava																						0.5			X			0.5	
Trifarina angulosa								1		2.5	0.5			0.5				1				X		X					
Uvigerina peregrina											1			0.5	1			X											
Vaginulinopsis sublegumen											0.5																		
Valvulineria laevigata																								X					
Webbinella hemisphaerica		2.5																											
QUATERNARY PLANKTONICS																													
TOTAL No./30 cc	/	/	1	/	2	1	1	2	1	1	3	2	9	4	1	/	/	8	1	1	3	52	12	2	10	1	10	/	/
Globigerina bulloides								1			1																		
Globigerina falconensis													1																
Globigerina quinqueloba-left																						8							
Globigerina quinqueloba-right																									2				
Globigerinita uvula													1									8							
Globorotalia truncatulinoides							1						1																
Neogloboquadrina pachyderma																													
-left						1							1									12		2	8		1		
-right													2		1			8	1	1	3		2				2		
juveniles			1		2			1	1	1	2	2	3									24	10			1	7		
REWORKED (CRETACEOUS)																													
TOTAL No. /30 cc	/	/	/	/	/	/	/	4	/	1	/	1	3	108	1	44	5	32	2	6	12	552	178	128	144	/	49	16	1
BENTHICS																													
Spiroplectammina sp.																									2				
Caucasina elongata													1									4							
Eouvigerina aculeata										1																			
Eouvigerina americana																				1					4		1		
Eouvigerina subsculptura																4						12		6			4	1	
Osangularia navarroana																					1			2			1	1	
Praebulimina carseyae														6								12	2				1		
Praebulimina kickapooensis														2										4					
Praebulimina reussi														10		2		8		1	3	8	4	6	6		1		
Pyramidina rotata								1						26	1	22	5	8	2	4	1	68	44	34	46		9	5	
Pyramidina rudita																								2					
Pyramidina triangularis														10								4							
Spirobolivina rosula																											1		
PLANKTONICS																													
Gumbelitria cretacea								2				1	2	18		4	1				3	308	72	64	60		15	3	1
Heterohelix globulosa								1						14								60	34	16	18			3	
Heterohelix pulchra														2				16			1	4			2		1		
planktonics (unidentified)														20		8					3	56	22	14	16		15	3	

Table 1: continued.

%). The total number of QB specimens/sample do not increase but are consistent with the overlying fauna (34 - 189 specimens/sample). There are a few planktonic specimens present (juveniles or N. pachyderma). The first appearance of reworked specimens occurs in this fauna (4 specimens at 7.82 m).

3. Elphidium excavatum - Elphidium subarcticum - Islandiella helenae assemblage. Samples 14 (13.83m) to 18 (18.69 m) contain much higher numbers of QB specimens (108 - 3992 specimens/ sample) in a fauna dominated by E. excavatum (53.0 - 62.0 %). Subdominant are C. reniforme (3.0 - 10.0%) and I. helenae (3.0 - 13.0 %). Buccella frigida is also consistently present (3.0 - 6.0 %). Epistominella takayanagii is also present in this assemblage (0.5 - 3.0 %). A few planktonic specimens are present in some samples, all N. pachyderma. The first peak of reworked forms (108 specimens/sample) occurs in the top sample of this assemblage and there are reworked specimens in every sample. The most common reworked species is Pyramidina referata.

4. Low number Elphidium excavatum - Cassidulina reniforme assemblage. Samples 19 (20.70 m) to 21 (24.58 m) show a drop in QB total numbers. The assemblage is similar to the fauna overlying it except for the drop in total numbers. It is dominated by E. excavatum (53.0 - 62.0 %), with C. reniforme (7.0 - 14.0 %) and I. helenae (3.0 - 7.0 %) as the subdominant species. There is a slight increase in the occurrence of B. frigida (4.0 - 8.0%) and E. subarcticum, H. orbiculare and C. lobatalus are consistently present in low numbers (< 5.0 %). There are a few specimens of N. pachyderma left coiled and there are almost no reworked specimens (2 - 12/sample) present.

5. An Elphidium excavatum - Cassidulina reniforme - Epistominella takayanagii fauna is present in samples 22 (25.39 m) to 25 (30.29 m). The total number of QB specimens has increased (544 - 1592 specimens /sample) and the number of QB species also increases noticeably (up to 30). The numbers of E. excavatum have dropped slightly (39.0 - 52.0 %) and the numbers of C. reniforme (8.0 - 18.5 %) and E. takayanagii (7.0 - 13.5 %) have increased slightly. Other cold shelf species are also consistently present in low numbers (B. frigida, C. lobatalus, I. helenae and G. subglobosa). These samples show the highest numbers of planktonic specimens and species, and there are higher numbers of reworked specimens in each sample (128 - 552 specimens/sample), of up to nine species, though most are Gumbelitrea cretacea and Pyramidina referata.

6. Elphidium excavatum assemblage. This assemblage, dominated by E. excavatum (62.0 - 75.0 %) occurs in samples 26 (31.40 m) to 28 (34.58 m) and shows a drop in the total numbers of QB specimens and species, and a drop in the occurrences of C. reniforme (2.0 - 15.0%) and I. helenae (0 - 0.5 %). B. frigida and C. lobatalus remain consistently present. Planktonics are completely absent in some samples, few are present in others. The reworked specimens show similar trends.
7. An Elphidium excavatum - Elphidium subarcticum - Glabratella wrightii assemblage occurs at the base of the hole in sample 29 (36.20 m). There is a sharp drop in the total numbers of QB specimens (43/sample) but an increase in the number of QB species. The numbers of E. excavatum drop sharply (18.0 %), E. subarcticum increase (11.5 %) and G. wrightii is also co-dominant (16.0 %). There is also a noticeable miliolid component (M. subrotunda and Q. seminula) to this fauna. There is also a slight increase in the numbers of E. bartletti and C. lobatalus. There are no planktonic specimens and only one reworked specimen in this sample.

Panuke Borehole

Twelve distinct assemblages are recognized:

1. An Elphidium bartletti - Elphidium subarcticum fauna appears in the surface sample (sample 1 - 0.00 m) with a total of 42 QB specimens in the sample; it is 47.0% E. bartletti and 23.0% E. subarcticum. Eggerella advena is subdominant (12.0%). There are a few specimens of N. pachyderma left coiled and no reworked specimens are present.

2. Samples 2 (4.55 m) to 6 (8.91 m) are almost devoid of foraminifera (< 6 QB specimens/sample) and this has been termed "barren zone A". What few specimens are present are E. bartletti, E. excavatum or C. reniforme. There are no planktonic or reworked specimens present.

3. Elphidium excavatum - Cassidulina reniforme - Epistominella takayanagii assemblage. Samples 7 (9.86 m) and 8 (10.26 m) show an abrupt change of fauna. The total numbers of QB specimens increases markedly (up to 2984 QB specimens/sample) and there is high species diversity. The assemblage contains E. excavatum as the most common species (45.5%), subdominant are C. reniforme (17.5 - 19.0%) and E.

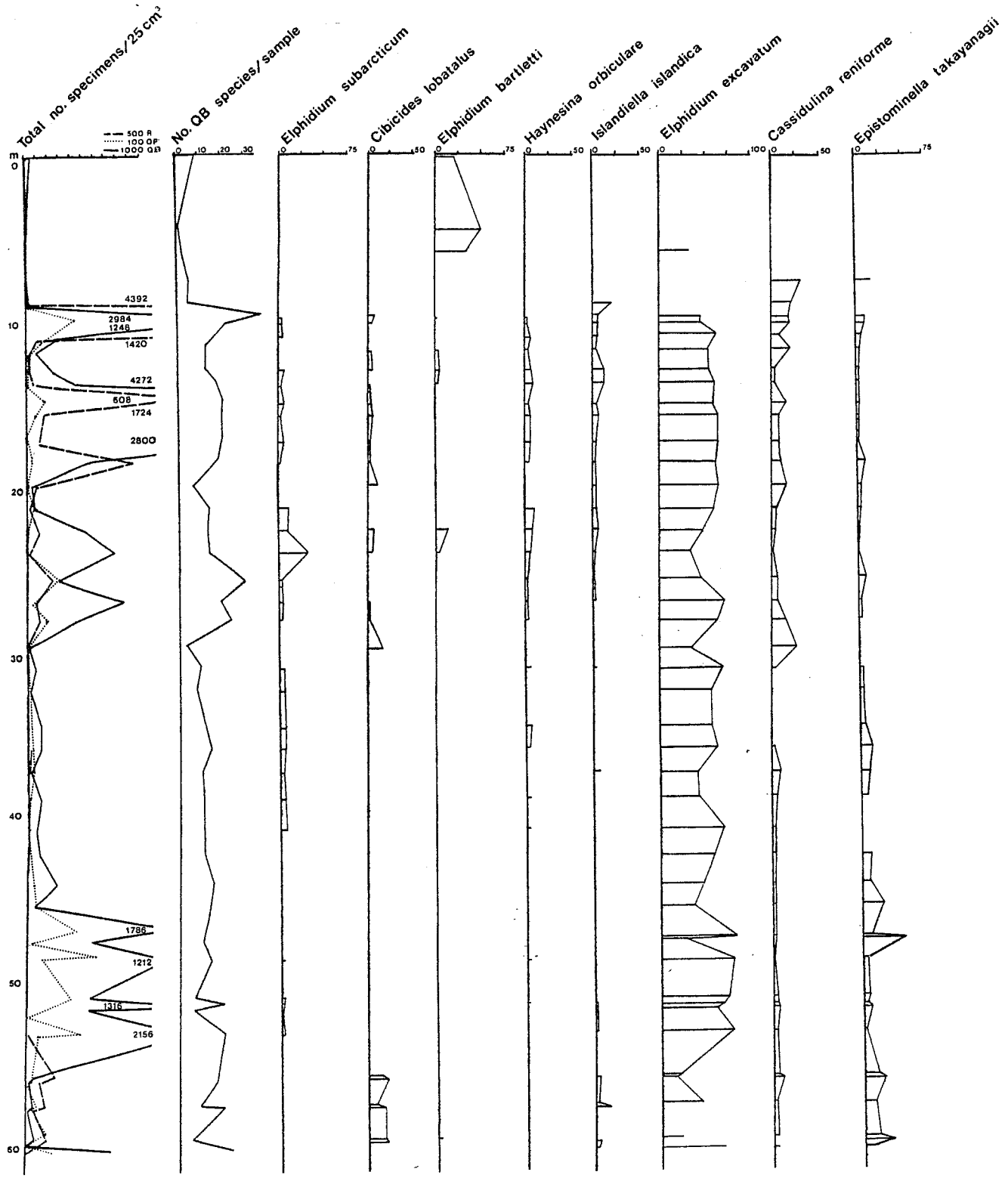

Figure 3: Panuke borehole. Relative percent occurrences of the eight most common Quaternary benthic species plotted down hole. Horizontal bars are actual values for the corresponding levels.

SAMPLE NO.	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
DEPTH	0	4.55	5.84	6.82	7.89	8.91	9.86	10.26	10.96	11.9	12.87	13.85	14.77	15.82	17.22	18.6	20.05	21.41	22.65	24.06	25.6	26.85	28.27	29.71
TOTAL NO. QB/25 CC	66	2	3	/	6	5	2984	1252	245	86	212	427	4272	1724	2800	576	49	65	516	758	275	826	425	7
SPLIT COUNTED	/	/	/	/	/	/	1/8	1/4	/	/	/	3/4	1/16	1/4	1/8	1/2	/	/	1/2	1/2	/	1/2	/	/
QUATERNARY BENTHICS																								
Eggerella advena	12	50					X			1											X			
Quinqueloculina agglutinata																								
Silicosigmoilina groenlandica																								
Spiroplectammina biformis																							X	
Textularia torquata					16.5																			
Trochammina lobata						20																		
Astrononion gallowayi						20								X						X				
Bolivina pseudoplicata																								
Bolivina skagerrakensis									0.5														X	
Bolivinita quadrilatera																								
Brizalina lanceolata								0.5					X								X		0.5	
Brizalina lowmani							X								X						X			
Brizalina pseudopunctata																		1.5				X		
Brizalina spathulata							X	X					0.5											
Brizalina subaenariensis							0.5	X				X	X	0.5	X	X					X			
Buccella frigida					16.5		4.5	7	5.5	6	6	4.5	5.5	3.5	5.5	5		6		3	5	3.5	3.5	
Bulimina aculeata							0.5		1		0.5		X	X	0.5						0.5			
Buliminella borealis							X			1				X	X	1					1	0.5		
Cassidulina reniforme					33.5	20	17.5	19	8	18.5	4	7	14.5	8	9	11	14	4.5	4.5	0.5	9.5	10	15	28
Cibicides fletcheri							X									0.5								
Cibicides lobatalus	1.5						7	2	2	3.5	4.5	X	1.5	3.5	1	1.5	10		4.5	4	3	X	0.5	14
Cibicidoides corpulentus																						0.5		
Cibicidoides floridanus														0.5										
Cibicidoides pseudoungerianus																								
Cibicidoides robertsonianus																					X			
Discorbinella subbertheloti								X				X												
Discorbis squamata													X			X	2						X	
Elphidium bartletti	47	50	33				0.5			2.5	3	1		X	X				12.5	0.5		0.5	X	
Elphidium excavatum	10.5		33				45.5	45.5	63	54.5	55	60	59	66	64.5	62	65.5	58.5	51	33.5	57.5	69.5	64	34
E. excavatum f. gunteri																X								
Elphidium groenlandicum																						0.5	X	
Elphidium subarcticum	23						1	3	3		5	2	5.5	2.5	6	1.5		11	10	39.5	1	1	2	
Eoeponidella pulchella							X	X													0.5		X	
Epistominella exigua																							X	
Epistominella takayanagii					16.5		10.5	10	6	4.5	1	1	2.5	1.5	1	8.5	2	3	X	X	9.5	2	4.5	
Epistominella vitrea																							X	
Eponides pusillus								1								X								
Fissurina cucurbitasema																								
Fissurina marginata							X																	
Fissurina orbignyana							X																	
Fursenkoina fusiformis							0.5											1.5				1		
Gavelinopsis lobatalus						20	X	X	0.5										0.5					
Glabratella crassa							X								X									
Glabratella wrightii							2	3		1	1	X	2.5	1		1		8	5	6.5	1	3		
Glandulina laevigata																								
Globocassidulina subglobosa		33					1				1.5	1.5	X	1	1	X	2	1.5		0.5	1		3	14
Gyroidina orbicularis							0.5	X	1			X	X	X		1								
Gyroidina quinqueloba	1.5								0.5	1			X								2.5			
Gyroidina soldanii									1												X			
Hanzawala asterizans																								
Haynesina depressula																					X			
Haynesina nana																						0.5		
Haynesina orbiculare							0.5	0.5	3	1	6.5	10	2.5	5.5	3.5	1.5		9	4.5	5		1	1.5	

Table 2: Foraminiferal data, 0 - 30.0 m, Panuke borehole. Relative species abundance data for the Quaternary benthic species; total numbers for the Quaternary planktonic and Reworked species. X < 0.5%.

SAMPLE NO.	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
QUATERNARY BENTHICS (con't)																								
Hoeglundina elegans																								
Islandiella helenae						20	5	4	6.5	3.5	12	12	2	6	3	2.5	4	1.5	4.5	0.5	X	2.5		
Lagena distoma													X											
Lagena gracillima							X																	
Lagena meridionalis																								
Lagena semilineata																							X	
Lagena sulcata																								
Laryngosigma hyalascidia																								
Lenticulina atlantica																								
Lenticulina gibba																		1.5						
Melonis barleeanum							0.5	0.5													1		X	
Miliolinella circularis																								
Miliolinella subrotunda																			0.5					
Nonionella auricula																								
Nonionella stella							X																	
Nonionellina labradorica							0.5	1		1	0.5		1		1	1					X			
Oolina borealis								X																
Osangularia rugosa								X																
Parafissurina fusuliformis							X																	
Patellina corrugata																					X			
Pateoris hauerinoides																								
Pullenia osloensis							X														1			
Pullenia subcarinata																							X	
Pyrgo williamsoni																								
Pyrulina cylindroides																			X					
Quinqueloculina elongata							1								X						X	X		
Quinqueloculina seminula	3											X						4.5	2	5.5	X		1	
Quinqueloculina stalkeri																					X	1	1.5	
Quinqueloculina vulgaris												X												
Rosalina araucana					20															X				
Rosalina globularis																								
Siphogenerina raphanus								X																
Stainforthia concava							X														X			
Stilostomella antillea									0.5															
Trifarina angulosa							X		0.5			1		0.5	0.5			3			0.5	0.5	1	
Trifarina bradyi																							X	
Triloculina trihedra																								
Uvigerina peregrina	1.5																							
Vaginulinopsis sublegumen							X																	
Vavulineria laevigata																								
QUATERNARY PLANKTONICS																								
TOTAL NOS.	2	2	/	/	1	2	216	64	4	1	1	1	16	8	/	4	1	7	2	2	27	6	14	/
Globigerina bulloides																								
Globigerina quinqueloba-left							88	8													3		1	
Globigerina quinqueloba-right							8	4	1											2			1	
Globigerinita uvula																					1			
Globorotalia truncatulinoides																								
Neogloboquadrina pachyderma																								
-left	2	1				1	80	28		1	1		16	4		4		3			10		6	
-right		1				1	8	16				1		4							7		3	
juveniles							40	8	3									4	2		6	6	2	

Table 2: continued.

SAMPLE NO.	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
REWORKED (CRETACEOUS)																								
TOTAL NO.	/	2	/	/	/	1	4392	1420	41	11	6	23	608	60	48	466	33	19	48	2	133	36	53	/
BENTHICS																								
Alabamina sp. 1																					1			
Caucasina elongata																					6		1	
Dentalina solvata																		1						
Eouvigerina aculeata																4					1	2	1	
Eouvigerina americana							32																	
Eouvigerina subsculptura							36	12	3					8		28	1		2		5		3	
?Nonionella robusta																								
Osangularia navarroana								4				1				6	1				2		1	
Praebulimina carseyae							48	16	1		2	1	48	8		8		1			1			
Praebulimina kickapooensis							8	4								2					1		3	
Praebulimina reussi							8	20	3	3	1			4	8	8	2		4		4	8	5	
Pyramidina referata							1216	356	6	1		4	208	8	8	72	4	5	12		13	4	18	
Pyramidina rudita									1															
Pyramidina triangularis								4					16	4					6		2	2	1	
Stilostomella pseudoscripta																					1		1	
Uvigerina canariensis									1															
PLANKTONICS																								
Gumbelitrea cretacea		1					1728	640	12	7		10	208	20	16	134	9	4	22		40		8	
Heterohelix globulosa		1				1	664	164	6		2	3	128	4		92	9	2	6	2	23	10	10	
Heterohelix pulchra								12	2							8					6			
Heterohelix striata																								
planktonics (unidentified)							616	188	6		1	4		4	16	104	7	6	2		27	10	1	

Table 2: continued.

SAMPLE NO.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
DEPTH	31.22	32.71	34.84	36.1	37.59	39.19	40.9	42.55	44.19	45.85	47.51	47.59	48.89	50.76	51.6	51.8	53.5	55.41	55.57	57.36	57.43	59.89	60	60.12
TOTAL NO. QB/25 CC	61	31	110	124	20	128	96	108	282	79	1796	580	1212	568	1316	518	2156	69	47	68	28	88	10	750
SPLIT COUNTED	/	/	/	/	/	/	/	/	/	/	1/4	1/2	1/4	1/2	1/4	1/2	1/4	/	/	/	/	/	/	1/2
QUATERNARY BENTHICS																								
Eggerella advena																								
Quinqueloculina agglutinata										1			X		0.5									X
Silicosigmoilina groenlandica		3	3	4	5	13.5	4	7.5	8	12	0.5													
Spiroplectammina biformis																								
Textularia torquata																								
Trochammina lobata																								
Astrononion galloway																								
Bolivina pseudoplicata																								
Bolivina skagerrakensis																		10			15	13.5		
Bolivinita quadrilatera																		3	4	3				
Brizalina lanceolata																								
Brizalina lowmani																			2				9	
Brizalina pseudopunctata				1																				
Brizalina spathulata																		6						
Brizalina subaenariensis					5																7	4.5		
Buccella frigida	8	13	21	17	15	19.5	1	3.5	10.5	2.5	3.5	6	7.5	11	11.5	22	7.5	3	11	7.5	7	7	27	4.5
Bulimina aculeata					5		1												2	1.5				
Buliminella borealis	5	10	3.5	1.5		9	7	9	11	6.5	0.5	6	1				X	6				2		
Cassidulina reniforme	3.5			1	10	2.5	4	2	0.5	1	1		0.5	4.5	6	8.5	3	4.5	7	1.5	15	5.5		5.5
Cibicides fletcheri																								
Cibicides lobatalus		3									X	0.5						7.5	20.5	7.5	15	13.5	18	
Cibicidoides corpulentus																								
Cibicidoides floridanus																								
Cibicidoides pseudoungerianus													X											
Cibicidoides robertsonianus										1														
Discorbinella subbertheloti																		3	13.5		7	1	9	
Discorbis squamata			1	1				1							X							1		
Elphidium bartletti									X											3	7	1		
Elphidium excavatum	70.5	58	54.5	62	35	36	71	60	49.5	37	85	23	82.5	74	66	59	78	18	13.5	45		23		71
E. excavatum f. gunteri						0.5																		
Elphidium groenlandicum																								
Elphidium subarcticum	3.5	6.5	5	5	5	4.5	7	1	3	1			2	1	0.5	X	0.5							X
Eoeponidella pulchella			1					1		1					0.5		X							0.5
Epistominella exigua																		1.5						
Epistominella takayanagii	1.5	3	5.5	3	10	9.5		12	11.5	28	7.5	57	4	4	4.5	9	4	15	23	12		7	27	4.5
Epistominella vitrea																								
Eponides pusillus									X											1.5				
Fissurina cucurbitasema											0.5						X							X
Fissurina marginata																								X
Fissurina orbignyana																								
Fursenkoina fusiformis		3	1	1.5	5	0.5	4	2	2.5	2.5	0.5	4	0.5		0.5		1			1.5				3
Gavelinopsis lobatalus	1.5					0.5						0.5	X		X		X							
Glabratella crassa																								
Glabratella wrightii			1																					
Glandulina laevigata									X															X
Globocassidulina subglobosa			1	1.5														1.5				1		
Gyroidina orbicularis																			2		7	8		
Gyroidina quinqueloba									0.5	1			X											
Gyroidina soldanii									1									9		4.5		3.5		
Hanzawaia asterizans																						1		
Haynesina depressula															0.5		X							1
Haynesina nana																								
Haynesina orbiculare	5		2.5	1.5		4	1		X				X		1									

Table 3: Foraminiferal data, 30.0 - 61.0 m, Panuke borehole. Relative species abundance data for the Quaternary benthic species; total numbers for the Quaternary planktonic and Reworked species. X 0.5%.

SAMPLE NO.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
QUAT. BENTHICS (con't)																								
Hoeglundina elegans																			2			1		
Islandiella helenae	5				5				X						X	1.5	1	1.5	2	3	15		9	1
Lagena distoma																								
Lagena gracillima																								
Lagena meridionalis										1														
Lagena semilineata																								
Lagena sulcata																						1		
Laryngosigma hyalascidia																								X
Lenticulina atlantica																			4					
Lenticulina gibba																								
Melonis barleeanum				1														4.5				1		
Miliolinella circularis														1.5										
Miliolinella subrotunda															1		0.5			4.5				
Nonionella auricula							1																	X
Nonionella stella																	X							
Nonionellina labradorica								1		1	X	1.5	X				X	1.5	2					X
Oolina borealis																								
Osangularia rugosa																								
Parafissurina fusuliformis																								
Patellina corrugata																								
Pateoris hauerinoides																								
Pullenia osloensis																								3.5
Pullenia subcarinata																				1.5				
Pyrgo williamsoni															X									X
Pyrulina cylindroides																								
Quinqueloculina elongata															2.5		X	2			X			X
Quinqueloculina seminula				1							0.5		X	4	1		0.5							0.5
Quinqueloculina stalkeri													X		1									
Quinqueloculina vulgaris																	0.5			1.5				
Rosalina araucana	1.5								1															X
Rosalina globularis																						2		
Siphogenerina raphanus																								
Stainforthia concava			1					1		4	X				0.5		X							0.5
Stilostomella antillea																								
Trifarina angulosa																		1.5	2	4.5		2		
Trifarina bradyl																								
Triloculina trihedra																								0.5
Uvigerina peregrina																		3	2		7			
Vaginulinopsis sublegumen																								
QUATERNARY PLANKTONICS																								
TOTAL NOS.	/	1	2	3	1	3	4	3	8	9	48	10	60	22	40	2	44	9	3	10	6	15	/	22
Globigerina bulloides														2										
Globigerina quinqueloba-left										1	4	2	20				4					1		
Globigerina quinqueloba-right									1	1				4	4		4		1	1				
Globigerinita uvula										1	4													
Globorotalia truncatulinoides																					2	1		
Neogloboquadrina pachyderma																								
-left		1	1		1	1	3	1	5	1	28	6	24	12	8	2	12	6	2	2		6		4
-right			1			1	1			1	12	2	12					2		1		5		
juveniles				3		1		2	2	4			4	2	28		24	1		6	4	2		18

Table 3: continued.

SAMPLE NO.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
REWORKED (CRETACEOUS)																								
TOTAL NO.	/	/	3	5	1	1	/	1	1	/	/	/	/	/	/	/	8	136	64	145	28	190	8	4
BENTHICS																								
Alabamina sp. 1																								
Caucasina elongata																			1	1				
Dentalina solvata																								
Eouvigerina aculeata																								
Eouvigerina americana																				4	4	4		
Eouvigerina subsculptura			1															5	2					
?Nonionella robusta									1															
Osangularia navarroana																				2		3		
Praebulimina carseyae																		2	5	1		5		
Praebulimina kickapooensis																		3	1	2		4		
Praebulimina reussi																		5		1	2	12	4	
Pyramidina referata				5														33	13	31	6	25		2
Pyramidina rudita																								
Pyramidina triangularis			1			1												1	5	1		1		
Stilostomella pseudoscripta																				1		1		
Uvigerina canariensis																								
PLANKTONICS																								
Gumbelitrea cretacea					1												8	46	20	56	8	57	3	
Heterohelix globulosa			1	1				1										38	6	20	4	45	1	2
Heterohelix pulchra																		1		3		6		
Heterohelix striata																				2				
planktonics (unidentified)				2															11	17	4	27		

Table 3: continued.

takayanagii (10.0%). I. helenae (4.0 - 5.0%) and B. frigida (4.5 - 7.0%) are also consistently present. There are scattered occurrences of various shelf species; i.e. Gavelinopsis lobatalus, Brizalina spp., Fissurina spp., Rosalina spp., N. labradorica. The Quaternary planktonic assemblage is larger (64 - 216 specimens/sample) and more varied, though it is all cold water species N. pachyderma left and right coiled and G. quinqueloba left and right coiled. This fauna also contains a large reworked component; there is a peak of reworked specimens in sample 7 with 10 reworked species present. The reworked fauna is dominated by Gumbelitrea cretacea, Heterohelix globosa, Pyramidina referata, Eouvigerina spp. and Praebulimina spp.

4. An Elphidium excavatum - Cassidulina reniforme - Islandiella helenae fauna is present in samples 10 (10.96 m) to 17 (18.60 m). The total number of QB specimens has dropped (86 - 245 specimens/sample) as has the QB species diversity. The fauna is still dominated by E. excavatum (54.5 - 63.0%), with C. reniforme (4.0 - 18.5%) and I. helenae (2.0 - 12.0%) as the subdominant species. The percent occurrences of E. takayanagii (1.0 - 6.0%) and B. frigida (4.5 - 6.0%) have dropped. There is also the consistent presence of E. subarcticum, G. subglobosa and H. orbiculare. There are some planktonic specimens present - N. pachyderma left and right coiled and the number of reworked specimens/sample (6 - 608) is extremely variable with up to 10 reworked species present.

5. An Elphidium excavatum - Cassidulina reniforme fauna is present in samples 18 (20.05 m) to 20 (22.65 m). E. excavatum and C. reniforme are present in numbers similar to the fauna overlying but there is a drop in the percent occurrence of I. helenae (1.5 - 4.5%), and a slight increase in the percent of H. orbiculare (4.5 - 9.0%) and G. wrightii (5.0 - 8.0%). There are a few planktonic specimens present, all N. pachyderma and juveniles. There is a small reworked component.

6. An Elphidium excavatum - Elphidium subarcticum assemblage is present in one sample (21) at 24.06 m. The occurrence of E. excavatum has dropped to 33.5% and that of E. subarcticum increased to 39.5%. There are only 2 planktonic specimens and 2 reworked specimens present.

7. An Elphidium excavatum - Cassidulina reniforme fauna is present from samples 22 (25.60 m) to 24 (28.27 m). Elphidium excavatum continues to dominate (57.5 - 69.5%) and C. reniforme is subdominant (10.0 - 28.0%). Total number of QB specimens have increased slightly (275

-826 specimens/sample) and species diversity has increased. There are also scattered occurrences of warm water shelf species; i.e. Brizalina spp., Cibicdoides spp., Gyroidina spp., Epistominella spp. and Lagena sp. There is also a miliolid component to the fauna, i.e. Pateoris hauerinoides and Quinqueloculina spp. There are a few planktonic specimens, mostly N. pachyderma and G. quinqueloba. There is a reworked component, though not large (36 - 133 specimens/sample) it does contain up to 14 identified species.

8. Sample 25 (29.71 m) contains only 7 badly abraded specimens, this has been termed "barren zone B". What specimens are present are of E. excavatum, C. lobatalus, G. subglobosa and C. reniforme. There are no planktonic specimens and no reworked specimens present.

9. The next assemblage is actually a coupling of two faunas alternating with one another: an Elphidium excavatum - Buccella frigida fauna alternating with an Elphidium excavatum - Epistominella takayanagii fauna in samples 26 (31.22 m) to 35 (45.85 m). There are low total numbers and low QB species diversity in both members of the assemblage. There are high percent occurrences of E. excavatum (50.0 - 85.0%) accompanied by B. frigida (up to 21.0%) in one member of the assemblage; and low percent occurrences of E. excavatum (35.0%) accompanied by E. takayanagii (10.0 - 28.0%) in the other member of the assemblage. The numbers of C. reniforme have dropped and Buliminella borealis, Stainforthia concava and Quinqueloculina seminula are consistently present. There are a few planktonic specimens and almost no reworked ones present.

10. The Elphidium excavatum - Buccella frigida / Elphidium excavatum - Epistominella takayanagii alternating faunas continue with high QB total numbers (518 - 2156 specimens/sample) in samples 36 (47.51 m) to 42 (53.50 m). This fauna couple is similar to the fauna directly above except for the marked increase in the number of QB specimens present. High percent occurrences of E. excavatum (49.5 - 85.0%) are accompanied by B. frigida (up to 22.0%) as the subdominant species; and low percent occurrences of E. excavatum (23.0 - 37.0%) are accompanied by E. takayanagii (up to 57.0%) as the dominant species. C. reniforme is almost absent and I. helenae is absent from most samples. No other species are consistently present. There is an increase in the number of planktonic specimens present (2 - 60 specimens/sample) and species present though

the species continue to be indicative of cold water. There are no reworked specimens present.

11. An Elphidium excavatum - Cassidulina reniforme - Buccella frigida - Cibicides lobatalus fauna is present in samples 43 (55.41 m) to 48 (60.0 m), with a drop in the total number of QB specimens (10 - 88/sample) and an increase in QB species diversity. Overall the percent occurrence of E. excavatum drops considerably (0 - 45.0%); with C. lobatalus (7.5 - 20.5%), B. frigida (3.0 - 27.0%) and C. reniforme (0 - 15.0%) all co-dominating with E. excavatum. Bolivina skagerrakensis, Discorbinella subbertheloti and H. orbiculare are also present in most samples of this fauna. The number of planktonic specimens has decreased slightly (3 - 15/sample) and are mostly N. pachyderma and juveniles. There is also a reworked component to this fauna, though not large (8 - 190 specimens/sample), there are up to 12 identified reworked species present. The dominant reworked species continue to be Pyramidina referata, Gumbelitrea cretacea and Heterohelix globosa .

12. The sample at the base of the hole (sample 49 at 60.12 m) contains an Elphidium excavatum dominated (71.0%) fauna. There is a minor occurrence of both B. frigida (4.5%) and C. reniforme (5.5%). QB species diversity has increased and there are traces (1 or 2 specimens) of many cold water shelf species. There are a few planktonic (almost all juvenile) and reworked specimens present.

DISCUSSION

Paleo-environmental Interpretation

The Quaternary benthonic foraminiferal assemblages observed downhole are almost entirely calcareous, though more agglutinated specimens have been found in these boreholes than have been found in similar studies (i.e. Miller and Scott, 1984; Miller, 1987b). The possibility that geotechnical sampling/processing methods were destroying the agglutinated foraminifera could not be overlooked. However, the standard micropaleontological sampling techniques applied in this study show sampling techniques not responsible for the absence of agglutinated foraminifera. The low numbers of agglutinated foraminifera observed here may be due in part to poor preservation. Bernstein et al. (1978) have reported that agglutinated foraminifera dissolve in deep sea subsurface sediments. Schnitker et al. (1980) report that agglutinated foraminifera can dissolve if there are high levels of bacterial activity, conditions unlikely in glacial / arctic type environments. Other workers reporting on Scotian Shelf surface and subsurface sediments have noted the presence of agglutinated forms (Vilks and Rashid, 1976; Mudie et al., 1983; Scott et al., 1984). Almost totally calcareous assemblages have been noted from cold marine environments (i.e. Lagoe, 1977) and the absence of agglutinated foraminifera in the preserved fauna implies their absence in the living population.

The upper two assemblages in both the Como borehole (low number - Elphidium subarcticum assemblage from 0.20 to 5.71 m; Elphidium bartletti - reworked Elphidium excavatum assemblage from 6.79 to 12.84 m); and Panuke borehole the surface (Elphidium bartletti - Elphidium subarcticum - Eggerella advena) assemblage and the underlying "barren zone A" (from 4.55 - 8.91 m) are interpreted as containing E. subarcticum, E. bartletti and E. advena as the 'in situ' indigenous component superimposed on the reworked remnants of an older assemblage/ assemblages. Specimens of these three species are well preserved and have a fresh appearance. However, these surface assemblages do not correspond directly to the present day assemblages (or lack of) reported living on Sable Island Bank (Williamson, 1982, 1983; Williamson et al., 1984; Medioli et al., 1986). Williamson (1982, 1983) and Williamson et al. (1984) completed a regional study of the Scotian Shelf and reported that surface samples from Sable Island Bank (also

Western Bank, Middle Bank and Banquereau) were virtually barren of foraminifera. He did report a Cibicides lobatalus - Islandiella islandica (= G. subglobosa) fauna from some banks (i.e. LaHave Bank, Emerald Bank and St. Anne Bank); banks 50-100 m deep and with a coarse bedrock substrate. Williamson (1983) and Williamson et al. (1984) also concluded, as a result of living - total foraminiferal distribution studies; that the presence of E. excavatum was largely relict and the tests had been transported. Williamson noted that the tests appeared ragged and worn, an observation also made in this study. Most of the surficial self sediments in this region represent post - glacial sorting and redeposition of glacial deposits (Williamson et al., 1984). The upper two assemblages in each borehole must be within the Holocene reworked Sable Island Sand and Gravel Formation. Williamson et al. (1984) note that continuing sediment sorting and winnowing may account for the absence of foraminifera on Sable Island Bank. Medioli et al. (1986) using the Williamson studies as a baseline for comparison, have reported on samples collected from an area concentrated around Sable Island. Generally, they found the unusually sparce and irregular distributions difficult to interpret. Samples which appear have been collected in the vicinity of the Como and Panuke wellsites (Medioli et al., 1986, figures 2 and 7) are either barren of foraminifera or dominated by the agglutinated species Adercotryma glomerata. Medioli et al. (1986) do report E. advena as the dominant species present at some stations directly north of Sable Island, but those stations in the vicinity of these two wellsites contained < 5.0% of this species.

Poag et al. (1980) report E. subarcticum as the dominant Elphidium living in the northern part of the trough and basin on the New Jersey outer continental shelf. Poag et al. (1980) correlate this Elphidium fauna with the shallowest locations, which in turn correlate with the lowest salinity, lowest winter temperatures and in part, coarsest sediment and maximum water turbulence.

Minor occurrences of other shelf species (B. frigida, C. reniforme, L. helenae and Quinqueloculina spp.) are probably both indigenous and relict.

Williamson (1983) has synthesized the bottom water hydrography on the continental margin and showed that the entire Sable Island Bank is affected to a depth of 50 m by the water mass he named Water Mass No. 3, characterized by salinities of 33 - 34 $^{o/oo}$ and temperatures of 4 - 8^{o} C.

The planktonic foraminifera are almost all N. pachyderma, characteristic of this water mass.

There are five underlying faunas in the Como borehole. The third fauna, occurring from 13.83 - 18.69 m, the E. excavatum - E. subarcticum Islandiella helenae fauna, is probably an immediate post - glacial/late glacial fauna. I. helenae is a co-dominant component of many immediate post - glacial faunas (Miller, 1987a; Miller et al., 1985; Scott et al., 1984; Vilks et al., 1974; Vilks and Rashid, 1976; Vilks, 1980). It is also a major component of outer deep estuarine assemblages (Schafer and Cole, 1978; Scott et al., 1980).

Underlying this, from 20.7 - 24.58 m, is a late glacial E. excavatum - C. reniforme low number fauna, very similar to the late glacial faunas found all along the Eastern Canadian margin. E. excavatum and C. reniforme are well known dominant components of these late glacial assemblages (Miller and Scott, 1984; Miller et al., 1985; Miller, 1987a, 1987b; Scott et al., 1984; Vilks et al., 1974; Vilks and Rashid, 1976; Vilks, 1980). The lower numbers may be due to higher sedimentation rates, lower productivity (due to ice cover?) or local reworking by grounded ice or subaerial erosion.

The fifth assemblage, the E. excavatum - C. reniforme - E. takayanagii assemblage, occurring from 25.39 to 30.29 m, is not a glacial fauna, but may be a late glacial / immediate post glacial assemblage, very similar to that found by Miller and Scott (1984) in the Louisburg boreholes on Banquereau, and by Miller (1987b) in the Cohasset borehole (assemblage 3). It also resembles some of the late and post glacial shelf faunas found in basins on the Scotian Shelf (Vilks and Rashid, 1976; Scott et al., 1984) and Labrador Shelf (Vilks et al., 1974). E. takayanagii seldom appears in such high numbers (7.0 - 13.5%). Miller and Scott (1984) reported it co-dominant (10.0 - 30.0%) in the late glacial assemblage in the Louisburg boreholes and cited references (Leslie, 1965; Schafer and Cole, 1978) also reporting similar though modern occurrences in shallow water depths. In modern environments it prefers shallow (inner shelf) water depths, slightly reduced salinities (32 - 33$^{o/oo}$, Leslie, 1965), calm, cold waters (Schafer and Cole, 1978) and a fine substrate, as could be found under floating ice or proximal to an ice shelf. MacNeil (1986) has found a C. reniforme - E. takayanagii fauna at the base of a piston core from outer Notre Dame Bay, Labrador Shelf. Scott (1987) reports E. excavatum and E. takayanagii as the dominant

(glacial) species at Site 613 (DSDP Leg 95), New Jersey Transect; though deposited in approximately 2400 m of water. He suggests that an E. excavatum - E. takayanagii fauna is a higher salinity cold water counterpart of the slightly lower salinity more tolerant E. excavatum - C. reniforme fauna.

The subdominant species (B. frigida, I. helenae, G. subglobosa and C. lobatalus) are also indicative of cold, marine shelf conditions. This assemblage is not a true cold shelf assemblage because of the absence of agglutinated forms (Murray, 1973; Vilks et al., 1982; Williamson, 1982, 1983; Williamson et al., 1984). Another indication that this is not a cold shelf fauna is the low diversity; other cold inner shelf species (i.e. Globobulimina, Nonionellina, Oolina, Lagena) that are usually found in conjunction with those species found here (Vilks, 1968, 1969; Vilks et al., 1974; Lagoe, 1977; Rodrigues and Hooper, 1982; Williamson, 1983; Williamson et al., 1984) are also absent. The planktonic foraminifera are all indicative of cold water (N. pachyderma, G. quinqueloba, G. nitida and G. uvula).

The sediments occurring from 31.40 to 34.58 m contain a fauna dominated by E. excavatum and low species diversity. All subdominant species (B. frigida, C. reniforme and E. takayanagii) are characteristic of cold polar waters, either a marine shelf or glacial environment. The planktonic fauna indicate cold water mass conditions.

The key to placing these four faunas within a stratigraphic and (to some extent) chronological framework is the presence of reworked Cretaceous benthonic and planktonic foraminifera; appearing in large numbers in the third assemblage and in lower numbers in underlying assemblages 4, 5 and 6. This exact same phenomena was noted by Miller (1987b) in the Cohasset borehole. Scott and Medioli (1988) have found this late glacial - glacial E. excavatum - C. reniforme fauna in piston cores in Emerald Basin. In lower sections of the cores containing this fauna there was a reworked component similar (i.e. Praebulimina, Pyramidina, Heterohelix and Gumbelitria) to that found here, by Miller (1987b) in the Cohasset borehole and by Miller and Scott (1984) on Banquereau (though in much lower numbers on Banquereau). Scott and Medioli (1988) have noted from seismic records that the sediments containing these faunas (in Emerald Basin) in some instances directly overly glacial till and they are of the opinion that these faunas were deposited as a result of glacial erosive intervals which placed in suspension large amounts of Tertiary/

placed in suspension large amounts of Tertiary/ Cretaceous material. The ice was probably not grounded here as evidenced by the absence of till, but had been grounded at some point proximate to cause the reworking and redeposition of the Cretaceous faunas. King et al. (1970) have dredged up rocks of Cretaceous age just north of Sable Island and on Sable Island Bank. The Cretaceous foraminifera are very well preserved and probably have not been through more than one erosional cycle. These reworked Cretaceous sediments were probably deposited during the final 'deglaciation event'.

The occurrence of Cretaceous planktonic foraminifera in Pleistocene sediments is reported by Thomson (1983) as not unusual. Thomson (1983) reports specimens of Heterohelix, Hedbergella, Globotruncata and Eouvigerina in Pleistocene fluvio-lacustrine deposits in eastern Missouri. Thomson notes that these specimens are very well preserved and this leads Thomson to suggest that they were transported only short distances before redeposition. Thomson suggests that the source rocks were either transported as erratics and deposited in glacial drift before further erosion and final deposition occurred; or glacial lobes transported blocks of source rock, deposited them as tills and local erosion during the Wisconsinan time completed the breakdown of the Cretaceous sediments. Feyling-Hanssen (1971), Andersen (1971), Jørgensen (1971), Knudsen (1971a) and more recently Hald and Torren (1987) have found Upper Cretaceous specimens reworked into Quaternary faunas. Scott (1987) also reported scattered occurrences of Gumbelitria sp. and Heterohelix sp. at both Sites 612 and 613 (DSDP Leg 95), but occurring more prominantly at the base of Hole 613.

At the base of the Como borehole, at 36.20 m, is an E. excavatum - E. subarcticum - Glabratella wrightii assemblage. A similar fauna was reported by Miller and Scott (1984) in a short interval in Borehole 4 at the Louisburg wellsite. G. wrightii is usually found in intertidal to shallow subtidal environments (Schafer and Cole, 1978); it prefers a very sandy-gravelly substrate and turbulent water. It adapts well to diurnal and seasonal variations of temperature and salinity. This is often an attached species, it seems to replace C. lobatalus in some environments, particularily when there is little or no plant life.

This is probably some sort of shallow bank environment with a coarse substrate. The coarseness of the substrate probably accounts for the low

numbers of E. excavatum.

In the Panuke borehole there are ten faunas in the sediments underlying the Sable Island Sand and Gravel Formation. Faunas 3 (E. excavatum - C. reniforme - E. takayanagii) and 4 (E. excavatum - C. reniforme - I. helenae) were also seen in the Como borehole (though not in the same positions stratigraphically) and in the Panuke borehole are interpreted as being immediate post glacial/ late glacial faunas with the large reworked component a signal of deglaciation. The underlying E. excavatum - C. reniforme fauna (faunas 5 and 7) with the one E. excavatum - E. subarcticum sample (fauna 6) are interpreted as being late glacial, with only a very small reworked component. The occurrence of E. subarcticum is probably indicative of a temporary coarsening of substrate /increase in wave energy.

The sediments and faunas of samples 25 to 49 (29.71 to 60.12 m) stratigraphicaly underly the material sampled in the Cohasset (Miller, 1987b) and Como boreholes. The sediments in sample 25 show extensive reworking with a large amount of shell fragments; this coupled with the lack of foraminifera (fauna 8, "barren zone B") indicates a beach zone with subaerial exposure.

The sediments show a marked change from 30 to 49 m. These have been informally termed the "red beds", because the sediments were bright brick red silt and sand, alternating with layers of finely laminated bright red clay. These "red beds" contained faunas 9 and 10, each with the same major species, but with fauna 9 containing much lower total numbers of QB specimens. Since these faunas are very similar the difference in total numbers is attributed to different sedimentation rates, with an increase occurring in the upper 14 m (31.22 to 45.85 m) of these "red beds". What is interesting about these two faunas is that each one in turn is a coupling of two faunas; an Elphidium excavatum - Buccella frigida fauna alternating with an Elphidium excavatum - Epistominella takayanagii fauna. This alternation of faunas can be directly correlated with the sediment type and grain size; the sandy layers contain the E. excavatum - E. takayanagii fauna (low percent occurrences of E. excavatum) and the clay layers contain the E. excavatum - B. frigida fauna (high percent occurrences of E. excavatum). The causes and origin of these marked , sharp changes in grain size are beyond the scope of this report and won't be commented on here. Both faunas are indicative of cold shelf (non glacial) conditions.

The complete lack of reworked foraminifera probably indicates that little if any ice rafted sediment was being deposited. The absence of C. reniforme and I. helenae coupled with the consistent presence of Stainforthia concava, Buliminella borealis and Quinqueloculina seminula probably indicate a higher salinity, close to normal marine conditions.

From 55.41 to 60. 0 m there is an E. excavatum - C. reniforme - B. frigida - C. lobatalus fauna (fauna 11) with a large variation in the percent occurrences of E. excavatum. Again, these variations can be correlated with a change in sediment texture, the sandy sediments containing the low numbers of E. excavatum and the higher numbers of C. lobatalus. This is also a non glacial fauna, the presence of C. lobatalus indicates coarser sediment, shallower water, an increase in wave energy (no major ice cover) and coupled with the presence of C. reniforme possibly a slight reduction in salinity. There is a reworked component to this fauna, which indicates some deposition from ice rafted sediment.

At the base of the hole (60.12 m) is fauna 12, an E. excavatum fauna indicating an earlier glacial period. The lack of reworked specimens probably indicates substantial ice cover, which would also account for the reworked component in the overlying non glacial fauna.

Regional and Chronological Framework

There is little chronological control on these samples. C_{14} dates are not yet available.

The sharpest faunal boundary occurs at 13.83 m (52.33 m b.s.l.) in the Como borehole and at 9.86 m m (54.86 m b.s.l.) in the Panuke borehole. Above this mark the two assemblages present in each borehole contain both modern and reworked components. They are interpreted as being reworked during and subsequent to the last marine transgression; these sediments have possibly been subaerially exposed and eroded during the low sea level stand and subsequent sea level rise. This faunal boundary at 13.8 m in the Como borehole almost coincides with Regional Reflector R1 (at 14 m), recognized on Banquereau (Amos and Knoll, 1987) and on Sable Island Bank (Amos, unpub. data) as the erosional surface representing the base of the Holocene transgression. Taylor (1987, pers.

comm.) also recognizes a seismic reflector at this horizon, but he is of the opinion that the reflector is a result of a change in sediment characteristics and grain size (the presence of a 'clay' layer) and that the base of the transgression may be higher in the section. This faunal boundary in the Panuke borehole (9.86 m) lies almost 10 m above the R1 reflector (at 19 m). McLaren and Boyd (1987) recognize a seismic reflector at 51 m in the Sable 1985 borehole which they refer to as R1. McLaren and Boyd (1987) and Scott et al. (1988) have extrapolated seismically a date of10,950 YBP, based on a peat horizon from the West Olympia B-42 borehole to the Sable 1985 borehole where it occurs at 48.8 m , just above R1. They have also extrapolated a date of 9,930 YBP from the West Olympia O-51 wellsite to 40.8 m in the Sable borehole (Scott et al., 1988). The date at the 13.5 m level (50.9 m b.s.l.) in the Cohasset hole (Amos, unpub. data) is 9,420 YBP which corresponds well with the West Olympia date.

The faunas straddling R1 (faunas 3 at the Como site and 3 and 4 at the Panuke site) are immediate post glacial faunas. The presence and high numbers of Cretaceous specimens were probably due to deposition by the melting ice during the final 'deglaciation event'. Scott (in Boyd et al., 1988; Scott et al., 1988) report a late glacial fauna accompanied by a large number of reworked (identified only as Tertiary/ Cretaceous) forms at 56.3 m in the 1985 Sable borehole, which compares favourably with the peaks reported here; in the Como borehole at 52.3 m (13.8 + 38.5 m), in the Panuke borehole at 54.8 m (9.86 + 45 m) and reported previously in the Cohasset borehole at 55.8 m (13.34 + 37.4 m, Miller, 1987b). This upper faunal boundary occurs within a 3.5 m (b.s.l.) range in all four boreholes. In three instances (Cohasset, Como and Panuke) this faunal boundary lies above R1. This suggests that the late glacial fauna and causative glacial activity postdates the last marine transgression and that there was ice cover on Sable Island Bank as sea level rose around it.

McLaren and Boyd (1987) have extrapolated another date of 30,000 YBP from one of the West Olympia boreholes, a date from shell material, to 55 m in the Sable Borehole; which is probably an 'old' date due to contamination of reworked material.

The underlying four faunas found at the Como site are all interpreted as being in the Emerald Silt Formation or its equivilent) and appear to

indicate two periods of local ice cover (faunas 4 and 6) within the late Wisconsinan. These two periods show an intervening interval (fauna 5) of cold, hyposaline, inner shelf, open water conditions. At the base of the hole is fauna 7 , probably also indicative of open water conditions. This shallow bank fauna may have occurred during the sea level rise, occurring immediately after the mid-Wisconsinan low sea level stand at approximately 26,000 YBP. It may correlate with this same fauna found in one of the Louisburg boreholes on Banquereau (Miller and Scott, 1984). Regional Reflector R2 is recognized on Banquereau (Amos and Knoll, 1987) and Sable Island Bank (Amos, unpub. data). McLaren and Boyd (1987) and Boyd et al. (1988) recognize a reflector they call R2 in the Sable borehole at 62 m; though it doesn't appear to coincide with the reflector recognized and named R2 on Banquereau (Amos and Knoll, 1987). Amos and Knoll (1987) interpret this reflector as representing an erosional event and low sea level stand on Banquereau and Boyd interprets it (1987, pers. comm.) as representing a low sea level stand on Sable Island Bank. Material taken from the 72 m level in the Sable borehole dates at 37,210 YBP (Boyd et al., 1988; Scott et al., 1988), which supports a correlation with oxygen isotope stage 3. Not enough seismic control is available at the Como borehole to determine if R2 passes through this site and at what depth it is present.

The faunas at Panuke (underlying the top four already discussed) follow similar patterns to those seen at the other two sites. .The three underlying faunas (faunas 5, 6 and 7) are interpreted as being glacial and are attributed to the last major phase of glaciation on the Scotian Shelf. Fauna 8, "barren zone B" coincides with R2 and thus indicates the mid-Wisconsinan low sea level stand.

The four faunas at the bottom of the section are more difficult to interpret, in part because this portion of the section has never been sampled before. However, all four are older than mid-Wisconsinan, the top three are indicative of non glacial cold shelf/ bank conditions and the fauna at the base of the hole may indicate an earlier glacial period.

One further observation should be noted. None of the three holes contain similar sequences, and there may be a variety of reasons for this. In these environments a shift in water depth of a few meters can cause a complete change in fauna. This area was subject to extensive local erosion and reworking during deglaciation and the transgression which may make

correlation impossible. Finally, Boyd et al. (1988) have reported extensive subglacial channeling throughout this area during the late Pleistocene and local channeling would completely change the facies very quickly, over very short distances.

CONCLUSIONS

1. Seven distinct Quaternary benthic foraminiferal assemblages have been recognized in the Como borehole. These seven assemblages are: a low number Elphidium subarcticum assemblage; an Elphidium bartletti - (reworked) Elphidium excavatum assemblage; a post glacial E. excavatum - E. subarcticum - I. helenae assemblage; a late glacial/immediate post glacial E. excavatum - C. reniforme assemblage; an E. excavatum - E. takayanagii - C. reniforme cold water shelf assemblage; an E. excavatum glacial assemblage and an E. excavatum - E. subarcticum - Glabratella wrightii bank assemblage.

2. Twelve distinct assemblages are recognized in the Panuke borehole, they are: an E. barletti - E. subarcticum - E. advena surface fauna, "barren zone A", an E. excavatum - C. reniforme - E. takayanagii cold shelf fauna, an E. excavatum - C. reniforme - I. helenae immediate post glacial fauna, three late glacial faunas, E. excavatum - C. reniforme, E. excavatum - E. subarcticum and E. excavatum - C. reniforme, "barren zone B", alternating E. excavatum - B. frigida with E. excavatum - E. takayanagii low number cold shelf assemblage followed by the same sequence with higher numbers, an E. excavatum - C. reniforme - B. frigida - C. lobatalus bank/shelf fauna and an E. excavatum glacial fauna.

3. The upper two assemblages in each borehole contain modern and relict components, they are reworked and they lie above Regional Reflector R1, the acoustic reflector believed to represent the erosional surface at the base of the last marine transgression (Amos and Knoll, 1987). These upper two faunas in each hole occur within the Sable Island Sand and Gravel Formation.

4. The underlying five assemblages at Como and the next six assemblages at Panuke are glacial marine or glacial related; the upper 2 m at Como and upper 10 m at Panuke appear to be above R1. The immediate post glacial faunas (one at Como and two at Panuke) contain high numbers of reworked Cretaceous foraminifera interpreted as being eroded and transported by glacial ice, then redeposited with Quaternary sediments and foraminifera during the final deglaciation event. These uppermost glacial marine faunas lying in part above R1 postdate the transgression.

In the Como borehole there are two faunas indicative of glacial activity/ice cover alternating with a cold shelf fauna and at the base a cold shelf/bank fauna.

In the Panuke borehole the remaining faunas indicate glacial conditions; including the fauna immediately underlying the "barren zone B" (which coincides with R2 the acoustic reflector believed to represent the mid-Wisconsinan low sea level stand).

5. The four faunas at the bottom of the stratigraphic section at Panuke are indicative of cold shelf/bank conditions; except for the fauna at the base of the hole, which is a glacial marine fauna.

6. Local depositional environments, erosion, reworking and extensive subglacial channeling, result in varied foraminiferal assemblages and eliminate the possibilities of regional correlation between boreholes.

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APPENDIX A

Faunal Reference List

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

The generic classification is in accordance with Loeblich and Tappan (1964) except for Haynesina (Banner and Culver, 1978).

Species are listed alphabetically, first agglutinated, then calcareous.

Quaternary Benthonic Foraminifera

Eggerella advena Cushman. MILLER ET AL., 1982a, p. 2362, pl. 1, fig. 14.
Quinqueloculina agglutinata Cushman. MILLER ET AL., 1982a, p.2364, pl.1, fig. 18.
Silicosigmoilina groenlandica Cushman. LOEBLICH and TAPPAN, 1953, p. 38-39, pl. 4, figs. 7-9.
Spiroplectammina biformis (Parker and Jones). MILLER ET AL., 1982a, p. 2364, pl. 1, fig. 9.
Textularia torquata Parker. MILLER ET AL., 1982a, p. 2364, pl. 1, fig. 10.
Trochammina advena Cushman. COLE, 1981, p. 37, pl. 8, fig. 3.
Trochammina lobata Cushman. SCOTT ET AL., 198), p. 231, pl. 2, figs. 3-4.
Trochammina nitida Brady. BARKER, 1960, p. 84, pl. 41, figs. 5-6.
Trochammina ochracea (Williamson). MILLER ET AL., 1982a, p. 2364, pl. 1, figs. 16-17.

Amphicoryna separans (Brady). BARKER, 1960, p. 136, pl. 64, figs. 16-19.
Astrononion gallowayi Loeblich and Tappan. LOEBLICH and TAPPAN, 1953, p. 90-92, pl. 17, figs. 4-7.

Bolivina pseudoplicata Heron-Allen and Earland. SCOTT ET AL., 1980, p. 226, pl. 4, fig. 3.
Bolivina skagerrakensis Qvale and Nigam. QVALE and NIGAM, 1985, p.6, pls. 1-2.
Bolivinita quadrilatera (Schwager). BARKER, 1960, p. 86, pl. 42, figs. 8-12.
Brizalina lanceolata (Parker). POAG, 1981, p. 45, pl. 25, fig. 5; pl. 26, fig. 5.
Brizalina lowmani (Phleger and Parker). POAG, 1981, p. 46, pl. 25, fig. 3; pl. 26, fig. 3.
Brizalina pseudopunctata (Hoeglund). MILLER ET AL., 1982a, p. 2364, pl. 2, fig. 21.
Brizalina spathulata (Williamson). SCOTT, 1987, p. 327, pl. 1, fig. 10.
Brizalina subaenariensis (Cushman). SCOTT, 1987, p. 327, pl. 1, fig. 11.
Buccella frigida (Cushman). MILLER ET AL., 1982a, p. 2364, pl. 3, figs. 9-10.
Bulimina aculeata d'Orbigny. POAG, 1981, p. 48-49, pl. 21, fig. 1.
Buliminella borealis Haynes. HAYNES, 1973, p. 114-116, text-fig. 22:1-3.
Cassidulina laevigata (d'Orbigny). [Islandiella laevigata (d'Orbigny)]. POAG, 1981, p. 70, pl. 17, fig. 2, pl. 18, fig. 2.
Cassidulina reniforme Nørvang. MILLER ET AL., 1982a, p. 2362, pl. 2, fig. 8.
Cibicides fletcheri Galloway and Wissler. HAYNES, 1973, p. 171-172, text-fig. 35, nos. 1-3.
Cibicides lobatalus (Walker and Jacob). VILKS ET AL., 1982, p.226, pl. 1, fig. 20.
Cibicidoides corpulentus Phleger and Parker. POAG, 1981, p. 52-53, pl. 31, fig. 1; pl. 32, fig. 1.
Cibicidoides floridanus Cushman [Cibicidoides "floridanus" (Cushman) formae bathyalis and sublittoralis]. POAG, 1981, p. 53-54, pl. 29, figs. 1-2, pl. 30, figs. 1-2.
Cibicidoides pseudoungerianus Cushman. [Cibicides pseudoungerianus Cushman.] BARKER, 1960, p.194, pl. 94, fig. 9.
Cibicidoides robertsonianus (Brady). POAG, 1981, p. 54-55, pl. 5, fig. 1, pl. 6, fig. 1.
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