LATEST PLEISTOCENE-HOLOCENE PALEOCEANOGRAPHIC TRENDS ON THE INNER SCOTIAN SHELF OFF THE SOUTH SHORE OF NOVA SCOTIA: BENTHONIC FORAMINIFERAL EVIDENCE

by

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ABSTRACT

Two piston cores, 78-005-112 and 77-002-15, from the Inner Scotian Shelf off the South Shore of Nova Scotia provide the basis for a micropaleontological study of paleoceanographic trends. The study of benthonic foraminifera provides an accurate determination of paleoenvironments because certain species are restricted to narrow ranges of physical and chemical parameters.

The basal unit of core 78-005-112, with an Elphidium excavatum f. clavata - Cassidulina reniforme faunal assemblage, represents a "warm" ice margin fauna. A barren zone, which overlies the basal faunal assemblage, may signify a rapid change in environment with rapid deposition. A decrease in the ice margin fauna suggests latest glacial or early post-glacial conditions. An assemblage with the co-dominant species of Islandiella teretis and Globobulimina auriculata represents the mid-Holocene hypsithermal. The agglutinated foraminifera of the surface assemblage have been statistically related to Inner Labrador Current water. The Holocene paleoceanography is similar to that reported for offshore basins.

The faunal assemblage of the basal unit of core 77-002-15 represents a shallow, warmer water type of ice margin. An overlying sequence barren of fauna may be related to increased sedimentation rates or lower pH conditions. This event is followed by restricted bay fauna which gradually changes to an open bay assemblage, without Eggerella advena. The fauna of the surface assemblage suggests nearshore conditions, with the addition of some shelf fauna. A radiocarbon date of 14,000 + 200 BP was obtained from the base of the core (400-425 cm). The significance of this date lies in its age and its position relative to sea level. It has been suggested that sea level was 110 m lower than present at 14,000 BP. However, the marine fauna indicates that sea level could not have been 110 m lower at 14,000 BP.

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INTRODUCTION

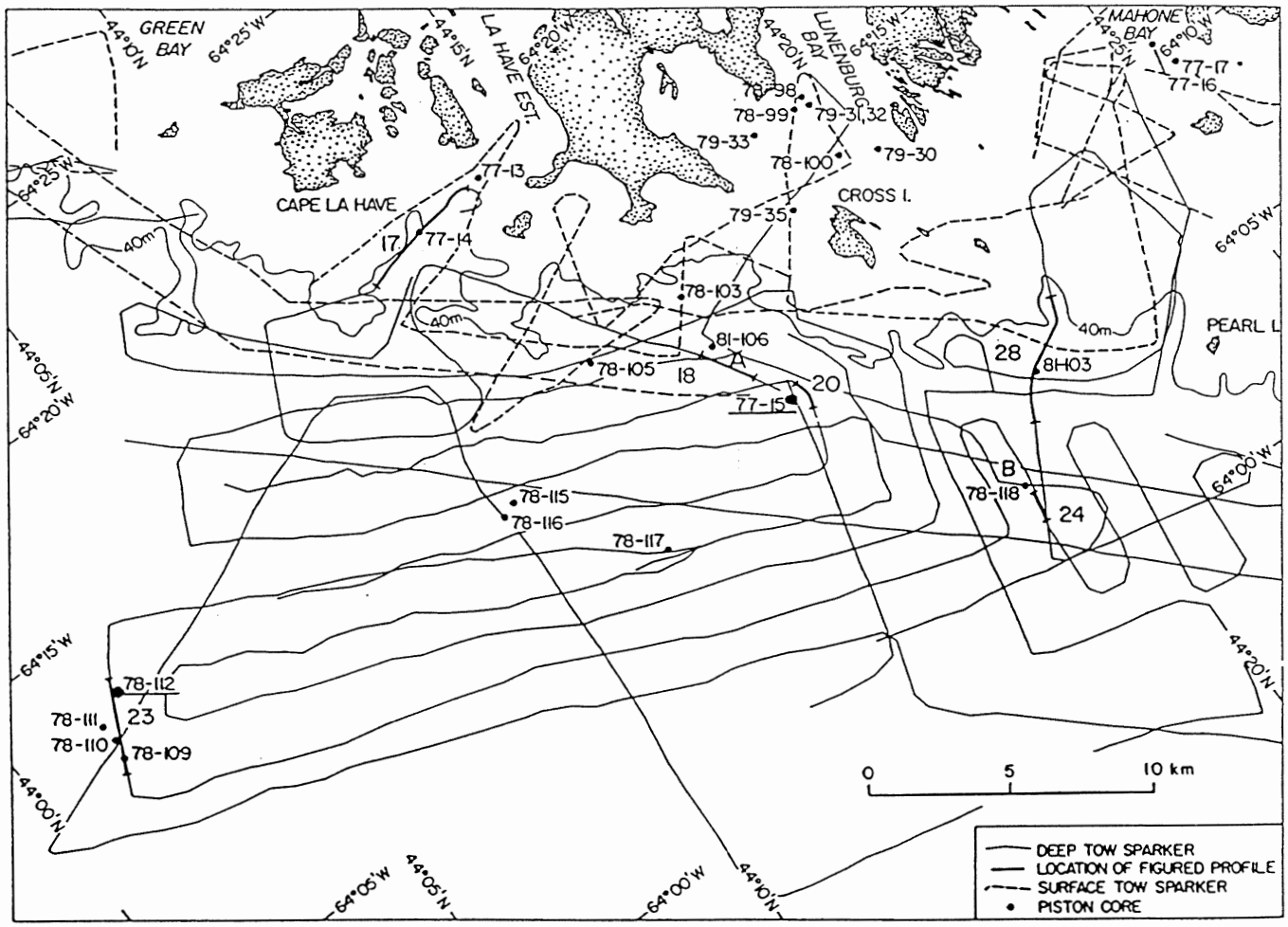
Foraminifera are members of the Phylum Protozoa. The common denominator of all the members of this phylum is their unicellular, or acellular, organization. The phylum is divided into classes on the basis of the type of locomotor apparati present (Boersma, 1977). Because foraminifera are non-flagellate and possess flowing protoplasmic extensions termed pseudopodia, they are placed in the Class Sarcodina.

Foraminifera have two modes of life: planktonic and benthonic. Benthonic foraminifera, of which there are reported to be 10,000 living species, live on the sea bottom or in the water directly above it. Benthonic foraminifera live at all depths of the ocean -- from the marginal marine zones to the abyssal plain (Boltovskoy and Wright, 1976).

Benthonic foraminiferal assemblages are controlled by parameters whose variability and importance change depending on the environment. Environmental variability is high in marginal marine environments and physical parameters (temperature, salinity, elevation relative to sea level, or a temporal variation of these parameters) are the strongest influence on assemblage composition. Due to the sensitivity of some benthonic species to their environment, these species are useful in the reconstruction of paleoenvironments.

By using two piston cores, 78-005-112 and 77-002-15 (see Figure 1), it is the aim of the present work to reconstruct the glacial-postglacial paleoceanography of the inner shelf off Nova

Figure 1: Location of seismic and reflection profiles and cores in study area (Piper et al., 1986).


GREEN BAY
44°0'N
64°25'W
44°15'N
LA HAVE EST.
64°20'W
LUNENBURG BAY
44°20'N
64°15'W
MAHONE BAY
44°25'N
64°10'W
77-17
77-16
79-38
78-99
79-31,32
79-33
78-100
79-30
CAPE LA HAVE
77-13
CROSS I.
79-35
17
77-14
40m
64°25'W
64°05'W
78-103
81-106
78-105
18
20
77-15
28
81H03
PEARL L
44°05'N
64°20'W
B
78-118
24
64°00'W
78-115
78-116
78-117
64°15'W
78-112
23
78-111
78-110
78-109
44°00'N
44°20'N
0
5
10 km
64°05'W
44°05'N
64°00'W
44°10'N
DEEP TOW SPARKER
LOCATION OF FIGURED PROFILE
SURFACE TOW SPARKER
PISTON CORE

Scotia through benthonic foraminiferal assemblages.

PREVIOUS INVESTIGATIONS

There have been relatively few publications dealing with foraminiferal distribution off Nova Scotia, however, the distributions are well known. Bartlett (1964a,b) documented foraminiferal occurrences in St. Mary's Bay and Mahone Bay and, to some extent, on the Inner Scotian Shelf.

Analysis and documentation of the data available for recent foraminifera on the Atlantic Canadian continental shelf indicates locality concentrations (Williamson, 1983). Other areas studied on a localized scale have included the following: Bartlett (1964a) on the southeast continental shelf; Barbieri and Medioli (1969) on the Scotian shelf; Walker (1976), inshore, near Halifax; Clark (1971) off Clam Bay; Scott et al. (1980) off Chezzetcook; and Cole and Ferguson (1975) on Canso Strait foraminifera. A recent foraminiferal study by Williamson (1983) presents an overall synthesis of regional distribution on the continental margin off Nova Scotia.

Mapping of surficial sediments on the Scotian margin, which detailed the distribution of shelf lithologies and sediment facies, was completed by the Geological Survey of Canada (King, 1970; MacLean and King, 1971; Drapeau and King, 1972; Fader et al., 1977; MacLean et al., 1977; King and Fader, 1986). Piper et al. (1986) have completed a thorough investigation of the marine geology off the South Shore, Nova Scotia.

There have been several studies of the physical oceanography of the eastern Canadian margin. Characteristics of waters on the Scotian Shelf are best described by McLennan (1954) and Houghton et al. (1978).

PHYSICAL SETTING

Physiography

The west-southwest trend of the Nova Scotia coastline is approximately parallel to both the strike of the Meguma basement and the continental shelf break. At sea, this structural trend is represented by a series of ridges and depressions which are well developed to the south of Lunenburg as far seaward as the 50 m isobath. Between Port Hebert and Liverpool Bay, a transverse south-southeast trend dominates seafloor relief Piper et al., 1986)

Seaward of the 60 m isobath, the submarine topography becomes irregular with few linear trends. The physiography is also characterized by locally discontinuous, sinuous valleys 1 to 2 km wide and 20 to 50 m deep that, in places, widen into flat-floored basins. These basins slope gently seaward and can occur in a variety of water depths. Isolated shoals rise above the flat-floored basins between the valleys (Piper et al., 1986)

The Scotian Shelf is characterized by a well-defined, rough inner shelf which is an offshore continuation of the land area (King and Fader, 1986). The three main sediment types which are distinguished include muds, sands and gravels.

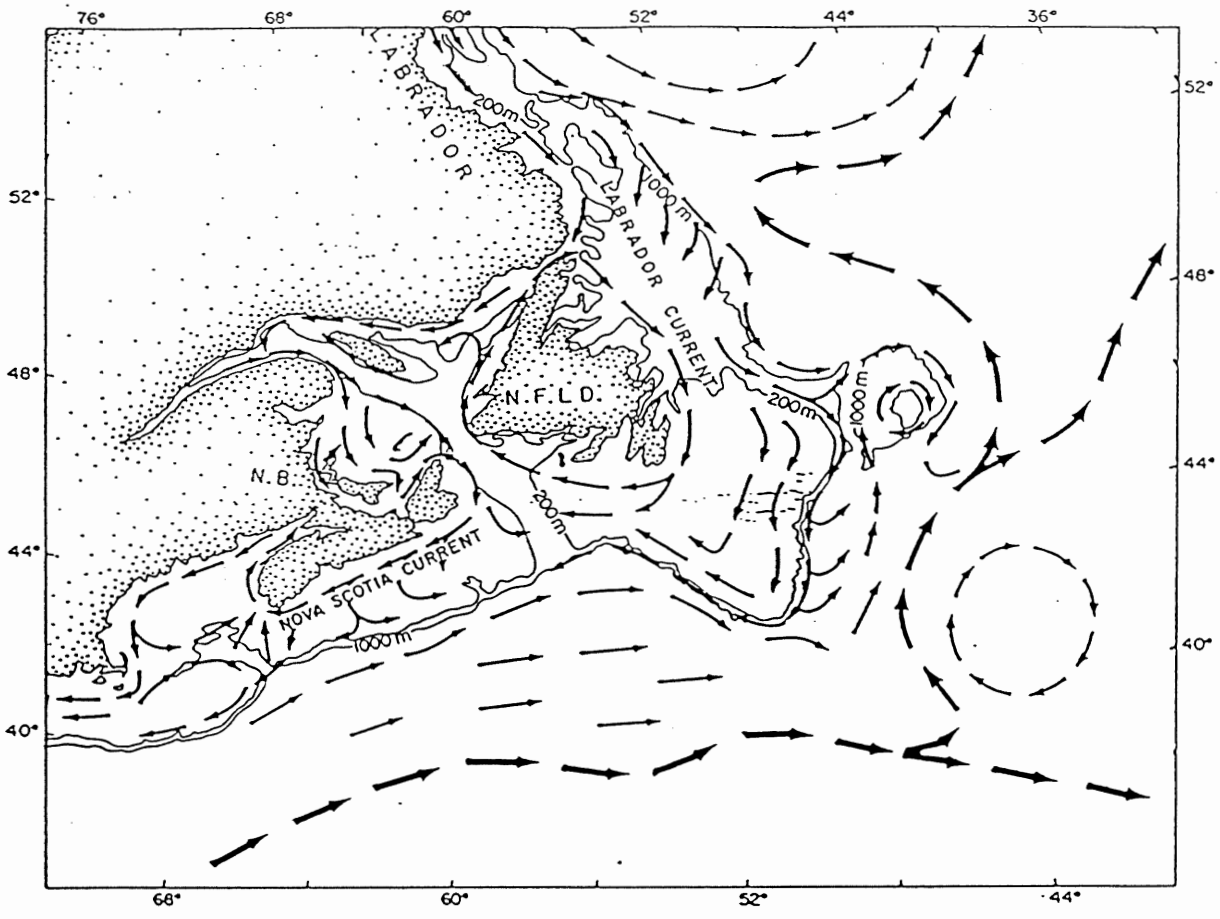
In the nearshore region, predominantly muddy sediments are restricted to sheltered bays. Muds, possibly equivalent to the LaHave Clay of King (1970), also accumulate in basins, with sandy-muds or muddy-sands at basin margins close to major sand bodies (Piper et al., 1986). Predominantly sandy sediments, possibly equivalent to the sand facies of King's (1970) Sable Island Sand and Gravel, are found in basins on the innermost part to the shelf, never more than 4 km from the shore. In most such basins, there is a rapid seaward transition to sandy-gravel of gravelly-sands. The gravelly sediments may be equivalent to the gravel facies of the Sable Island Sand and Gravel (Piper et al., 1986).

Oceanography

Two major current systems carry the continental shelf water off Canada in a southerly direction. The Labrador Current flows over the continental margin off Labrador and over the Grand Banks. The components of the Labrador Current are derived from the West Greenland Current, waters that originate in northern Baffin Bay, with a small but important Hudson Bay component along the inner shelf (Scott et al., 1984). Some Labrador Current water flows into the study area through the Cabot Strait (Fig. 2). This cold, relatively fresh water (<< 33 parts per thousand) continues off Nova Scotia as the southwest-flowing Nova Scotia Current (Williamson, 1983).

The general surface circulation on the Scotian Shelf is cyclonic. The Nova Scotia Current flows to the southwest along

Figure 2: Modern surface oceanographic current patterns present today in the study area (Scott et al., 1984).


76°
68°
60°
52°
44°
36°
52°
48°
44°
40°
LABRADOR
200m
1000m
LABRADOR CURRENT
N.F.L.D.
200m
1000m
N.S.
200m
NOVA SCOTIA CURRENT
1000m

the inner shelf and is then entrained by the northeast-flowing Gulf Stream along the continental margin.

On the Scotian Shelf, both regional temperature and salinity differences in bottom waters are determined by the proportions of the various source waters that have been included in the mixing process (Scott et al., 1984). Waters along the Inner Scotian Shelf are dominated by the colder Cabot Strait (Gulf of St. Lawrence) waters which also contain considerable additions of water from the Inner Labrador Current. The Inner Scotian Shelf bottom water, in particular, is established from the surface water from the Cabot Strait, and has a salinity of 31.8 % and a temperature range of 3 to 6 degrees Celsius (Williamson, 1983).

Acoustic Stratigraphy

Piper et al. (1986) have provided a summary of the acoustic stratigraphy south of Cross Island. Four main acoustic stratigraphic units have been discerned. These units overlie a widespread, discontinuous till unit which rests directly on bedrock and has been termed the early till. Seismic reflection profiles for cores 78-005-112 and 77-002-15 are shown in Figures 3 and 4, respectively.

Unit a is a transparent draped acoustic unit. This unit is composed of cohesive laminated clays passing down into sands and gravels.

Unit b is well stratified and thins rapidly southwards. This unit is probably composed of sands and gravels.

Unit c, a ponded stratified unit, rests unconformably on

Figure 3: Seismic reflection profile through core 78-005-112 showing bedrock (B), till (T) and acoustic units a and d (Piper et al., 1986).

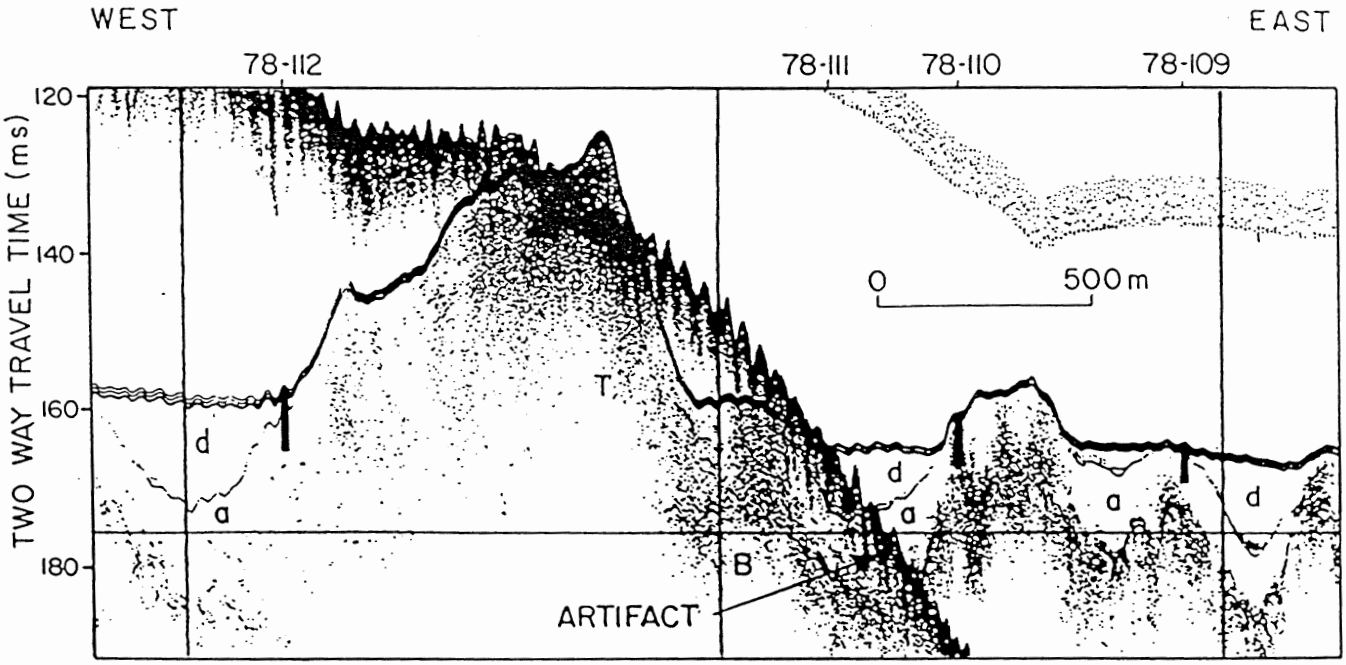
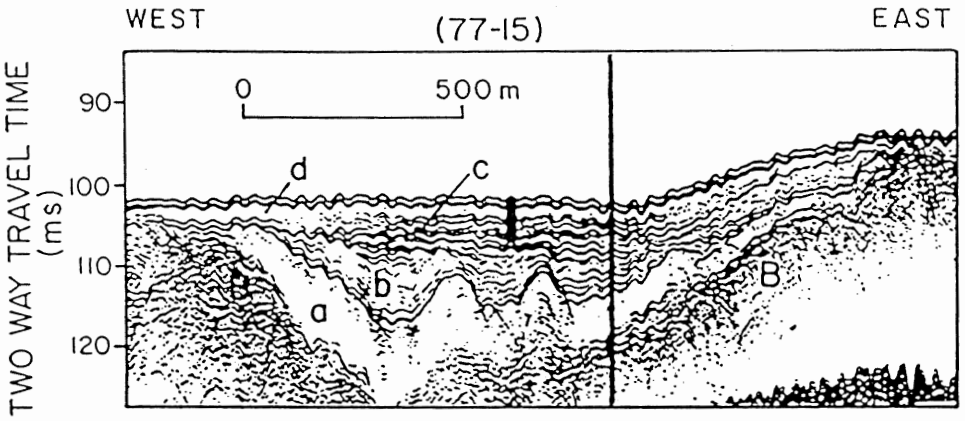

WEST
EAST
78-112
78-111
78-110
78-109
120
140
160
180
TWO WAY TRAVEL TIME (ms)
0
500 m
T
d
a
B
ARTIFACT

Figure 4: Seismic reflection profile through core 77-002-15 showing bedrock (B) and acoustic units a, b, c and d. Core 77-002-15 is 500 m south of the profile in a location with a similar acoustic sequence: vertical bar shows the approximate projection (Piper et al., 1986).


WEST
(77-15)
EAST
0
500 m
90
100
110
120
TWO WAY TRAVEL TIME (ms)
d
c
b
a
B
B

units a and b. Unit c is comprised of cohesive clays passing down into sands and gravels.

Finally, unit d is a ponded, acoustically transparent unit of muds which are probably equivalent to the LaHave Clay (King, 1970).

METHODS

The two piston cores, 77-002-15 and 78-005-112, were X-rayed to provide information on features not seen at the surface of the working half of the core. The sedimentology of the cores was then described using the Munsell soil colour charts.

Ten cubic centimeter samples were extracted from the core at 20 cm intervals. Samples were also extracted above and below sedimentological boundaries. The samples were then wet-sieved through a 500 micron screen to retain sediment clasts, shell fragments and larger foraminiferal specimens. A 63 micron screen, placed below the 500 micron screen, allowed for the retention of the foraminifera. The use of a 63 micron screen is reliable for the retention of smaller species and juvenile species (Schroder et al., 1987). The samples were stored in a mixture of distilled water and denatured alcohol.

In samples containing excess amounts of sand after sieving, a float and sink procedure was used. Sediments were first dried, then sprinkled into carbon tetrachloride to float off the foraminifera, while the denser clastics sank.

Samples with more than 600 specimens were split, using an

Otto microsplitter, into a fraction containing approximately 300 individuals. It has been statistically estimated that a minimum of 300 species must be counted to detect a species that constitutes one percent of the total population with a certainty of 95 percent. Therefore, ecological information obtained from low population counts must be carefully evaluated (Williamson, 1983).

Foraminifera were counted using a binocular microscope at 40x magnification. A type slide was prepared to indicate different species types in the two cores. The photographs of key species were taken at the Bedford Institute of Oceanography using a Cambridge Stereoscan 180 S.E.M. with Polaroid 55 N/P film.

RESULTS

Core 78-005-112

Core 78-002-112 (lat. 44 02.5'N; long. 64 08.55'W) is one of four cores collected 25 km offshore from Cape LaHave in 120 m of water. The core was taken from a sediment-filled valley near the southwest corner of the detailed area south of Cross Island.

From 5.41 to 5.15 m subbottom (msb), there is a short interval with low numbers of species and individuals. This interval is characterized by less than 15 specimens per sample (see Figure 5; Table 1).

The zone from 5.00 to 3.20 msb is represented by several taxa. Numbers of specimens are low (27-116 specimens/20cc), but higher than the lower most section. The most abundant species is Cibicides lobatulus, with lesser percentages of Elphidium excavatum formae (clavata, magna), Islandiella islandica, Elphidium subarcticum, Cassidulina reniforme and Haynesina orbiculare.

From 3.12 to 2.96 msb, species diversity increases significantly with notable additions to the fauna of Nonionellina labradorica and Trifarina fluens; no one species dominates.

The interval from 2.79 to 2.40 is marked by an abrupt decrease in the number of individuals to levels too low for characterization of the fauna.

Starting at 2.22 msb, total populations become abruptly more abundant. Elphidium excavatum f. clavata dominates a long sequence from 2.22 to 0.98 msb. From 2.22 to 1.60 msb, this taxon

Figure 5: Foraminiferal abundances and percentage occurrences of key species in core 78-005-112.

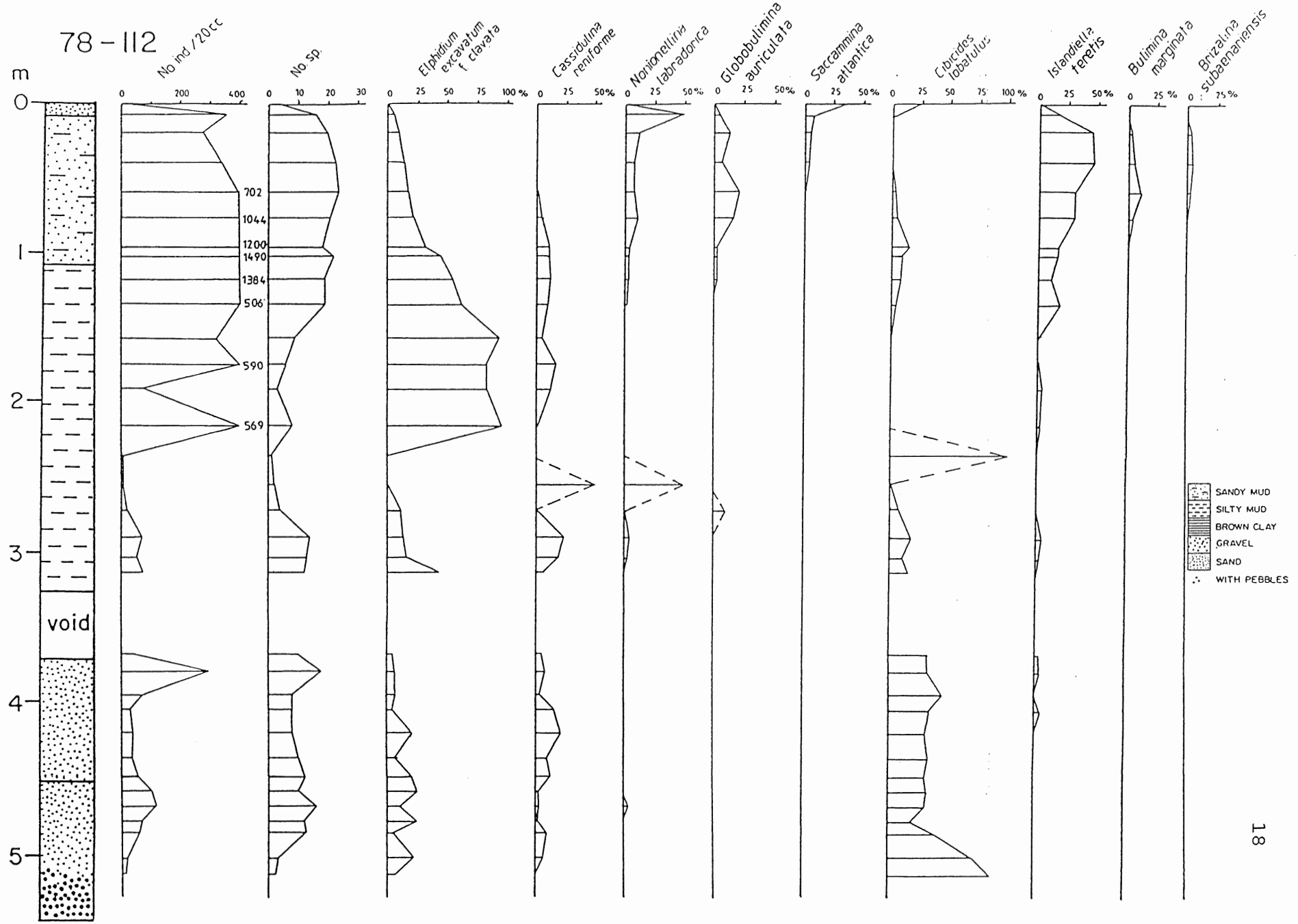

78 - 112
m
0
1
2
3
4
5
void
No ind / 20 cc
0
200
400
No. sp.
0
10
20
30
Elphidium excavatum f. clavata
0
25
50
75
100 %
Cassidulina reniforme
0
25
50%
Nonionellina labradorica
0
25
50%
Globobulimina auriculata
0
25
50%
Saccammina atlantica
0
25
50%
Cibicides lobatulus
0
25
50
75
100 %
Islandiella? teretis
0
25
50%
Bulimina marginata
0
25 %
Brizalina subaenariensis
0
25 %
702
1044
1200
1490
1384
506
590
569
SANDY MUD
SILTY MUD
BROWN CLAY
GRAVEL
SAND
WITH PEBBLES

Table I: Percentage occurrences of foraminiferal species in core 78-05-112 (X = less than 1%, planktonics were not differintiated into species).

Depth in core (cm)	0	7	20	40	60	78	98	104	120	137	160	178	195	220	240	260
No. of species	3	16	20	23	24	21	18	22	19	19	9	6	3	8	1	2
Total no. of individuals/ 20 cc	8	355	274	340	702	1044	1200	1490	1384	506	319	590	88	569	1	2
Ammobaculites sp.	37															
Astrononion gallowayi		X	X		X	X	1	X	X		X					
Brizalina pseudopunctata				R				R								
Brizalina subaenariensis			1	3	R											
Buccella frigida		8			R	1	2	2	2	R						
Bulimina aculeata				R			2									
Bulimina marginata			1	5	11	3		R	R							
Buliminella elegantissima			R	R												
Cassidulina reniforme				R	R	3	10	10	11	8	3	15	12	1		50
Cibicides lobatulus	25	2		R	3	4	16	15	9	6	R	R		R	100	
Cribrostomoides crassimargo		R														
Eggerella advena			1	R	R					R						
Elphidium bartletti					R	R		R	R	R	2			1		
Elphidium excavatum f. clavata		5	9	13	17	22	33	42	54	60	91	83	85	95		
Elphidium excavatum f. magna																
Elphidium excavatum f. selseyensis					R											
Elphidium subarcticum			R	R	R	R	3	R	1	R		R				
Epistominella exigua						R										
Epistominella takayanagii							R									
Fissurina marginata		1			R	R		R	R	R						
Fursenkoina fusiformis		R	1	4	4	7	2	3	4	2		R		R		
Fursenkoina loeblichi				R												
Glabratella wrightii								R								
Globobulimina auriculata		4	13	11	20	15	2	3	2	R						
Haynesina orbiculare					R	R	2	R			R			1		
Islandiella islandica			2	R	2	1	3	2	R	1	R			R		
Islandiella teretis		18	46	47	30	28	15	16	11	17	R	1	3	R		
Lagena sp.			R	R	R	R	2	R	R							
Nonionella turgida		R	R	R	R	3	1	R	R	R						
Nonionellina labradorica		50	12	7	7	9	4	3	3	R						50
Oolina sp.			R			R	1	R	R	R						
Quinqueloculina seminulum																
Reophax scorpiurus										R						
Saccammina atlantica	38	7	6	4	1			R		R						
Trifarina fluens		R	2	R	R	R	2		R	R						
Trochammina ochracea		R	R	R												
Trochammina squamata		R	R	R	R											
planktonics		R	R	R	R	R	R	R	R	R	R					

Depth in core (cm)	277	296	310	320	376	388	404	414	430	447	460	470	480	490	498	515	526
No. of species	4	14	13	12	10	18	8	8	8	10	12	10	16	12	13	3	2
Total no. of individuals/ 20 cc	18	66	50	72	29	299	63	27	35	33	55	102	116	70	59	14	8
Ammobaculites sp.																	
Astrononion gallowayi				3													
Brizalina pseudopunctata																	
Brizalina subaenariensis																	
Buccella frigida				1	3	H				3	4		H	3	3		
Bulimina aculeata																	
Bulimina marginata																	
Buliminella elegantissima																	
Cassidulina reniforme		24	18	7	10	7	2	15	20	9	13	2	3	1	10	7	
Cibicides lobatulus	6	17	10	14	31	32	44	33	29	33	27	30	28	17	32	72	88
Cribrostomoides crassimargo																	
Eggerella advena																	
Elphidium bartletti	72	1	6	1	3	3	6	7		3	2		4	4	10		
Elphidium excavatum f. clavata	11	15	16	44	3	12	13	4	20	6	20	25	9	24	3	21	12
Elphidium excavatum f. magna					7	2			6	9	5		4	6	2		
Elphidium excavatum f. selseyensis																	
Elphidium subarcticum		3	8	6	21	12	9		8	6	2	13	18	13	8		
Epistominella exigua																	
Epistominella takayanagii											2						
Fissurina marginata			2	1		2											
Fursenkoina fusiformis						3							H				
Fursenkoina loeblichi																	
Glabratella wrightii																	
Globobulimina auriculata	11			1													
Haynesina orbiculare		5	18	10	3	5	2	15	6	3	4		4	6	5		
Islandiella islandica		5	4	10	14	11	13	15	8	24	11	17	11	17	14		
Islandiella teretis		5	2	1	3	4		7							3		
Lagena sp.		3	2			2						3	4	6			
Nonionella turgida		3				1											
Nonionellina labradorica		3	2			H							4				
Oolina sp.		8	2			H			3		5	H	2	1	3		
Quinqueloculina seminulum						4		4					2		2		
Reophax scorpiurus																	
Saccammina atlantica																	
Triforina fluens		8	10			2	5				5	4	4	1			
Trochammina ochracea																	
Trochammina squamata																	
planktonics		1								3		H	H		3		

comprises 83 to 95 percent of the assemblage. This interval is also characterized by an increased abundance of Cassidulina reniforme.

Percentages of E. excavatum f. clavata range from 33 to 60 percent from 1.39 to 0.98 msb. This interval is characterized by increased amounts of Islandiella teretis and Cibicides lobatulus, together with low but significant percentages of Nonionellina labradorica and Globobulimina auriculata. The number of individuals increases dramatically during this interval.

In a short interval from 0.80 to 0.40 msb, Islandiella teretis is the dominant species, with Bulimina marginata, G. auriculata, N. labradorica and E. excavatum f. clavata as sub-dominants. There are also lesser, but important, percentages of Brizalina subaenariensis.

Between 0.20 and 0.07 msb, E. excavatum f. clavata decreases with a resulting increase in N. labradorica. From 0.02 to 0 msb, Saccammina atlantica dominates with Ammobaculites spp. in a low number assemblage.

Core 77-002-15

Core 77-002-15 (lat. 44 16.05'N; long. 64 08.55'W) was collected from an inner shelf basin, five km southeast of Cross Island, in 66 m water depth.

The interval from 5.43 to 2.62 msb is dominated by three species: Elphidium excavatum f. clavata, Eggerella advena and Cassidulina reniforme. There are also significant percentages of

Figure 6: Foraminiferal abundances and percentage occurrence of key species in core 77-002-15.

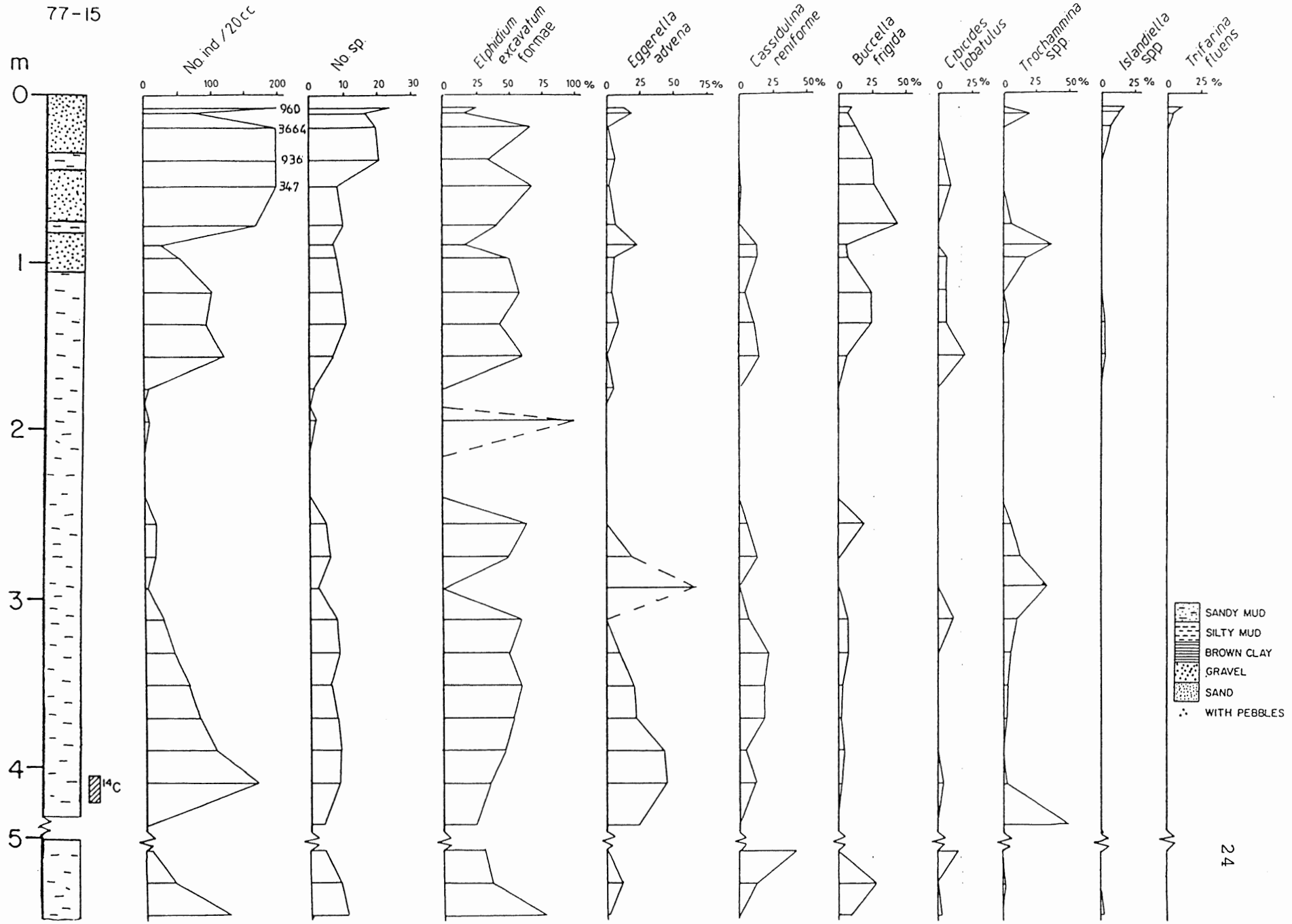

77-15
m
0
1
2
3
4
5
No ind / 20 cc
0
100
200
960
3664
936
347
No sp.
0
10
20
30
Elphidium excavatum formae
0
25
50
75
100 %
Eggerella advena
0
25
50
75%
Cassidulina reniforme
0
25
50%
Buccella frigida
0
25
50%
Cibicides lobatulus
0
25%
Trochammina spp
0
25
50%
Islandiella spp
0
25 %
Trifarina fluens
0
25 %
14C
SANDY MUD
SILTY MUD
BROWN CLAY
GRAVEL
SAND
WITH PEBBLES

Table II: Percentage occurrences of foraminiferal species in core 77-002-15 (X = less than 1%, planktonics were not differentiated into species).

Depth in core (cm)	0	11	20	40	56	80	92	100	121	140	160	180	191	200	220
No. of species	24	17	15	21	8	10	7	8	10	11	7	1		2	
Total no. of individuals/20 cc	347	71	960	3664	936	169	25	53	103	92	119	4		8	
Ammobuculites sp.	X														
Astrononion gallowayi	1	1	1	5	R	R					2				
Bolivina pseudoplicata				R											
Brizalina pseudoplicata															
Buccella frigida	8	6	13	25	27	43	4	6	24	24	6				
Buliminella elegantissma					R										
Cassidulina reniforme		1		1	2		12	13	3	11	14				
Cibicides lobatulus	2		4	9		R		6	5	5	18				
Eggerella advena	13	20	R	7	1	6	24	6	3	9		4			
Elphidium bartletti	3		R	R		R			R	3					
Elphidium excavatum f. clavata	26	17	67	34	67	35	16	51	58	41	58			88	
Elphidium excavatum f. selseyensis						4			3					12	
Elphidium subarcticum	6		3	5											
Fissurina marginata	2	1	R	2											
Fursenkoina fusiformis	1		R	2	R						R				
Glabratella wrightii				R						1					
Globobulimina auriculata	R														
Guttulina lactea	R			R											
Haynesina orbiculare		6		4											
Islandiella islandica	12	10	7	R					R	1	2				
Islandiella teretis	3	3	R												
Lagena sp.	R	1	R	R		1									
Nonionella turgida	R														
Nonionellina labradorica	4	6													
Oolina sp.	1		R												
Patellina corrugata				R											
Quinqueloculina seminulum					2										
Reophax gracilis										1					
Rosalina columbiensis															
Saccammina atlantica	2	3													
Spiroplectammina biformis	R														
Textularia earlandi				R											
Triforina fluens	10	4	R						R						
Trochammina inflata		1													
Trochammina ochracea	R	7		R			12	4	R	1					
Trochammina squamata	3	11		R		7	24	11		2					
planktonics	R	1	R	R		2	0	4							

Depth in core (cm)	232	246	262	282	301	320	340	360	380	400	420	445	501	520	540
No. of species			5	6	2	8	9	6	8	9	9	4	4	9	11
Total no. of individuals/20 cc			17	16	3	27	45	65	81	106	170	4	14	43	144
Ammobuculites sp.															
Astrononion gallowayi															
Bolivina pseudoplicata															
Brizalina pseudoplicata						4	4						14	2	
Buccella frigida			18			7	7	2	1	3	1			28	10
Buliminella elegantissma															
Cassidulina reniforme			6	13		7	20	17	16	3	11		43	12	2
Cibicides lobatulus						11				H	4		14		2
Eggerella advena				19	67		9	20	23	42	44	25		12	1
Elphidium bartletti							4			H	2				3
Elphidium excavatum f. clavata			65	50		59	49	58	52	47	35	25	29	37	38
Elphidium excavatum f. selseyensis															39
Elphidium subarcticum															
Fissurina marginata			6			4									
Fursenkoina fusiformis															
Glabratella wrightii															
Globobulimina auriculata															
Guttulina lactea															
Haynesina orbiculare															
Islandiella islandica															2
Islandiella teretis															
Lagena sp.							2	2	4	H	H			2	
Nonionella turgida															
Nonionellina labradorica				6										2	
Oolina sp.															
Patellina corrugata															
Quinqueloculina seminulum										H				2	2
Reophax gracilis															
Rosalina columbiensis									1		H				
Saccammina atlantica															
Spiroplectammina biformis															
Textularia earlandi															
Trifarina fluens															H
Trochammina inflata															
Trochammina ochracea				6	33	4	2	2	1			25			
Trochammina squamata			6	6		4	2		1	H	2	25		2	H
planktonics															

Buccella frigida near the top and bottom of this interval (see Figure 6; Table II), and persistent but low occurrences of Trochammina spp. Part of the core, from 5.00 to 4.50 msb, is missing.

From 2.48 to 1.80 msb, there is a barren or near-barren sequence except for small numbers of E. excavatum f. clavata and Elphidium excavatum f. selseyensis from 2.02 to 2.00 msb, and small numbers of E. advena from 1.82 to 1.80 msb. The interval from 2.48 to 1.80 msb is characterized by high organic content.

From 1.60 to 0.92 msb, there is a long sequence in which the two main species are E. excavatum f. clavata and B. frigida. There are also lesser percentages of E. advena, C. reniforme and C. lobatulus. At the bottom of this interval, the percentages of E. excavatum f. clavata and B. frigida are greater, but decrease toward the top of the interval. At the top of this interval, the percentages of E. advena, Trochammina squamata and T. ochracea increase.

From 0.80 to 0.20 msb, the dominant species are E. excavatum f. clavata and B. frigida, often comprising up to 80 percent of the fauna. There are minor of C. lobatulus and E. advena.

From 0.13 to 0.08 msb, the dominant species are E. excavatum f. clavata, E. advena and Islandiella islandica. Islandiella teretis, B. frigida and Nonionellina labradorica are present, but with smaller percentages. There are also increased percentages of T. ochracea and T. squamata.

SIGNIFICANCE OF FORAMINIFERAL FAUNAS

Core 78-005-112

This core exhibits a biostratigraphic sequence which has been observed in other cores on this shelf; however, this core is in relatively shallow water. A late glacial fauna is dominated (30-90 percent) by Elphidium excavatum f. clavata; an early post-glacial fauna dominated by Islandiella teretis; a mid-Holocene fauna which contains Nonionellina labradorica and Globobulimina auriculata with reduced E. excavatum clavata; and, finally, an agglutinated low-number fauna in the late Holocene (Scott et al., 1984).

Elphidium excavatum f. clavata - Cassidulina reniforme assemblages dominate late glacial deposits in nearshore zones on both sides of the Atlantic Ocean (Vilks, 1981).

At present, the distribution of E. excavatum f. clavata may represent over 20 percent of the total population in areas that are characterized by winter ice and by surface waters having reduced salinities (for example, arctic and cold-temperate waters). Some of these areas include the continental shelf off southeastern Beaufort Sea (Vilks et al., 1979), Hudson Bay (Leslie, 1965) and Bay of Fundy (Scott and Medioli, 1980). Surface sediments, however, on the continental shelf off Nova Scotia and Labrador are almost barren of E. excavatum f. clavata, while in sub-surface fossil sediments there are increasing percentages of the E. excavatum f. clavata assemblage. Scott et al. (1984) have suggested that the large amounts of meltwater

occurring along the former ice margin produced an estuarine-like environment.

The basal unit, from 5.41 to 3.76 msb, is dominated by Cibicides lobatulus. The distribution of this species, as well as Islandiella islandica, seems to be constrained by the character of the local substrate, which is a function of energy in the environment. In particular, these two species are restricted to coarse sand, gravel and rough bedrock (Williamson et al., 1984). Significant correlations have been made with I. islandica with higher salinity and percent gravel.

Starting at 3.22 msb, the assemblage of E. excavatum f. clavata and C. reniforme dominates the core. It has been proposed that the E. excavatum f. clavata - C. reniforme fauna represents a "warm" ice margin fauna (Vilks, 1981; Scott and Medioli, 1980). This fauna represents an adjacent ice margin where sea-water temperatures were relatively high as compared with present-day glacial marine environments in the Canadian Arctic (Scott et al., 1984).

The barren zone from 2.79 to 2.40 msb may signify a rapid change in environment with rapid deposition. This is supported by the higher diversity fauna below this level and the lower diversity, typical ice-margin fauna above it.

From 2.22 to 0.70 msb, the co-dominance of E. excavatum f. clavata and C. reniforme represents the "warm" ice margin environment. From 1.39 to 0.98 msb, the decrease in percentage of E. excavatum f. clavata and C. reniforme species, together with

increased I. teretis, G. auriculata and N. labradorica suggests latest glacial or early post-glacial conditions. Because there are no modern analogues, the temperature and salinity which the E. excavatum f. clavata - C. reniforme assemblage typifies is unknown. However, the increase in other species suggests increases in salinity; that is, there is less meltwater.

From 0.80 to 0.07 msb, the co-dominant species of the assemblage are I. teretis and G. auriculata, with the subdominant species N. labradorica, Bulimina marginata and Brizalina subaenariensis. Elphidium excavatum f. clavata is greatly reduced. This assemblage presently occurs over a large part of the Emerald and LaHave Basins. This assemblage has been statistically related to normal marine salinities (34-35 parts per thousand) and warmer waters (8-12 C) (Williamson, 1984). Scott et al. (1984) have related a similar assemblage on the northern Scotian shelf to the mid-Holocene hypsithermal.

The increase in Saccammina atlantica toward the top of the core may be explained by an area of intense temperature and salinity gradients (Williamson, 1984). In present-day waters, this gradient is explained by the juxtaposition of slope-derived central basin waters with water of the Labrador and Nova Scotia currents.

The surface assemblage is dominated by S. atlantica and Ammobaculites spp. This faunal type has been statistically related to cold (1-2 C) and relatively fresh (31-33 parts per thousand) water of Inner Labrador current origin which now flows

across the inner Scotian Shelf (Mudie et al., 1983).

Core 77-002-15

The assemblage of the basal unit, from 5.43 to 2.62 msb, is similar to the restricted bay fauna discussed by Bartlett (1964b) or the open bay fauna of Scott et al. (1980). The open bay fauna is characterized by species like Eggerella advena and E. excavatum f. clavata, but not the C. reniforme which occurs in the interval. This interval is additionally characterized by the presence of shallow water, nearshore forms such as Trochammina squamata, Trochammina ochracea, Buccella frigida and Cibicides lobatulus. The combination of E. excavatum f. clavata and C. reniforme suggests a warm ice margin and the additional species may represent a shallow, warmer water type of ice margin.

At present, on the continental shelf off Nova Scotia, Eggerella advena is restricted to Chedabucto, Gaberous, Mahone and St. Margeret's Bays and to shallow banks off Sable Island; however, it is a common estuary species (Scott et al., 1980). This species is strongly correlated with depth and percent sand; the species is inversely correlated with percent mud.

From 3.01 to 1.80 msb, there is a sequence barren or nearly barren of fauna. The sparseness of the foraminiferal tests may indicate the occurrence of conditions too severe for biological activity (Vilks, 1969). Also, the sedimentation rate may have increased during this time, thereby diluting the tests. This interval is characterized by a large amount of organic matter.

This organic matter may have caused low pH conditions that dissolved the calcareous forms.

From 1.60 to 0.92 msb, the fauna represents the restricted bay fauna described by Bartlett (1964b). However, the increased percentages of Buccella frigida, Cassidulina reniforme and Cibicides lobatulus indicate an increasing open bay influence.

From 0.82 to 0.20 msb, there is an open bay assemblage, without Eggerella advena. This assemblage closely resembles the open bay assemblage of Bartlett (1964b). From 0.13 msb to the surface, additional species such as Cibicides lobatulus, Fissurina marginata, Globobulimina auriculata and Nonionellina labradorica suggest nearshore conditions. However, this interval is characterized by the addition of shelf fauna such as Astrononion gallowayi, Trifarina fluens, Islandiella islandica and Haynesina orbiculare.

A radiocarbon date of 14,000 + 200 BP (I-10467) was obtained from total organic carbon in the mud from the base of the core (400-425 cm). Palynological samples taken from the base of the core contained low numbers of pre-Quaternary palynomorphs and very little reworked thermally altered kerogen. These facts help support the validity or accuracy of the radiocarbon date (Piper et al.,1986). The significance of this date lies in its age and its position relative to sea level.

DISCUSSION

Core 78-005-112

The Holocene paleoceanography that is observed in core 78-005-112 is similar to the paleoceanography reported in offshore basins. Distinct Late Pleistocene-Holocene paleoceanographic events have been observed, for example, in the Emerald and Canso Basins (Scott et al., 1984; Vilks and Rashid, 1976).

In the Canso Bank Basin, core 80-004-33 is 11 m in length and contains a complete Holocene section. The basal unit of core 80-004-33 (1060-1064 cm) is dominated by an E. excavatum f. clavata - C. reniforme assemblage. This section can probably be related to the early post-glacial section of core 78-005-112 from 1.06 to 0.98 msb. Other paleoceanographic events that may be correlated between the two cores include an early post-glacial phase, the Holocene hypsithermal, and the present-day climatic cooling influence of the Inner Labrador Current.

Core 77-002-15

In present day conditions, Eggerella advena is the most common arenaceous foraminiferal species in bay environments. E. advena is also characteristic of the nearshore biofacies where it is frequently associated with Elphidium spp. (Bartlett, 1964b).

The significance of E. advena in the glacial sequence of core 77-002-15 is that it has not been observed in other ice margin fauna. The presence of E. advena may be related to the physical

conditions of at the core site (for example, the nature of the substrate). The occurrence of this species with the ice margin fauna may also be related to the water level.

The basal unit of core 77-002-15, from 5.43 to 2.62 msb, is characterized by open bay fauna. However, this interval is also typlified by nearshore foraminifera. The nearshore area is usually marked by coarser substrates (silts, sands and gravels), lower temperature and turbulence. The open bay biofacies, with its greater depths, is a dumping area for taxa transported from landward biofacies - this may explain the occurrence of nearshore fauna with bay fauna. The presence of nearshore fauna with the "warm" ice margin fauna may indicate the deposition of tests in shallower water than the ice margin fauna is usually deposited.

The period from 16,000 to 10,000 BP represents the period of lowest sea level, its subsequent transgression, and the disappearance of ice influence in the offshore (King and Fader, (1986). The age of a submarine terrace, which marks the position of the lowest sea level, has been dated as between 15,100 and 14,465 BP (King and Fader, 1986). Milliman and Emery (1968) suggested that the lowest stand of 125 m occurred at 15,000 BP. King and Fader (1986) have estimated that low stand of elevation at 14,000 BP was 110 m lower than at present. The marine sequence of core 77-002-15 occurs at 66 m below present sea level. At 14,000 BP in core 77-002-15, the faunal assemblage is comprised of E. excavatum f. clavata, Eggerella advena and Cassidulina reniforme. The presence of marine fauna suggests that sea level

could not have been more than about 60 m lower than present, not 110 m lower as suggested by (King and Fader, 1986).

Piper et al. (1986) have stated that the deposition of mud at 14000 BP in core 77-002-15 may be due to either a 60 m lowering of sea level or ice-damping of waves at a time when sea level was high. The former explanation is consistent with the hypothesis of gradual rise in sea level.

CONCLUSIONS

78-005-112:

- a late-glacial fauna is dominated by an Elphidium excavatum f. clavata - Cassidulina reniforme assemblage.

- the onset of the early post-glacial is represented by the presence of Islandiella teretis.

- the mid-Holocene hypsithermal is represented by a faunal assemblage comprised of co-dominants Globobulimina auriculata and Nonionellina labradorica as well as Islandiella teretis, Bulimina marginata and Brizalina subaenariensis.

- the modern foraminiferal assemblage in core 78-005-112 is dominated by agglutinated foraminifera, such as Saccammina atlantica, which have been related to waters of the Inner Labrador Current.

77-002-15:

- an open bay fauna dominates the basal unit of this core, with species such as Eggerella advena and Elphidium excavatum f. clavata. The nearshore foraminifera present indicate a shallower,

warm water type of ice margin.

- a barren section is followed by a restricted bay fauna, with increasing open bay influences towards the top of the core.

- the surface fauna indicates nearshore conditions.

- marine fauna indicate that sea level could not have been more than about 60m lower than present.

Regarding both cores:

- in both cores, periods of environmental stress or high sedimentation rate have resulted in a sequence barren or nearly barren of fauna. The high sedimentation rate may be related to the large amounts of meltwater occurring along the former ice margin, producing estuarine-like conditions. The large amount of organic material in core 77-002-15 suggests that pH was lowered, thereby dissolving the calcareous tests.

SYSTEMATIC TAXONOMY

The following foraminiferal species have been compared with the type collection of M. Williamson. Other primary references have included Williamson (1983), Vilks (1969) and Scott (1987). The format for the systematic taxonomy follows the Ocean Drilling Program format. The 39 benthonic species are listed in alphabetical order with respect to genus name. Specimens of the Lagena, Oolina and Ammobaculites families were identified to genus level only.

Ammobuculites spp. Cushman, 1910

Astrononion gallowayi Loeblich and Tappan

Astrononion gallowayi Loeblich and Tappan, 1953, p. 90, pl. 17, figs. 4-7.

Bolivina pseudoplicata Heron-Allen and Earland

Bolivina pseudoplicata Heron-Allen and Earland, 1930, p.81, pl. 3 figs. 36-40.

Brizalina pseudopunctata (Hoeglund)

(Plate 1, Fig. 9)

Bolivina pseudopunctata Hoeglund, 1947, p. 273, pl. 24, fig. 5, pl. 32, figs. 23, 24.

Brizalina subaenariensis (Cushman)

(Plate 1, Fig. 10)

Bolivina subaenariensis Cushman, 1922a, p. 46, pl. 7, fig. 6.

Buccella frigida (Cushman)

Pulvinulina frigida Cushman, 1922b, p. 144.

Bulimina aculeata d'Orbigny

(Plate 1, Fig. 3)

Bulimina aculeata d'Orbigny, 1826, p. 269, no. 7.

Bulimina marginata d'Orbigny

Bulimina marginata d'Orbigny, 1826, p. 269, pl. 12, figs. 10, 12.

Buliminella elegantissima (d'Orbigny)

Bulimina elegantissima d'Orbigny, 1839, p. 51, pl. 7, figs. 13, 14.

Cassidulina reniforme Norvang

(Plate 2, Figs. 11, 12)

Cassidulina crassa d'Orbigny var. reniforme Norvang, 1945, p. 41, text figs. 6c-h.

Cibicides lobatulus (Walker and Jacob)

Nautilus lobatulus Walker and Jacob in Kanmacher, 1798, p.642, pl. 14, fig. 36.

Cribrostomides crassimargo (Norman)

Haplophragmium crassimargo Norman, 1892, p.17.

Eggerella advena (Cushman)

Verneuilina advena Cushman, 1922a, p. 141.

Elphidium bartletti (Cushman)

Elphidium bartletti Cushman, 1933, p. 4, pl. 1, fig. 9.

Elphidium excavatum (Terquem) formae

Formae used in this paper are informed taxonomic designations that are described in detail in Miller et al., 1982.

Elphidium subarcticum Cushman

(Plate 1, Fig. 18)

Elphidium subarcticum Cushman, 1944, p. 27, pl. 3, figs. 34, 35.

Epistominella exigua (Brady)

(Plate 2, Figs. 8, 9)

Pulvinulina exigua Brady, 1884, p. 696, pl. 103, figs. 13, 14.

Epistominella takayanagii Iwasa

(Plate 2, Figs. 5-7)

Epistominella takayanagii Iwasa, 1955, p. 16, 17, text figs. 4a-c.

Fissurina marginata (Montagu)

Vermiculum marginatum Montagu, 1803, p. 524.

Fursenkoina fusiformis (Williamson)

(Plate 1, Figs. 12, 13)

Bulimina pupoides d'Orbigny var. fusiformis Williamson, 1858, p. 64, pl. 5, figs. 129, 130.

Fursenkoina loeblichi (Williamson)

Glabratella wrightii (Brady)

Discorbina auriculata Brady, 1881, p. 413, pl. 21, fig. 6.

Globobulimina auriculata (Bailey)

Bulimina auriculata Bailey, 1851, p. 12, pl. 1, figs. 25-27.

Guttulina lactea

Haynesina orbiculare (Brady)

Nonionia orbiculare Brady, 1881, p. 415, pl. 21, fig. 5.

Islandiella teretis (Tappan)

(Plate 2, Fig. 13)

Cassidulina teretis Tappan, 1951, p. 7, pl. 1, figs. 30a-c.

Islandiella islandica (Norvang)

Cassidulina islandica Norvang, 1945, p. 41, text-figs. 7-8.

Lagena spp. Walker and Jacob

Genus Lagena Walker and Jacob in Kanmacher, 1798.

Nonionella turigida (Williamson)

(Plate 1, Figs. 21, 22)

Rotalina turigida Williamson, 1858, p. 50, pl. 4, figs. 95-97.

Nonionellina labradorica (Dawson)

Nononina labradorica Dawson, 1860, p. 191, fig. 4.

Oolina spp.

Genus Oolina

Patellina corrugata Williamson

Patellina corrugata Williamson, 1858, p. 46, pl. 3, figs. 86-89.

Quinqueloculina seminulum (Linne)

Serpula seminulum Linne, 1758, p. 786.

Reophax gracilis (Kiaer)

Nodulina gracilis Kiaer, 1900, p. 24, text-figs. 1-2.

Reophax scorpiurus (de Montfort)

Reophax scorpiurus de Montfort, 1808, p.330.

Rosalina columbiensis (Cushman)

Discorbis columbiensis Cushman, 1925, p. 43, pl. 6, fig. 13.

Saccammina atlantica (Cushman)

Proteonina atlantica Cushman, 1944, p. 5, pl. 1, fig. 4.

Spiroplectammina biformis (Parker and Jones)

Textularia agglutinans d'Orbigny var. biformis Parker and Jones, 1865, p. 370, pl. 15, figs. 23, 24.

Textularia earlandi Parker

Textularia earlandi Parker, 1952a, p. 458 (footnote).

Trifarina fluens (Todd)

Anglogerina fluens Todd in Cushman and Todd, 1947, p. 67, pl. 16, figs. 6, 7.

Trochammina "inflata"?

Trochammina inflata (Montagu), Williamson, 1983, p. 212, pl. 2, figs. 12, 13.

Trochammina ochracea (Williamson)

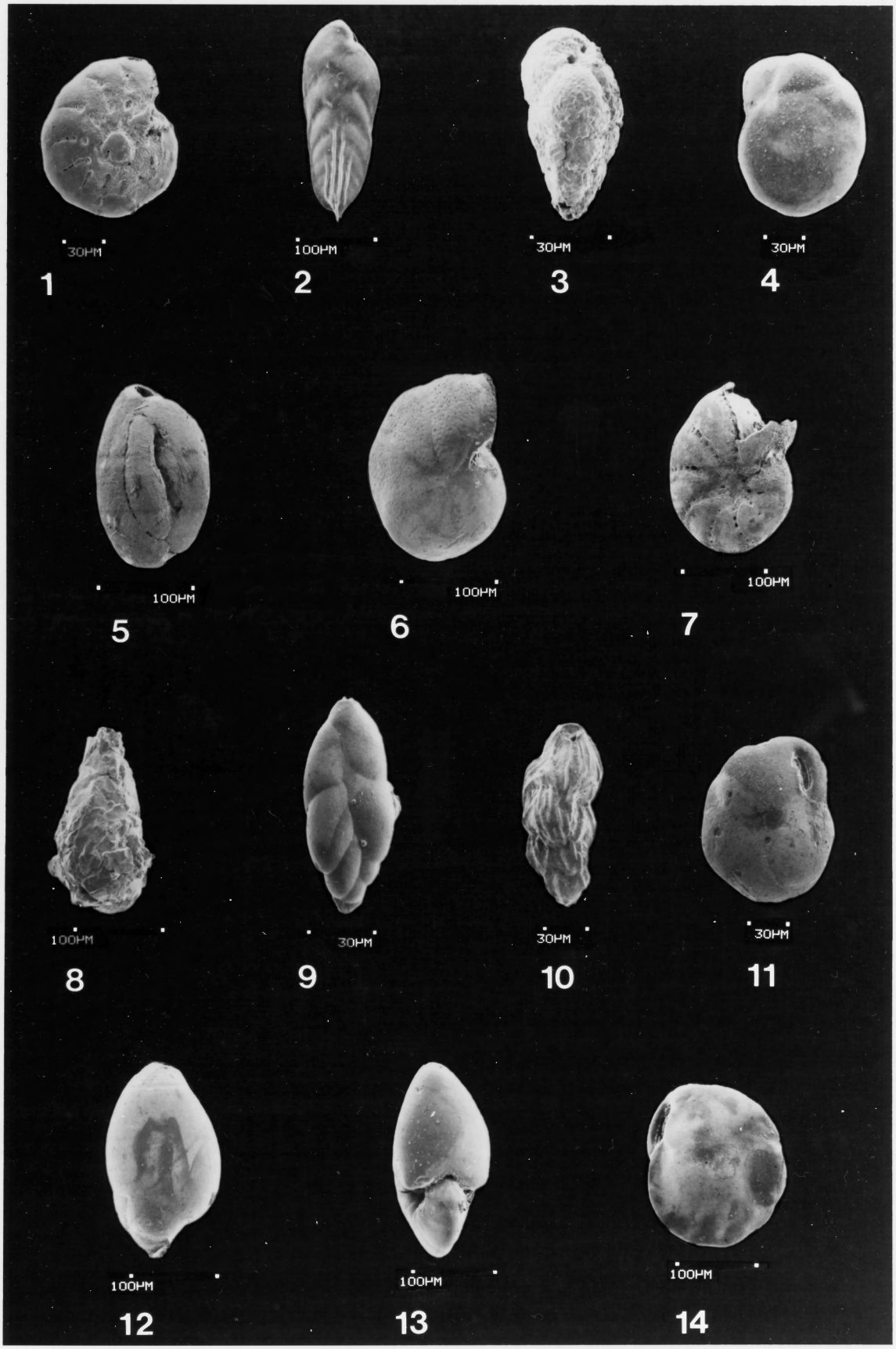
Rotalina ochracea Williamson, 1858, p. 5, pl. 4, fig. 112, pl. 5, fig. 113.

Trochammina squamata Parker and Jones

Trochammina squamata Parker and Jones, 1865, p. 407, pl. 15, figs. 30, 31a-c.

PLATE I

1. Elphidium excavatum f. clavata Cushman
2. Brizalina subaenariensis Cushman
3. Eggerella advena (Cushman)
4. Buccella frigida (Cushman)
5. Quinqueloculina seminulum (Linne)
6. Cibicides lobatulus (Walker and Jacob)
7. Elphidium bartletti (Cushman)
8. Saccammina atlantica (Cushman)
9. Fursenkoina fusiformis (Williamson)
10. Trifarina fluens (Todd)
11. Islandiella teretis (Tappan)
12. Globobulimina auriculata (Bailey)
13. Nonionellina labradorica (Dawson)
14. Cassidulina reniforme Norvang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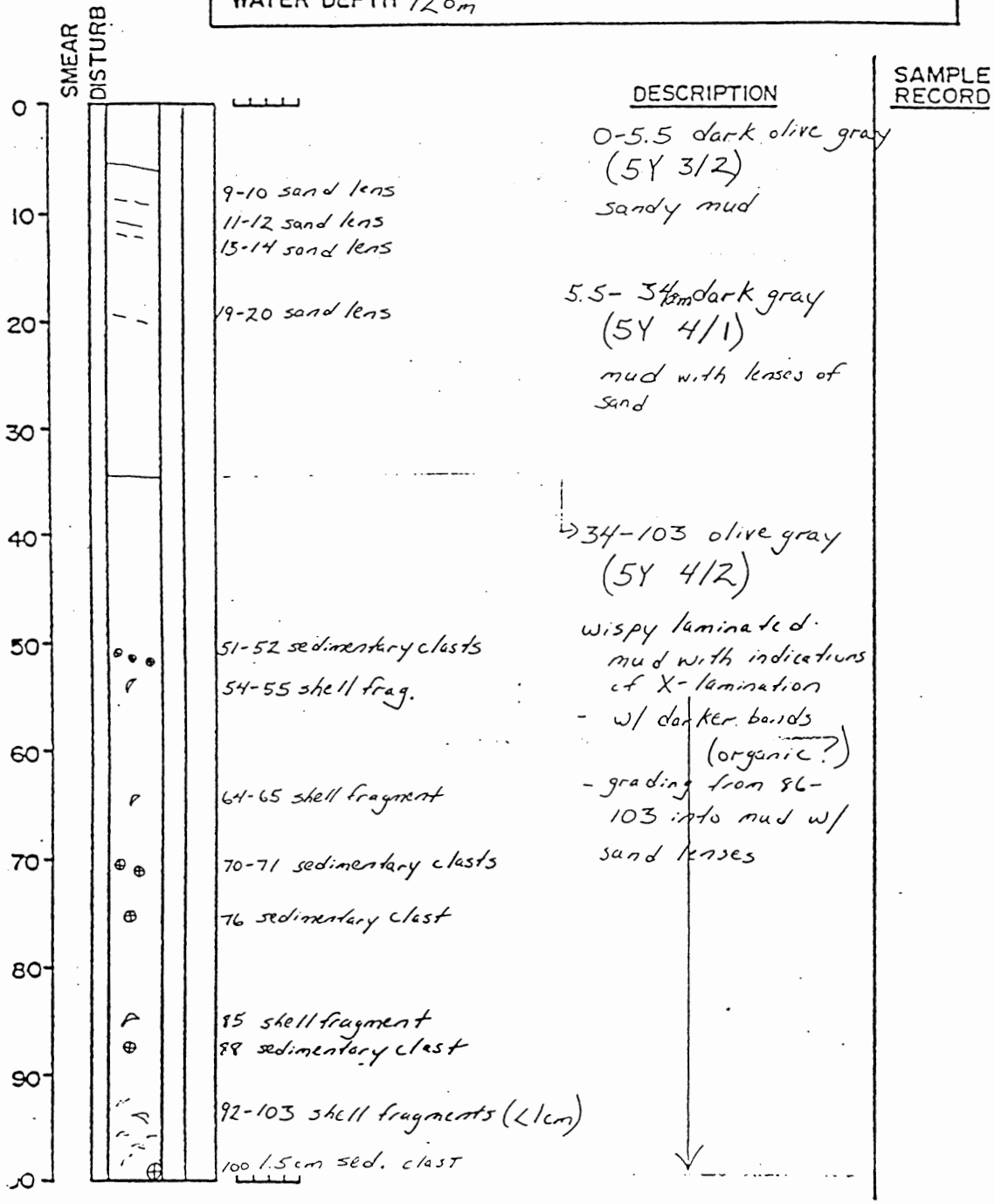
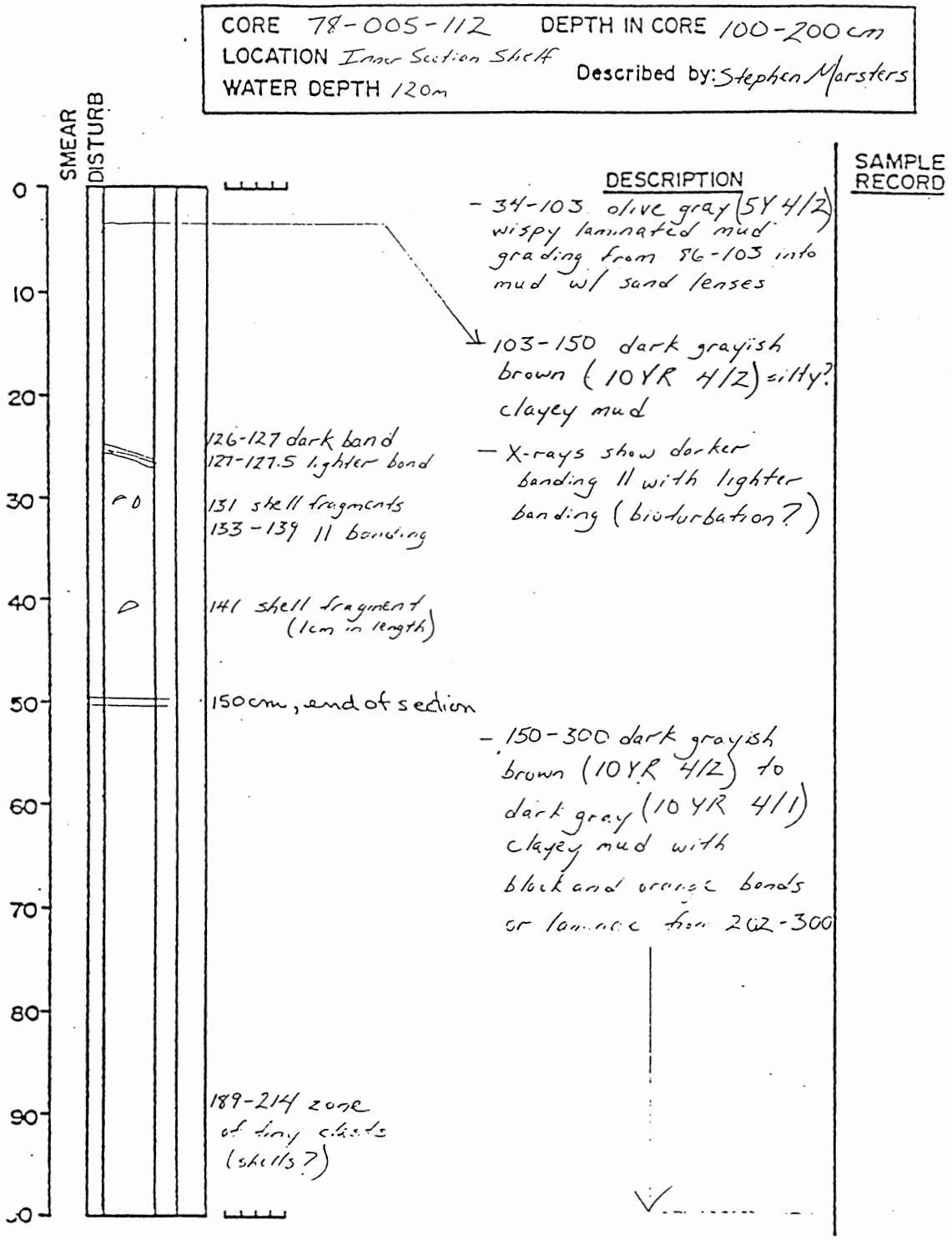
APPENDIX

CORE 78-005-112 DEPTH IN CORE 0-100 cm
LOCATION Inner Scotian Shelf Described by: Stephen Marsters
WATER DEPTH 120m

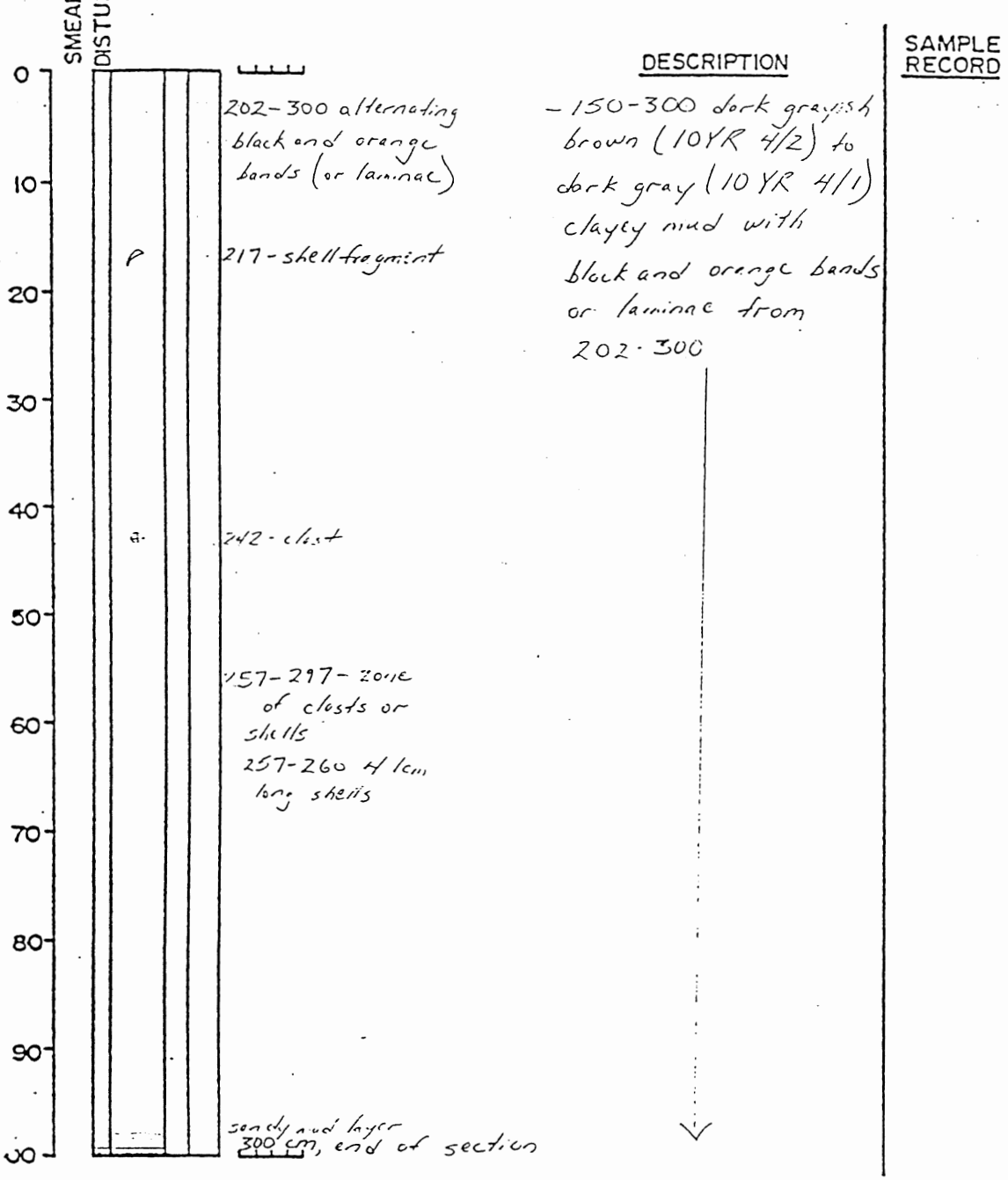


General comments: Munsell Soil Color Chart



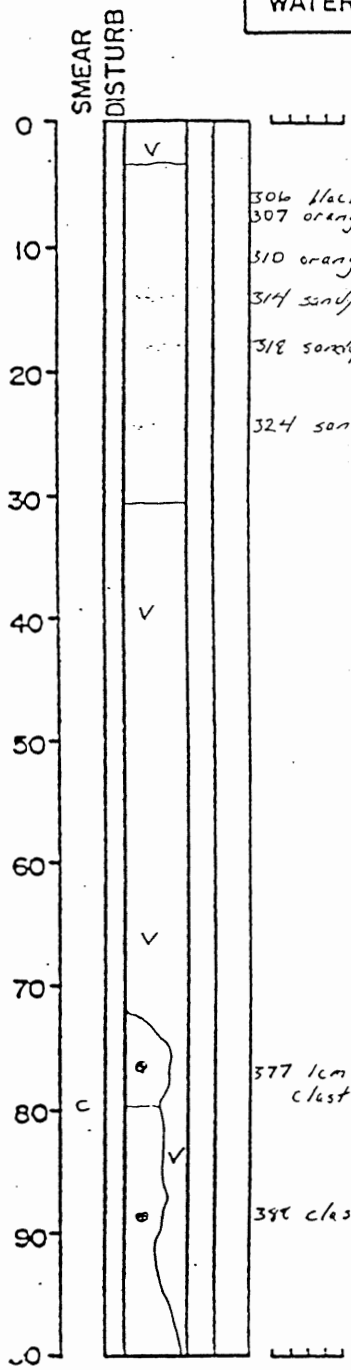
General comments: Munsell Soil Color Chart

CORE 78-005-112 DEPTH IN CORE 200-300
LOCATION Inner Scotian Shelf
WATER DEPTH 120m
Described by: Stephen Masters



General comments: Munsell Soil Color Chart

CORE 78-005-112 DEPTH IN CORE 300-400 cm
LOCATION Inner Scotian Shelf
WATER DEPTH 120m
Described by: Stephen Marsters



DESCRIPTION

- 300-303 - void
- 303-330.5 dark gray (10YR 4/1) silty to sandy mud with black and orange banding (pyrite?)
- also, sandy (~2.0 ϕ) layers

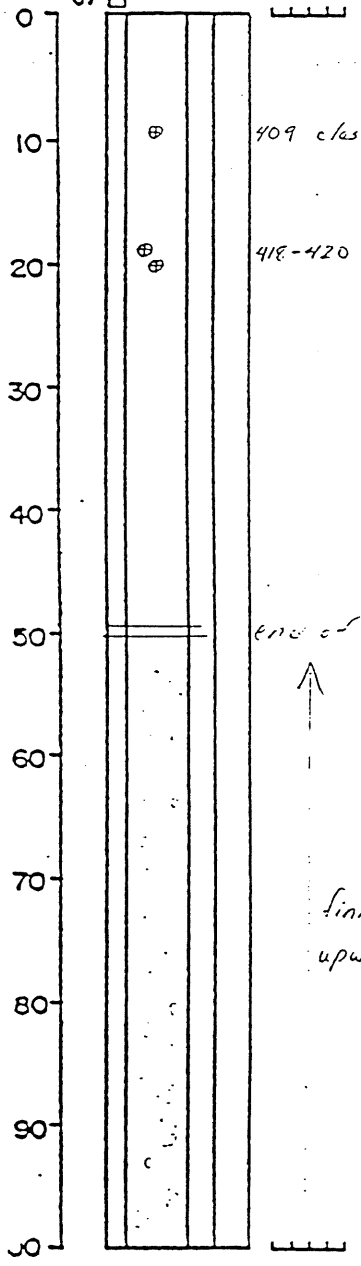
- 373-380 same as from 303-330.5

- 380-450 sand (2.0 ϕ) with some mud to 410, sediment unsorted with clasts up to 2cm in diameter; clasts sub-angular to subrounded; clasts (Imud/2mud → 2cm).

SAMPLE RECORD

General comments:

CORE 78-005-112 DEPTH IN CORE 400 - 500cm
LOCATION Inner Scotian Shelf Described by: Stephen Marsters
WATER DEPTH 120m



DESCRIPTION

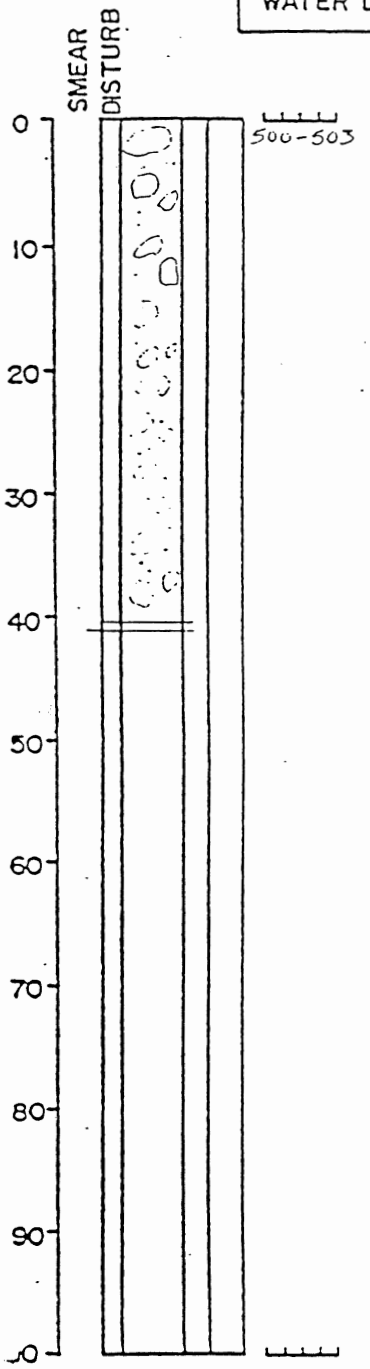
- 380-450 sand (2.0 ϕ) with some mud to 410, sediment unsorted with clasts ranging in diam. from 1mm, /2mm → 2cm; clasts subangular to subrounded; sorting better from 423-450

- 450 - 541 fining upwards sequence
- 450 - 470 - fairly well sorted sand (2.0 to 1.5 ϕ) w/ a few clasts up to 4mm in length, some mud, clasts: subangular
- 470 - 500 - poorly sorted sequence with sand (1.0 ϕ) to clasts which are up to 1cm in length

SAMPLE RECORD

General comments:

CORE 78-005-112 DEPTH IN CORE 500-541 cm
LOCATION Inner Scotian Shelf
WATER DEPTH 120m
Described by: Stephen Marsters



DESCRIPTION

- 500-541 very poorly sorted sequence w/ sand (2.0 ϕ) to clasts/pebbles which are up to 4cm in length; clasts subangular to subrounded

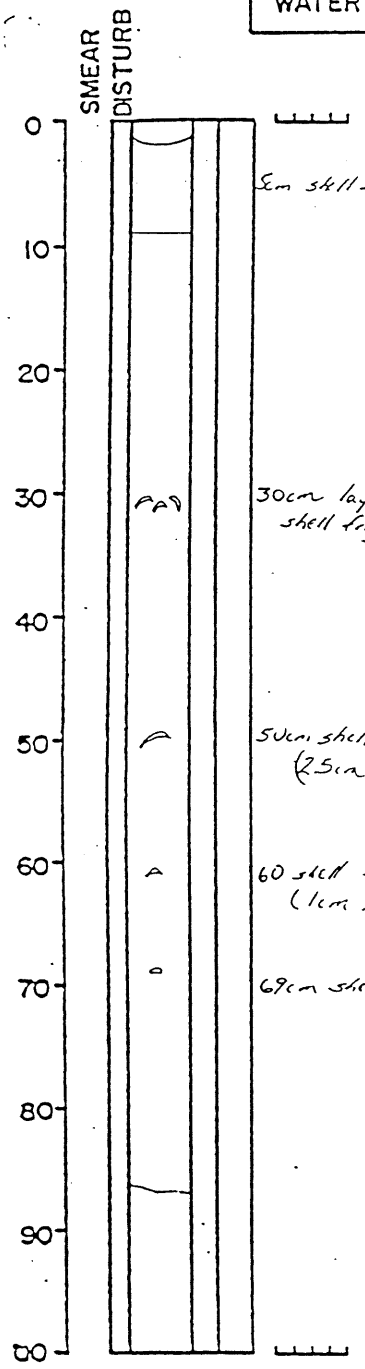
- overall, from 450-541 the sequence gets progressively poorer in sorting and involves a definite gradation from sand → pebbles/clasts

SAMPLE RECORD

General comments:

Dec 187

CORE 77-002-15 DEPTH IN CORE 0-100cm
LOCATION Inner Scotian Shelf
WATER DEPTH 66m
Described by: Stephen Marsters



DESCRIPTION

0-9cm dark olive gray (5Y 3/2) sandy mud

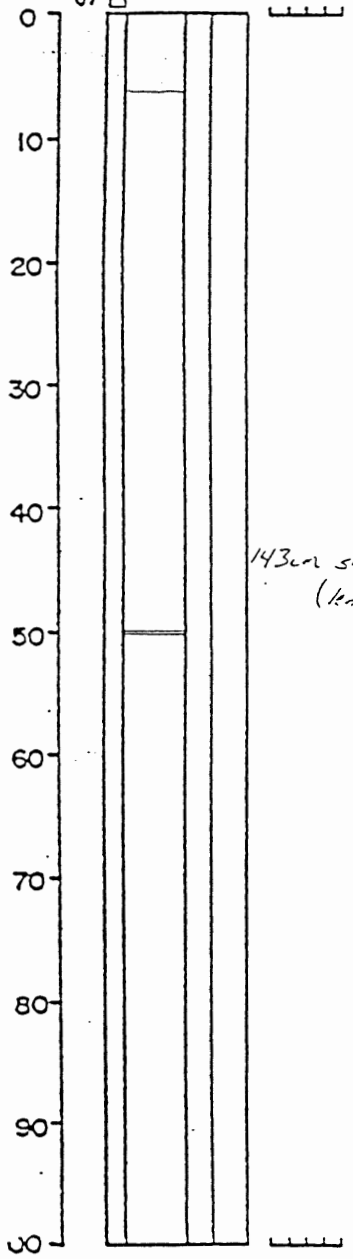
9-88cm dark grayish brown (2.5Y 4/2) to grayish brown (2.5Y 5/2) silty mud with several broken shell pieces

88-106 cm sand

SAMPLE RECORD

General comments: Munsell Soil Color Chart

CORE 77-002-15 DEPTH IN CORE 100-200cm
LOCATION Inner Scotian Shelf
WATER DEPTH 66m
Described by Stephen Marsters



DESCRIPTION

0-106cm sand

106-150cm olive gray (5Y 4/2) mud

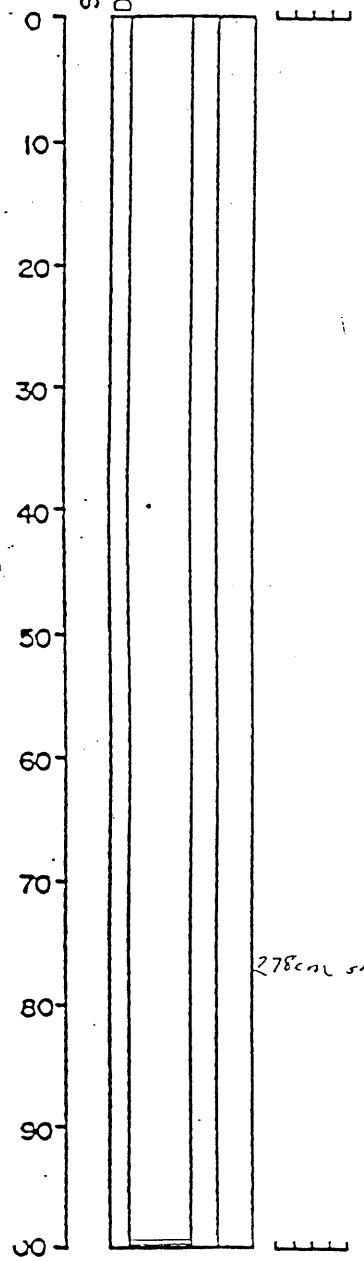
143cm shell fragment (length of 7mm)

150-300cm olive gray (5Y 4/2) mud

SAMPLE RECORD

General comments: Munsell Soil Color Chart

CORE 77-002-15 DEPTH IN CORE 200-300cm
LOCATION Inner Scotian Shelf
WATER DEPTH 66m
Described by: Skipka Masters



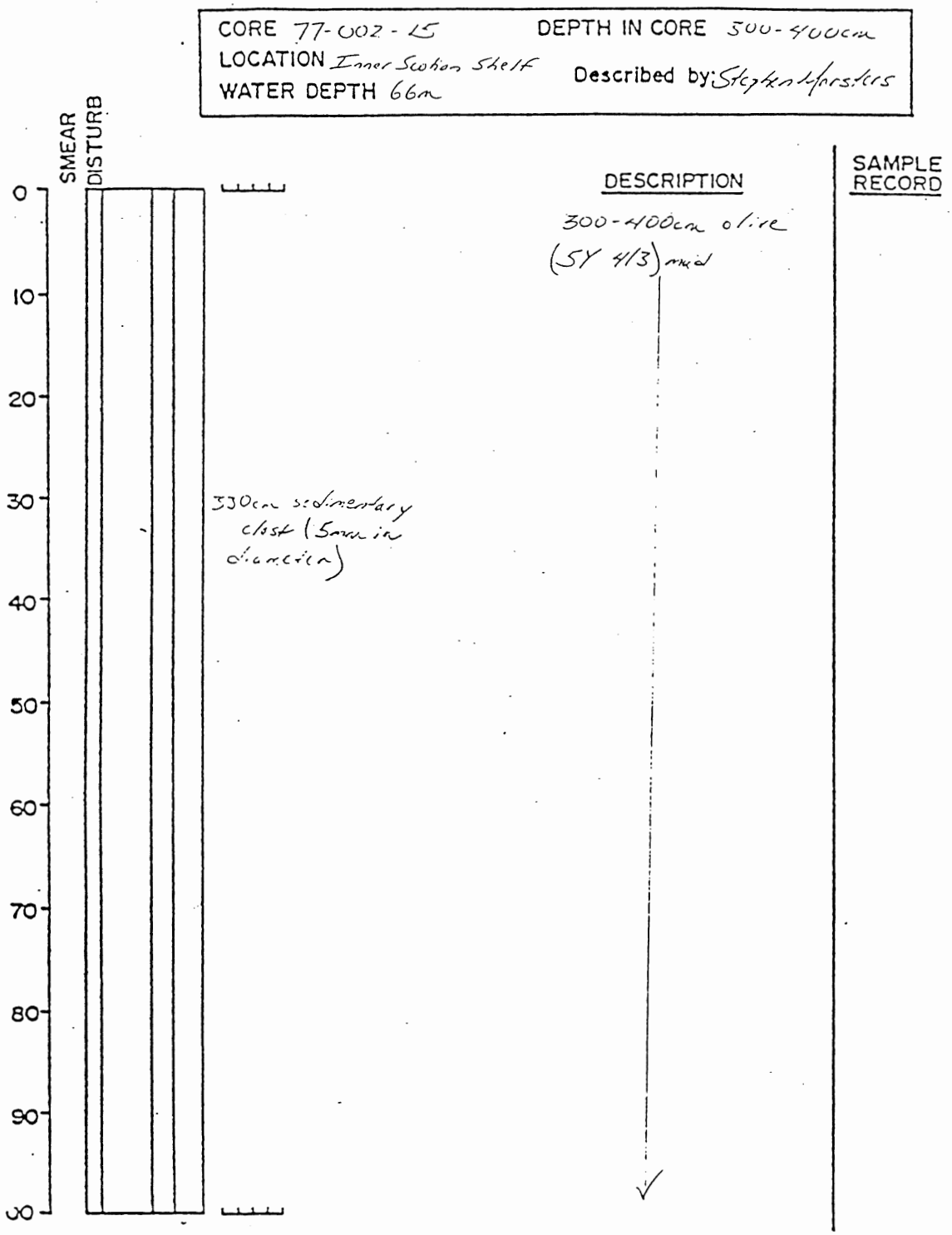
DESCRIPTION

200-300cm olive gray (5Y 4/2) mud

SAMPLE RECORD

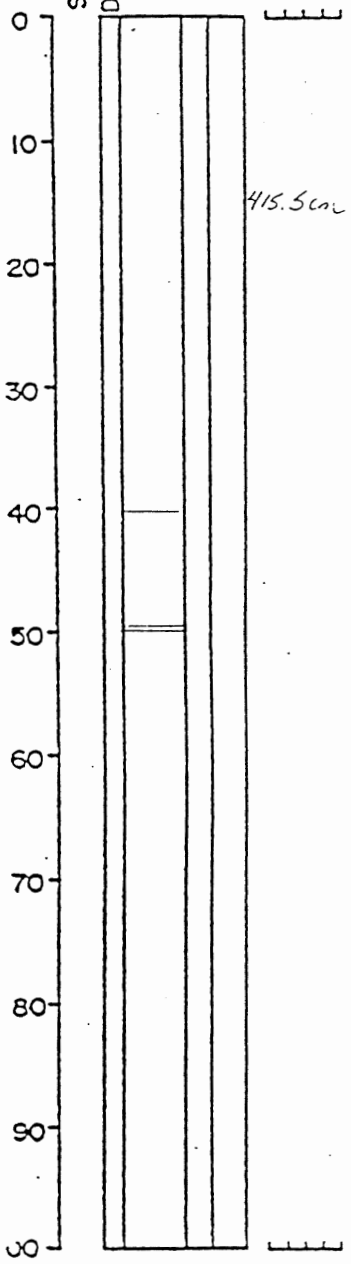
✓

General comments: Munsell Soil Color Chart



General comments: Munsell Soil Color Chart

CORE 77-052-15 DEPTH IN CORE 400-450cm
LOCATION Inner Section Shelf
WATER DEPTH 66m
Described by: Stephen Honeyman



DESCRIPTION

400-441 olive (5Y 4/3) mud

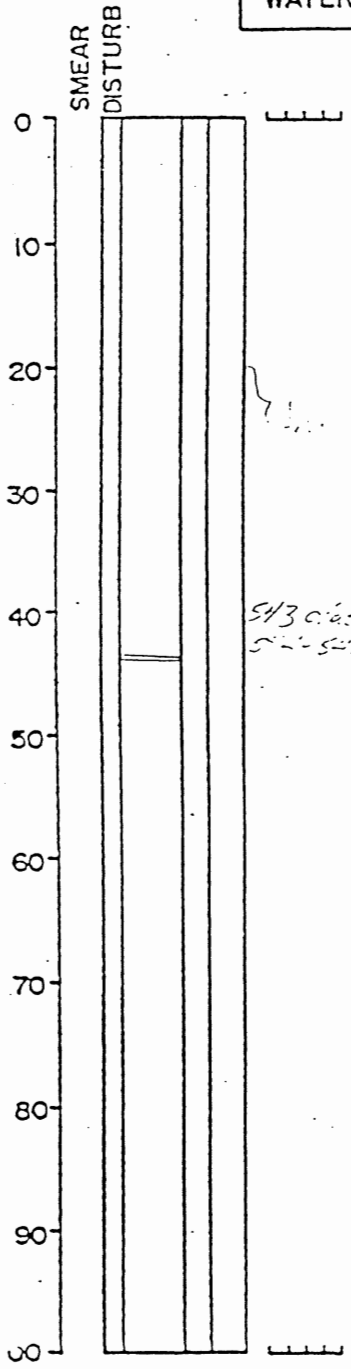
415.5cm shell fragment

441-450cm dark gray (5Y 4/1) mud

SAMPLE RECORD

General comments:

CORE 77-002-15P DEPTH IN CORE 500-543cm
LOCATION Inner Scotian Shelf
WATER DEPTH 66m
Described by: Stephen Harsters



DESCRIPTION

500-543 gray (5Y 5/1) — very dark gray (5Y 3/1) mud w/ transition to sandy mud at bottom of core

SAMPLE RECORD

General comments: