LATE QUATERNARY BIOSTRATIGRAPHY OF TWO SHALLOW BOREHOLES, COHASSET A-52 WELLSITE, SABLE ISLAND BANK

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ABSTRACT

Thirty samples from two shallow geotechnical boreholes from the Cohasset A-52 wellsite on Sable Island Bank, Scotian Shelf have been analysed for Quaternary benthonic, Quaternary planktonic and reworked foraminifera. Six distinct Quaternary benthic foraminiferal assemblages have been recognized. These six assemblages are: a low number Elphidium subarcticum - Cibicides lobatalus assemblage; a reworked Elphidium excavatum - E. subarcticum assemblage; a late glacial/immediate post glacial E. excavatum - C. reniforme - E. takayanagii assemblage; a low number assemblage; an E. excavatum - C. reniforme warm water shelf assemblage and an E. excavatum - E. takayanagii cold water shelf assemblage. The upper two assemblages each contain modern and reworked components; 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). Both of these faunas lie within the Sable Island Sand and Gravel Formation. The underlying four assemblages occur within the Emerald Silt or its stratigraphic equivalent, the upper 4 - 5 m which appears to be above R1. The late glacial fauna contains high numbers of reworked Cretaceous foraminifera interpreted as being eroded and transported by glacial ice, then redeposited with Quaternary sediments and Quaternary foraminifera during the final deglaciation event. The low number assemblage is interpreted as being deposited during either: a high sedimentation event, a period of lower productivity, a period of reworking by grounded ice, or reworked during subaerial exposure and a lower sea level stand. Occurring within the sediments containing this fauna is Regional Reflector R2, believed to represent a mid Wisconsinan erosional event and low sea level stand occurring at the end of isotopic stage 3 (26,000 to 30,000 YBP). The warm water shelf fauna is interpreted as being deposited during an interglacial event and the cold shelf fauna during a colder period preceeding this warmer event.

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. Other data comes from Scott et al. (1984), Ruffman et al. (1985) and Jacques, McClelland Geosciences, inc. (1985) who 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 is an unpublished report by Miller and Scott (1984) which describes the Quaternary micropaleontology of two shallow geotechnical boreholes at the Louisburg J-47 wellsite on central Banquereau.

In 1986 Jacques, McClelland Geosciences, inc. was contracted by Petro-Canada to drill one borehole and complete geotechnical tests at the Cohasset A-52 wellsite on Sable Island Bank. This site is 12 km southwest of Sable Island (Figure 1). The Geological Survey of Canada was invited to participate in the sampling program in order to help define the geological section. Samples were collected from two boreholes. The Geological Survey subsequently contracted Marine G.E.O.S. (Geological Exploration and Offshore Services; DSS Contract No. 23420-6-M981/01-0SC) 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

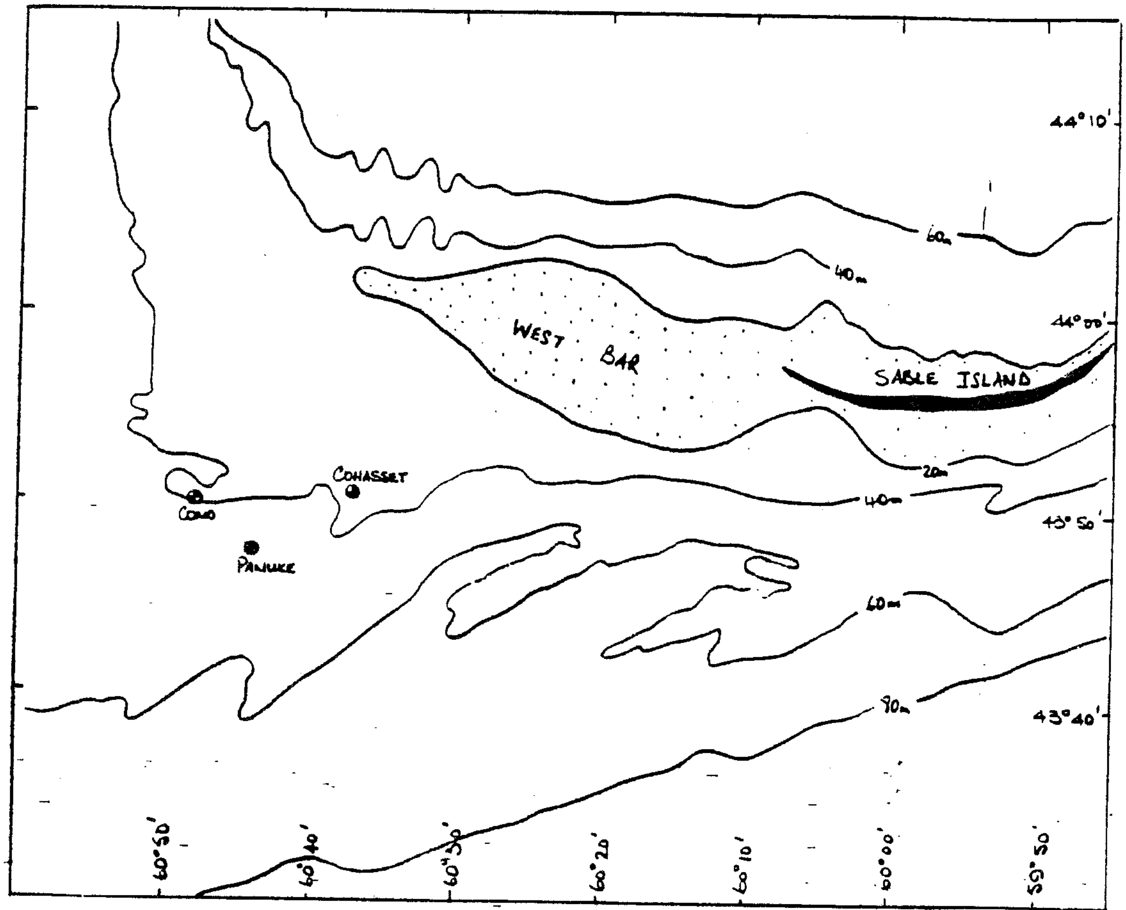

FIG. 1. LOCATION DIAGRAM

Two borings were drilled at the Cohasset A-52 wellsite (Figure 1, above from Amos, 1987). Boring 1 was drilled in 37.4 m. of water to a depth of 30 m at 43° 51' 06.60" N, 60° 37' 40.11" W. Boring 2 was drilled 88 m away, in a water depth of 40.2 m at 43° 51' 04.76" N, 60° 37' 38.16" W to a depth of 46 m and sampled from 30 to 46 m. (Jacques, McClelland Geosciences, inc., 1986).

PREVIOUS WORK

Pre-Quaternary Geology

The bedrock geology of the Scotian Shelf has been studied extensively, (King, 1980; King and Fader, 1986). Only brief mention will be given here to characteristics related to this study.

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 sediments prograde across the shelf and 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 the controlling factors 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 map the bank using acoustics (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; Mudie, 1980, 1982; King, 1980; 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 equivilent of the Emerald Silt, composed of reworked deposits of Scotian Shelf Drift and Emerald Silt.

The last glacial advance was fully developed by about 26,000 YBP (Amos and Knoll, 1987). 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 sea level at -21 m at approximately 8,000 YBP. More recently Scott et al. (1988) suggest a mimium sea level stand of -78 m at 15,000 YBP for 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. One exception is a report completed by Miller and Scott (1984) 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. This work will be referred to in the discussion section of this report.

LABORATORY METHODS

Thirty samples were chosen for biostratigraphic analysis. There were three types of samples available. The processing and analytical methods used were predicated by the sample type. These methods are described:
Sample type 1. Bagged raw bulk samples. Grain size analysis was performed by A.G.C. on 13 samples and the dried fraction (63-2000 was retained. These 13 samples were annotated by Jacques-MacClelland as: 1-2B, 1-3B, 1-8B, 1-9A, 1-11, 1-13A, 1-16, 1-17, 1-19, 2-5B(2), 2-7A, 2-8, 2-9(1).
Sample type 2. Bagged samples washed by Jacques, MacClelland, size fraction 74-4000μ . Grain size analysis was performed by Jacques-MacClelland (1986). Thirteen samples were washed through 500 and 63μ sieves to remove the dried drilling mud. These thirteen samples were : 1-1, 1-2A, 1-3C, 1-6, 1-10, 1-12, 1-15, 1-20(1), 1-21(1), 2-2, 2-3, 2-4, 2-6.

The sand fraction from the above 26 samples were weighed and standarized to whole sample weights using the grain size analysis results. Then an appropriate portion, equal to 10 gms. of whole sample was weighed out. The foraminifera were concentrated by floatation twice with CCl_4 (Scott, 1987). Most samples, particularily those in the top 20 m, contained low numbers of foraminifera; in these instances additional sample was treated and the foraminifera added to those already obtained. Total number of grams of sediment analysed are given for each sample on Table 1.

Twenty samples were also made available which had been previously processed and floated only once. The foraminifera from the float had been picked and mounted on slides. Unfortunately, these samples were not uniform in size and grain size analysis had not been completed on most samples so the foraminiferal counts obtained could not be standardized to a whole sample weight. Grain size analyses were available for four of these samples. These four samples: 1-14B(1), 1-20(2), 2-5A, 2-9(2) were weighed, total weight calculated and the sample floated a second time. This second float was counted and added to the count obtained from the slide of the first float.

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.

Because all of these samples are not uniform in size all data are normalized to 10 gms. dry weight of whole sample. The sample weight, total number of foraminifera in each of the three catagories, the number of foraminifera in each catagory per 10 gms. of dry raw sample and the relative species abundances for the Quaternary benthic foraminiferal species are given on Table 1. The data (total numbers) of Quaternary planktonic and reworked benthonic and planktonic specimens, by species, are also listed.

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 (physically worn/abraded) specimens equalled or were greater than the number of Quaternary specimens. It was also noted that the number of reworked specimens varied greatly from sample to sample. It was decided to identify this material, in an attempt to locate the source rock. The distinct and easily recognizable species of Heterohelix, Gumbelitria and Praebulimina were identified first. Gumbelitria cretacea and Heterohelix spp. are all restricted to the Maastrictian and based on this two major assumptions have been 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 (R) (mostly Upper Cretaceous) species. Relative species abundance data 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 and the number of QB species in each sample are plotted on Figure 2.

Six distinct assemblages are recognized down hole.

1. Low number Elphidium subarcticum - Cibicides lobatalus assemblage. Samples 1-1 (0.0 m) to 1-9A (10.2 m) are almost barren of foraminifera (total number of QB specimens < 30/total sample; < 4 specimens /10 gms.). There are too few specimens to show any statistically valid trends. However, the assemblage is dominated by Elphidium subarcticum (6.5 - 56.0%) and E. excavatum (18.0 - 67.0%). C. lobatalus is also consistently present (5.0 - 22.0%) in all but the top two samples. Specimens of these three species do not show as much reworking as do scattered specimens of Buccella frigida, Cassidulina reniforme, Glabratella wrightii, Islandiella helenae, Quinqueloculina spp., Rosalina spp. and Trifarina angulosa. There are only scattered planktonic specimens (< 9/sample), all Neogloboquadrina pachyderma left and right coiled. There are a few reworked specimens of the Cretaceous species Gumbelitria cretacea and Heterohelix globulosa.

2. Reworked Elphidium excavatum - Elphidium subarcticum assemblage. Samples 1-10 (11.9 m) to 1-13A (16.7 m) contain slightly higher numbers of foraminifera (number of QB < 72/total sample; < 13 specimens/10 gms.). E. excavatum remains the dominant species (38.0 - 64.0%). E. subarcticum is subdominant at 11.9 (20.0%0 and 13.4 m (17.0%). Islandiella helenae is consistently present (4.0 - 14.0%), Haynesina orbiculare present at 13.4, 15.1 and 16.7 m (3.0 - 14.0%) and Cassidulina reniforme from 11.9 m down hole (3.0 - 5.0%). There are very few planktonic specimens (< 7/total sample; < 1.5 specimens/10 gms.) and they are mainly N. pachyderma. The total number of reworked specimens increases steadily down hole (39 specimens/total sample; 13 specimens/ 10 gms.); ?Pyramidina referata is the dominant reworked species.

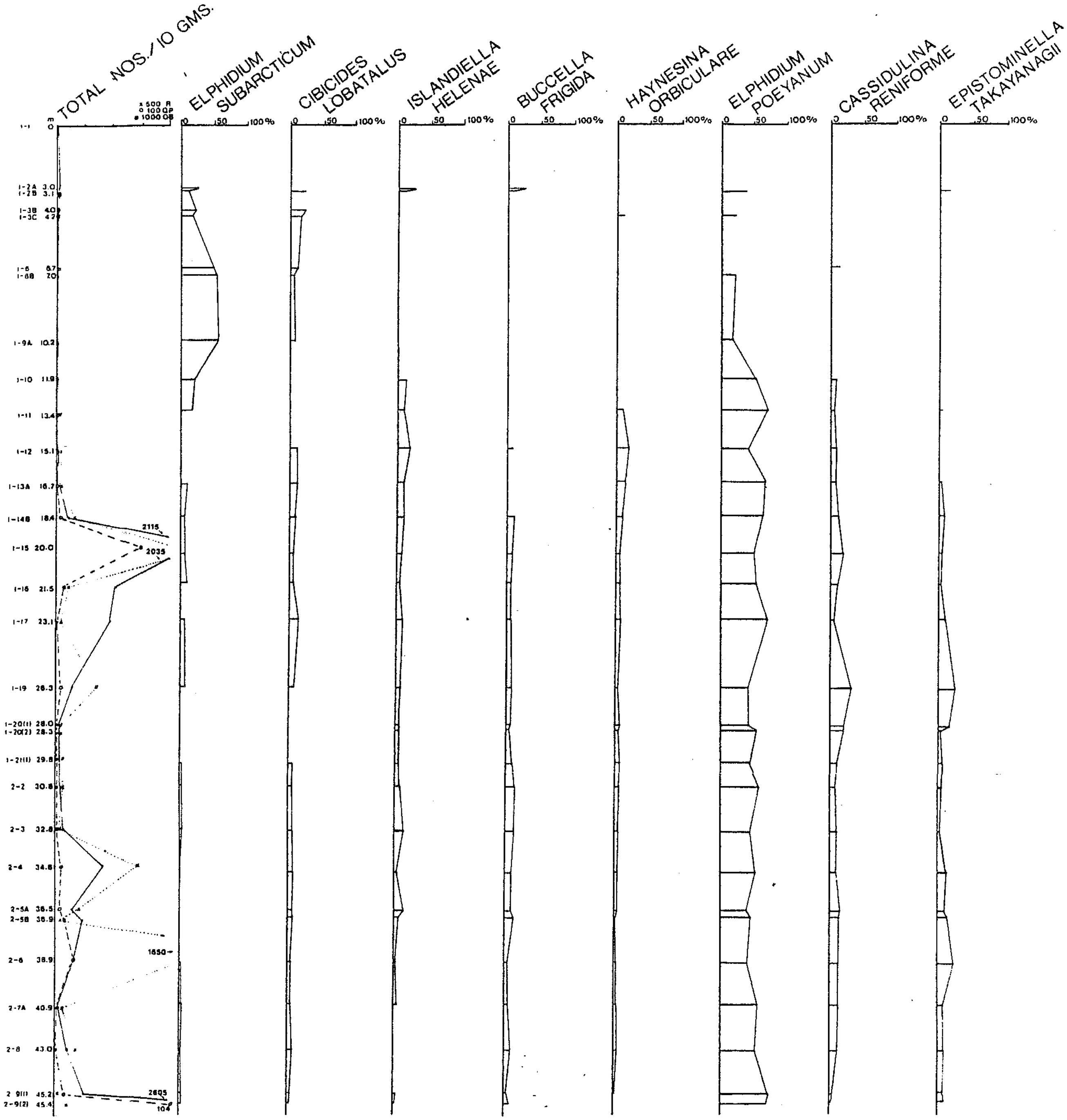

Figure 2: Percent occurrences of the eight most common Quaternary Benthic foraminiferal species plotted down hole. Horizontal bars are actual values for that corresponding level. Elphidium poeyanum should be Elphidium excavatum.

SAMPLE NO.	1-1	1-2A	1-2B	1-3B	1-3C	1-6	1-8B	1-9A	1-10	1-11	1-12	1-13A	1-14B	1-15	1-16	1-17	1-19	1-20(1)	1-20(2)	1-21(1)	2-2	2-3	2-4	2-5A	2-5B	2-6	2-7A	2-8	2-9(1)	2-9(2)
DEPTH	0	3	3.1	4	4.2	6.7	7	10.2	11.9	13.4	15.1	16.7	18.4	20	21.5	23.1	26.3	28	28.3	29.8	30.8	32.8	34.8	36.5	36.9	38.9	40.9	43	45.2	45.4
TOTAL NO. QUAT. BENTHICS	6	4	29	9	13	12	19	61	20	72	21	55	212	8256	526	490	155	41	126	143	143	104	610	395	1660	1595	199	242	261	9744
NOS. GMS. SEDIMENT	40	41	20	31	54	27	50	51	60	55	69	30	20	39	10	10	12	33	90	79	41	18	15	103	70	16	33	24	10	37
NO. SPECIMENS/10 GMS.	1.5	1	1.5	3	2	0.5	4	12	3.5	13	21	18	105	2117	524	490	134	12	14	18	35	58	415	39	237	997	60	100	261	2605
SPLIT COUNTED	/	/	/	/	/	/	/	/	/	/	/	/	/	1/32	1/2	1/2	/	/	/	/	/	/	1/2	/	/	3/16	/	/	/	1/16
Eggerella advena							5																							
Spiroplectammina earlandi																											0.5			
Trochammina advena				11																										
Ammonia beccarii					7.5					1.5																				
Amphicoryna sublineata																									0.5				0.5	
Astacolus crepidulus														0.5																
Astrononion gallowayi												2								0.5		1	0.5	1		X				X
Bolivina decussata															0.5												0.5			
Bolivina pseudoplicata																												0.5		
Bolivinita quadrilatera													X		0.5									1		X				
Brizalina lanceolata																			0.5											
Brizalina lowmani																								0.5	0.5					
Brizalina spathulata												2					1			0.5			0.5	3				0.5		
Brizalina subaenariensis																0.5	1.5						0.5	X		1.5				X
Buccella frigida		25	3								5		5	3	3	4	2.5	7.5	3.5	5	10	10.5	8.5	5.5	9.5	6	4	6	1	3
Bulimina aculeata													X	0.5	0.5										0.5		0.5			
Buliminella borealis											5			0.5	1.5		1						0.5	1	1	1		1	1	1
Cassidulina reniforme						8.5			5	3	5	4	12	17.5	11.5	2	18	15	16	8.5	5.5	8.5	4.5	13	9.5	9.5	8	8	3	3
Cassidulina teretis																						1	0.5							
Chrysalidinella dimorpha																									0.5					
Cibicides lobatalus			21	22	15	8.5	5	5			10	6	4	3.5	3	3	4			2	5.5	5	6.5	3	6.5	3	2	5.5	2	2
Cibicidoides corpulentus																				0.5				0.5		0.5	0.5			
Cibicidoides floridanus																								X						
Cibicidoides mollis																	1													
Cornuspira distincta								1.5		1.5															0.5					
Cyclogyra involvens						8.5																								
Dentalina baggi																										X				
Discorbinella subbertheloti														1.5									0.5	0.5	2	1	0.5			
Discorbis mira								1.5												0.5										
Discorbis squamata														0.5										2		1		0.5		
Ehrenbergina pacifica									5																					
Elphidium bartletti					7.5	17	5	10										5		3.5		3	0.5		0.5		0.5			X
Elphidium excavatum			34.5		23		21	18	55	64	38	62	59	53.5	60	65	39	39	52	46	58	44	55	42	47.5	40.5	60.5	57	75	73
Elphidium subarcticum	67		6.5	22	15	50	53	56	20	17		6	1	6	7	9.5	4.5			6	2	2	2		1.5	1	4	3	2.5	3
Eoeponidella pulchella											5													X		0.5	0.5			
Epistominella arctica															0.5						0.5									
Epistominella exigua																				3.5				2		2.5	0.5			
Epistominella takayanagii			10.5							1.5		2	5	5	1	3	21	10	0.5	4	3	2	8	7.5	9	22	5	7	5	7
Epistominella vitrea	16.5																							X						
Eponides pusillus										1.5		2								0.5			0.5	1						
Fissurina exsculpta																							0.5						0.5	
Fissurina marginata			6.5	11				1.5	5					0.5	0.5				0.5			1					0.5			X
Fursenkoina fusiformis	16.5		6.5		7.5					1.5			X			0.5			0.5				0.5	3	1	1	0.5	3	1	X
Gavelinopsis lobatalus								1.5					X										0.5	X				1		
Glabratella crassa			3																											
Glabratella wrightii		25				8.5		1.5			5		2	1	3	0.5	1.5	12.5	3.5	2		3	0.5	1		0.5	2	1		0.5
Glandulina laevigata																														X
Globocassidulina subglobosa								5				2	1	1	3	2.5			0.5	2	1.5	4	3.5	0.5	0.5	0.5	2	2	2	0.5
Guttulina austriaca																								1					0.5	
Guttulina dawsoni																														X
Gyroidina orbicularis												2											0.5	1	0.5					
Gyroidina quinqueloba														0.5		0.5	1			0.5			0.5			1				X
Gyroidina soldanii														0.5												X				

Table 1: Foraminifera data. Relative species abundance data for Quaternary benthic species; total numbers for Quaternary planktonic and Reworked species. X ∠ 0.5%.

SAMPLE NO.	1-1	1-2A	1-2B	1-3B	1-3C	1-6	1-8B	1-9A	1-10	1-11	1-12	1-13A	1-14B	1-15	1-16	1-17
DEPTH	0	3	3.1	4	4.2	6.7	7	10.2	11.9	13.4	15.1	16.7	18.4	20	21.5	23.1
QUATERNARY BENTHICS (con't)																
Hanzawaia asterizans													X			
Hanzawaia concentrica																0.5
Haynesina depressula																
Haynesina nana																
Haynesina orbiculare					7.5					3	14	8	4	1	4	4.5
Hoeglundina elegans															0.5	
Islandiella helenae		25	3						5	4	14	8	3.5	3.5	3	5
Islandiella norcrossi																
Lagena laevis																
Loxostomum porrectum																
Melonis barleeanum												2				
Miliolinella subrotunda																
Nonionella atlantica																
Nonionella auricula		25														
Nonionella turgida																
Nonionellina labradorica			3							1.5				0.5	0.5	
Nuttallides decorata														0.5		
Oolina caudigera																
Oolina costata																
Oolina melo																
Oridosalis umbonatus																
Pateoris hauerinoides				11												
Pseudoeponides japonicus																
Pseudopolymorphina suboblonga																
Quinqueloculina elongata					7.5								X	0.5		
Quinqueloculina seminula							10.5									
Quinqueloculina stalkeri																
Quinqueloculina vulgaris																
Rosalina araucana					7.5					1.5						
Rosalina globularis				11						1.5						
Stainforthia concava																
Stetsonia horvathi				11												
Trifarina angulosa									5				X		1	
Triloculina trihedra																
Uvigerina asperula																
Uvigerina peregrina														0.5		
QUATERNARY PLANKTONICS																
TOTAL NO./SAMPLE	/	2	1	9	1	2	2	5	1	7	2	1	6	320	6	/
NO. SPECIMENS/10 GMS.	/	0.5	0.5	3	0.5	0.5	0.5	1	<0.5	1.5	<0.5	<0.5	3	74	6	/
Globigerina bulloides																
Globigerina quinqueloba - left													1			
Globigerina quinqueloba - right																
Globigerinita glutinata																
Globigerinita nitida																
Globigerinita uvula											1		5			
Globorotalia crassiformis																
Globorotalia inflata																
Globorotailia truncatulinoides														32		
Neogloboquadrina pachyderma																
left		1	1	8	1	2	2	3		4	1	1		96	4	
right		1		1				2		1				32	2	
juveniles									1	2				160		

SAMPLE NO.	1-19	1-20(1)	1-20(2)	1-21(1)	2-2	2-3	2-4	2-5A	2-5B	2-6	2-7A	2-8	2-9(1)	2-9(2)
DEPTH	26.3	28	28.3	29.8	30.8	32.8	34.8	36.5	36.9	38.9	40.9	43	45.2	45.4
QUATERNARY BENTHICS (con't)														
Hanzawaia asterizans								0.5	0.5	X				
Hanzawaia concentrica														
Haynesina depressula								X						
Haynesina nana			0.5									0.5		
Haynesina orbiculare	1	7.5	4	5	4	3	1.5	1.5	0.5	1.5	1.5	2	0.5	
Hoeglundina elegans	1											0.5		
Islandiella helenae	4	2.5	0.5	2	6	10.5	1.5	11	5	0.5	1.5		1	0.5
Islandiella norcrossi										0.5				
Lagena laevis														X
Loxostomum porrectum								1						
Melonis barleeanum			3.5	0.5	1.5		0.5	X	0.5	0.5				
Miliolinella subrotunda		2.5		1.5							0.5		2	2
Nonionella atlantica									X		1.0			
Nonionella auricula														
Nonionella turgida													0.5	X
Nonionellina labradorica				1.5		1	0.5	2						X
Nuttallides decorata											0.5			
Oolina caudigera										X				
Oolina costata				0.5										
Oolina melo							0.5		0.5					
Oridosalis umbonatus								X						
Pateoris hauerinoides														
Pseudoeponides japonicus											0.5			
Pseudopolymorphina suboblonga													0.5	
Quinqueloculina elongata								0.5					0.5	0.5
Quinqueloculina seminula				1.5					0.5			0.5	3	2
Quinqueloculina stalkeri			0.5							X				
Quinqueloculina vulgaris			3.5											1
Rosalina araucana								1.5		X		0.5		X
Rosalina globularis				0.5				1	2					
Stainforthia concava				0.5										X
Stetsonia horvathi											0.5			
Trifarina angulosa				0.5	2		0.5	2.5	0.5	1	2.5		1	
Triloculina trihedra														X
Uvigerina asperula								X					0.5	X
Uvigerina peregrina						1			0.5			1		
QUATERNARY PLANKTONICS														
TOTAL NO./SAMPLE	5	2	1	39	1	3	6	46	64	25	7	3	9	394
NO. SPECIMENS/10 GMS.	4	0.5	<0.5	0.5	<0.5	1	4	4	9	17	2	1	9	104
Globigerina bulloides								1						16
Globigerina quinqueloba - left				1			2			10			3	32
Globigerina quinqueloba - right	1								8	5				
Globigerinita glutinata										5				
Globigerinita nitida	1											1		32
Globigerinita uvula				2							2			
Globorotalia crassiformis												2		
Globorotalia inflata									8				3	
Globorotailia truncatulinoides														
Neogloboquadrina pachyderma														
left	1	1	1	35	1	2	4	21	32	5	3		1	154
right	2			1				6	16					64
juveniles	1	1					1	18			2		3	96

Table 1: continued.

Cohasset Borehole: Foraminiferal Data

SAMPLE NO.	1-1	1-2A	1-2B	1-3B	1-3C	1-6	1-8B	1-9A	1-10	1-11	1-12	1-13A	1-14B	1-15	1-16	1-17	1-19	1-20(1)	1-20(2)	1-21(1)	2-2	2-3	2-4	2-5A	2-5B	2-6	2-7A	2-8	2-9(1)	2-9(2)
DEPTH	0	3	3.1	4	4.2	6.7	7	10.2	11.9	13.4	15.1	16.7	18.4	20	21.5	23.1	26.3	28	28.3	29.8	30.8	32.8	34.8	36.5	36.9	38.9	40.9	43	45.2	45.4
REWORKED (CRETACEOUS)																														
TOTAL NO./SAMPLE	/	/	3	/	3	1	/	/	/	2	6	39	142	7616	50	14	206	10	6	37	63	14	534	1049	1635	2540	80	238	19	192
NO. SPECIMENS/10 GMS.	/	/	1.5	/	0.5	<0.5	/	/	/	<0.5	1	13	71	1953	50	14	177	3	4	5	15	8	360	103	233	1650	25	99	19	51
BENTHICS																														
Spiroplectammina laevis																													1	
Caucasina elongata													1																	
Dentalina legumen																								1						
Eouvigerina americana										1	1			64			4						20		24	16				
Eouvigerina subsculptura													1	64			1	1			1			8		43		1		
Lagena apiculata																								1						
Nodosaria aspera																								1						
?Nonionella robusta																												3		
Osangularia navarroana													1																	
Praebulimina carseyae														64			1			1	1		2	29		48		5		
Praebulimina kickapooensis												3	1	32			3				2		4	8		6	1	3		16
Praebulimina reussi													5	192			4	2		1		2	22	34	60	53	4	2		
Pseudouvigerina seligi					1																		2							
?Pyramidina referata											1	29	33	2528	30	10	92	2		9	15		124	365	360	459	30	67	5	112
Pyramidina triangularis												1	2		2		1						4	16						
Stilostomella bradyi																								4						
PLANKTONICS																														
Gumbelitria cretacea			2		2	1				1	2	3	89	2272	8	2	30	2	3	4	21	9	290	244	912	1568	16	107	10	32
Heterohelix globulosa			1								2		4	1376	2		32		1	11	6	1	28	119	128	411	12	16	1	16
Heterohelix pulchra														96										9		37				

Table 1: continued.

3. Elphidium excavatum - Cassidulina reniforme - Epistominella takayanagii fauna. Samples 1-14B (18.4 m) to 1-19 (26.3 m) contain a fauna dominated by E. excavatum (39.0 - 65.0%); sub-dominant are C. reniforme (2.0 - 18.0%) and E. takayanagii (1.0 - 21.0%), H. orbiculare (1.0 - 4.0%), Buccella frigida (2.5 - 5.0%), I. helenae (3.0 - 5.0%), G. wrightii and C. lobatalus (3.0 - 4.0%) are also consistently present. There are scattered occurrences of 'warm' water species Hanzawaia asterizans, H. concentrica and the deep water species Uvigerina peregrina as well as numerous 'cold' water shelf species. These samples have much higher numbers of foraminifera (211 - 8256 specimens/total sample; 105 - 2117 specimens/10 gms.) with a peak occurring at 20.0 m. The planktonic assemblage is much more varied and shows correspondingly higher numbers also. Species include N. pachyderma (left and right coiled), Globigerina quinqueloba, Globigerinita nitida and G. uvula.

There are also much higher numbers of reworked specimens, again the peak occurring at 20.0 m (7936 specimens/total sample; 2035 specimens/10 gms.). The dominant species are Gumbelitria cretacea, ?Pyramidina referata and Heterohelix globulosa, specimens of Praebulimina spp. and Eouvigerina spp. are also present.

4. Low number assemblage. Samples 1-20(1) (28.0 m) to 2-3 (32.8 m) contain much lower numbers of foraminifera (< 143 specimens/total sample; < 58 specimens/10 gms.) though the fauna is similar to the one immediately overlying. E. excavatum remains dominant (39.0 - 58.0%) and there are slightly higher numbers of C. reniforme (5.5 - 16.0%) and B. frigida (3.5 - 10.5%). There is a corresponding drop in the numbers of planktonic and reworked specimens.

5. Samples 2-4 (34.8 m) to 2-8 (43.0 m) also contain a fauna dominated by E. excavatum (40.0 - 60.5%), C. reniforme (4.5 - 13.0%) and E. takayanagii (7.5 - 22.0%) but they are accompanied by scattered occurrences of 'warmer' water shelf species; i.e. Brizalina lowmani, B. earlandi, Cibicidoides corpulentus, ?Discorbinella sp., Hanzawaia asterizans, Rosalina araucana and R. globularis, in addition to 'colder' water shelf species B. frigida, Buliminella borealis, C. lobatalus, E. subarcticum, G. wrightii, Guttulina spp., H. orbiculare, I. helenae, G. subglobosa, Melonis barleeanum, Fursenkoina fusiformis and Trifarina angulosa. This is a very varied fauna with higher numbers than the overlying assemblage. (198 - 1640 specimens/total sample; 39 - 997

specimens /10 gms.). Numbers of planktonic specimens are also higher and the planktonic fauna is also varied; including isolated 'warmer' water mass specimens of Globigerina bulloides, Globorotalia inflata and G. crassiformis. There are peaks of reworked specimens in samples 2-5B and 2-6 (up to 2640 specimens/total sample; 1650 specimens/10 gms.) with up to 16 identified reworked species.

6. Samples 2-9(1) (45.2 m) and 2-9(2) (45.4 m) contain approximately 75.0% E. excavatum and minor occurrences of 'cold' water shelf species E. takayanagii (5.0 - 7.0%), E. subarcticum (2.5 - 3.0%), C. reniforme (3.0%0) and C. lobatalus (2.0%). The planktonic fauna is dominated by N. pachyderma but there are also specimens of G. bulloides, G. quinqueloba and G. nitida. There are only a few reworked specimens.

DISCUSSION

Paleo-environmental Interpretation

The six Quaternary benthonic foraminiferal assemblages observed are almost entirely calcareous. Only three agglutinated specimens were found. This 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. 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 some cold marine environments (i.e. Lagoe, 1977) and their absence in the preserved fauna implies their absence in the living population.

The upper two assemblages (low number Elphidium subarcticum - Cibicides lobatalus assemblage from 0.0 to 10.2 m; reworked Elphidium excavatum - Elphidium subarcticum assemblage from 11.9 to 16.7 m) are both interpreted as containing E. subarcticum and C. lobatalus as the 'in situ' indigenous component superimposed on the reworked remnants of an older assemblage. Specimens of these two species are well preserved and have a fresh appearance. However, this assemblage does 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 - Globocassidula 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 shelf sediments in this region represent post - glacial sorting and redeposition of glacial deposits (Williamson et al., 1984). Both these assemblages 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 Cohasset well site (Medioli et al., 1986, figures 2 and 7) are either barren of foraminifera or dominated by the agglutinated species Adercotryma glomerata.

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, coarsest sediment and maximum water turbulence.

Minor occurrences of other shelf species (B. frigida, C. reniforme, G. wrightii, I. helenae, Quinqueloculina spp., Rosalina spp. and T. angulosa) 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.

The third assemblage, the E. excavatum - C. reniforme - E. takayanagii assemblage, occurring from 18.4 to 26.3 m, is probably a late glacial / immediate post glacial assemblage, very similar to that found by Miller and Scott (1984) in the Louisburg boreholes on Banquereau. 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 the Labrador Shelf (Vilks et al., 1974). E. excavatum and C. reniforme are well known dominant components of these late glacial assemblages; E. takayanagii seldom appears in such high numbers (1.0 - 21.0%). 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 high salinity cold water counterpart of the slightly lower salinity more tolerant E. excavatum - C. reniforme fauna.

The subdominant species (B. frigida, I. helenae, G. wrightii, 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 components of a cold shelf fauna (Vilks, 1968, 1969; Vilks et al., 1974; Lagoe, 1977; Rodrigues and Hooper, 1982; Williamson, 1983; Williamson et al., 1984) are also absent. The scattered occurrences of the 'warm' water species Hanzawaia asterizans, H. concentrica and deep water species Uvigerina peregrina are interpreted as being reworked. The planktonic foraminifera are all indicative of cold water (N. pachyderma, G. quinqueloba, G. nitida and G. uvula).

The key to placing this fauna within a stratigraphic and (to some extent) chronolgical framework is the large number of reworked Cretaceous benthonic and planktonic foraminifera. 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 and by Miller and Scott (1984) on Banquereau (though in much lower numbers on Banquereau). Scott (1984 pers. comm., cited in Miller and Scott, 1984) and

Scott and Medioli (1988) have noted from seismic records that the sediments containing these faunas (in Emerald Basin) in some instances directly overlie 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 Cretaceous/Tertiary sediments. 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.

The low number assemblage occurring from 28.0 to 32.8 m contains the glacial E. excavatum - C. reniforme fauna. The lower numbers may be due to higher sedimentation rates, lower productivity (due to ice cover?) or reworking by grounded ice or subaerial erosion.

From 34.8 to 43.0 m is a fauna dominated by E. excavatum and C. reniforme but this is a varied shelf fauna. The majority of this fauna is composed of species occurring on cold and temperate marine shelves

(Loeblich and Tappan, 1953; Vilks, 1969; Knudsen, 1971a; Osterman, 1984). However, there are numerous occurrences of 'warmer' water shelf species (i.e. of Brizalina, Cibicidoides, ?Discorbinella, Hanzawaia, Rosalina); species reported by Phleger and Parker (1951) and Poag (1981) as living in the Gulf of Mexico today. The numbers of planktonic specimens are higher and the planktonic fauna contain 'warmer' water mass species G. bulloides, G. inflata and G. crassiformis. There are also peaks of reworked Cretaceous species. These 'warm' water forms may be reworked; or they are more likely part of an indigenous warmer water interglacial/estuarine fauna. The specimens of E. excavatum show good preservation and varied ornamented morphology, indicative of warmer and possibly estuarine waters (Miller et al., 1982b).

The sediments occurring at the base of the borehole (45.2 to 45.4 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.

Regional and Chronological Framework

There is little chronological control on these samples. The C_{14} dates (Amos, 1987, unpub. data) show inversions, probably due to contamination of reworked material.

The sharpest faunal boundary occurs at 18.4 m. Above this mark the two assemblages present contain both modern and reworked components. These assemblages are interpreted as being reworked during and subsequent to the Holocene transgression; these sediments have been subaerially exposed and eroded during the low sea level stand and subsequent sea level rise. Initially sea level rose quickly and the "reworking" time was shorter; perhaps explaining why the samples from 11.9 to 16.7 m contain higher numbers and are not as broken and eroded as the specimens from the assemblage above. This faunal boundary at 18.4 m lies a few metres above Regional Reflector R1 (at approximately 23.0 m subsurface), recognized on Banquereau (Amos and Knoll, 1987) and on Sable Island Bank (Amos, unpub. data) as the erosional surface representing the base of the Late

Wisconsinan /Holocene transgression. Taylor (1987, pers. comm.) also recognizes a seismic reflector near 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. McLaren and Boyd (1987) recognize a seismic reflector at 51 m subsurface 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 of 10,950 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 well site to 40.8 m b.s.l. in the Sable borehole (Scott et al., 1988). The date at the 13.5 m (+ 37.4 m = 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 fauna appearing 5 m above R1 and extending to approximately 3.5 m below it (18.4 to 26.3 m) is a late glacial/immediate post glacial fauna. 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) and Scott et al. (1988) report a late glacial fauna accompanied by a large number of reworked (identified only as Tertiary/ Cretaceous) forms first appearing at 56.3 m in the 1985 Sable borehole, which compares favourably with the peak reported here at 55.8 m (18.4 + 37.4 m). b.s.l. McLaren and Boyd (1987) and Boyd et al. (1988) have extrapolated another date of 30,000 YBP from the West Olympia wellsite, based on shell material, to 55 m in the Sable borehole; which may be an 'old' date due to contamination of reworked material.

The low number assemblage (28.0 to 32.8 m) also shows evidence of reworking though not as extensive as the uppermost two faunas. Within this assemblage falls Regional Reflector R2 at 33.0 m subsurface, also recognized on Banquereau (Amos and Knoll, 1987) and Sable Island Bank (Amos, unpub. data). McLaren and Boyd (1987) and Boyd et al. (1988) recognize, in the Sable borehole at 62 m, a reflector they call R2; though it does not appear to be the reflector identified and named R2 by Amos and Knoll (!987). Amos and Knoll (1987) interpret this reflector as representing an erosional event and low sea level stand on Banquereau. Boyd interprets it (1987, pers. comm.) as representing a low sea level stand on Sable Island Bank. The foraminifera show evidence of reworking, but there is no conclusive foraminiferal evidence of subaerial exposure. The possibility of a high sedimentation event, or reworking by grounded ice can't be eliminated. Scott et al. (1988) noted an interval from 65 - 80 m in the Sable borehole which for the most part was barren of foraminifera.

Below the low number assemblage is the warm water fauna (34.8 to 43.0 m). Scott (in Boyd et al., 1988; Scott et al., 1988) also sees a warm water estuarine fauna at 67.6 m in the Sable borehole which he interprets as possibly an interglacial fauna. Material taken from 72 m in the hole dates at 32,000 YBP (Boyd et al., 1988; Scott et al., 1988) which they state supports a correlation with the oxygen isotope stage 3 interstadial. Lignite/coal at the 39 m (76.4 m b.s.l.) mark in the Cohasset hole dates at 33,740 YBP (Amos, unpub. data).

The fauna at the base of the hole represents colder conditions before the warm water event. The presence of Cretaceous species indicates there is a noticeable reworked component in both the lower - most faunas and sediments.

CONCLUSIONS

1. There are six Quaternary benthonic foraminiferal faunas recognized in the Cohasset A-52 borehole. These six faunas are: 1) a low number *Elphidium subarcticum* - *Cibicides lobatalus* assemblage (0.0 to 10.2 m); 2) a reworked *Elphidium excavatum* - *E. subarcticum* assemblage (11.9 to 16.7 m); 3) a *Elphidium excavatum* - *Cassidulina reniforme* - *Epistominella takayanagii* fauna (18.4 to 26.3 m); 4) a low number assemblage (28.0 to 32.8 m); 5) an *E. excavatum* - *C. reniforme* warmer water fauna (34.8 to 43.0 m) and 6) an *E. excavatum* - *C. reniforme* cold shelf fauna (45.2 to 45.4 m).
2. The upper two assemblages contain a reworked component and this component in each assemblage was reworked during and subsequent to the Late Pleistocene/Holocene transgression. These two assemblages are within the Sable Island Sand and Gravel Formation. The base of the lower of these two assemblages does not correspond with R1, -the acoustic reflector interpreted as representing the erosional surface at the base of the transgression.
3. The third foraminiferal assemblage is a late glacial/immediate post glacial fauna. It contains high numbers of reworked Cretaceous foraminifera interpreted as being carried in Cretaceous sediments, eroded and transported by glacial ice and redeposited in Quaternary sediments during the late stages of deglaciation. This fauna extends 5 m above R1.
4. The fourth assemblage contains low numbers of foraminifera. This fauna may have been deposited by a colder water mass, or during a period of high sedimentation, lower productivity, reworking by grounded ice or subaerial erosion. Regional reflector R2 occurs within the sediments containing this faunal unit.
5. The fifth assemblage contains numerous warmer water shelf species and is interpreted as representing an interglacial event.
6. The sixth assemblage is a colder water shelf assemblage representing colder conditions pre-dating the warm water event.

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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.
Spiroplectammina earlandi (Parker). HAYNES, 1973, p. 31-32, pl. 3, fig. 5; pl. 8, fig. II.
Trochammina advena Cushman. COLE, 1981, p. 37, pl. 8, fig. 3.

Ammonia beccarii (Linné). SCOTT and MEDIOLI, 1980, p. 35, pl. 5, figs. 5-9.
Amphicoryna sublineata (Brady). BARKER, 1960, p. 134, pl. 63, figs. 19-21.
Astacolus crepidulus (Fichtel and Moll). BARKER, 1960, p. 142, pl. 67, fig. 20.
Astrononion gallowayi Loeblich and Tappan. LOEBLICH and TAPPAN, 1953, p. 90-92, pl. 17, figs. 4-7.
Bolivina decussata Brady. BARKER, 1960, p. 110, pl. 53, figs. 12-13.
Bolivina pseudoplicata Heron-Allen and Earland. SCOTT ET AL., 1980, p. 226, pl. 4, fig. 3.
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 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 reniforme Nørvang. MILLER ET AL., 1982a, p. 2362, pl. 2, fig. 8.
Cassidulina teretis Tappan. COLE, 1981, p. 107, pl.11, fig. 13.
Chrysalidinella dimorpha (Brady). BARKER, 1960, p. 94, pl. 46, figs. 20-21.
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 mollis (Phleger and Parker). POAG, 1981, p. 54, pl. 29, fig. 4; pl. 30, fig. 4.
Cornuspira distincta Cole. COLE (in prep).
Cyclogyra involvens (Reuss) [(Cornuspira involvens (Reuss)]. LOEBLICH and TAPPAN, 1953, p. 49, pl. 7, figs. 4-5.
Dentalina baggi Galloway and Wissler. LOEBLICH and TAPPAN, 1953, p. 54-55, pl. 9. figs. 10-15.
Discorbinella subbertheloti (Cushman). BARKER, 1960, p. 184, pl. 89, fig. 10.
Discorbis mira (Cushman). [Discorbis (?) mira (Cushman)]. BARKER, 1960, p. 180, pl. 87, fig. 8.
Discorbis squamata Parker. PARKER, 1952, p. 418, pl. 6, figs. 10-11.
Ehrenbergina pacifica (Cushman). BARKER, 1960, p.112, pl. 55, figs 4,6,7.
Elphidium bartletti Cushman. MILLER ET AL., 1982a, p. 2362, pl. 2, fig. 5.
Elphidium excavatum (Terquem) [Elphidium excavatum formae (Terquem)]. MILLER ET AL., 1982b, p. 116-144, pls. 1-6.
Elphidium subarcticum Cushman. MILLER ET AL., 1982a, p. 2364, pl. 2, fig. 4.

Eoeponidella pulchella (Parker). COLE, 1981, p. 94, pl. 19, fig. 51.
Epistominella arctica Green. [Stetsonia horvathi Green]. SCOTT, 1987, p. 329, pl. 2, figs. 1-2.
Epistominella exigua (Brady). SCOTT, 1987, p. 327, pl. 2, figs. 8-9.
Epistominella takayanagii Iwasa. MILLER ET AL., 1982a, p. 2362, pl. 2, figs. 11-12.
Epistominella vitrea Parker. POAG, 1981, p. 63-64, pl. 5, fig. 3; pl. 6, fig. 3.
Eponides pusillus Parr. PARR, 1950, p. 360, pl. 14, fig. 16.
Fissurina exsculpta Brady. BARKER, 1960, p. 119, pl. 58, fig. 1.
Fissurina marginata (Montagu). MILLER ET AL., 1982a, p. 2364, pl. 2, figs. 13-14.
Fursenkoina fusiformis (Williamson). MILLER ET AL., 1982a, p. 2362, pl. 2, fig. 19.
Gavelinopsis lobatalus (Parr). SCOTT, 1987, p. 327, pl. 2, figs. 16-17.
Glabratella crassa Dorreen. LOEBLICH and TAPPAN, 1964, p. 588-589, fig. 464:1.
Glabratella wrightii (Brady). MILLER ET AL., 1982a, p. 2364, pl. 2, figs. 16-17.
Glandulina laevigata d'Orbigny. LOEBLICH and TAPPAN, 1953, p. 81-82, pl. 16, figs. 2-5.
Globocassidulina subglobosa (Brady). [Islandiella subglobosa (Brady)]. POAG, 1981, p. 70-71, pl. 17, fig. 3; pl. 18, fig. 3.
Guttulina austriaca d'Orbigny. KNUDSEN, 1971b, p. 211-212, pl. 4, figs. 8-9.
Guttulina dawsoni (Cushman and Ozawa). KNUDSEN, 1971b, p. 212-213, pl. 4, fig. 10.
Gyroidina orbicularis d'Orbigny. COLE, 1981, p. 112, pl. 20, figs. 8-9.
Gyroidina quinqueloba (d'Orbigny). COLE, 1981, p. 112, pl. 20, figs. 10-11.
Gyroidina soldanii d'Orbigny [Gyroidina neosoldanii (Brotzen)]. BARKER, 1960, p. 220, pl. 107, figs. 6-7.
Hanzawaia asterizans (Fichtel and Moll). HANSEN and ROEGL, 1980, p. 173-179, pl. 1, figs. 8-11, 13-15.
Hanzawaia concentrica (Cushman) [Hanzawaia concentrica (Cushman) forma typica]. POAG, 1981, p. 67-68, pl. 39, fig. 2; pl. 40, fig. 2.
Haynesina depressula (Walker and Jacob). BANNER and CULVER, 1978, p. 200-211, pl. 10.
Haynesina nana (Vilks) [Protelphidium nanum (Vilks)]. COLE, 1981, p. 101, pl. 13, fig. 5.

Haynesina orbiculare (Brady). MILLER ET AL., 1982a, p. 2362, fig. 7.
Hoeglundina elegans (d'Orbigny). POAG, 1981, p. 69, pl. 19, fig. 3; pl. 20, fig. 3.
Islandiella helenae Feyling-Hanssen and Buzas. VILKS ET AL., 1982, p. 226, pl. 1, fig. 14.
Islandiella norcrossi (Cushman). KNUDSEN, 1971b, p. 248-249, pl. 8, figs. 1-2.
Lagena laevis (Montagu). LOEBLICH and TAPPAN, 1953, p. 61, pl. 11, figs. 5-8.
Loxostomum porrectum (Brady). BARKER, 1960, p. 106, pl. 52, fig. 22.
Melonis barleeanum (Williamson) [Nonion zaandamae Van Voorthuysen]. LOEBLICH and TAPPAN, 1953, p. 87, pl. 16, figs. 11-12.
Miliolinella subrotunda (Montagu). KNUDSEN, 1971b, p. 197, pl. 2, figs. 10-12. COLE, 1981, p. 109, pl. 14, fig. 4.
Nonionella auricula (Heron-Allen and Earland). VILKS ET AL., 1982, p. 226, pl. 1, fig. 23.
Nonionella turgida (Williamson). SCOTT, 1987, p. 328, pl. 1, figs. 21-23.
Nonionellina labradorica (Dawson). MILLER ET AL., 1982a, p. 2364, pl. 2, fig. 22.
Nuttallides decorata (Phleger and Parker). POAG, 1981, p. 74, pl. 5, fig. 2; pl. 6, fig. 2.
Oolina caudigera Wiesner. LOEBLICH and TAPPAN, 1953, p. 67-68, pl. 13, figs. 1-3.
Oolina costata (Williamson). LOEBLICH and TAPPAN, 1953, p. 68, pl. 13, figs 4-6.
Oolina melo d'Orbigny. LOEBLICH and TAPPAN, 1953, p. 71-72, pl. 12, figs. 8-15.
Oridosalis umbonatus (Reuss) [Eponides umbonatus (Reuss)] . BARKER, 1960, p. 216, pl. 105, fig. 2.
Pateoris hauerinoides (Rhumbler). LOEBLICH and TAPPAN, 1953, p. 42-43, pl. 6, figs. 8-12.
Pseudoeponides japonicus (Uchio). LOEBLICH and TAPPAN, 1964, p. 598, fig. 474:5,6
Pseudopolymorphina suboblonga Cushman and Ozawa. KNUDSEN, 1971b, p. 218-219, pl. 5, figs. 8-9.
Quinqueloculina elongata Natland. COLE, 1981, p. 50, pl. 13, fig. 11.
Quinqueloculina seminula (Linné). MILLER ET AL., 1982a, p. 2364, pl. 1, fig. 19.

Quinqueloculina stalkeri Loeblich and Tappan. LOEBLICH and TAPPAN, 1953, p. 40-41, pl. 5, figs. 5-9.
Quinqueloculina vulgaris (d'Orbigny). COLE, 1981, p. 50, pl. 8, fig. 7.
Rosalina araucana (d'Orbigny) [Discopulvinulina (?) araucana (d'Orbigny)] . BARKER, 1960, p. 178, pl. 86, figs. 10-11.
Rosalina globularis d'Orbigny. BARKER, 1960, p. 178, pl. 86, fig. 13.
Stainforthia concava (Hoeglund). COLE, 1981, p. 91, pl. 9, fig. 5.
Stetsonia horvathi Green. LAGOE, 1977, p. 126, pl. 4, figs. 17, 22.
Trifarina angulosa (Williamson [Trifarina fluens (Todd)]. VILKS ET AL., 1982, p. 226, pl. 1. fig. 15.
Triloculina trihedra Loeblich and Tappan. LOEBLICH and TAPPAN, 1953, p. 45, pl. 4, fig. 10.
Uvigerina asperula Czjzek. SCOTT, 1987, p. 329. pl. 1, fig. 5.
Uvigerina peregrina Cushman [Uvigerina peregrina (Cushman) formae typica, parvula, hispidocostata]. POAG, 1981, p. 86-88, pl. 27, figs. 1-3; pl. 28, figs. 1-3.

Quaternary Planktonic Foraminifera

All references are to SAITO ET AL., 1981.

Globigerina bulloides (d'Orbigny), p. 40, pl.7, figs. 1a-d.
Globigerina quinqueloba Natland (left and right coiled), p. 48, pl. 10.
Globigerinita glutinata (Egger), p. 17, pl. 22.
Globigerinita nitida (d'Orbigny), [Candeina nitida (d'Orbigny)], p. 75, pl. 21.
Globigerinita uvula (Natland), p. 81, pl. 24, figs. 3a-d.
Globorotalia crassiformis (Galloway and Wissler), p. 129, pl. 43, figs. 2a-d.
Globorotalia inflata (d'Orbigny), p. 124, pl. 41, figs. 1a-d.
Globorotalia truncatulinoides (d'Orbigny), p. 159, pl. 54, figs. 1a-d.
Neogloboquadrina pachyderma (Ehrenberg) (left and right coiled), p. 106-108, pl. 34

Reworked Benthonic Foraminifera

Spiroplectammina laevis (Roemer). NYONG and OLSSON, 1984, p. 450, pl. 1, fig. 18.

Caucasina elongata (d'Orbigny). GRADSTEIN and ATGERBERG, 1982, pl.6, fig.5

Dentalina legumen (Reuss). McNEIL and CALDWELL, 1981, p. 192-193, pl. 15, fig. 21.

Eouvigerina americana Cushman. GALLITELLI, 1957, p. 148, pl. 34, figs. 1-5.

Eouvigerina subsculptura McNeil and Caldwell. McNEIL and CALDWELL, 1981, p. 231-232, pl. 18, figs. 20-21.

Lagena apiculata (Reuss). McNEIL and CALDWELL, 1981, p.200, pl. 16, fig. 7.

Nodosaria aspera Reuss. FRIZZEL, 1954, p. 90, pl. 10, fig. 9.

?Nonionella robusta Plummer. FRIZZEL, 1981, p. 107, pl. 15, figs. 10a-c.

Osangularia navarroana Cushman. McNEIL and CALDWELL, 1981, p.275-277, pl. 23, figs. 6a-c.

Praebulimina carseyae (Plummer). McNEIL and CALDWELL, 1981, p.222-223, pl. 18, fig. 9.

Praebulimina kickapooensis (Cole). McNEIL and CALDWELL, 1981, p. 225-226, pl. 18, figs. 10-11.

Praebulimina reussi (Morrow). McNEIL and CALDWELL, 1981, p. 225-226, pl. 18, fig.12.

Pseudouvigerina seligi (Cushman). OLSSON, 1960, p.30, pl. 4, fig. 23.

?Pyramidina referata (Jennings) [Bulimina referata Jennings]. OLSSON, 1960, p. 32, pl. 5, figs. 3-4.

Pyramidina triangularis (Cushman and Parker) [Bulimina triangularis Cushman and Parker]. FRIZZEL, 1954, p. 116, pl. 17, figs. 9a-b.

Stilstomella bradyi (Cushman). SCOTT, 1987, p. 329, pl. 1, fig. 15.

Reworked Planktonic Foraminifera

Gumbelitria cretacea Cushman. SMITH and PESSAGNO, 1973, p. 15-16, pl. 1, figs. 1-8.
Heterohelix globulosa (Ehrenberg). McNEIL and CALDWELL, 1981, p. 234-239, pl. 19, figs. 1-2.
Heterohelix pulchra (Brotzen). McNEIL and CALDWELL, 1981, p. 241-243, pl. 19, fig. 4.