Paleoceanographic Trends on the Northern Scotian Shelf

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ABSTRACT

Paleoceanographic trends are recorded and reflected in the preservation of benthonic foraminiferal assemblages in ocean floor sediments. This study presents a succession of foraminiferal assemblages from an 8m core taken within St.Anne's Basin on the N.E. Scotian Shelf.

This micropaleontological study reveals the changes in bottom water characteristics from approximately 8000 yrs.b.p. During the early postglacial a fauna dominated by I. teretis indicates cold water temperatures, similar to the present Outer Labrador Current. From approximately 5000-7000 yrs.b.p. a warm water fauna reflects the mid-Holocene hypsithermal. The next change in bottom water occurred in the last 5000 yrs.b.p. with an abrupt cooling which is associated with a greater influence of the Outer Labrador Current. The most recent change has occurred in the last 2000yrs. with an abrupt cooling associated with influence of the Inner Labrador Current. A warm water fauna at the surface was determined to be displaced, probably from a topographic high just to the south.

The main paleoceanographic trends are due to north-south shifts in the position of the Gulf Stream and Labrador Currents and to varying degrees of influence of each.

Distinct Holocene-Pleistocene paleoceanographic events have been previously distinguished in several basins on the Scotian and Labrador Shelf. The record presented here closely resembles a record from a core in nearby Canso Basin in that it reflects an almost complete Holocene record.

INTRODUCTION

The phylum Protozoa includes the order Foraminifera which is single celled marine organisms generally of microscopic size (i.e. less than 1mm in diameter). The test can be a secreted calcareous shell or may be agglutinated, i.e. made of foreign particles like sand or shell fragments, cemented by an organic matrix. It may consist of a single chamber or more likely, several adjoining chambers. Foraminifera in this study are benthonic but there are a number of planktonic species as well.

The study of foraminifera provides an accurate determination of paleoenvironments because of their sensitivity to environmental conditions. Most benthonic species are restricted to a narrow range of temperatures and salinities (Boltovoskoy and Wright, 1976). This, and the fact that benthonic foraminiferal tests are generally deposited in situ, make them very good paleoenvironmental indicators.

Planktonic foraminifera are not as important as indicators of bottom water physical conditions because they live in the water column, they can be transported out of their natural habitat before being deposited and their environmental range is more restricted. This group of microfossils (benthonic foraminifera) is extremely abundant in marine environments worldwide, occurring at all depths, from near shore to abyssal plain. The fact that near shore areas reflect the subtler changes in climatic conditions in comparison to deep sea areas which collect sediment at a slower rate (therefore omitting small scale events) makes foraminifera a valuable tool to correlate both large and small scale oceanographic events through

geologic time.

This particular study of the Scotian Shelf features a micropaleontological record within an intra-shelf basin. These areas are of particular interest because erosion is less likely to occur here and sedimentation rate is higher than other areas (up to 1 m/1000 yrs) adjacent to or on the continental shelf (Scott et al.,1984). To study the direct impact of the last glaciation (the Wisconsinan glaciation) to interglacial period in the continental shelf environment , this is the most ideal location for study to provide the most complete Pleistocene-Holocene record (Mudie et al.,1984).

Much work has been carried out on the relationship of foraminiferal assemblages to bottom water characteristics within the Eastern Canadian continental shelf. Particular work by Williamson (1982, 1983) and Williamson et al. (1984) on the Scotian Shelf has provided results of modern assemblages and their associated bottom water masses within this area. This work on present day assemblages is the basis for interpretation of paleoceanographic changes.

The objective of this study of benthonic foraminifera within St. Anne's Basin is to provide a complete proglacial-Holocene record in an area directly affected by the last glaciation, 15000 yrs b.p. This, in conjunction with a concurrent study by B. Souchen, will provide a history of paleocurrent trends on the Northern Scotian Shelf and establish whether or not there is a link between Gulf of St. Lawrence and Scotian Shelf paleocurrent trends.

PREVIOUS WORK

Much work has been done on the sedimentology and surficial geology of the Scotian Shelf. Relevent to this study includes works primarily by King (1970, 1980), MacLean and King (1971), MacLean et al. (1977) and Cok (1970). Foraminiferal distributions on the shelf have been studied by Bartlett (1964a,b), Barbieri and Medioli (1969), Williamson (1982, 1983) , Williamson et al. (1984) and Scott et al. (1984).

Oceanographic trends and water mass characteristics have been charted off the eastern Canadian coast, and those pertinent to this study include Houghton et al (1978), Robe (1971), McLellan (1954a,b, 1957), Gatien (1975) and Warner (1970).

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The Scotian Shelf between the Laurentian Channel and 61° W longitude is topographically very complex in comparison to the western area of the shelf which is characterized by broad basins and large banks. The N.E. area of the shelf is characterized morphologically, by an inner shelf bordering Nova Scotia, a central shelf area of basins and banks, and outer shelf broad banks (MacLean and King, 1971, see Fig.1). The central shelf basins have an origin attributed to glacial erosion or old Tertiary drainage patterns (King and Fader, 1985) and range in depth from 200-400m (Scott et al., 1984). In general, they are regarded as sites of deposition but subsequent research with seismic data and surficial foraminiferal data indicates erosion does occur within basins.

Much research has been carried out on sediments covering the Scotian Shelf. The consensus is that the unconsolidated material covering the basement rock is glacially derived (Cok, 1970; King, 1970; MacLean et al., 1977). Glacial till features have been identified and mapped as end moraines , possible limits to the Wisconsinan glaciation (King, 1969, 1970), and lateral moraines (Josenhans 1983).

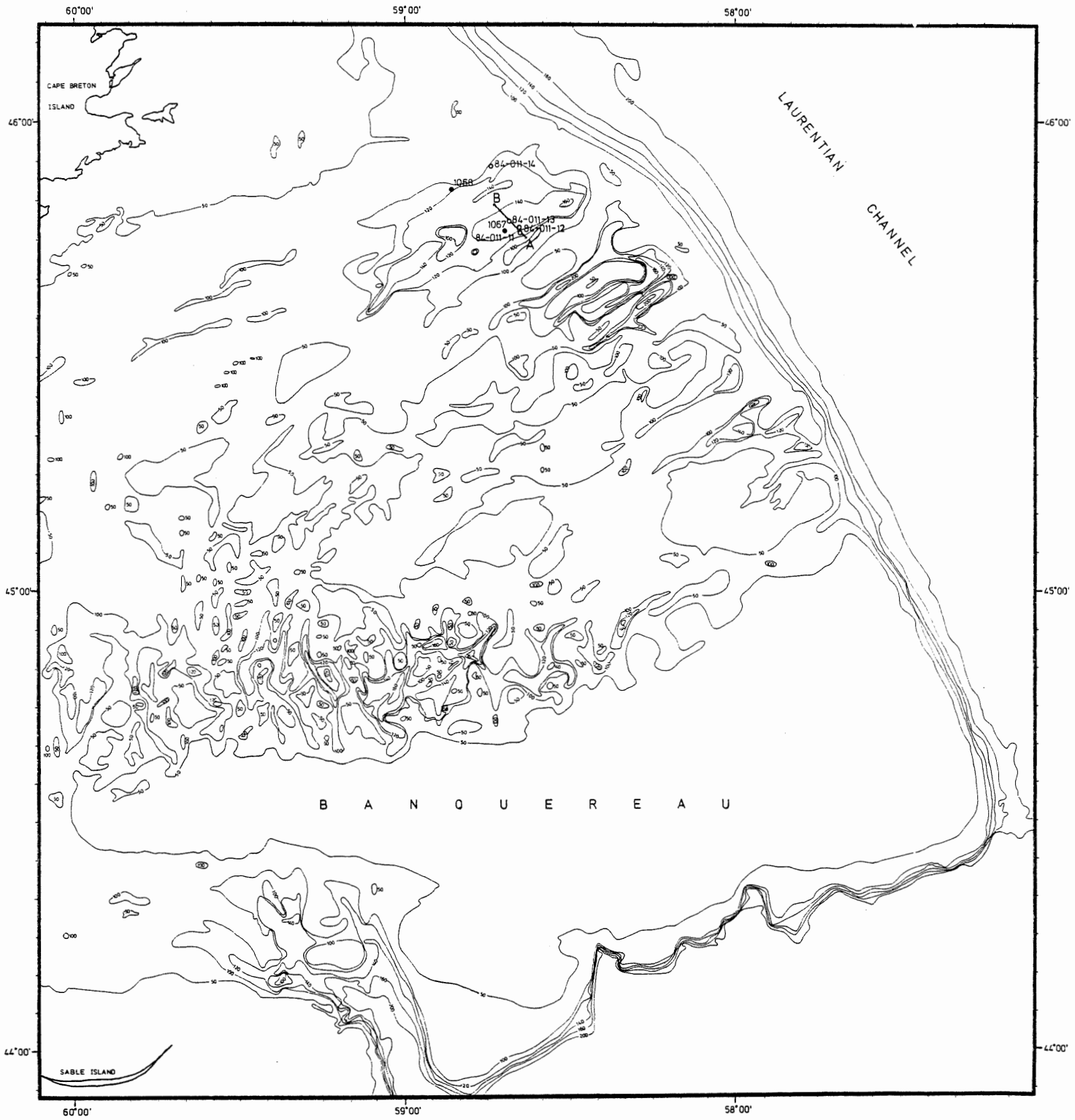
King (1967, 1970) identified five sedimentary units overlying Tertiary basement rock of the shelf. This succession comprises Scotian Shelf Drift, Emerald Silt, Sambro Sand, Lahave Clay, and Sable Island Sand and Gravel, some of which are contemporaneous. The Scotian Shelf Drift includes glacial till and within the study area, the Scatarie end moraine. Emerald Silt and Sambro Sand represent proglacial deposits which interfinger, in areas, with glacial debris

indicating that they are, in part, contemporaneous. LaHave Clay overlies Scotian Shelf Drift and Emerald Silt and is chronologically equivalent to Sable Island Sand and Gravel. LaHave Clay has an origin attributed to, in general, winnowing of silt and clay from glacial debris on the banks during the Holocene transgression and deposited in topographic depressions. Deposition of this clay has probably continued until the present through winnowing by storm waves and bottom currents on the banks. The Sable Island Sand and Gravel is a lateral equivalent to the LaHave Clay and occurs on banks and the inner shelf. This unit is a result of reworking of glacial drift on the banks, removing the silt and clay fractions to be deposited in lower lying areas.

St. Anne's Basin is a relatively small basin north of the Misaine Bank, S.E. of St. Anne's Bank and approximately 40km south of Cape Breton Island (Fig.1). It is approximately 6.7km long by 2.9km wide and lies generally parallel to the inner shelf. Core 84-011-12 was taken in 270m water depth, close to the center of the basin. Approximatly 7.7km to the north of the core site an outcrop of Scatarie end moraine occurs. Seismic data of the core site reveal penetration solely into LaHave Clay within a sedimentologically disturbed area. (see fig.2). King (1970) describes LaHave Clay as a dark grey clayey silt grading locally to sandy silt and occassionally to silty clay.

A concurrent study on core 84-011-11, approximately 0.6 km south of the area under study, and closer to the basin slope, shows a very thin Holocene LaHave Clay unit overlying Emerald Silt.

Fig.1 Bathymetry and core locations from the continental shelf off Cape Breton Island.



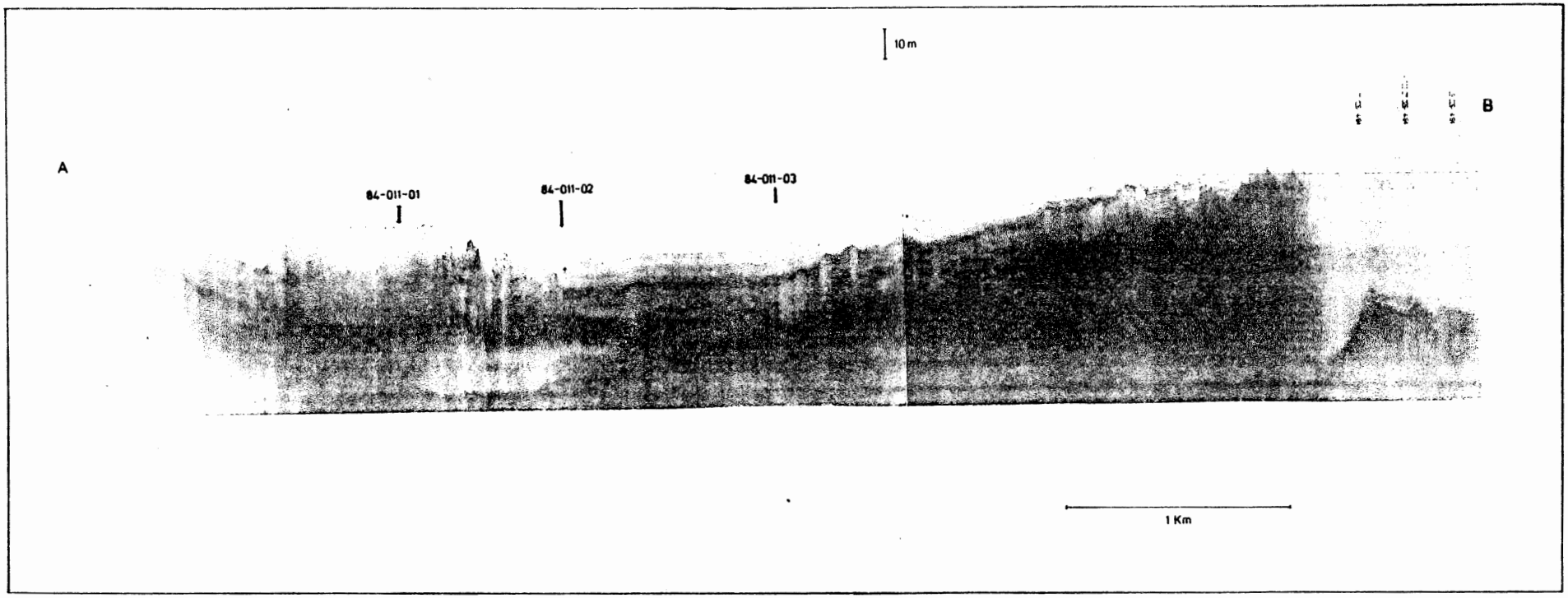
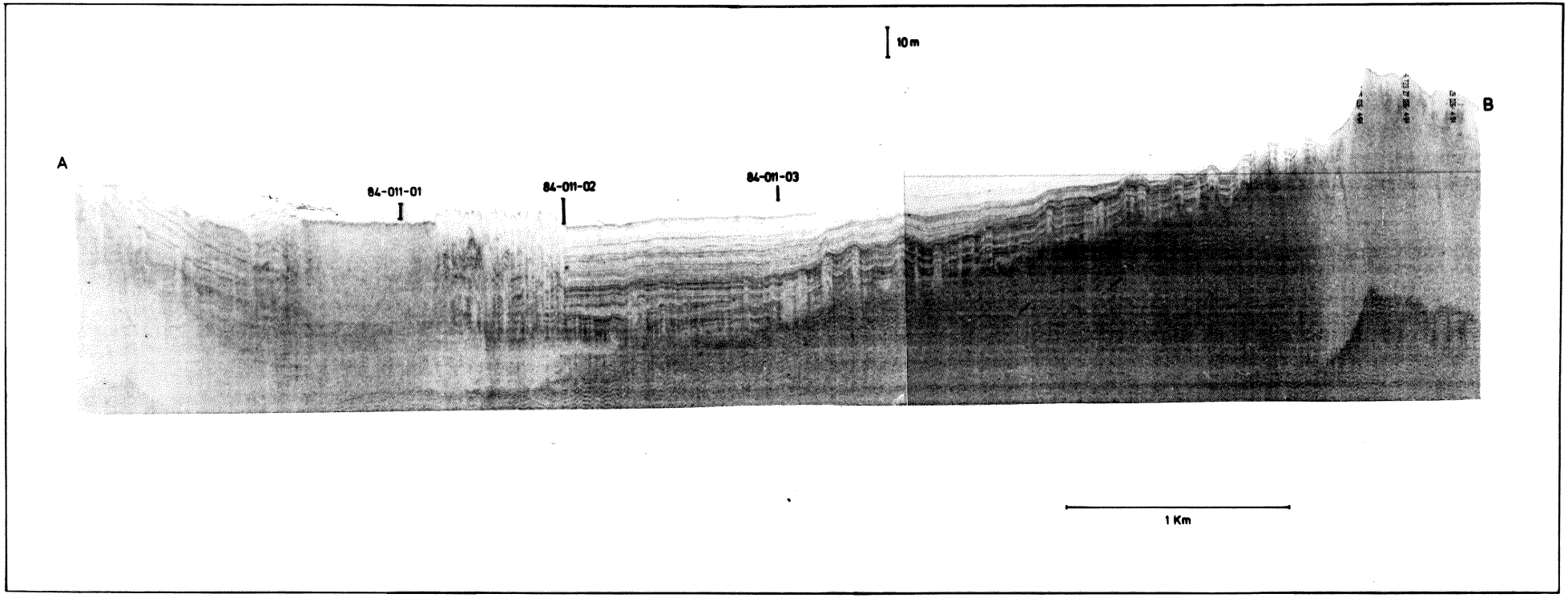


Fig.2 Huntec seismic profile of St. Anne's Basin with core sites 84-011-11,12,13 indicated as 84-011-01,02,03


10 m
A
B
84-011-01
84-011-02
84-011-03
1 Km

OCEANOGRAPHY

Since oceanographic trends directly influence the distribution of foraminiferal assemblages, an understanding of these trends today is an invaluable aid to the determination of paleoceanography through fossil assemblages.

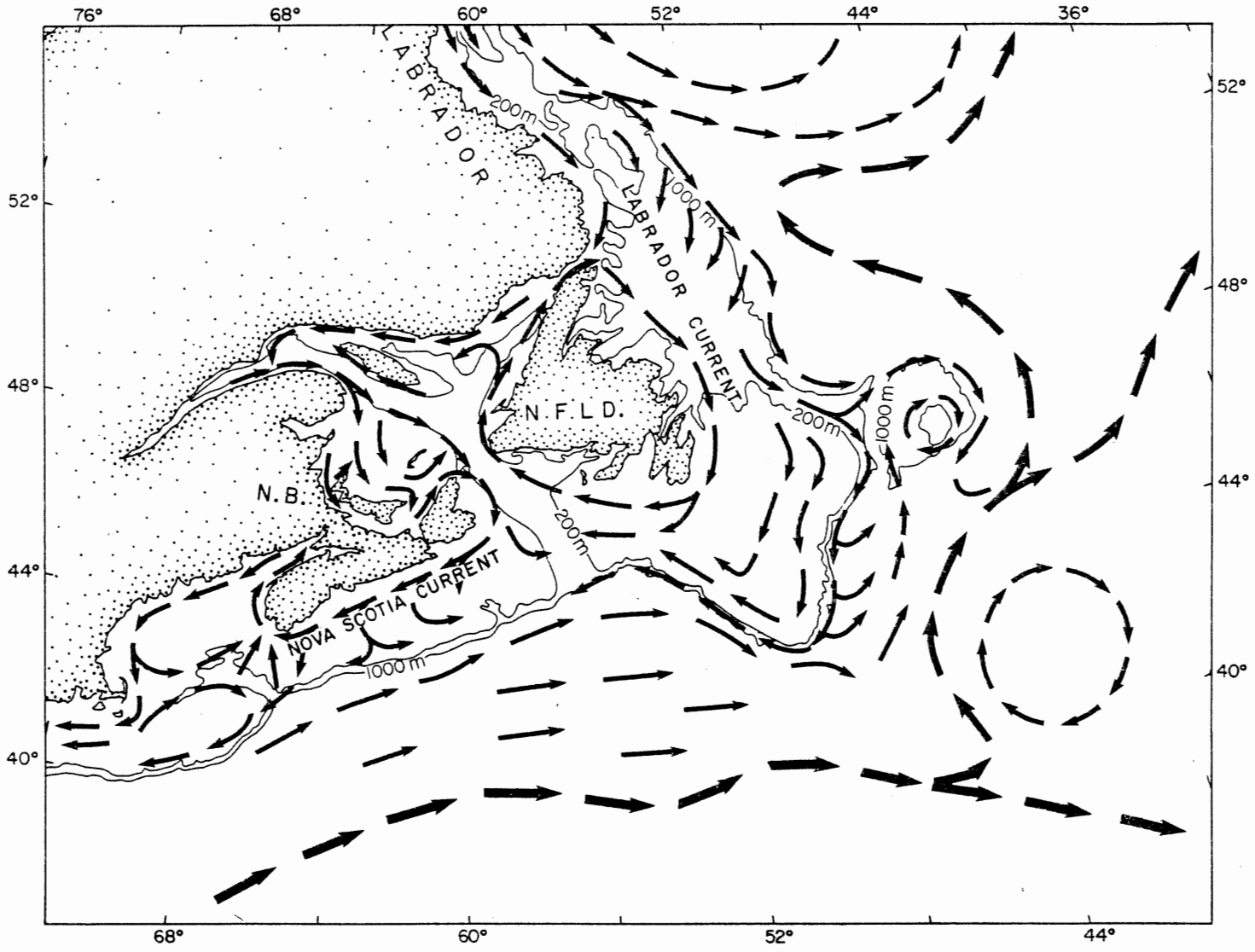
The physical conditions of a particular water mass offshore depend on the varying degrees of regional runoff, meltwater, precipitation and mixing with warmer, more saline offshore waters. In addition, seasonal variation in the upper water column are produced.

The oceanography off eastern Canada has been well documented (fig.3, Robe, 1971). Water currently flowing past the Maritime coast originates in the Arctic and interacts with the Gulf Stream off the Scotian Shelf. The Labrador Current is fed by several sources and is therefore made of several basically unmixed components. That part of the Labrador Current which is fed by the West Greenland Current in the Davis Strait flows along the continental margin at 600-800m water depth over the Labrador Shelf and Grand Banks. The shallow part of the Labrador Current which flows between Labrador and Newfoundland, into the Gulf of St. Lawrence and the study area by way of the Cabot Strait originates in northern Baffin Bay. This part also contains an inner shelf component which originates from Hudson Bay and the Beaufort Sea (Dunbar, 1951). This component is colder and relatively fresher than the offshore branch. It becomes the Nova Scotia Current as it flows S.W. over the Scotian Shelf. The Gulf Stream flows N.E. further offshore and this warm, saline water interacts to varying degrees with the Scotian Current to form the

slope waters to depths of 300-400m (McLellen, 1957; Gatien, 1975). Hachey (1961) described this water mass as North Atlantic water diluted with approximately 20% coastal water. Through the work of McLellen (1954a,b) and Houghton et al. (1978) a well documented distribution of water masses has been made for water flowing over the Scotian Shelf. Cold, relatively fresh bottom water from the Gulf of St. Lawrence, which contains a considerable Inner Labrador Current influence, predominates over the northeast area of the Shelf. This has a temperature ranging from 0-4°C and a salinity of approximately 32.3‰. This covers the St. Anne's Bank and Basin, the Canso Bank and Basin, the Misaine Bank and Basin and the Banquereau Bank.

To the southwest there is an increased presence of warm, more saline slope water which is in large part, influenced by the Gulf Stream. The boundary between these two is subject to fluctuation. This is documented in Fournier et al. (1977) in terms of the relative influence of nutrient-rich slope water in the shelf off Nova Scotia.

Fig.3 Modern oceanographic patterns off eastern Canada (Scott et al., 1984)



METHODS

Piston and gravity cores were collected in April 1984 from St.Anne's Basin (see Fig.1) by the research vessel C.S.S. Dawson of the Bedford Institute of Oceanography. The site for this core, 84-011-12, was selected on the basis of high-resolution seismic reflection profiles taken by a Huntec deep tow seismic system (Fig.2)

In the laboratory, both the 129cm. gravity core and the 797cm. piston core were split, X-rayed, and described (see Fig.4 and Appendix 1). Detailed descriptions of the cores include sediment type, sediment color (according to the Munsell color chart), and sedimentological features (ie. bioturbation, graded bedding, laminations, etc.) recognized from visual inspection of the cores and the X-rays.

Samples of 10cc were taken from the gravity core at 10cm intervals. The piston core was sampled at 10cm intervals for the top 120cm and 20cm from 120-780cm and where significant sedimentological changes occurred.

Each sample was then wet sieved through a 500 micron sieve to retain coarse particles (ie. shell fragments, pebbles, etc.) and a 63 micron sieve to retain foraminifera. The 63 micron sieve has been shown to be reliable in preserving the smaller species and juvenile species otherwise lost (Schroder, 1986). Both these fractions were retained together in alcohol for preservation.

The sample taken at depth 448 - 450cm within the piston core contained a high sand content and was therefore dried and floated in carbon-tetrachloride (S.G.=1.58) to separate the lighter

foraminifera from the sand.

Those samples with an estimated 2400 specimens or more, were split into 1/8 fractions using a water column wet splitter (Thomas, 1985). This was done to ensure a minimum number of 300 specimens counted within a split, which has been statisically proven as an accurate limit to determining species population abundances (Douglas, 1978).

All samples were examined under a binocular microscope, usually at 40X, for foraminiferal species identification and determination of relative abundances of each species. A type slide was prepared as reference material containing a representative sample of each of the 47 species recorded. In addition, representative specimens of 20 of the most dominant species were then photographed using a Cambridge Stereoscan 180 SEM using Polaroid 55N/P film, at the Bedford Institute of Oceanography (Plate 1).

Pollen analysis was carried out on both cores to provide an additional factor to be correlated with foraminiferal results. Both cores were sampled at 20cm intervals providing a total of 50 samples. Each 2 cc sample was processed for pollen as outlined in Ogden (1959). Analysis of various slides was carried out by P. Mudie.

RESULTS

The core under study was taken where a Huntec seismic section (see Fig.2) reveals an extended Holocene section of post-glacial sediments (LaHave Clay). Bottom water now within St.Anne's Basin is dominated by Inner Labrador Current water with temperatures ranging from 0-3 C and salinity within the relatively fresh 31-33 ‰ range (Williamson, 1983).

Seismic Stratigraphy

Figure 2 is a Huntec seismic profile taken NW-SE across the deepest part of St.Anne's Basin and includes the core sites of 84-011-11,12,13 (see Fig.1). The profile shows Scotian Shelf Drift (glacial till) as a uniform dense grey pattern of incoherent reflectors overlying the bedrock as a continuous sheet of ground moraine. The Scatarie end moraine of Scotian Shelf occurs as a topographic high to the north of 84-011-13.

Directly beneath core 84-011-11 there appears to be a liftoff moraine. This appears on the seismic profile as an area of uniform dense grey pattern of incoherent reflections. Liftoff moraines are linear features, generally steep sided, and are generally recognized by an abrupt termination of the Emerald Silt reflectors. King and Fader (1985) provide evidence that these features are contemporaneous with glaciomarine Emerald Silt.

Emerald Silt forms a wedge from the end moraine at B to near the basin flank at A. Most of this unit which overlies Scotian Shelf Drift, is what King and Fader (1985) describe as high amplitude, continuous, coherent reflectors. These appear on the profile as

smooth, closely spaced parallel reflections which vary in intensity vertically. Most of this facies conforms with the morphology of the underlying glacial till. The lower half of core 84-011-11 penetrates into this unit.

The LaHave Clay overlies Emerald Silt and can be defined as a facies of low amplitude, continuous coherent reflections to no reflections. Core 84-011-12 and the upper half of core 84-0111-11 penetrate solely into this unit, and the upper half of core 84-011-11.

Core 84-011-12 is located on the flank of a seismically disturbed area. It appears as a slight topographic high in which Emerald Silt reflectors are very disturbed but are still basically parallel and capped with a layer of LaHave Clay.

Foraminifera

The bottom three samples of the piston core are dominated by three species: Islandiella teretis, Cassidulina reniforme and Elphidium excavatum. These samples contain relatively few numbers of species, ranging from 8 to 11 and also relatively few individuals, from 198 to 278. Few planktonic species occur within this unit. This assemblage can be attributed to conditions during the late glacial period; they represent the end of deposition of late glacial sediment.

The next two samples (700-702, 720-722cm) are characterized by an I teretis, Nonionellina labradorica (and to a lesser degree, Globobulimina auriculata) assemblage which closely resembles the Outer Labrador Current assemblage which now occurs on the outer parts of the Labrador Shelf (Vilks et al.,1984). These two samples contain the fewest number of species of all the samples with five species in the 700-702cm sample and three species within the 720-722cm sample. They also contain relatively few numbers of individuals- 36 and 15, respectively. Few planktonic species occur within this interval.

From 680 to 560cm there is a distinct occurrence of Brizalina subaenariensis indicating a interval of warm water conditions. Within this period there is also an increase in the total number of individuals (from 20 to 3648) and an increase in the number of species from the previous interval (from 8 to 18). In addition, there is a slight increase in the number of planktonic foraminifera , indicating more stable surface water conditions. This section of the core can be correlated with the mid-Holocene hypsithermal (based

on pollen), and this environment now occurs within the Emerald Basin (Williamson, 1984).

B. subaenariensis disappears above 560cm and from this point to 14cm the fauna is dominated by I. teretis, C. reniforme and N. labradorica. This again resembles the Outer Labrador Current assemblages but the increase of I. teretis indicates progressive cooling of this water mass. The total number of agglutinated foraminifera reach a maximum at 458cm and correspondingly planktonic foraminifera are absent. Directly above this, at 440cm, the total number of planktonic and benthonic foraminifera peak to a maximum. At 326cm G. auriculata all but disappears until the top 14cm of the core.

Within the top 14cm the fauna increases in the number of agglutinated species and decreases in the number of planktonic species. The assemblage is comprised of B. subaenariensis, N. labradorica, I. teretis and to a lesser degree C. reniforme. The agglutinated species are composed to a large degree of Adercotryma glomerata which characterizes the assemblage now living on the northern Scotian Shelf today and represents Inner Labrador Current conditions (Williamson et al., 1984).

The gravity core can be correlated with the top 100cm of the piston core, but has an additional 20cm on the top.

Depth down borehole	sur	10	20	32	40	52	60	70	80	90	100	110	120	SUR	9.5	14	20	30	40	50	60	70	80	90	100	110	120	140	160	179	200	215
Species #	22	18	14	18	20	22	14	18	19	19	16	18	15	23	24	25	25	22	18	22	19	19	18	21	22	23	24	19	25	22	18	17
Individuals	485	402	248	1326	1027	1502	1047	1292	1876	759	894	512	1522	600	943	1690	2202	2603	2328	5484	6244	7232	3003	3704	6995	6180	2752	4856	3339	4184	912	3157
Adercotryma glomerata	5	1		3	3	1	1		1	1	1	1	X	4	3	2	3	1	1	1	1	1	X	1	1	1	1	1	2	1	1	1
Astrononion gallowayi																																
Brizalina pseudopunctata		X	3	1	1	X	3	1	1	X	3	X			X	X	1	2	2	3	2	2	1	2	3	3	X	2	X	2	X	
B. subaenariensis	14	1				X								29	23	2	X								X							
Buccella frigida	7	3	1	2	2	1	2	2	3	3	6	7	4	3	3	4	1	3	5	5	4	2	1	2	1	2	2	2	2	4	2	4
Bulimina aculeata	1					X			X					X	X	X	X	X		X									X			
B. exilis	1					X		1		X			X	1	X	X	1	1		X	1	X		1	X	X	X	X	1	1	1	1
B. marginata	3			1	1	X		X	X	X		X	X	4	5	1	X	X		X		X	X	X	X	X	1		X	X	X	X
Cassidulina reniforme	3	8	10		23	21	25	25	24	22	36	10	14	7	7	16	19	22	27	25	24	28	26	27	27	29	35	31	29	35	9	16
Cibicides lobatulus		28	2			X		X				X								X			X								X	X	1
C. pseudoungerianus																																
Dentalina spp.																																
Eggerella advena																										X	X	X		1	1	
Elphidium bartletti																																
E. excavatum			9		5	3	10	12	15	13	10	11	12	1	2	9	6	13	6	12	5	5	2	7	4	8	10	4	3	6	9	12
Epistominella takayanagii	10			3				X				1														X				X	X		
Fissurina marginata																	X				X											
Fursenkoina fusiformis	7	8	5		4	2	1	X	1	1	3	1		3	4	5	7	5	3	5	4	4	1	4	16	26	1	7	1	3	9	1
Globobulimina auriculata	5	4	15	9	5	3	3	1	3	2	1	3	1	4	2	2	2	1	2	1	1	X	2	1	X	X	X	1	2	X	X	X
Oridorsalis umbonatus					1	2	X		X		X	X	X	X	X	X	X	X		X	1	1	1		1	X	X	1	2	1	X	
Islandiella teretis	8	24	31	49	36	45	42	45	38	40	30	54	52	14	17	40	40	41	40	34	42	41	41	39	25	20	31	25	28	30	60	50
Lagena spp.		X	X	X	X	1		X	X	X	X	X	X		2		X	X	X	X	X	1	X	X	X	X			X			
Melonis spp.																																
Nonionella turgida																													X			
Nonionellina labradorica	9	11	23	8	11	14	8	8	9	12	4	6	13	11	14	7	10	6	8	4	7	5	12	6	8	6	9	8	6	7	4	7
Psammosphaera fusca	1	X			1					X		X		X		1	X							X					X			
Pseudopolymorphina novangliae																																
Pullenia osloensis	10	1	1	1	2	3	5	1	3	2	2			4	7	2	3	3	1	5	5	7	11	6	10	3	7	14	16	7	1	5
P. subcarinata									X								X	X	1	X	1	X		X	1	X	X	X	1	X		X
Pyrgo williamsoni																																
Quinqueloculina seminulum		X		X		X					1			2	1	X	X	X	X	X						X	X	X		X		
Recurvoides turbinatus	X	1		X	X		X	X	X	X				X	1		X	X	X		X		X	X						X		
Rectoglandulina rotundata																																
Reophax arctica	3	5	4	6	2	X	1	1		X	1		X	3	3	2	2	X	1	X	X	X	X	1		X	X	X		X		
R. fusiformis																X													X			
R. scorpiurus	3	1	4	3	2									X	1	X										X	X		X			X
R. scottii																			X					1	X	X	X	X		1	X	1
Robertinoides charlottensis																						X	X		X	X	X					X
Saccammina atlantica																											X					
S. difflugiformis	1			3	1	X		X	X	1	X	X	1	5	2	1	1	X		X		1	X				X		X			
Textularia torquata	4		1	1	1	X			X	X				1	X	1	X	X	X	1	X			1	X	X	X	X	1	1	X	
Trifarina fluens	3	1	2	1	X	1	1	1	1	1	2	4	3	2	1	2	1	X	2	2	1	1		X	X	X	1	X	X	1	X	1
Trilocullina trihedra																																
Trochammina globigeriniformis	1																															
T. inflata														1	1	X											X					
T. lobata																																
T. nana																																
Planktonics (raw numbers)	73	80	84		54		191	100	189	54	160	30	106	61	130	144	234	322	284	376	328	552	350	540	640	376	412	504	229	216	28	283

Table1 Percentage occurrences of Foraminiferal species.

Depth down borehole	240	248	260	280	300	309	320	326	340	360	380	400	420	440	448	458	480	500	520	540	560	580	600	620	640	660	680	700	720	740	760	780
Species #	16	19	12	21	18	19	22	17	16	19	21	22	20	17	25	8	21	24	13	16	16	13	15	14	18	14	8	5	3	11	8	9
Individuals	3095	806	195	1492	483	1108	639	826	262	626	972	555	7344	5040	664	88	1034	1213	303	456	702	3648	122	1392	2072	109	20	36	15	278	198	249
Adercotryma glomerata	1	1		1			1				x	x	x	1	1	13																
Astrononion gallowayi							x			1	1		x	1	3		1	2		2					x							
Bolivina pseudopunctata	3	x		1			x			1			2	3	5		1	x												1	2	
B. subaenariensis													x	x	1		1	1	1		44	59	43	5	41	19	15			5	7	1
Buccella frigida	4	7		4	3	2	5	x	2	2	3	3	3	2	4		1	1				x			x	2	5					7
Bulimina aculeata													x																			
B. exilis	1	x	1	1	1	1	2	x	1	1	1	x	1	2	1		1	x			x		x	1	1	1						1
B. marginata		x	x	1	x	x	2	x	2	1	1	1			1						2											
Cassidulina reniforme	42	14	2	32	11	27	8	26		13	19	17	29	23	21	29	11	17		4	1	4	2	18	3	6				22	26	31
Cibicides lobatulus	x	x	x	x	x	x	2	x	2	2	4	3	2	1	2		3	5	40	35	1	1	x		2	10	15	8	7	7	2	4
C. pseudoungerianus																		1	8	3												
Dentalina spp.													x																			
Eggerella advena	1	1		x					1					x																		
Elphidium bartletti											x		x																		x	
E. excavatum	4	9	2	3	10	5	12	5	6	9	18	4	6	5	6		3	1	5	8	x	1	x	2	4	1	5	2		24	36	26
Epistominella takayanagii							x				1												x									
Fissurina marginata												x		1	x			x														
Fursenkoina fusiformis	16	7	2	1		x	3	1	5	x	2	1	2	5	5		1	1	4	1	x	x	x	1	1	3	5			1	3	2
Globocassidulina subglobosa			2	1	1	2		7	8	4	2	5	x	x	3	8	2	6	10	4	15	2	8	5	8	22		28		1		
Gyroidina soldani				2	x	1	1	5	2	3	2	4	4	x	x		1	1		1	x	2	5	3								
Islandiella teretis	14	42	70	27	49	34	29	6	28	8	12	14	6	10	4	13	3		1	25	2	2	2	16	8	6	30	33	73	28	21	26
Lagena spp.						x								2	2		1	1		2		x		1	x	1						
Melonis spp.																			14	2												
Nonionella turgida														x																		
Nonionellina labradorica	8	11	16	8	17	11	18	29	36	30	19	14	7	4	12			11	12	8	27	13	30	27	23	30	15	28	20	6	5	2
Psammosphaera fusca					x	x		x							x						1			1						1		
Pseudopolymorphina novangliae																			x													
Pullenia osloensis	4	2	2	12	1	11	9	16	3	19	13	25	36	35	25		50	46		2	4	16	8	21	8	4	5					2
P. subcarinata	x			1						1	1	1	x	1	1		1	1							x							
Pyrgo williamsoni					x		x						x	x			x	2		1						1						
Quinqueloculina seminulum		x			1	2	x	1	2	4	x	2		1	x	8	1	2	2	1						5						
Recurvoides turbinatus		x																														
Rectoglandulina rotundata												x													x							
Reophax arctica	x	x						x								8					1											
R. fusiformis			x	x	1	x	2	x	1		x	1			1	8	x	x	2		1			x	1							
R. scorpiurus	x	x		1	2	x	1	1	1	1	x	1			x		1		1	1		x	x	x	x							
R. scotti							x																									
Saccorhizoides charlottensis															x																	
Saccammina atlantica																																
S. difflugiformis					1	1	2			x	x	2		x					1		1		x		x							
Textularia torquata	x	1		x																												
Trifarina fluens		x	2	2	1	x	2		1	x	x	1		1	3		x															
Triloculina trihedra													1					1														
Trochammina globigeriniformis														1																		
T. inflata																																
T. lobata														1				x														
T. nana														x		13																
Planktonics (raw numbers)	168	90	33	134	49	94	48	116	48	214	317	316	896	912	664	38	557	282	189	500	42	200	37	172	44	7	1	5		20	4	10

table1 Percentage occurrences of Foraminiferal species

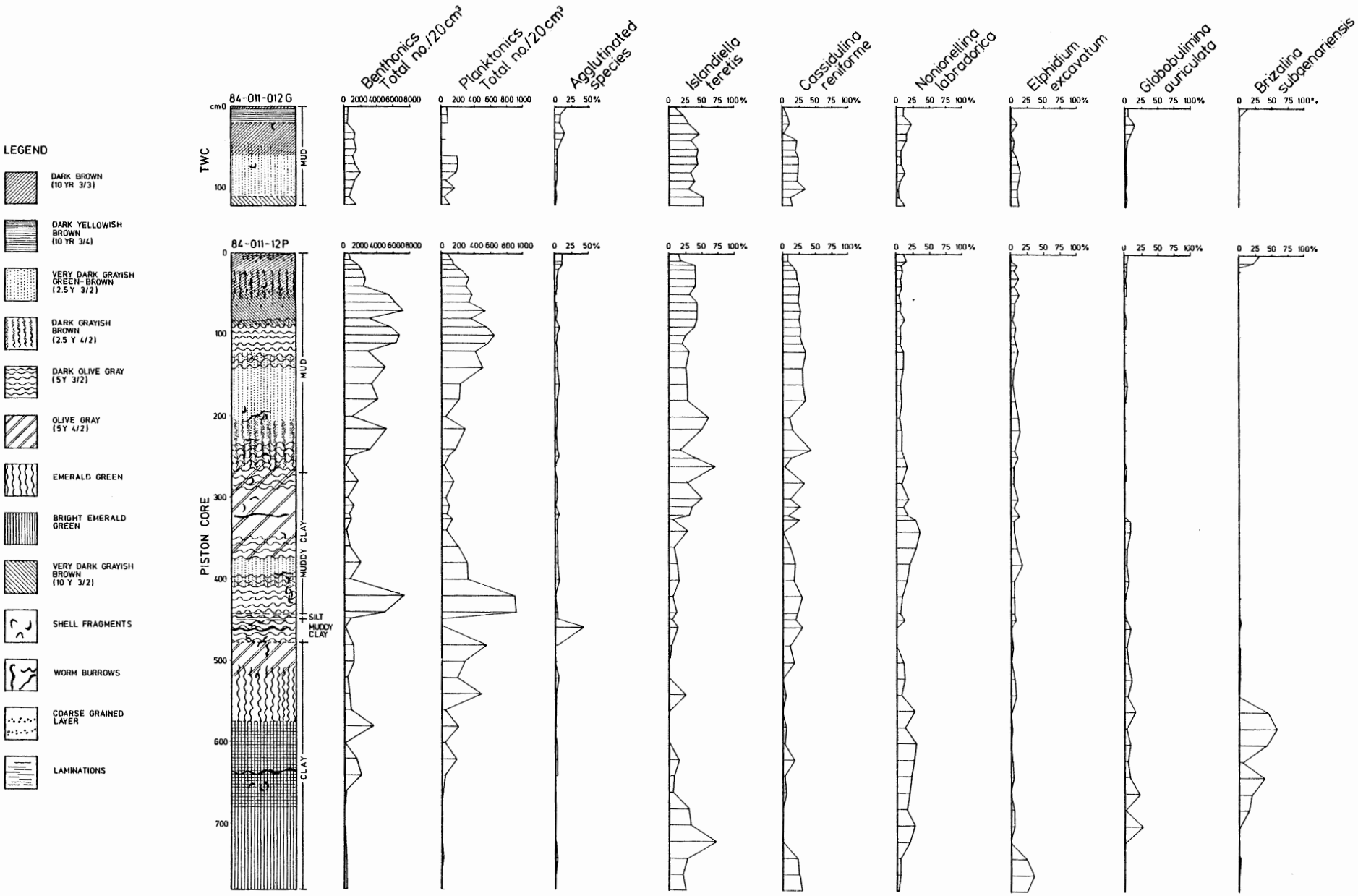


Fig.4 Foraminiferal abundances and percentage occurrences of key species

Pollen

A brief analysis was preformed by P.J. Mudie (personal communication) on five strategically located samples within the piston core and the surface of the gravity core.

The surface sample of the gravity core contains weed pollen (ie. Zea, etc.) indicating that this sample is representative of modern flora. It also contains other pollen genera prevalent in modern conditions, ie. Pinus, Abies, Picea, etc. but little or no earlier material is present as in the foraminiferal results. The top of the piston core reveals the same results but with more slightly abnormal palynomorphs (ie. Miocene acritarchs). The sample taken at 20-22cm reveals the same results as the surface sample in that it contains Pinus, Abies, Picea, etc. but no warm water or modern weed pollen occurs.

Analysis of sample 600-602cm, which is within the bottom water hypsithermal reveals that this is well below the terrestrial hypsithermal, by approximately 1000 yrs. This sample can be correlated with the base of zone C1 or the top of zone B in the pollen stratigraphy of Scott et al. (1984), approximately 6000 yrs.b.p. It contains shrub pollen and no Tsuga (a warm climate indicator). Sample 640-642cm. is also within the bottom water hypsithermal and using pollen analysis can be correlated with the zone B of the Canso Basin core (Scott et al.,1984). This is well below the terrestrial warming period- approximately 7000 yrs.b.p.

A brief analysis of sample 780-782cm, at the base of the piston core reveals the presence of palynomorphs related to conditions present after 8000 yrs., which places a maximum time limit to the

age of the core.

DISCUSSION

The basal 40cm of core 84-011-12 aredominated by an assemblage of Islandiella teretis, Cassidulina reniforme and Elphidium excavatum. The E. excavatum- C. reniforme assemblage has been previously suggested to be a "warm" ice margin fauna. This represents conditions close to a glacial margin but warmer than glacial margin conditions now occurring in the Canadian Arctic (Scott and Medioli, 1980; Vilks, 1981). The distinct presence of I. teretis within this interval however suggests the influence of somewhat colder temperature than that present during the immediate end of the glacial cycle. This would represent a time after deglaciation when the Outer Labrador Current was introduced. This, in conjunction with the fact that planktonics are absent, indicating relatively freshwater conditions, suggests that this period represents conditions after proglacial. Pollen analysis carried out on sediments at this level within the core was only specific enough to determine that its age is younger than 8000 yrs.b.p.

Benthonic foraminifera deposited after this interval indicate the distinct presence of Outer Labrador Current water after deglaciation. This faunal assemblage of Nonionellina labradorica, I teretis and Globobulimina auriculata also represents the present day Outer Labrador Current flowing over the outer parts of the Labrador Shelf (Vilks et al., 1984). This water mass is relatively cool, but warmer than that currently on the inner Scotian Shelf. Scott et al. (1984) studied a core fron Canso Basin which is very similar, in terms of sediment and faunal type, to core 84-011-12. The presence of N. labradorica at intervals within that core was correlated with

a substantial warming and/or a raise in salinity of Scotian Shelf water just following deglaciation.

The next 140cm interval contains a high abundance of Brizalina subaenariensis which is documented by Williamson (1984) to be a warm water species in modern environments (ie. the Emerald Basin which has a relatively high Gulf Stream influence today). In addition, an increase in the total number of calcareous species and individuals is related to warmer conditions as is the increase of planktonic foraminifera. This sequence plausibly represents the mid-Holocene hypsithermal, a warm interval from 7000 to 5000 yrs.b.p. with bottom water temperatures of 4-8°C (Scott et al., 1984).

Analysis of the pollen in this interval reveals the absence of Tsuga. In the Canso Basin core of Scott et al. (1984) an abundance of this pollen corresponds to the warm conditions of the terrestrial hypsithermal, between 4000 and 6500 yrs.b.p. The warm interval on land occurs approximately 1000 yrs. after the benthonic foraminiferal hypsithermal because changes within the water mass characteristics due to global climatic events are reflected within bottom water fauna before terrestrial fauna.

The sequence from 560-14cm reflects an assemblage dominated by I.teretis, C. reniforme and N. labradorica. As previously stated, this represents Outer Labrador Current conditions but the progressive increase in I. teretis represents continual cooling from the mid-Holocene to the present. This cooling trend was also documented within the Scott et al. (1984) study of eastern Canada in which the Canso Basin core recorded the same cooling during the last 5000 yrs., and a more marked increase in the last 2500 yrs. This cooling is probably due to the increased influence of the cold Inner

Labrador Current from the Gulf of St. Lawrence which now prevails in the surrounding area and in St. Anne's Basin (Houghton et al., 1978).

The top 14cm of the piston core reflects, in part, the assemblage present today within the N.E. area of the Scotian Shelf (Williamson, 1984). This fauna is marked by a distinct abundance of agglutinated benthonic species, particularly a large amount of Adercotryma glomerata. This is produced by cold inner margin Labrador Current of less than normal salinity. Within this interval there is an even greater abundance of calcareous fauna; particularly B. subaenariensis. Two other cores taken in close proximity to the core under study- 84-011-11, 0.6km to the south and 84-011-13 taken 1km to the north- also contain this warm water assemblage component on the surface. According to the seismic section (see Fig.2) taken in this area, a topographic high occurs south of core 84-011-11 and may have been the source of reworked sediment which was deposited on the surface of all three cores. This must have been a local event because a study of three surface samples to the north and east of cores 84-011 by Williamson (1984) did not reveal the presence of this warm water assemblage. Williamson (1984) documented that wholescale slumping may result in displaced assemblages (Coulbourn, 1980)

The assemblage contained within the top section of the core, with the exception of the reworked material discussed, bears a close resemblance also to that now within the Gulf of St.Lawrence. Here, the assemblage contains key species such as I. teretis, Reophax arctica, A. glomerata, etc. (Schafer and Cole, 1978; Rodrigues and Hooper, 1982). This evidence suggests that the Labrador Current

which flows into the Gulf of St.Lawrence then flows south through the Cabot Strait and affects the Scotian Shelf.

A brief analysis of the palynomorphs from the top of the piston core revealed that this is not absolute recent material and also reveals the presence of a very few reworked Miocene acritarchs. This, and the fact that there are fewer amounts of agglutinated benthic species than expected according to the study by Williamson (1984), indicates that the very top portion of the piston core has been contaminated by reworked material. Analysis of the surface of the gravity core shows the presence of modern pollen (weed; ie. Zea, etc.) which has been introduced into the adjacent terrestrial environment by early settlers from Europe. In addition, the trends of foraminiferal abundances reveal an additional 20cm on the top of the gravity core that was missed by the piston core.

SUMMARY

Core 84-011-12 is an 8m, almost entire Holocene record of the Lahave Clay unit of King (1970) deposited within St. Anne's Basin. Analysis of the palynomorphs reveals five distinct sedimentological intervals within this time span.

1. The basal 40cm of the core reflects the conditions of an early post glacial environment. The Scatarie end moraine immediately to the north of the core site indicates how close the ice margin was up until the end of the last glacial period. According to a concurrent study on core 84-011-11 (Souchen, 1986) immediately to the south, which penetrates the Pleistocene Emerald Silt, this proglacial deposit would be expected immediately below 84-011-12.

2. Above this basal interval, 40cm of early Holocene postglacial sediments occurs. The fauna at this period represents bottom water conditions similar to the present Outer Labrador Current which reflects considerable increase in salinity from the preglacial.

3. The next 140cm (700-560cm) is a sequence reflecting the Mid-Holocene hypsithermal in which conditions were similar to those now within the Emerald Basin (Williamson, 1984). Temperatures range from 7-10°C (which is a 4-8°C rise in temperatures from the early Holocene) and salinity from 33.5 to 35‰. This unit is between 5000 and 7000yrs.b.p.

4. Above this, to 14cm in the core, the sediments reflect Outer Labrador Current conditions, pushing southward the influence of the Gulf Stream Current which produced the adjacent lower interval. This interval has been progressively cooled as more and more influence of the cold Inner Labrador Current is felt. Pollen analysis within this

interval indicates that the terrestrial hypsithermal occurred approximately 1000yrs after the oceanographic hypsithermal. This was documented in Scott et al.(1984) and proves that climatic changes are reflected within bottom water on continental shelves before occurring on land.

5. The top 14cm of the core reflect a mixture of Inner Labrador Current fauna which is presently within St. Anne's Basin, and the same warm water fauna which occurs to the south, in Emerald Basin (Williamson, 1984). Two other cores taken within this area also show this mixing but samples further to the north do not. This could be due to reworked material produced by slumping from the topographic high to the south. The Inner Labrador Current has a temperature ranging from 0-3 °C and salinity from 31-33 ‰. The distinct occurrence of this water mass from the Gulf of St. Lawrence has exerted a greater influence of its physical conditions on the N.E. Scotian Shelf, pushing warm water conditions of the Gulf Stream south.

Water depths of less than 300m on the N.E. Scotian Shelf reflect progressive cooling over the last 4000-5000yrs b.p. and terrestrial cooling has started after this. Therefore ocean cooling has promoted cooler conditions on land. This is a result of the southward advance of the cold Inner Labrador Current, originating in the Arctic, flowing into the Gulf of St. Lawrence and onto the northeast Scotian Shelf.

The Holocene record presented here closely fits the overall Holocene water mass situation for the Canso Basin core presented in Scott et al. (1984). This core is a record of Outer Labrador Current from 10000-7500yrs. b.p., slope-Gulf Stream mixture from

7500-5000yrs. b.p. (mid-Holocene hypsithermal), Outer Labrador Current from 5000-2500yrs. b.p., and Inner Labrador Current from 2500yrs. b.p. to the present.

TAXONOMY

This study is not taxanomic in nature therefore only an abbreviated taxonomy has been included, without descriptions. The primary references used for species identification includes Williamson (1983) and Cole (1981). The original citations, the most important synonyms, and the most recent citations have been listed in alphabetical order for all 47 species in this study. Illustrations of representative specimens of 20 of the most important species have been presented in Plate 1. This iconography does not illustrate the variability within taxon morphology. All genera are in accordance with Loeblich and Tappan (1964).

Astrononion gallowayi Loeblich and Tappan, 1953.

Astrononion gallowayi LOEBLICH AND TAPPAN, 1953, p.90, pl.17, fig.4-7. WILLIAMSON, 1984, p.227, pl.4, fig.12.

Adercotryma glomerata (Brady, 1878)

Lituola glomerata BRADY, 1878, p. 433, pl. 20, figs. 1a-c.
Adercotryma glomerata (Brady). LOEBLICH and TAPPAN, 1952, p. 141, figs. 1-4; VILKS, 1969, p. 44, pl. 1, fig. 15; GREGORY, 1971, p. 173, pl. 11, figs. 9-11; COLE, 1981, p. 29, pl. 4, figs. 5,6. WILLIAMSON, 1984, p.208, pl.1, fig.16.

Brizalina pseudopunctata (Hoeglund, 1947)

Bolivina pseudopunctata HOEGLUND, 1947, p. 273, pl. 24, fig. 5, pl. 32, figs. 23,24. COLE, 1981, p.67, pl.11, fig.12.

Brizalina subaenariensis (Cushman, 1922)

Bolivina subaenariensis CUSHMAN, 1922, p. 46, pl. 7, fig. 6. WILLIAMSON, 1984, p.218, pl.3, fig.11.

Buccella frigida (Cushman, 1922)

Pulvinulina frigida CUSHMAN, 1922, p. 12 (144)

Eponides frigida (Cushman) CUSHMAN, 1931, p. 45.

Buccella frigida (Cushman) ANDERSON, 1952, p.144, text-figs. 4,5,6. WILLIAMSON, 1984, p.223, pl.4, fig.4,5.

Bulimina aculeata d'Orbigny, 1826

Bulimina aculeata d'ORBIGNY, 1826, p. 269, no. 7. BRADY, 1884, p. 406, pl. 51, figs. 7-9. WILLIAMSON, 1984, p.220, pl.3, fig.12.

Bulimina elongata d'ORBIGNY, 1846, p. 187, pl. 11, figs. 19,20.

Bulimina elongata d'Orbigny var. subulata CUSHMAN and PARKER, 1937, p. 51, pl. 7, figs. 6,7.

Bulimina elongata d'Orbigny var. lesleyae ATKINSON, 1969, p. 534, fig. 6, no. 2. HAYNES, 1973, p. 119, pl. 10, fig. 6; text-fig. 24, no. 9.

Bulimina gibba FORNASINI, 1902, p. 378, pl. 10, figs. 32,34.

Bulimina gibba/elongata Fornasini and d'Orbigny. MURRAY, 1971, p. 117, pl. 48, figs. 1-8.

Bulimina elegans d'Orbigny. BRADY, 1884, p. 398, pl. 50, figs. 1-4.

Bulimina exilis Brady,1884

Bulimina elegans var. exilis BRADY, 1884, p. 399, pl. 50, figs. 5,6. Bulimina exilis Brady. CUSHMAN and PARKER, 1940, p. 11, pl. 2, figs. 18-21. WILLIAMSON, 1984, p.220, pl.3, fig.15.

Bulimina marginata d'Orbigny, 1826.

Bulimina marginata d'Orbigny, 1826, p. 269, pl. 12, figs. 10-12. WILLIAMSON, 1984, p.219, pl.3, fig.13.

Cassidulina reniforme Norvang, 1945

Cassidulina crassa reniforme NORVANG, 1945, p. 41, text-figs. 6e-h. Cassidulina islandica Norvang. LOEBLICH and TAPPAN, 1953, p. 118, pl. 24, fig. 1.

Cassidulina crassa d'Orbigny. NORVANG, 1958, p. 36, pl. 9, figs. 24,25.

Cassidulina crassa minima BOLTOVSKOY, 1959, p. 100, pl. 13, fig. 12.

Cassidulina bradshawi UCHIO, 1960, p. 68, pl. 9, figs. 11,12.

Cassidulina subacuta (Gudina). FEYLING-HANSSEN, 1976, p. 354, pl. 2, figs. 14-19.

Cassilaminella subacuta GUDINA, 1966, p. 67, pl. 7, figs. 4,5; pl. 13, fig. 3.

Cassidulina reniforme Norvang. RODRIGUEZ, HOOPER and JONES, 1980, p. 58, pl. 2, figs. 2,4,6; pl. 3, figs. 3,6,9,11,12; pl. 5,figs. 10-12.

Cibicides lobatulus (Walker and Jacob, 1798)

Nautilus lobatulus WALKER and JACOB, 1798, p. 642, pl. 14, fig. 36. Cibicides lobatulus (Walker and Jacob). CUSHMAN, 1931, 118k, pl. 21, fig. 3. WILLIAMSON, 1984, p.226, pl.4, fig.10,11.

Cibicides pseudoungerianus (Cushman, 1922)

Truncatulina pseudoungerianus CUSHMAN, 1922, p.97, pl.20, fig.9. Cibicides pseudoungerianus (Cushman). FEYLING-HANSEN, 1964, p. 340, pl.19, fig. 4-6; SCHAFER AND COLE, 1978, p22; SCHNITKER 1971, p.196, pl.9, fig.7. WILLIAMSON, 1984, p.226, pl.4, fig.17,18.

Genus Dentalina Risso, 1826.

- number of species, not differentiated.

Eggerella advena (Cushman,1922)

Verneuilina advena CUSHMAN, 1922, p. 141.
Eggerella advena (Cushman). CUSHMAN, 1937, p. 51, pl. 5, figs. 12-15. WILLIAMSON, 1984, p.214, pl.2, fig.3.

Elphidium bartletti CUSHMAN, 1933.

Elphidium bartletti CUSHMAN, 1933, p. 4, pl. 1, fig. 9. WILLIAMSON, 1984, p.224, pl.5, fig.10.

Elphidium excavatum (Terquem,1876) group

Polystomella excavata TERQUEM, 1876, p. 429, pl. 2, figs. 2a-f.

Elphidium incertum (Williamson) var.clavatum CUSHMAN, 1931, p. 20, pl. 7, fig. 10.

Elphidium excavatum (Terquem) clavata Cushman. FEYLING-HANSSEN, 1972, p. 339, pl. 1, figs. 1-9; pl. 2, figs. 1-9.

Elphidium excavatum (Terquem). HERON-ALLEN and EARLAND, 1932, p. 439, pl. 16, figs. 22,23. WILLIAMSON, 1984, p.224, pl.5, fig.9

note: This study has not differentiated Elphidium excavatum, E. bartletti, and E. subarcticum.

Epistominella takayanagii IWASA, 1955. Miller ET AL.,1982, p.236, pl.2, fig.11,12.

Epistominella takayanagii IWASA, 1955, p. 16, text-fig. 4.

Fissurina marginata (Montagu, 1803)

Vermiculum marginatum MONTAGU, 1803, Test. Brit., p.524.

Lagina sulcata var. marginata (Montagu). PARKER and JONES, 1865, p.355, pl.13, fig.42, 43 only.

Lagena marginata (Walker and Jacob). BRADY, 1884, p.476, pl.59, fig.22 only.

Entosolenia marginata (Montagu?). CUSHMAN, 1948, p.65, pl.7, fig.7.

Fissurina marginata (Montagu). LOEBLICH and TAPPAN, 1953, p.77, pl.14, figs.6-9. WILLIAMSON, 1984, p.217, pl.3, fig.8.

Fursenkoina fusiformis (Williamson, 1858)

Bulimina pupoides fusiformis WILLIAMSON, 1858, p. 63, pl. 5, figs. 129,130.

Bulimina fusiformis Williamson. HOEGLUND, 1947, p. 232, pl. 20, fig. 3, text-figs 219 - 233.

Virgulina fusiformis (Williamson). FEYLING-HANSSEN, 1964, p. 307, pl. 14, figs. 15-18.

Fursenkoina fusiformis (Williamson) WILLIAMSON, 1984, p.226, pl.5, fig.1

Globobulimina auriculata (Bailey, 1951) gullmarensis HOEGLUND, 1947.

Globobulimina auriculata (Baily) gullmarensis HOEGLUND, 1945, p. 252, pl. 20, fig. 6; pl. 21, fig. 5; pl. 22, fig. 6; text-figs. 258-265, 268, 269, 271. WILLIAMSON, 1984, p.221, pl.3, fig.17.

Gyroidina soldanii d'Orbigny, 1826

Rotalia (Gyroidina) soldanii d'ORBIGNY, 1826, p. 278, no. 5, mod. 36. WILLIAMSON, 1984, p.228, pl.5, fig.5,6.

Gyroidina neosoldanii BROTZEN, 1936, p. 158.

Islandiella teretis (Tappan, 1951)

Cassidulina laevigata d'Orbigny. BRADY, 1884, p. 428, pl. 54, figs. 1-3.

Cassidulina teretis TAPPAN, 1951, p. 7, pl. 1, fig. 30a-c.

Islandiella teretis (Tappan). VILKS, 1969, p. 49, pl. 3, fig. 5. WILLIAMSON, 1984, p.219, pl.5, fig.18.

Genus Lagena Walker and Jacob, 1798.

- number of species, not differentited.

Genus Melonis de Montfort, 1808.

- species not differentiated.

Nonionella turgida (Williamson, 1858)

Rotalina turgida WILLIAMSON, 1858, p. 50, pl. 4, figs. 95-97.

Nonionina turgida (Williamson). BRADY, 1884, p. 731, pl. 109, figs. 17-19.

Nonionella turgida (Williamson). CUSHMAN, 1930, p. 15, pl. 6, figs. 1-4. WILLIAMSON, 1984, p.228, pl.4, fig.13.

Nonionellina labradorica (Dawson, 1860)

Nonionina labradorica DAWSON, 1860, p. 191, fig. 4.

Nonion labradorica (Dawson). CUSHMAN, 1927, p. 148, pl. 2, figs. 7,8.

Nonionellina labradorica (Dawson). VOLOSHINOVA, 1958, p. 142. WILLIAMSON, 1984, p.227, pl.4, fig. 14,15.

Psammosphaerica fusca Schulze,1875.

Psammospherica fusca SCHULZE, 1875, p.113,pl.2, fig.8. COLE, 1981,

p.12, pl.3, fig.4.

Pseudopolymorphina novangliae (Cushman, 1923)

Polymorphina lactea novangliae CUSHMAN, 1923, p. 146, pl. 39, figs. 6-8.
Pseudopolymorphina novangliae (Cushman). PARKER, 1952, p. 410, pl. 5, fig. 1. COLE, 1981, p.72, pl.16, fig.38,39.

Pullenia osloensis Feyling-Hanssen, 1954.

Pullenia osloensis FEYLING-HANSSEN, 1954, p.194, pl.1, fig.33-35. COLE, 1981, p.111, pl.13, fig.9.

Pullenia subcarinata (d'Orbigny, 1839)

Nonionina subcarinata d'ORBIGNY, 1839, p.28, pl. 5, figs. 23,24.

Pyrgo williamsoni (Silvestri, 1923)

Biloculina williamsoni SILVESTRI, 1923, p. 73.
Pyrgo williamsoni (Silvestri). LOEBLICH and TAPPAN, 1953, p.48, pl. 6, figs. 1-4. COLE, 1981, p.54, pl.9, fig.7.

Quinqueloculina seminulum (Linne, 1758)

Serpula seminulum LINNE, 1758, p. 786, pl. 2, fig. 1.
Quiqueloculina seminulum (Linne). CUSHMAN, 1929, p. 24, pl. 2, figs.

Rectoglandulina rotundata (Reuss, 1878)

Nodosaria rotundata REUSS, p/366, pl.xivi, fig.2

Pseudoglandulina rotundata (Reuss) CHAPMAN and PARR, 1937, p.62.

Rectoglandulina rotundata (Reuss) LOEBLICH and TAPPAN. 1955,p.6. BARKER, 1960, p.128, pl.LXI, fig.20-22.

Reophax arctica BRADY, 1881.

Reophax arctica BRADY, 1881, p. 99, pl. 2, fig. 2. WILLIAMSON, 1984, p.206, pl.1, fig.8.

Reophax fusiformis (Williamson, 1858)

Proteonina fusiformis WILLIAMSON, 1858, p. 1, pl. 1, fig. 1.

Reophax fusiformis (Williamson). BRADY, 1884, p. 290, pl. 30, figs. 7-11. COLE, 1981, p.24, pl.2, fig.9.

Reophax curtus CUSHMAN, 1920, p. 8, pl. 2, figs. 2,3.

Reophax scorpiurus BALKWILL and WRIGHT, 1885, p. 329, pl. 1B, fig. 5.

Reophax subfusiformis EARLAND, 1933, p. 74, pl. 2, figs. 16-19.

Reophax regularis HOEGLUND, 1947, p. 86, pl. 9, figs. 11,12; pl. 26, figs. 37-43; pl. 27, figs. 24-27.

Reophax scorpiurus (de Montfort, 1808)

Reophax scorpiurus DE MONTFORT, 1808, p. 330; LOEBLICH and TAPPAN,

1,2. WILLIAMSON, 1984, p.215, pl.3, fig.1.

1953, p. 24, pl. 2, figs. 7-10; LESLIE, 1965, p. 169, pl. 1, figs. 6,7. WILLIAMSON, 1984, p.207, pl.1, fig.9.

Reophax scottii CHASTER, 1892.

Reophax scottii CHASTER, 1892, p. 57, pl. 1, fig. 1. WILLIAMSON, 1984, p.207, pl.1, fig.11.

Robertinoides charlottensis (Cushman,1925)

Cassidulina charlottensis CUSHMAN, 1925, p. 41, pl. 6, figs. 6,7.
Robertina charlottensis (Cushman). CUSHMAN and PARKER, 1936, p. 97, pl. 16, fig. 12.
Robertinoides charlottensis (Cushman) LOEBLICH and TAPPAN, 1953, p. 108, pl. 20, figs. 6,7. COLE, 1981, p.117, pl.11, fig.8.

Saccammina atlantica (Cushman, 1944)

Proteonina atlantica CUSHMAN, 1944, p. 5, pl. 1, fig. 4.
Saccammina atlantica (Cushman) TODD and BRONNIMANN, 1957, p. 22, pl. 1, fig. 14. WILLIAMSON, 1984, p.205, pl.1, fig.2.

Saccammina diffluqiformis (Brady, 1879)

Reophax diffluqiformis BRADY, 1879, p. 51, pl. 4, figs. 3a,b.
Proteonina diffluqiformis (Brady). PHLEGER and PARKER, 1955, p. 2, pl. 1, figs. 4,5.
Saccammina diffluqiformis (Brady). TODD and BRONNIMAN, 1957, p. 52,

pl. 1, fig. 15. WILLIAMSON, 1984, p.205, pl.1, fig.3.

Textularia torquata PARKER, 1952.

Textularia torquata PARKER, 1952, p. 403, pl. 3, figs. 9-11. WILLIAMSON, 1984, p.212, pl.2, fig.4.

Trifarina fluens (Todd, 1940)

Angulogerina fluens TODD, in CUSHMAN and McCULLOCH, 1940, p. 288, pl. 36, fig. 1.
Trifarina fluens (Todd). LOEBLICH and TAPPAN, 1964. COLE, 1981, p.92, pl.11, fig.6.

Triloculina trihedra LOEBLICH and TAPPAN, 1953.

Triloculina trihedra LOEBLICH and TAPPAN, 1953, p. 45, pl. 4, fig. 10. WILLIAMSON, 1984, p.216, pl.3, fig.3.

Trochammina globigeriniformis (Parker and Jones, 1865)

Lituola nautiloidea globigeriniformis PARKER and JONES, 1865, p. 407, pl. 15, figs. 46,47.
Trochammina globigeriniformis (Parker and Jones). CUSHMAN, 1910, p. 124, tf. 193-195. WILLIAMSON, 1984, p.213, pl.2, fig.14.

Trochammina inflata (Montagu, 1808)
Nautilus inflatus MONTAGU, 1808, p. 81, pl. 18, fig. 3.

Trochammina inflata (Montagu). CARPENTER, PARKER and JONES, 1862, p. 141, pl. 11, fig. 5. WILLIAMSON, 1984, p.212, pl.2, fig.12,13.

Trochammina lobata Cushman, 1944

Trochammina lobata CUSHMAN, 1944, p. 18, pl. 2, fig. 10; PARKER, 1952, p. 408, pl. 4, figs. 8a,b; SCHNITKER, 1971, p. 212, pl. 1, fig. 18; COLE and FERGUSON, 1975, p. 14, pl. 4, figs. 5,6. WILLIAMSON, 1984, p.213, pl.2, fig.16.

Trochammina nana (Brady,1881)

Haplophragmium nana BRADY, 1881, p. 50.
Trochammina nana (Brady). CUSHMAN, 1920, p. 80, pl. 17, fig. 1. COLE, 1981, p.38, pl.5, fig.12.

PLATE 1

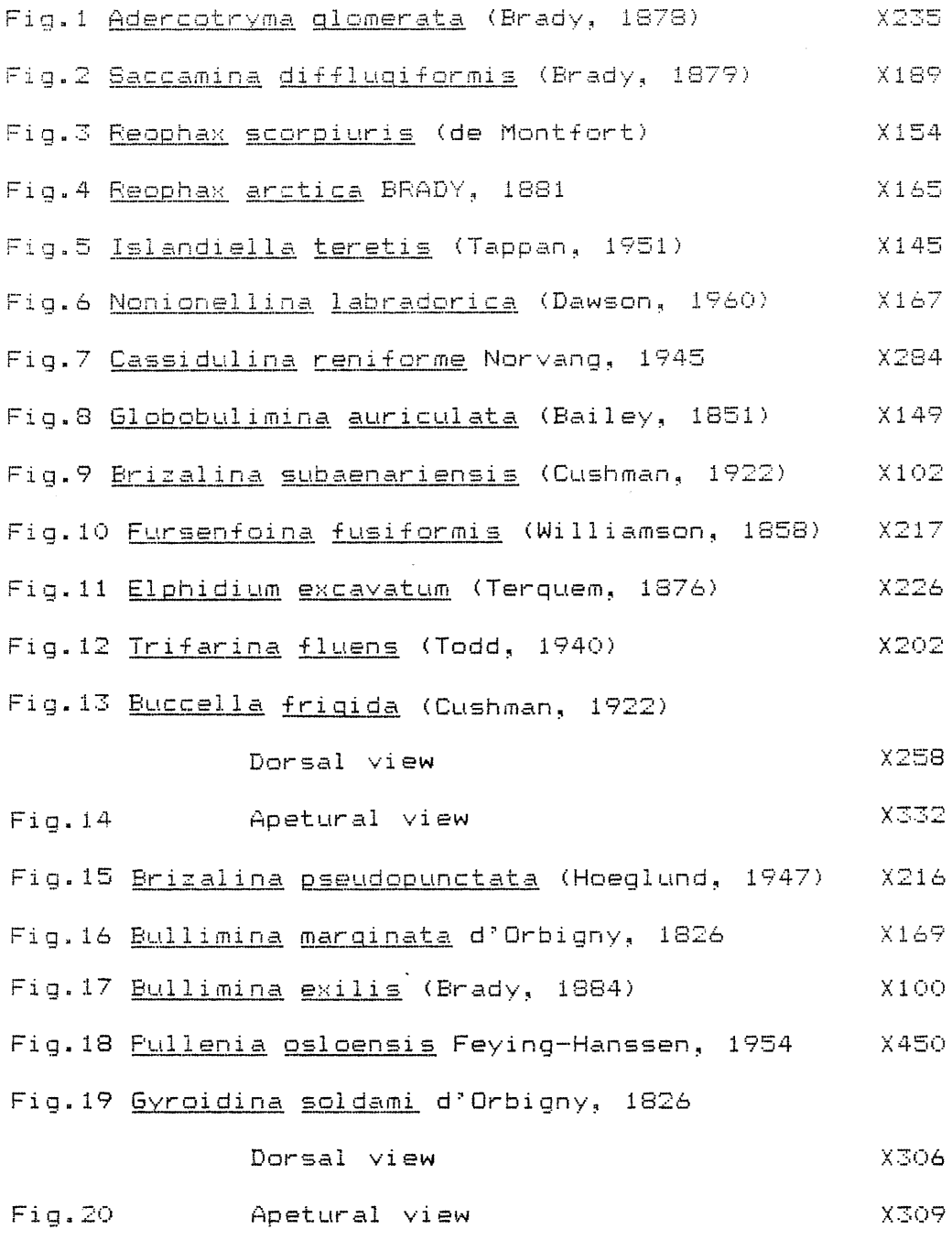


Fig.1 Adercotryma glomerata (Brady, 1878) X235

Fig.2 Saccamina difflugiformis (Brady, 1879) X189

Fig.3 Reophax scorpiuris (de Montfort) X154

Fig.4 Reophax arctica BRADY, 1881 X165

Fig.5 Islandiella teretis (Tappan, 1951) X145

Fig.6 Nonionellina labradorica (Dawson, 1960) X167

Fig.7 Cassidulina reniforme Norvang, 1945 X284

Fig.8 Globobulimina auriculata (Bailey, 1851) X149

Fig.9 Brizalina subaenariensis (Cushman, 1922) X102

Fig.10 Fursenfoina fusiformis (Williamson, 1858) X217

Fig.11 Elphidium excavatum (Terquem, 1876) X226

Fig.12 Trifarina fluens (Todd, 1940) X202

Fig.13 Buccella frigida (Cushman, 1922)
Dorsal view X258

Fig.14 Apetural view X332

Fig.15 Brizalina pseudopunctata (Hoeglund, 1947) X216

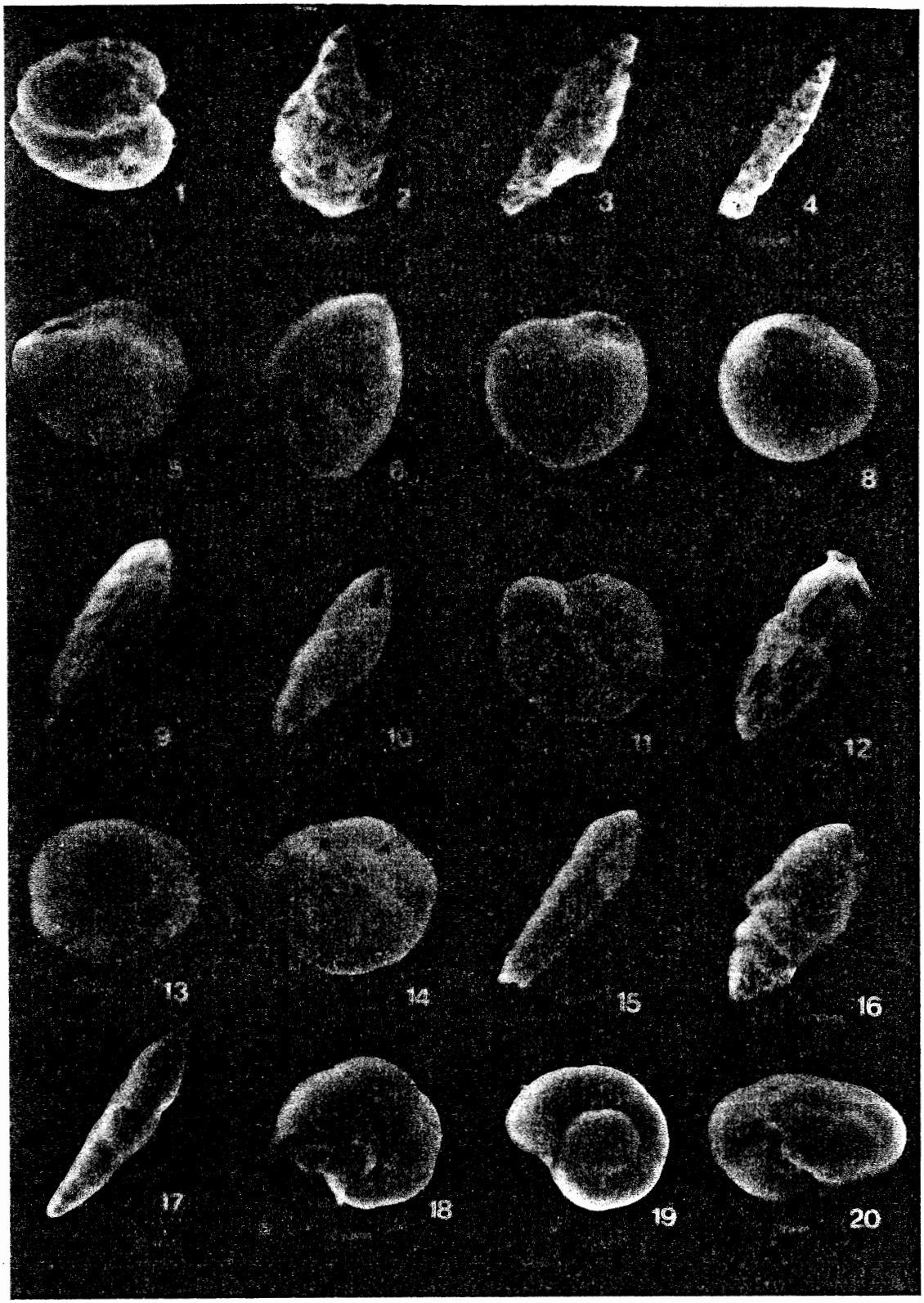
Fig.16 Bullimina marginata d'Orbigny, 1826 X169

Fig.17 Bullimina exilis (Brady, 1884) X100

Fig.18 Pullenia osloensis Feying-Hanssen, 1954 X450

Fig.19 Gyroidina soldami d'Orbigny, 1826
Dorsal view X306

Fig.20 Apetural view X309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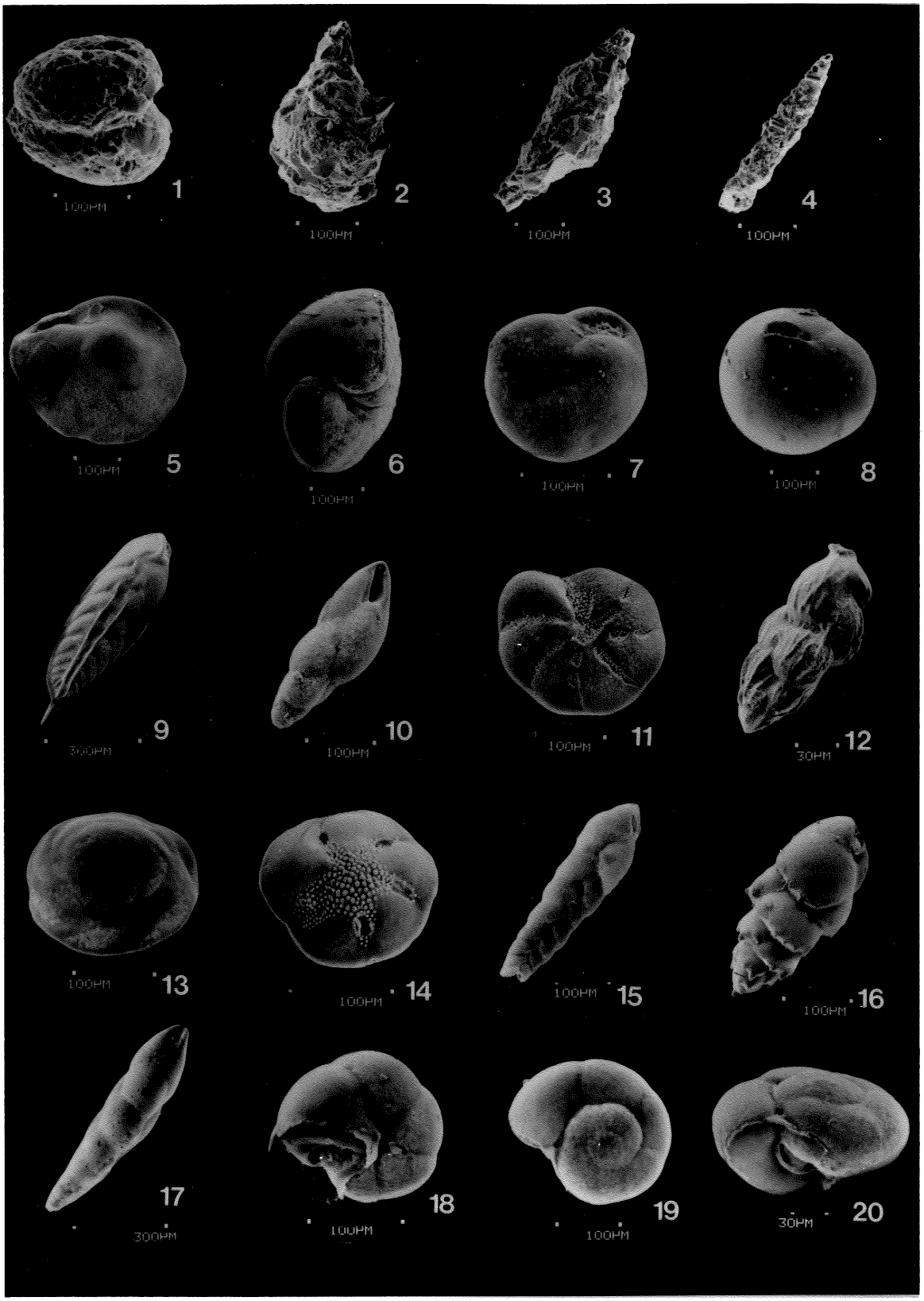
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ACKNOWLEDGEMENTS

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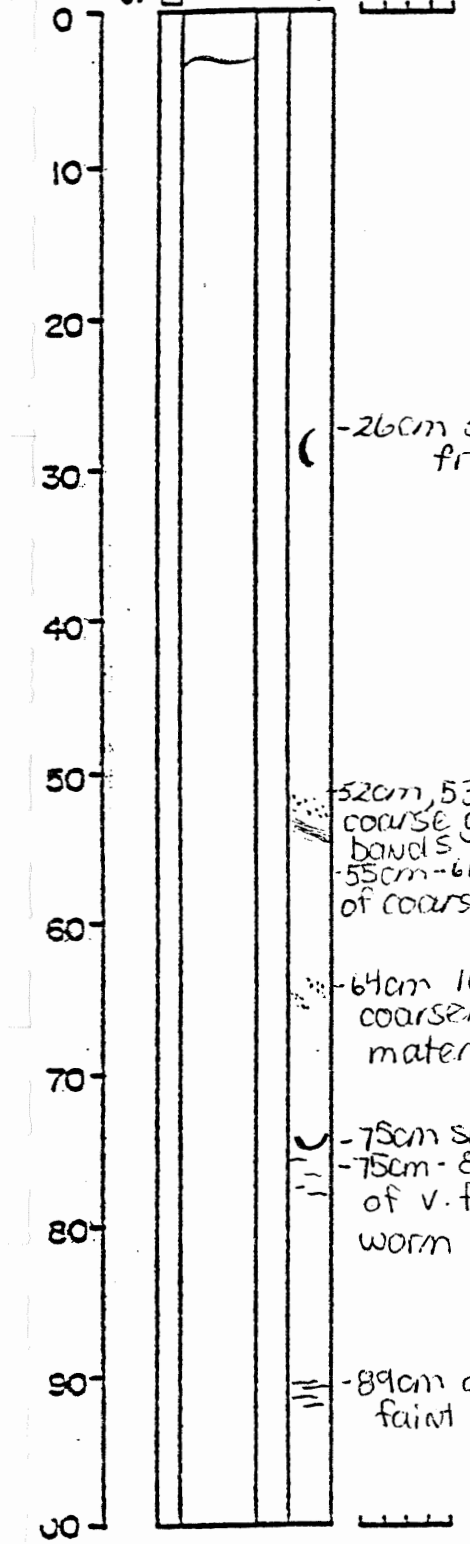
APPENDIX 1

Original description of core 84-011-12.

CORE 84-011-12 TWC DEPTH IN CORE 0-100 cm
LOCATION St. Anne's Basin
WATER DEPTH 270m
Described by: J. Freeman



DESCRIPTION

0-3cm 10yr 3/3 dark brown soft mud.

3-20cm 10yr 3/4 dark yellowish brown grading back into 10yr 3/3 (dark brown soft mud) around 20cm

20-45cm 10yr 3/3 dark brown soft mud.

45-60cm gradual color change from dark brown to v. dark greyish brown (2.5y 3/2) soft mud.

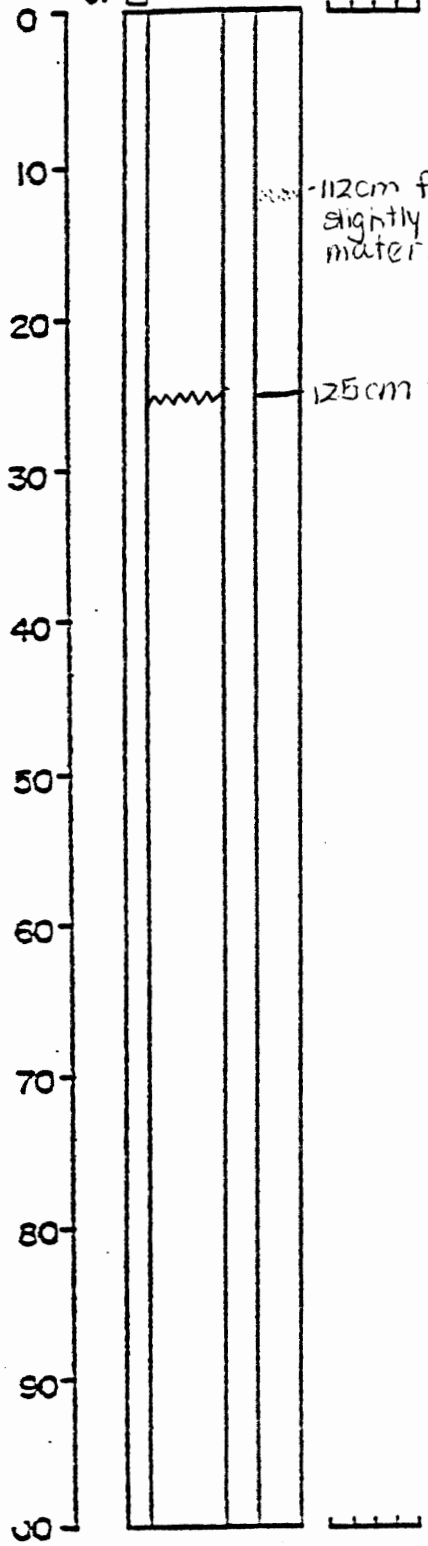
60-110cm 2.5 3/2 v. dark greyish brown, soft mud.

SAMPLE RECORD

General comments: Color standardized using Munsell Soil Color Charts.

CORE 84-011-12 TWC DEPTH IN CORE 100-125cm
LOCATION St. Anne's Basin
WATER DEPTH 270 m
Described by: J. Freeman

SMEAR DISTURB



DESCRIPTION

SAMPLE RECORD

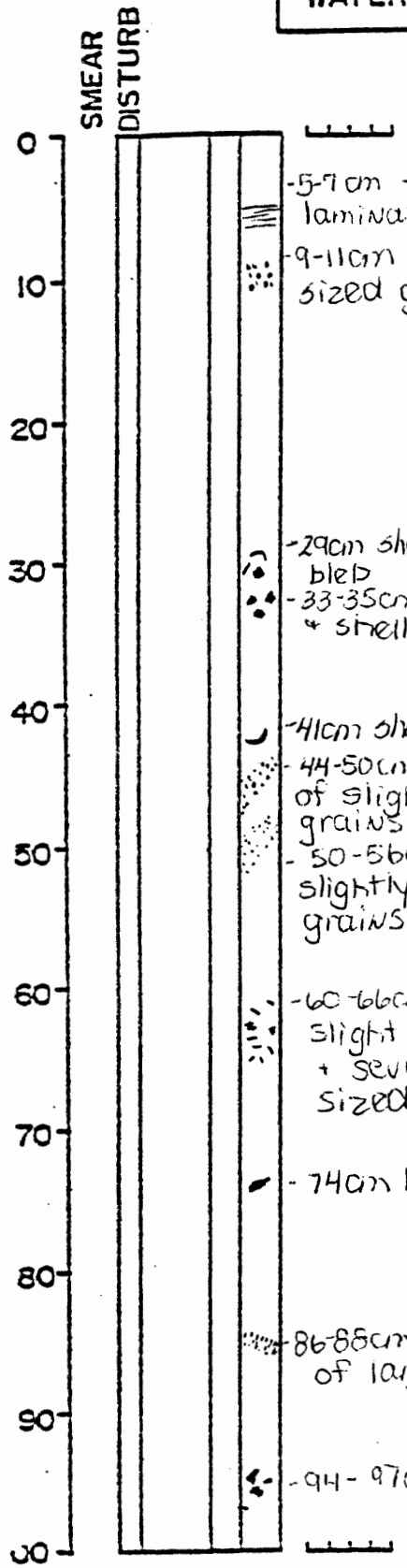
-112cm faint band of slightly cocuser grained material

- gradual color transition at ~ 110 cm to almost 10yr 3/2

125cm end of section

General comments:

CORE 84-011-12 P DEPTH IN CORE 0-100cm
LOCATION St. Anne's Basin
WATER DEPTH 270 m Described by: J. Freeman



DESCRIPTION

0-20cm 10yr 3/2 v. soft dark brown mud; first 20cm is stretched, some material seems to be missing. mud becomes slightly stiffer at ~20cm.

20-47cm. mixture of 10yr 3/3 dark brown mud and 2.5yr 4/2 dark greyish brown mud.

47-55cm mud seems to contain a higher amount of larger sized grains

47-56cm. gradual color change from above to 10yr 3/2 v. dark greyish brown soft mud

56-80cm 10yr 3/2 v. dark greyish brown soft mud

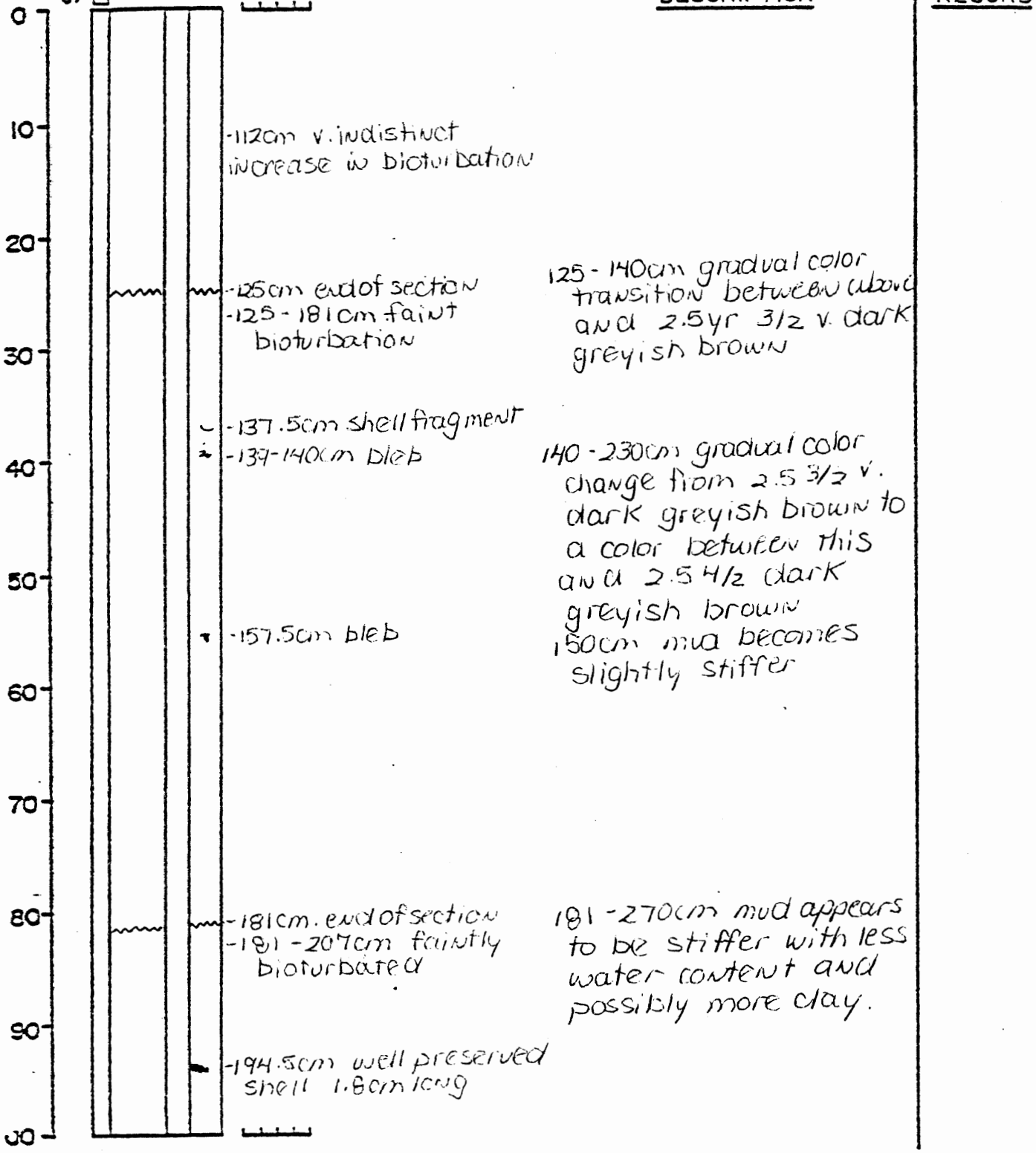
80-90cm transition area between 10yr 3/2 v. dark greyish brown to almost 5y 3/2 dark olive grey.

90-125cm color is between 10yr 3/2 v. dark greyish brown and 5y 3/2 dark olive grey.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 100-200cm
LOCATION St. Anne's Basin Described by: J. Freeman
WATER DEPTH 270 m



DESCRIPTION

125-140cm gradual color transition between above and 2.5yr 3/2 v. dark greyish brown

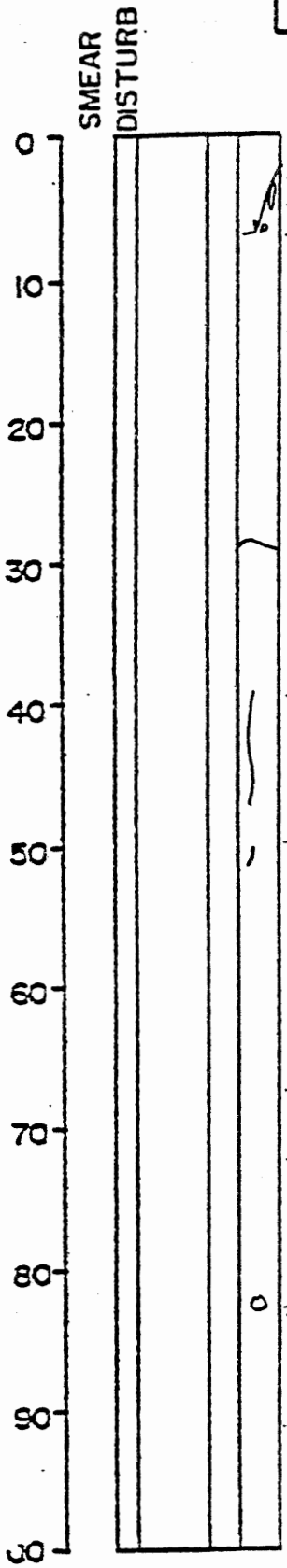
140-230cm gradual color change from 2.5 3/2 v. dark greyish brown to a color between this and a 2.5 4/2 dark greyish brown
150cm mud becomes slightly stiffer

181-270cm mud appears to be stiffer with less water content and possibly more clay.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 200-300cm
LOCATION St. Anne's Basin Described by: T. Freeman
WATER DEPTH 270m



DESCRIPTION

-201-205cm worm burrow
-202-204cm shell fragment
-205cm shell fragment
-207-211cm almost no bioturbation
-211-266cm faint bioturbation
-215-217cm faint laminations

-229.5cm worm burrow

230-263cm gradual color change from 2.5yr 3.5/2 dark-v.dark greyish brown to 5y 3.5/2 olive-dark olive grey

-239-246cm more distinct worm burrow

-248-250cm faint, darker layer
-250cm faint shell fragment

263-290cm gradual color change from 5y 3.5/2 olive-dark olive grey to 5y 4/2 olive grey

-266-272cm slight increase in bioturbation
-272-291cm faintly bioturbated

-283cm shell fragment

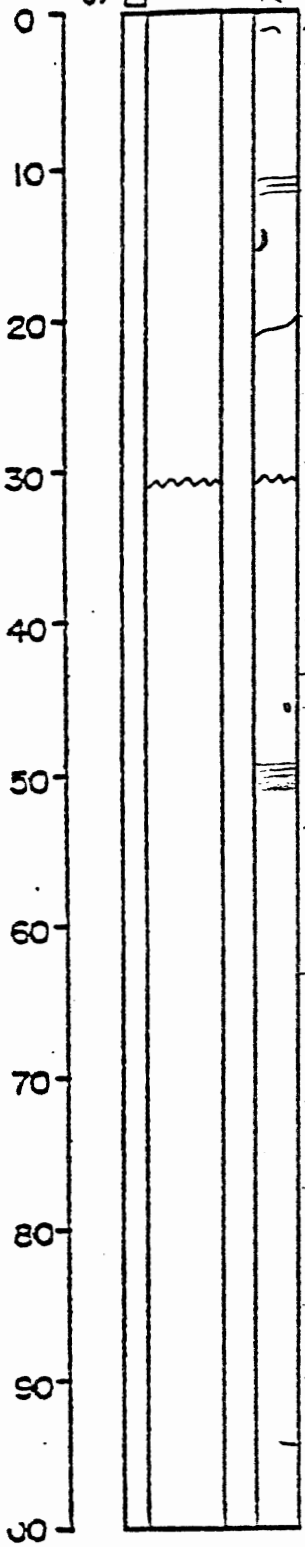
-291-303cm slight increase in bioturbation

290-350cm 5y 4/2 olive grey stiff mud - possibly an increase in clay content.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 300-400 cm
LOCATION St. Anne's Basin Described by: J. Freeman
WATER DEPTH 270 m



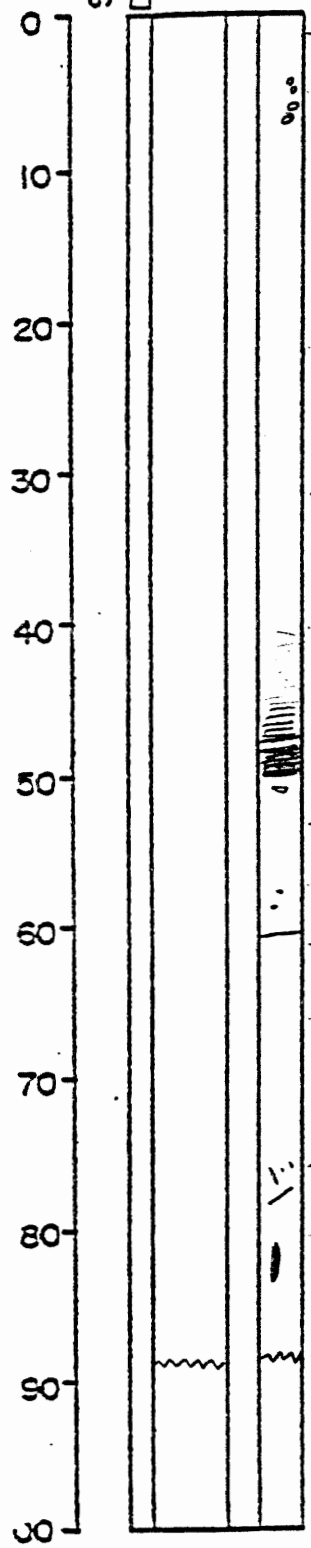
DESCRIPTION

-301cm shell fragment
-303-310cm almost no bioturbation
-311-312 cm three faint, lighter subhorizontal bands
-314.5cm shell fragment
-312-341cm faint bioturbation
-321cm subhorizontal worm burrow.
-226-229cm lighter band
-331cm end of x-ray
-332cm end of section
-345.5cm shell fragment
-347-349cm slight increase in bioturbation
-349-351cm lighter band with almost no bioturbation
-351-364cm faintly bioturbated
-364-367cm faint banding, little bioturbation
-367-375cm some increase in bioturbation
-375-385cm slight decrease in bioturbation
-385-390cm v. slight increase in bioturbation
-390-399cm little bioturbation
-396cm more distinct worm burrow
-350-375cm color change from 5y 4/2 olive grey to 5y 3/2 dark olive grey
-385cm transitional color change to 2.5yr 3/2 v. dark greyish brown.
-398-409 transitional color change to 5y 3.5/2 olive-dark olive grey.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 400-500 cm
LOCATION St. ANNE'S Basin
WATER DEPTH 270 cm Described by: J. Freeman



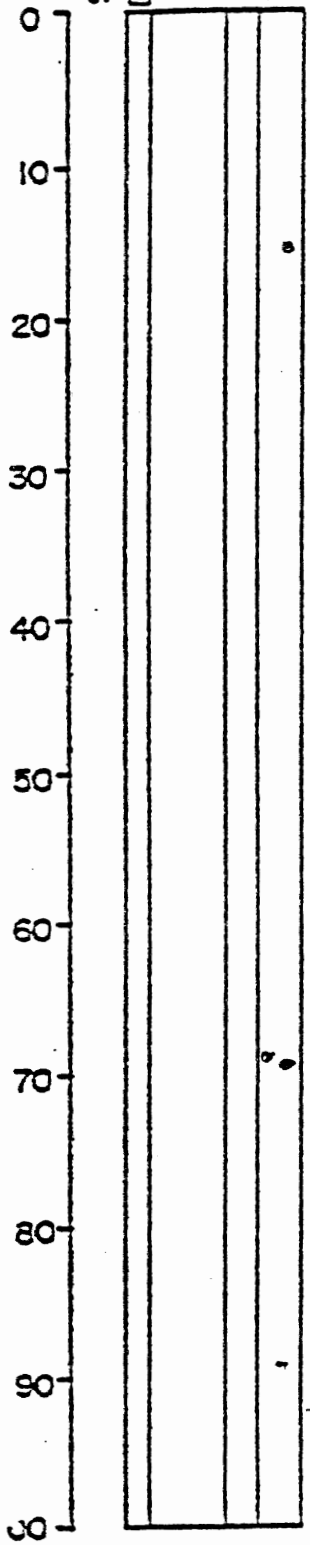
DESCRIPTION

399-423cm - v. little to no bioturbation
402-404cm 4 small shell fragments (approx. 4mm long)
409-443cm v. indistinct banding effect between 5Y 3.5/2 olive-dark olive grey and 2.5Y 3/2 v. dark greyish brown. material becoming stiffer
423-432cm slight increase in bioturbation
432-441cm v. faint bioturbation
441-450cm faint, light banding increasing to v. distinct with a sharp basal contact
443-450cm band of 5Y 4/2 olive grey
448-450cm band of silty material with a sharp basal contact
451cm shell fragment
450-460 almost no bioturbation
455-456cm 2 small shell fragments
460-5cm horizontal worm burrow
460-482cm v. faintly bioturbated
450-478cm continuation of indistinct banding of 5Y 3.5/2 olive-dark olive grey and 2.5Y 3/2 v. dark greyish brown
475-477cm 2 distinct worm burrows
480-488cm larger, vertical worm burrow
478 cm gradation into 5Y 4/2 olive grey. Corresponding to transition from clay mud into clay
488 cm end of section
488-506cm almost no bioturbation
490cm → many cracks due to stiffening material.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 500-600 cm
LOCATION St. Anne's Basin
WATER DEPTH 270m
Described by: J. Freeman



DESCRIPTION

-506-529cm v. little bioturbation

-514cm bleb of shell fragment

-529-593cm almost no bioturbation

-568cm blebs

-589.5cm bleb

-593-606cm some bioturbation

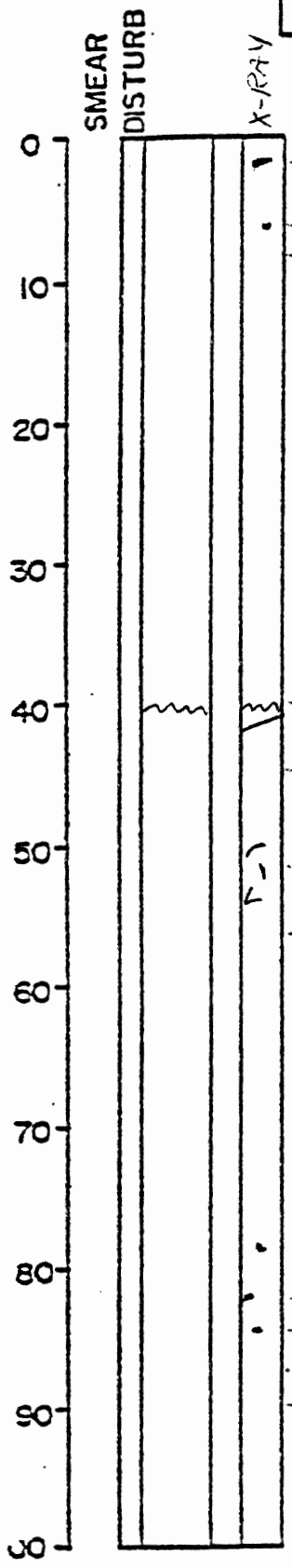
-507-518cm v. gradual color change to a lighter green - not on Munsell chart (emerald green) stiff clay.

-575cm v. slight transition into a brighter green not on Munsell chart but similar to 5Y 4.5/2 olive grey, STIFF, smooth clay.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 600-700cm
LOCATION St. Anne's Basin Described by: J. Freeman
WATER DEPTH 270m



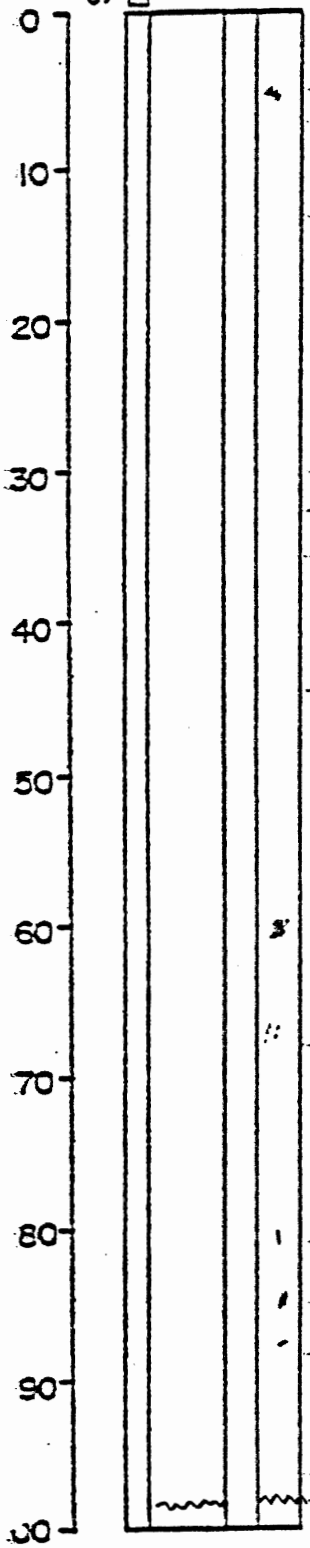
DESCRIPTION

- 602cm small bleb
- 606.5cm small bleb
- 606 - 640 cm v. little bioturbation
- 640cm end of section
- 641cm worm burrow
- 640 - 685cm v. little bioturbation
- 652 - 655cm possible shell fragment
- 655 - 688cm slight increase in bioturbation
- 678 cm bleb
- 682 cm small bleb
- 683.5cm small bleb
- 688 - 705cm slight increase in bioturbation
- 640 - 680cm gradual transition into a slightly paler color of above (not on munsell chart) stiff, smooth clay.

SAMPLE RECORD

General comments:

CORE 84-011-12P DEPTH IN CORE 700-800 cm
LOCATION St. Anne's Basin Described by: J. Freeman
WATER DEPTH 270m



DESCRIPTION

-705.5 cm bleb
-705 - 712 cm slight decrease in bioturbation
-712 - 730 cm almost no bioturbation
-730 - 733 cm some bioturbation
-733 - 736 cm no bioturbation
-736 - 745 cm some bioturbation
-745 - 797 cm almost no bioturbation
-759 - 5 cm bleb - possible shell fragment
-776 - 777 cm small granules
-780 cm bleb
-785.5 cm small bleb
-787 cm small bleb
-794 - 796 cm faint, light band
-797 cm end of section

SAMPLE RECORD

General comments:

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