POST GLACIAL PALEO-OCEANOGRAPHY, NORTHEAST NEWFOUNDLAND SHELF: PART II.

by

Ann A. L. Miller

Centre for Marine Geology

Dalhousie University

Halifax, Nova Scotia

B3H 3J5

March, 1987

Technical Report No. 4 (Part II), Centre for Marine Geology, Dalhousie University

Report submitted to Dr. G. Vilks and Dr. M. Lewis (Atlantic Geoscience Centre) in partial fulfillment of DSS Contract No.

OSSC. 23420-6-M840

ABSTRACT

Thirty-five sediment samples from six sediment cores (one Lehigh, three trigger weight and two piston) from three sites on Northeast Newfoundland Shelf were analysed for benthonic and planktonic foraminifera.

The data obtained from these cores has been added to the results obtained from previous analyses of three cores also from Northeast Newfoundland Shelf.

Four benthonic foraminiferal faunas were found in Cores 07TW and P: three post glacial and one glacial. These four assemblages are (downcore): an agglutinated (Inner Labrador Current - Late Holocene) assemblage, a N. labradorica (Outer Labrador Current - early to mid Holocene) fauna; a M. barleeanum - Pullenia spp. - C. laevigata ("cold", more saline offshore Labrador Current - post glacial; early Holocene assemblage; and a C. reniforme - E. excavatum - I. helenae - N. labradorica ("warm" ice margin - glacial/early post glacial; late Pleistocene) assemblage. Core 13LH contains a condensed sequence, probably containing two unconformities, the late and mid Holocene agglutiniated and N. labradorica assemblages unconformibly overlying a cold shelf fauna. The planktonic foraminifera accompanying this shelf fauna indicate an area free of continuous ice cover and a mixing of water masses.

Cores at sites 15, 16 and 17 contain the late Holocene agglutinated assemblage unconformably overlying a late Pleistocene sequence consisting of an ice shelf/ice margin fauna and barren/reworked zones. All three cores contain the shelf fauna at the base.

The post glacial record in Cores 07TW and P indicates a "warm" interval of lowered salinity immediately following deglaciation, followed by cooling (which has continued to the present day) and an early Holoceneincrease in salinity. Salinity has then continued to decrease since early Holocene times, to present day conditions.

The planktonic foraminifera in the surface sediments at sites 15, 16 and 17

indicate a mixing of Inner Labrador Current - Gulf Stream surface waters during the late Holocene at this site.

INTRODUCTION

This project (Part II) is a continuation and extension of previous work completed on three cores from two locations on the Northeast Newfoundland Shelf (Part I) (Miller et al., 1985). Forty-seven samples from two cores at the 83-033 site, 07 (TW and P) and one from site 15 (P) were previously analysed for benthonic and planktonic foraminifera. Five distinct benthonic foraminiferal assemblages were observed downcore in cores 07TW and P and are believed to represent a continuous post glacial depositional record. Core 15P contained only two distinct assemblages downcore; an agglutinated assemblage (interpreted as reflecting the presence of the Inner Labrador Current and therefore Late Holocene) overlying an E. excavatum - C. reniforme ("warm" ice margin - Late Pleistocene) assemblage. The implication is that the early to mid-Holocene sedimentary record (10,000-2,500 YBP) is absent at the Core 15 site, represented by a major unconformity.

The purpose of this work was to further analyse cores (15TW and P) from this site and two other sites (Cores 16TW and P, 17TW and P) in close proximity of this one, to determine if the apparent unconformity is regional or local; and verify that the stratigraphically youngest (agglutinated) assemblage is Late Holocene in age and reflects the presence of the Inner Labrador Current. In addition, Core 13LH was also analysed, collected from a location offshore of and between the Core 07 and Core 15, 16 and 17 sites; to extend the paleo-environmental interpretation and determine the completeness and continuity of the post-glacial record to the north central portion of the shelf.

CORE LOCATIONS

Six additional cores were selected for study, making nine in total, collected by the CSS HUDSON on cruise 83-033. These cores were collected employing a trigger weight (or gravity, hereafter referred to as TW), piston (P), or Lehigh (LH) coring devices. These (nine) cores are (see Figure 9): Cores 07 (TW and P) from 50° 52.97' N, 53° 18.0' W, water depth 457 m, just offshore of Notre Dame Channel; Core 13LH, from 50° 07.100' N, 51° 13.100' W, water depth 314 m, southeast of the Core 07 site and directly offshore of Lewisporte, Newfoundland and Cores 15 TW and P, from 48° 89.580' N, 51° 82.00' W, water depth 336 m, Cores 16TW and P, from 48° 91.430' N, 51° 80.300' W, water depth 304 m and Cores 17TW and P from 48° 90.870' N, 51° 80.800' W, water depth 304 m, all directly north of the Grand Banks and due east of Bonavista Bay.

The core sample intervals (Cores 13-17) are recorded on Tables 4 and 5 (along with the compilation of the foraminiferal data). Core intervals and data compilation for Cores 07TW and P are given on Table 1 (Part I).

PRESENT ENVIRONMENT

The Physiography, Oceanography and Surficial Foraminiferal Distribution are all outlined in Part I.

PREVIOUS WORK

Most previous work relevant to this study is outlined in Part I and will be

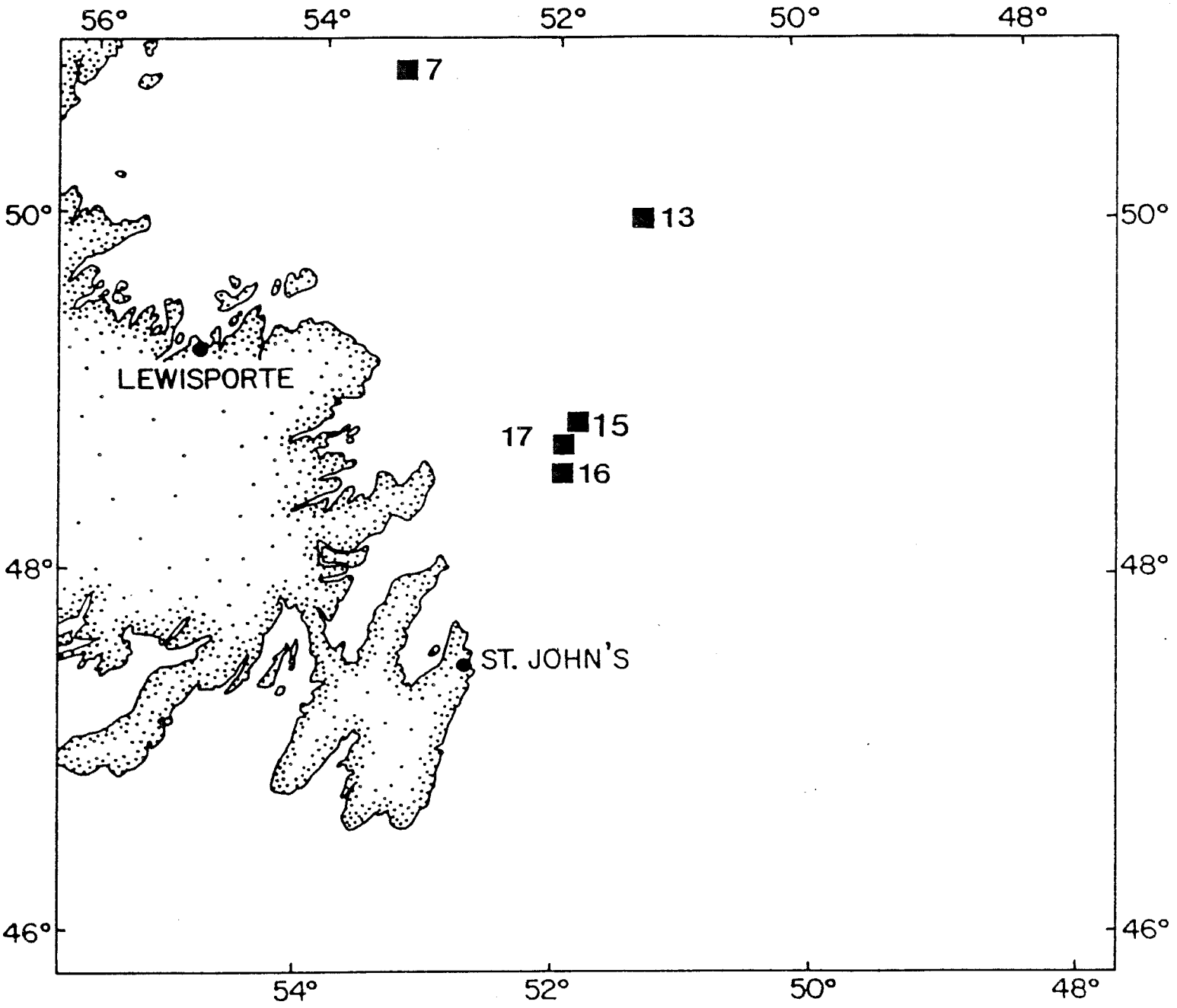

Figure 9: Location of the Core 13LH and Core 07, 15, 16, 17 (all TW and P) sites, Cruise 83-033. Exact locations given in the text (base map courtesy of G. Vilks).

discussed as a comparison is made with the results of this work. However, one additional study has been completed since the initial analyses of Cores 07 and 15 were done.

MacNeil (1986) has completed a detailed analysis of benthonic foraminifera in Cores 80-030-26TW and P, collected from a water depth of 267 m in Outer Notre Dame Bay (inshore of all cores studied during both phases of this work). MacNeil (1986) found a complex series of benthonic foraminiferal assemblages similar to that found by Scott et al. (1984) in Cores 78-023-20 (TW and P) from Notre Dame Channel, both interpreted as representing continuous post glacial depositional records.

LABORATORY METHODS

Thirty-five wet sediment (10 cc) core samples were received (intervals listed on Tables 4 and 5). All samples were processed as outlined in Part I. Those stored wet were wet split where appropriate; those samples containing a large amount of medium to coarse sand/granules were dried, the foraminifera concentrated by floatation and dry split where appropriate. The foraminiferal species were identified as they were encountered; an abbreviated faunal synonymy (one reference for each species) is given in Appendix C (supercedes Appendix A) and additional key slides have been deposited with Dr. G. Vilks (A.G.C.). The total or a minimum of 250 benthonic and the accompanying planktonic specimens were counted in each sample (whichever was smaller, splitting where appropriate). The raw quantitative count data and calculated percent data for the benthonic foraminifera in each sample are given in Appendix B (available from Dr. G. Vilks or the senior author). Percent data for the benthonic foraminiferal species and count data for the planktonic species are tabulated on Tables 4 and 5.

Table 4: Percent occurrences of all benthonic foraminiferal species in Cores 13LH and 15TW and P. Planktonic species are listed at the bottom in actual numbers. X = less than 0.5%. All samples 10 cc.

CORE NUMBER	13LH							15TW				15P															
DEPTH IN CORE	8-10	25-27	51-53	75-77	98-100	125-127	198-200	0-2	10-11	30-31	48-49	0-7	25-27	40-42	64-66	82-84	100-102	120-122	140-142	160-162	196-198	220-222	260-262	302-304	344-346	376-378	443-445
TOTAL NO. OF SPECIMENS	739	2360	880	105	622	1452	281	588	306	1560	816	202	952	222	97	124	113	61	109	22	83	50	45	/	/	157	247
Adercotryma glomerata	38.6							34.7	18.0	X	8.3	33.5	0.8	8.1													
Ammodiscus incertus								0.7																			X
Ammotium cassis																											
Astrammina sphaerica								2.0																			
Atlantiella atlantica																											
Cribrostomoides crassimargo									0.7	0.5		1.5	X														
Cribrostomoides jeffreysi	1.1							X																			
Eggerella advena																											
Eggerella scabra				0.8			1.0		1.4				0.5														
Haplophragmoides bradyi																				4.5							
Hemisphaerammina bradyi	4.0							2.7				1.5	0.5														
Hyperammina cylindrica																											
Recurvoides scitulus	2.2		0.9					1.7	2.0	4.6	3.9		15.1	9.0													
Reophax arctica	X							X		X		1.0	X														X
Reophax fusiformis	2.2											3.0		0.5													
Reophax gracilis									1.7	5.4	1.0		X			3.6		0.9									
Reophax scorpiurus	2.9							1.0	0.7		0.5																
Reophax scottii																											
Saccammina atlantica	6.5				1.0	X		10.6	3.6	X	2.0	3.0									1.2						
Saccammina sphaerica																											
Saccammina tubulata																											
Silicosigmoilina groenlandica																											
Spiroplectammina biformis	29.2		1.4		10.0	X		20.4	57.2	53.2	67.2	18.7	53.0	41.8	12.4	25.0	22.1	37.7	28.4	18.2	13.2						X
Textularia earlandi										1.2	1.0																
Textularia torquata	2.2							3.7	11.4	6.9	7.8	2.0	3.4	5.4		0.9					1.2						
Tholosina bulla																											
Tritaxis conica	1.1																										
Trochammina nana	4.3		0.5	0.8	2.3	2.5	X	2.7				8.3	1.0	6.3													
Trochammina ochracea																				4.5		2.2					
Astacolus crepidulus																0.9											
Astacolus hyalacrulus		X																									
Astrononion gallowayi	X			0.8			1.4	X			0.5															0.6	0.8
Brizalina pseudopunctata		X					0.7	X																			X
Buccella frigida		6.4	1.8	1.8	0.6	14.9	5.3	2.0	X			0.5		1.4	2.1	0.8	0.9	11.1	0.9			4.0	4.5			8.3	4.9
Bulimina marginata							X																				
Buliminella elegantissima						0.5													3.6		1.2						
Cassidulina laevigata																											
Cassidulina reniforme	1.4	2.7	18.6	12.4	45.3	28.4	15.3	4.4	0.7	5.9	0.5	2.5	3.6	9.5	43.3	8.1	40.7	16.4	35.8	4.5	42.2	46.0	31.0			39.5	26.7
Cibicides lobatalus			0.5	0.8		X	1.8	X					0.5													3.2	0.8
Cibicides pseudoungerianus							X																				
Cyclogyra involvens					X				0.7																		
Dentalina baggi																											
Dentalina frobisherensis																											
Dentalina ittai																											X
Dentalina pauperata																											
Discorbis squamata																										0.6	
Elphidium bartletti				0.8	X	1.1	1.0	X		X			0.6		5.6	6.2		2.8								1.9	1.6
Elphidium excavatum		29.3	30.0	23.0	4.6	7.7	21.6	2.0	0.7	17.3	1.5	2.0	20.1	9.0	26.8	52.4	20.4	24.6	24.8	68.2	33.7	28.0	28.8			21.7	12.9
Elphidium groenlandicum						X																					
Elphidium subarcticum	0.7	X		1.8		2.5	10.0						0.9									2.0				1.3	13.3
Epeponidella pulchella	X											1.0															
Epistominella takayanagii				0.8		X	X					3.5											4.5			1.9	2.0
Fissurina cucurbitasema							X														2.4	2.0					
Fissurina marginata					0.6	1.1	2.9	X				0.5														0.6	4.0
Fursenkoina fusiformis			0.5		3.2				X	2.6	2.1	1.0		0.9	9.3	1.6					3.6	2.0	2.2				
Gavelinopsis translucens												0.5															
Glabratella wrightii							0.7					0.5														2.6	2.0
Globobulimina auriculata		X				X							X														
Guttulina lactea							0.7																				
Gyroidina soldanii																											
Haynesina orbiculare	X	2.7	3.6	2.8	2.6	8.3	3.2		X	0.5	1.0		X		2.1	0.8		9.8	1.8		1.2	12.0					
Hoeglundina elegans									X																		
Islandiella helenae		18.3	31.8	45.7	22.5	13.8	9.3	0.7		0.9	2.5	1.0	1.3	1.6	2.1	5.6	3.6						4.5			11.5	6.9
Islandiella islandica		X					3.2					1.5		0.5									4.5				
Islandiella norcrossi		8.8	5.0		2.9	3.9	4.6			X	0.5			0.5								2.0	11.1			2.6	0.8

CORE NUMBER	13LH							15TW				15P																
DEPTH IN CORE	8- 10	25- 27	51- 53	75- 77	98- 100	125- 127	198- 200	0- 2	10- 11	30- 31	48- 49	0- 7	25- 27	40- 42	64- 66	82- 84	100- 102	120- 122	140- 142	160- 162	196- 198	220- 222	260- 262	302- 304	344- 346	376- 378	443- 445	
TOTAL NO. OF SPECIMENS	739	2360	880	105	622	1452	281	588	306	1560	816	202	952	222	97	124	113	61	109	22	83	50	45	/	/	157	247	
Lagena distoma																												
Lagena laevis							X																				X	
Lagena semilineata							X																					
Lagena striata																												
Laryngosigma hyalascidia																												
Laryngosigma williamsoni																												
Lenticulina gibba																												
Melonis barleeanum	0.7	0.5			X	1.4	1.8	0.7																			2.5	
Miliolinella chukchiensis							X																					
Nonionella auricula																											1.2	
Nonionella turgida						X																						
N. turgida var. digitata																												
Nonionellina labradorica	1.1	28.5	4.0	3.8			1.0	3.1				4.5		2.2	1.0								4.5			1.9	1.6	
Oolina costata							1.0																				1.6	
Oolina globosa																												
Oolina lineata																											X	
Oolina melo							1.0																				X	
Oolina squamosa																												
Oolina striatopunctata																											1.6	
Parafissurina hinatiostoma																												
Parafissurina tectulostoma																			0.9									
Pullenia bulloides																							2.2					
Pullenia osloensis							X					0.5																
Pullenia subcarinata														1.0														
Quinqueloculina arctica							X																					
Quinqueloculina seminula																												
Quinqueloculina stalkeri				0.8			X																				0.8	
Robertinoides charlottensis																												
Scutuloris tegminus																												
Sigmoidella pacifica		0.8																										
Stainforthia concava	X	0.5			3.5	6.1	X	X				0.5										2.0				0.6	X	
Stetsonia horvathi		0.5				7.7						2.5		0.9														
Trifarina angulosa	1.1			2.8		X	7.6	3.4				5.0														1.3	10.1	
Triloculina trihedra							X																					
Valvulineria laevigata						X																						
TOTAL NOS. PLANKTONICS	/	1	12	/	58	304	25	/	4	/	16	51	/	10	/	/	/	/	/	/	1	1	8	/	/	10	2	
Globigerina bulloides					2																							
G. quinqueloba - left coiled					10	92	5		1			5		3									4					
G. quinqueloba - right coiled					2	24	1					9											1			1		
Globigerinita glutinata							2					1		2													1	
Globigerinita uvula						8			1			9		1									2			1	1	
Globigerinoides ruber					10	20																						
Globorotalia scitula						8						1																
Neogloboquadrina deutertri																												
N. pachyderma - left coiled		1	12		24	108	16		2		8	17		2							1	1				3	1	
N. pachyderma - right coiled					4	40	1				8	9		2									1					
Orbulina universa					2																							
juveniles					4																					4		

Table 5: Percent occurrences of all benthonic foraminiferal species in Cores 16TW and P and 17TW and P. Planktonic species are listed at the bottom in actual numbers. X = less than 0.5%. All samples 10 cc.

CORE NUMBER	16TW				16P								17TW			17P							
DEPTH IN CORE	0-2	20-22	50-52	80-82	15-17	51-53	100-102	150-152	200-202	255-257	300-302	400-402	0-2	18-20	35-37	10-12	50-52	100-102	160-162	245-247	300-302	400-402
TOTAL NO. OF SPECIMENS	214	78	1244	1056	262	218	116	17	121	13	34	20	307	706	780	790	170	40	21	96	77	69
Adercotryma glomerata	41.8	33.3	2.9	1.5			1.7				2.9		39.4	0.8	0.8	0.5						
Ammodiscus incertus													X									
Ammotium cassis													0.7									
Astrammina sphaerica														0.6			0.6					
Atlantiella atlantica																						
Cribrostomoides crassimargo																	0.6					
Cribrostomoides jeffreysi													1.3									
Eggerella advena																						
Eggerella scabra																						
Haplophragmoides bradyi																						
Hemisphaerammina bradyi	6.5	5.1											4.6							1.2		
Hyperammina cylindrica	0.5																					
Recurvoides scitulum	1.0	5.1	2.6	5.7	0.3	0.5							3.9	4.5	2.8	4.5			1.0			
Reophax arctica													1.7									
Reophax fusiformis	2.3																					
Reophax gracilis				1.5	1.5		0.9	5.9	1.6				0.7	X		2.0	0.6					
Reophax scorpiurus																			4.8			
Reophax scottii														X								
Saccammina atlantica	14.5	7.7											3.6			X		5.0	4.8			
Saccammina sphaerica																0.6						
Saccammina tubulata																						
Silicosigmoilina groenlandica													X									
Spiroplectammina biformis	13.6	11.5	4.2	30.7	52.7	3.7	16.3	17.6	5.0				17.9	69.1	73.8	51.9	4.1	5.0		2.1		
Textularia earlandi						0.8	6.0		0.8	15.4							4.1		14.3			
Textularia torquata	4.7		X	2.6	9.6	0.5	2.6						1.7	2.3	3.8	7.1						
Tholosina bulla																						
Tritaxis conica		1.3																		1.2		
Trochammina nana	8.9											10.0	1.3	2.0		X						
Trochammina ochracea													1.3									
Astacolus crepidulus																						
Astacolus hyalacrulus																						
Astrononion gallowayi											2.9									1.0		
Brizalina pseudopunctata		1.3																				
Buccella frigida		2.6				1.4							2.6				0.6			4.2	6.5	10.1
Bulimina marginata			X																			
Buliminella elegantissima	0.5		0.7					58.8	18.2								5.9	7.5				
Cassidulina laevigata																						
Cassidulina reniforme	0.5	6.4	13.8	16.6	2.3	41.0	20.7		43.0	38.5	17.6	15.0	5.9	0.6	0.8	2.8	25.9	52.5	9.5	36.5	28.4	24.6
Cibicides lobatalus		1.3																			1.2	1.4
Cibicides pseudoungerianus																						
Cyclogyra involvens																						
Dentalina baggi																						
Dentalina frobisherensis																	2.5					
Dentalina ittai																						
Dentalina pauperata																						
Discorbis squamata																						
Elphidium bartletti			1.9	1.1	0.5	2.3	1.7		0.8		5.9	5.0		X	0.5	0.5	4.7			1.0		
Elphidium excavatum		6.4	66.5	27.6	26.4	29.4	37.9		16.5	20.0	26.5	25.0	3.6	17.0	13.4	26.1	30.6	5.0	52.4	24.0	14.2	20.3
Elphidium groenlandicum																					1.2	
Elphidium subarcticum	0.5											5.0									3.2	6.5	1.4
Eoeponidella pulchella																						
Epistominella takayanagii			X			0.8					5.9		0.7							1.0	1.2	1.4
Fissurina cucurbitasema																	2.5					
Fissurina marginata																	2.5				5.2	1.4
Fursenkoina fusiformis			1.3	6.1	0.5	5.5			4.1					X		8.2				1.0		
Gavelinopsis translucens																						
Glabratella wrightii													X									2.9
Globobulimina auriculata																	2.5					
Buttulina lactea						0.5	0.9															
Gyroidina soldanii																						
Haynesina orbiculare	0.5		1.9	1.9	0.9	2.8	10.4		2.5					0.6	1.8	1.0	9.4	7.5	9.5		1.2	
Hoeglundina elegans																						
Islandiella helenae		1.3	1.9	3.4	2.3	1.8				15.4	20.6	15.0	1.3	1.4	2.3	3.0	1.2	2.5	4.8	10.4	5.2	7.2
Islandiella islandica	1.4	1.3	X										1.3							1.0	3.7	1.4
Islandiella norcrossi		1.3				1.8					2.9		1.3				2.5			5.2	3.7	10.1

CORE NUMBER	16TW				16P								17TW			17P							
DEPTH IN CORE	0-2	20-22	50-52	80-82	15-17	51-53	100-102	150-152	200-202	255-257	300-302	400-402	0-2	18-20	35-37	10-12	50-52	100-102	160-162	245-247	300-302	400-402	
TOTAL NO. OF SPECIMENS	214	78	1244	1056	262	218	116	17	121	13	34	20	307	706	780	790	170	40	21	96	77	69	
Lagena distoma																							
Lagena laevis																							
Lagena semilineata																							
Lagena striata																							
Laryngosigma hyalascidia																							
Laryngosigma williamsoni																							
Lenticulina gibba																							
Melonis barleeanum		1.3	X							7.7		5.0	X				2.5					1.4	
Miliolinella chukchiensis																							
Nonionella auricula																					2.6		
Nonionella turgida																							
N. turgida var. digitata																							
Nonionellina labradorica	2.8	5.1											1.9							1.0		8.7	
Oolina costata																							
Oolina globosa																							
Oolina lineata																					1.2		
Oolina melo																						1.4	
Oolina squamosa																							
Oolina striatopunctata																							
Parafissurina himatiostoma																							
Parafissurina tectulostoma			0.9	0.8																			
Pullenia bulloides																							
Pullenia osloensis			0.7	0.8		0.8							X				2.3						
Pullenia subcarinata																							
Quinqueloculina arctica																				1.0			
Quinqueloculina seminula	0.5																						
Quinqueloculina stalkeri																							
Robertinoides charlottensis					X																		
Scutuloris tegminus																							
Sigmoidella pacifica																							
Stainforthia concava					0.5	6.4		11.8	5.8			5.0					1.2			1.0			
Stetsonia horvathi								5.9	0.8														
Trifarina angulosa	0.5	7.7									2.9	15.0	1.9							5.2	16.7	5.8	
Triloculina trihedra																							
Valvulineria laevigata																							
TOTAL NOS. PLANKTONICS	12	1	/	/	1	1	/	1	6	/	/	/	8	4	/	/	/	/	1	1	1	3	
Globigerina bulloides																							
G. quinqueloba - left coiled						1																	
G. quinqueloba - right coiled																						1	
Globigerinita glutinata																							
Globigerinita uvula					1														1				
Globigerinoides ruber																							
Globorotalia scitula													1										
Neogloboquadrina deutertri	10								2				3	4						1		1	
N. pachyderma - left coiled																							
N. pachyderma - right coiled																							
Orbulina universa																							
juveniles	2								4				3								1	1	

OBSERVATIONS

The faunal list of species present is compiled in Appendix C (supercedes Appendix A). The benthonic foraminiferal percent occurrence data is given on Tables 4 and 5.

Four faunal units (instead of five) are now recognized in Cores 07TW and P (Figure 14); as these faunal units have been revised since the completion of Part I they will be briefly reviewed here. They are (1) an agglutinated assemblage (07TW:0-98 cm, 07P:0-10 cm); (2) a Nonionellina labradorica - E. excavatum dominated assemblage (07P:10-50 cm); (3) a Melonis barleeanum - Pullenia spp. (P. bulloides, P. osloensis, P. subcarinata) - C. laevigata assemblage (07P:50-175 cm) and a E. excavatum - C. reniforme - I. helenae - N. labradorica assemblage (07:175-555 cm). Downcore percent occurrences of the dominant species are shown on Figure 2 (Part I).

The agglutinated assemblage in both cores has very low total numbers (< 225 specimens/10 cc) and is dominated by the agglutinated species Adercotryma glomerata, Reophax spp. (R. arctica, R. fusiformis, R. scorpiurus, R. scottii) and Saccammina atlantica accompanied by lower but consistent numbers of Silicosigmoilina groenlandica and Spiroplectammina biformis. Dominant calcareous species are Elphidium excavatum, Buccella frigida and Nonionellina labradorica; subdominant species are Cassidulina reniforme and Melonis barleeanum. There are lower (<7%) but consistent numbers of Islandiella helenae present. The planktonic foraminifera are almost all Neogloboquadrina pachyderma left coiled, but Globigerina bulloides and Globigerina quinqueloba are also present.

The overlap between the two cores (07TW and P) occurs at approximately 25-30 cm in core 07P. This is based on the absence of A. glomerata from 30 cm onwards downcore in core 07TW and the low total numbers in the first 30 cm of core 07P (Figure 2). It is interesting to note that the percent occurrences of I.

helenae, C. reniforme, E. excavatum and N. labradorica do not match exactly. However, the top of core 07P appeared to be (previously) disturbed when the core was sampled.

Faunal unit 2 (07P:10-50 cm) is defined by a peak in the percent occurrence (42.3%) of N. labradorica. At this point the benthonic assemblage becomes over 97% calcareous and remains that way downcore. E. excavatum is the co-dominant species; together at 28.5 cm they account for 80% of the benthonic assemblage. The planktonics continue to be dominated by N. pachyderma left coiled.

Faunal unit 3 (M. barleeanum - Pullenia spp. - C. laevigata assemblage, 07P:50-175 cm) is defined by a constant presence of C. laevigata (at least 7%) which peaks at 23.8% at 175 cm. There is also a consistent presence (3-6%) of M. barleeanum. From 50-125 cm there is a steady increase in the percent occurrence of Pullenia spp. (7.6-20.7%) peaking at 125 cm; then lower percentages (0.6-5.0%) of the same group. There are isolated occurrences of both genera downcore (175-555 cm), but both genera appear suddenly in significant amounts in the fauna at 175 cm and continue to the top of core 07P, though the Pullenia spp. numbers drop off towards the surface. Neither genus was present in core 07TW in any significant numbers, suggesting that they do not occur in the present day environment. The dominant species in this interval (50-175 cm) are E. excavatum and C. reniforme (in additon to C. laevigata). There are unusually low numbers of N. labradorica and I. helenae in this interval. Fursenkoina fusiformis, Stainforthia concava and Globobulimina auriculata are also present. There are also scattered occurrences of various shelf species present, e. g. Dentalina spp., Lagena spp. Laryngosigma spp. and Trifarina angulosa. This third faunal unit is also characterized by higher total numbers of specimens (almost 6000/10 cc at 100 cm) and planktonic forms as well (just over 600/10 cc at 125 cm). Planktonic species include over 90% N. pachyderma left coiled and minor occurrences of N. pachyderma right coiled, G. bulloides and G. quinqueloba.

Faunal unit 4, from 175-555 cm. is marked by low total numbers (<3000 benthonic specimens/10cc, < 300 planktonics/ 10 cc) and 45-83% (usually at least 60 %) E. excavatum and C. reniforme combined. The subdominant species are N. labradorica (up to 28.5%) and I. helenae (up to 21%). Buccella frigida, F. fusiformis, I. norcrossi and S. concava are consistently present.

Five faunal units (Figures 10 and 14) occur downcore in Core 13LH. The first faunal unit is Unit 1, the agglutinated assemblage. It occurs in Core 13LH from 0-25 cm and has low total numbers (< 1000 benthonic specimens/10 cc) and is dominated by the species A. glomerata and S. biformis, which account for almost 70% of the benthonic fauna. The remainder of the assemblage is very similar to that in core 07TW and P with the addition of Hemisphaerammina bradyi. The only calcareous species present are C. reniforme, E. subarcticum and T. angulosa. No planktonic foraminifera are present.

Underlying this assemblage is faunal unit 2 - the N. labradorica assemblage (15P:25-50 cm) defined by a 28.5% peak in the occurrence of N. labradorica accompanied by E. excavatum (approx. 39%). B. frigida, C. reniforme and M. barleeanum are also present. The benthonic faunal has higher total numbers (> 2000 specimens/10 cc) and becomes >97% calcareous downcore. The only planktonic species present is one specimen of N. pachyderma left coiled.

The next assemblage present is faunal unit 4 (50-100 cm) and is marked by a peak in the occurrence of I. helenae (30-45%) accompanied by C. reniforme (12-18%) and E. excavatum (23-30%). Haynesina orbiculare, B. frigida and N. labradorica are consistantly present in low numbers. Total number of benthonic specimens drops off sharply in this unit (105 specimens/10 cc at 75 cm). Planktonic specimens are all N. pachyderma left coiled.

Underlying unit 4 are two faunas not observed in Cores 07TW and P, now named faunal units 5 and 6. Unit 5 (13LH:100-<200 cm) is characterized by a dominance of C. reniforme and a co-dominance of I. helenae (together totalling 40-70% of

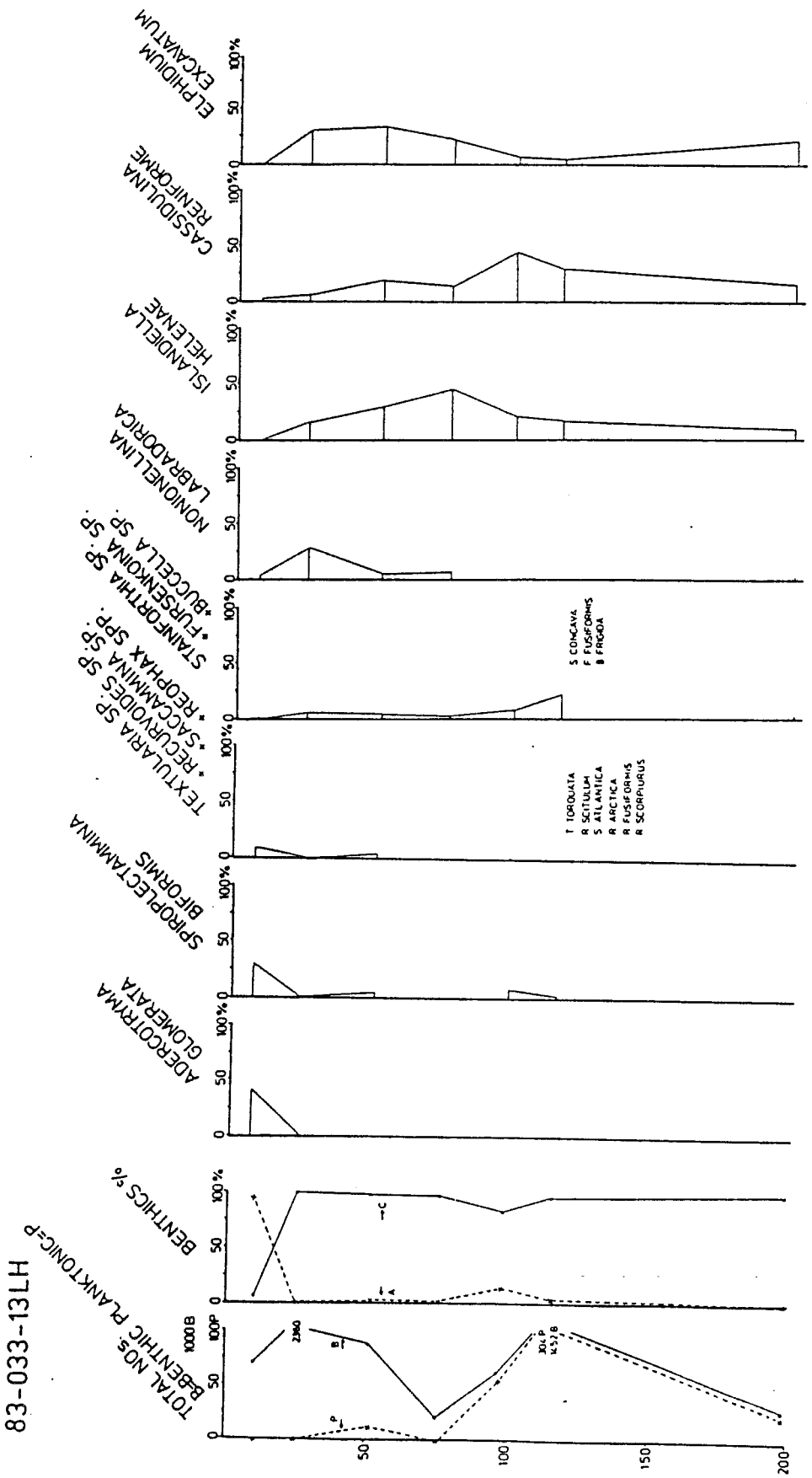

Figure 10: Downcore percent occurrences of the dominant benthonic foraminiferal species, Core 13LH.

the fauna from 100-125 cm) and lower percentages (<10%) of E. excavatum. N. labradorica is absent from this fauna. There is also a noticeable agglutinated component to this fauna, dominated by S. biformis and T. nana. Another occurrence to note is the higher numbers of planktonic specimens present (60-300/10 cc). Though N. pachyderma left coiled is the most common species N. pachyderma right coiled and G. quinqueloba (left and right coiled) are consistently present and there are also scattered occurrences of Globigerinita uvula, G. gluttinata, Globigerindides ruber and Globorotalia scitula.

At the base of the core (200 cm) Unit 6 occurs. C. reniforme and I. helenae drop to 25% (combined) and E. excavatum rises to 20%. In both units 5 and 6 there are also many calcareous shelf species present (e.g. Astrononion gallowayi, Brizalina pseudopunctata, Cibicides lobatalus, E. bartletti, E. subarcticum, Epistominella takayanagii, Fissurina marginata, H. orbiculare, S. concava, I. norcrossi and M. barleeanum are present as well as scattered occurrences of Lagena spp., Oolina spp., Pullenia spp. and Quinqueloculin spp. N. labradorica is almost completely absent in this fauna. Total numbers are lower in unit 6 but numerous planktonic species are still present.

Four faunal units occur in Cores 15TW and P (Figures 11 and 14). The top most unit (15TW:0-50 cm, 15P:0-40 cm) is the agglutinated fauna, as observed in Cores 07 and 13. Again S. biformis and A. glomerata are the dominant species, co-dominant are Textularia spp. (T. earlandi and T. torquata), R. scitulum, Reophax spp. (R. arctica, R. gracilis, R. scorpiurus) and S. atlantica. There are minor consistent occurrences of C. reniforme and E. excavatum in this assemblage and low numbers of I. helenae. There is very good overlap at the 30 cm mark in 15TW with the 25 cm assemblage in Core 15P; therefore the overlap occurs between 0-10 cm in Core 15TW and not more than 10 cm is missing from the top of Core 15P. The cross over between the calcareous and agglutinated per cent components occurs quite deep in Core 15P, at approximently 60 cm (Figure 11).

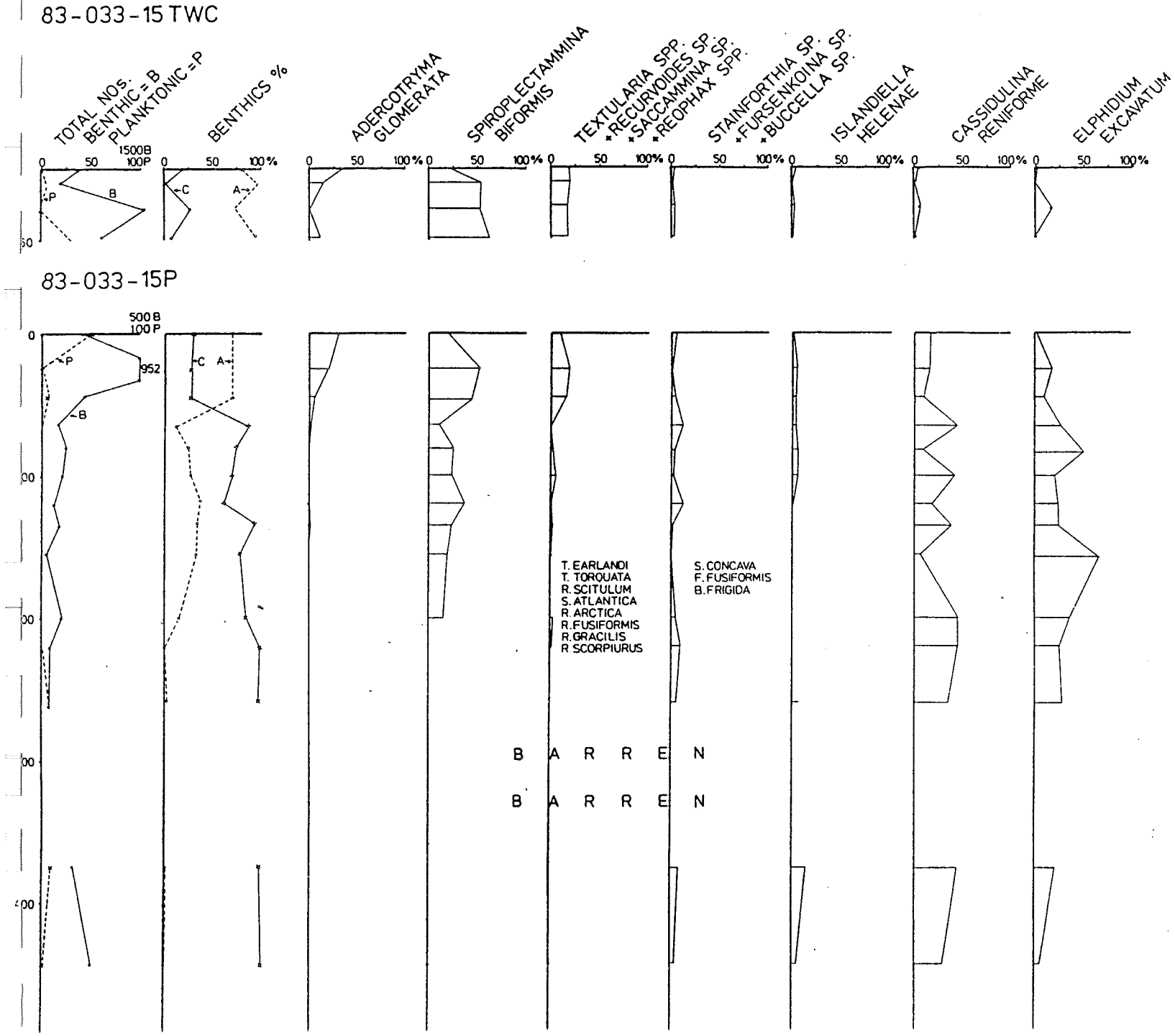

Figure 11: Downcore percent occurrences of the dominant benthonic foraminiferal species, Cores 15TW and P.

Total numbers of benthonic specimens are < 1500/10 cc, approximately 75 % of the fauna is agglutinated. Planktonic foraminifera are low in number (< 50) and the assemblage is dominated by N. pachyderma left coiled,though there is a varied planktonic assemblage present at the top of 15P.

Underlying unit 1 is a calacareous assemblage named faunal unit 7 (15P:40-200cm). It is dominated by C. reniforme, E. excavatum and an unusual occurrence of S. biformis; these three species can comprise up to 90% of the fauna. There are scattered minor occurrences of B. frigida, E. bartletti and H. orbiculare. Species diversity is low as are the total number of bethonic specimens (20-125 specimens/10 cc) and approximately 75% of the benthonic fauna is calcareous. Planktonic specimens are absent.

Underlying unit 7 is what is believed to be unit 4 (15P:200-260 cm), the C. reniforme - E. excavatum (total 60-75%) fauna observed in Cores 07P and 13LH, but in Core 15 almost lacking N. labradorica and I. helenae. There are low total numbers (benthonic) and only a few specimens of N. pachyderma left coiled.

Unit 6 (15P:260-450 cm) occurs directly beneath unit 7 and is the shelf fauna observed in Core 13LH. The dominant species is C. reniforme, subdominant species are E. excavatum, E. subarcticum, I. helenae, T. angulosa and B. frigida with occurrences of C. lobatalus, E. bartletti, E. takayanagii and I. norcrossi. Total numbers of benthonic specimens are low (45-250/ 10 cc) and planktonic numbers are low, but there is a varied assemblage present. There is also a barren zone absent of foraminifera at the 300 and 340 cm intervals.

Cores 16 TW and P and Cores 17 TW and P contain similar sequences as those found in Cores 15 TW and P. There are four faunal units recognized in Cores 16 TW and P (Figures 12 and 14). The agglutinated assemblage occurs from 16TW:0-50 cm, marked by the dominance of S. biformis and A. glomerata and very low numbers of C. reniforme and E. excavatum. N. labradorica also occurs. The top sample of Core 16P (15 cm) also contains this assemblage. The 50 cm sample in Core 16TW

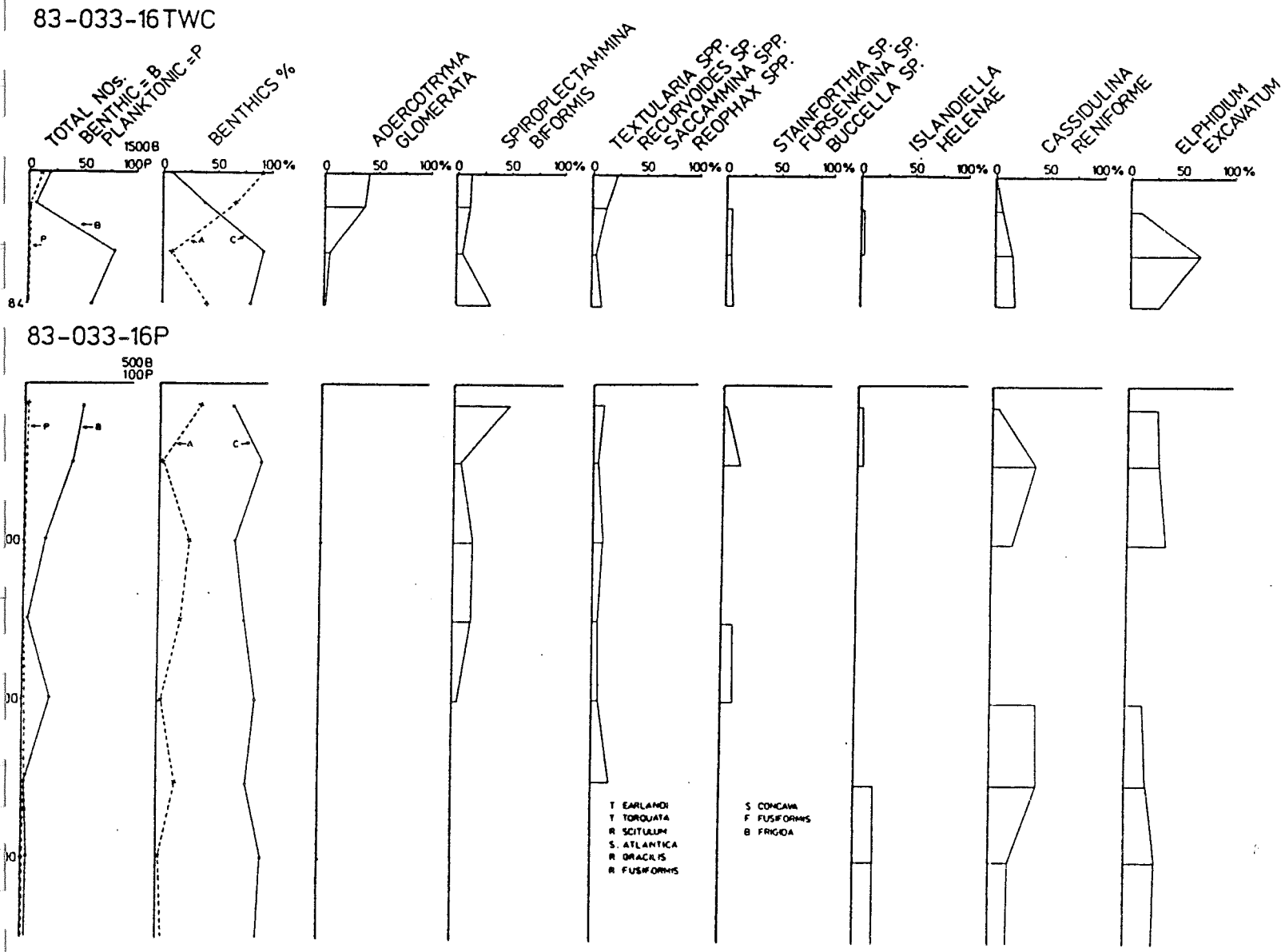

Figure 12: Downcore percent occurrences of the dominant benthonic foraminiferal species, Cores 16TW and P.

appears to match the 50 cm sample in Core 16P so the overlap occurs at the surface and there is little if any missing from the top of the piston core. The total number of benthonic specimens varies considerably (100-1300/ 10 cc) and there are few planktonic specimens.

Immediately underlying the agglutinated assemblage is faunal unit 7 (16TW:50-52 cm, 16P:50-150 cm), the C. reniforme - E. excavatum - S. biformis assemblage with an absence of N. labradorica and I. helenae. There are low numbers of H. orbiculare and E. bartletti present. Total numbers of benthonic specimens are low (<200/ 10 cc) and there is only one planktonic specimen present. In Core 16P:150-250 cm is an unusual assemblage believed to correlate with the barren zone in Core 15P. There are low numbers (<120/ 10 cc) and the assemblage is dominated by Buliminella elegantissima (58% at 150 cm). The sample at 200 cm also contains C. reniforme, E. excavatum and N. pachyderma left coiled. Both samples also contain S. biformis, Reophax gracilis, Stetsonia horvathi and Stainforthia concava. This is the only occurrence of this assemblage and it has been included with faunal unit 7 because it contains the three dominant species of this unit.

Underlying unit 7 is unit 6 (16P:250-440 cm) the shelf fauna, dominanted by C. reniforme and E. excavatum, co-dominanted by I. helenae with T. angulosa and E. bartletti. Total numbers are still low and planktonics are absent.

Cores 17TW and P (Figures 13 and 14) also contain unit 1 (the agglutinated assemblage) at the top (17TW:0-42 cm, 17P:0-10 cm). There doesn't appear to be a match between the assemblages in the two cores; the crossover between the calcareous and agglutinated per cent occurrences does not occur in the TW core. It is assumed that most of the agglutinated assemblage is missing from Core 17P.

Underlying unit 1 is unit 7 (17P:10-160 cm), the C. reniforme - E. excavatum - S. biformis assemblage, very similar to that seen previously in Cores 15P and 16P. These three species comprise 60-70% of the fauna. H. orbiculare, I.

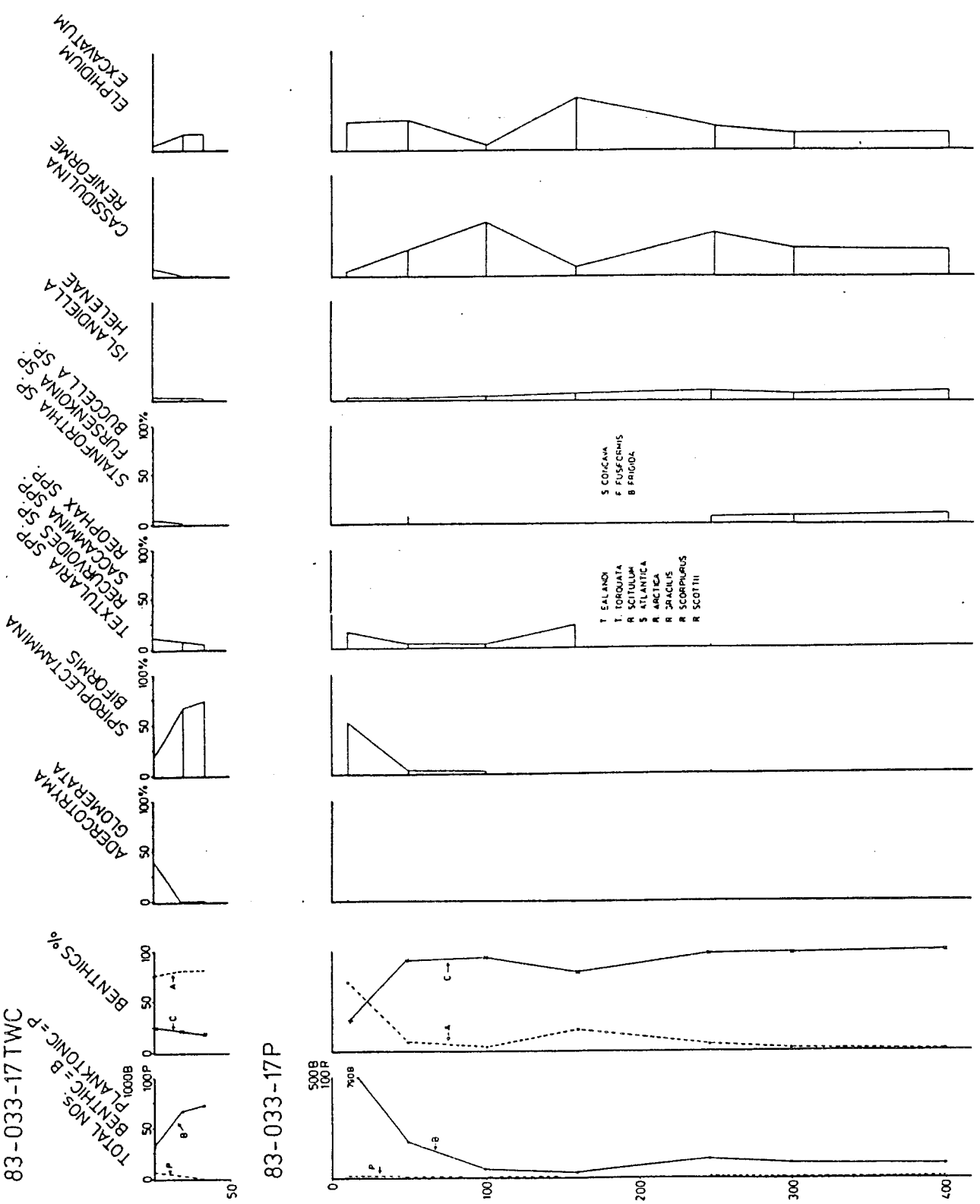

Figure 13: Downcore percent occurrences of the dominant benthonic foraminiferal species, Cores 17TW and P.

helenae are also consistently present. Total number of benthonic specimens are low (21-170 specimens / 10 cc). Some samples are barren of planktonic foraminifera; the sample at 160 cm contains one specimen of G. uvula.

Underlying unit 7 is unit 6 (17P:160-400 cm), the shelf fauna. Species diversity increases noticeably, though E. excavatum and C. reniforme continue to be the dominant species, the per cent occurrences of E. excavatum drop off to < 25%. Subdominant species are B. frigida, I. helenae, I. norcrossi and I. angulosa. E. subarcticum, E. takayanagii and I. islandica are also consistently present. In the lower most sample three planktonic specimens were present, one each of G. quinqueloba - right coiled, N. dutertrei and one juvenile.

DISCUSSION

Previous Work

Before interpreting the environment of deposition and inferred paleo-oceanography at these core sites, the post-glacial sequence at the three other locations (previously mentioned) on the continental margin will be reviewed, then comparisons with the results of this work will be made.

The first area of interest is one off Lake Melville in Labrador known as Cartwright Saddle; Cartwright Saddle core 12 has been extensively described and the data from it used in reconstructing post glacial environments (Mudie et al., 1984; Scott et al., 1984; Vilks and Mudie, 1978; Vilks, 1980, 1981). The data for this core is given in Scott et al. (1984).

The Cartwright Saddle surface sediments are influenced by Outer Labrador Current waters. The surface assemblage is dominated by N. labradorica (40-50%) and E. excavatum and also contains high total numbers of both benthonic and planktonic specimens (Scott et al., 1984). As piston core tops were the source

of surficial data it is possible that the true surface assemblage is missing. Another factor is the sieve size used in processing, for Cartwright Saddle cores it was 0.125 mm. Sieve fractions 0.063 - 0.125 mm for three Cartwright saddle core tops have been examined (Miller and Mudie, unpub. data) and the smaller fraction contains a noticeable portion of the fauna, which is small agglutinated/calcareous specimens, particularily data for core 12.

Beneath this N. labradorica fauna at Cartwright Saddle is a C. reniforme, I. teretis (=I. helenae) fauna with subdominant species E. excavatum. There is a noticeable decrease in the percent occurrence of N. labradorica. This fauna is interpreted as also being deposited beneath an Outer Labrador Current water mass during the early to mid Holocene, but a current slightly colder than the present day current.

The oldest post glacial fauna at Cartwright Saddle is the glacial marine fauna dominated by E. excavatum, C. reniforme and N. labradorica. This is a late Pleistocene fauna interpreted as being a "warm" ice margin fauna (Scott and Medioli, 1980b; Scott et al., 1984; Vilks, 1981). It is believed to have been deposited along a glacial ice margin, where sea water temperatures were relatively high compared with present day glacial marine environments (Scott et al. 1984).

The second area of interest is just inshore (west) of Cartwright Saddle, south of Groswater Bay; an area under the Inner Labrador Current water mass. A series of 6 piston cores, from water depths of 95-335 m taken on the inner shelf contain basal till overlain by a mixture of clay and sandy - gravelly mud (Vilks et al. 1984). These cores contain three distinct faunas downcore (Vilks et al., 1984). The core taken farthest offshore (core 82, in a 335 m water depth) contains a short (0-5 cm) sequence characterized by a predominantly (80%) agglutinated assemblage of A. glomerata, C. crassimargo and S. biformis. Only core 92, taken closest to shore (109 m of water), contains a longer sequence (107 cm) with an

agglutinated assemblage, though this 'inshore' assemblage is dominated by S. biformis, Reophax spp.. Eggerella advena and I. helenae (Vilks et al., 1984). this inshore fauna is quite diverse and contains other agglutinated and calcareous species. Underlying this assemblage is the C. reniforme, I. helenae and E. excavatum "warm" ice-margin fauna (Scott et al., 1984), the same Late Wisconsinan post glacial fauna found at the Cartwright Saddle location. The contact between these two faunas is sharp and coupled with acoustic and lithologic data is believed to represent an unconformity (Vilks et al., 1984).

The third "faunal" unit is barren of foraminifera except for the occasional occurrences of reworked tests and is interpreted as a period of relatively fast sedimentation of glacial material (Vilks et al., 1984). The boundary between the ice-margin fauna and barren zone is gradual (Vilks et al., 1984).

The third area of interest is on the Newfoundland, rather than the Labrador margin. Two cores from one site (78-023-20TW and P) in Notre Dame Channel (286 m of water) were obtained from an area where the sediments have been deposited in a uniform manner without truncations (Dale and Haworth, 1979). The piston core penetrated glacial till and has provided the most complete glacial - post glacial marine record available from the Newfoundland Shelf (Scott et al., 1984). Directly inshore of this location, MacNeil (1986) has extensively studied cores 80-030-26TW and P from a 267 m water depth in Outer Notre Dame Bay. It too contains what is believed to be a continuous glacial - post glacial record. The cores from these two sites contained somewhat similar foraminiferal assemblages; the sequence at these two locations is much more complex than that seen at either Cartwright Saddle or Groswater Bay. At both locations the surficial assemblage is the agglutinated S. biformis - A. glomerata assemblage followed downcore by the N. labradorica peak. After this point the assemblages do not correlate exactly. In core 26P the sequence is: a Reophax spp. dominated assemblage, an E. excavatum - I. helenae - C. reniforme fauna, a barren zone, an I. helenae - S.

biformis - T. nana fauna, a C. reniforme - E. excavatum - I. helenae - B. frigida - F. fusiformis (= F. fusiformis and S. concava) assemblage, an E. excavatum - C. reniforme unit, a barren zone, and at the base a C. reniforme - E. takayanagii assemblage (MacNeil, 1986). The offshore core, Core 20P, contains a C. reniforme - I. helenae fauna, the Reophax spp. assemblage and then four units dominated by C. reniforme / E. excavatum / I. teretis (= I. helenae) and F. fusiformis (=F. fusiformis and S. concava). Underlying these units is a zone dominated by S. biformis, then a E. excavatum - C. reniforme assemblage and at the base a barren zone (Scott et al., 1984). Scott (1987, pers. comm.) correlates the barren zones at the base of each core and is of the opinion that these sediments are glacial till deposited by a grounded ice sheet. The C. reniforme - E. excavatum - I. helenae - F. fusiformis dominated units in both cores are interpreted as occurring beneath a floating ice shelf (Scott et al., 1984). F. fusiformis as a dominant or sub-dominant species occurs in present day deep estuarine conditions (Scott et al. 1980; Miller et al., 1982b), in a quiet low-oxygen environment with slightly lowered salinities. The similar E. excavatum - C. reniforme fauna with an agglutinated component found near the base of both cores probably reflects one or more of the following: shallower, colder water, coarser sediment, higher sedimentation rates and reduced salinities. All of these conditions would be found on an ice margin, particularily a melting one.

Environmental Interpretation - Foraminifera

The A. glomerata - S. biformis assemblage which occurs at the surface of all cores (Figure 14) is interpreted as appearing in conjunction with the present day Inner Labrador Current. This assemblage corresponds well to the offshore agglutinated assemblage Vilks et al. (1982, 1984) find in the surficial sediments and the top portions of piston cores off Lake Melville and Groswater Bay. Scott et al. (1984) and MacNeil (1986) found this assemblage in their TW cores and the

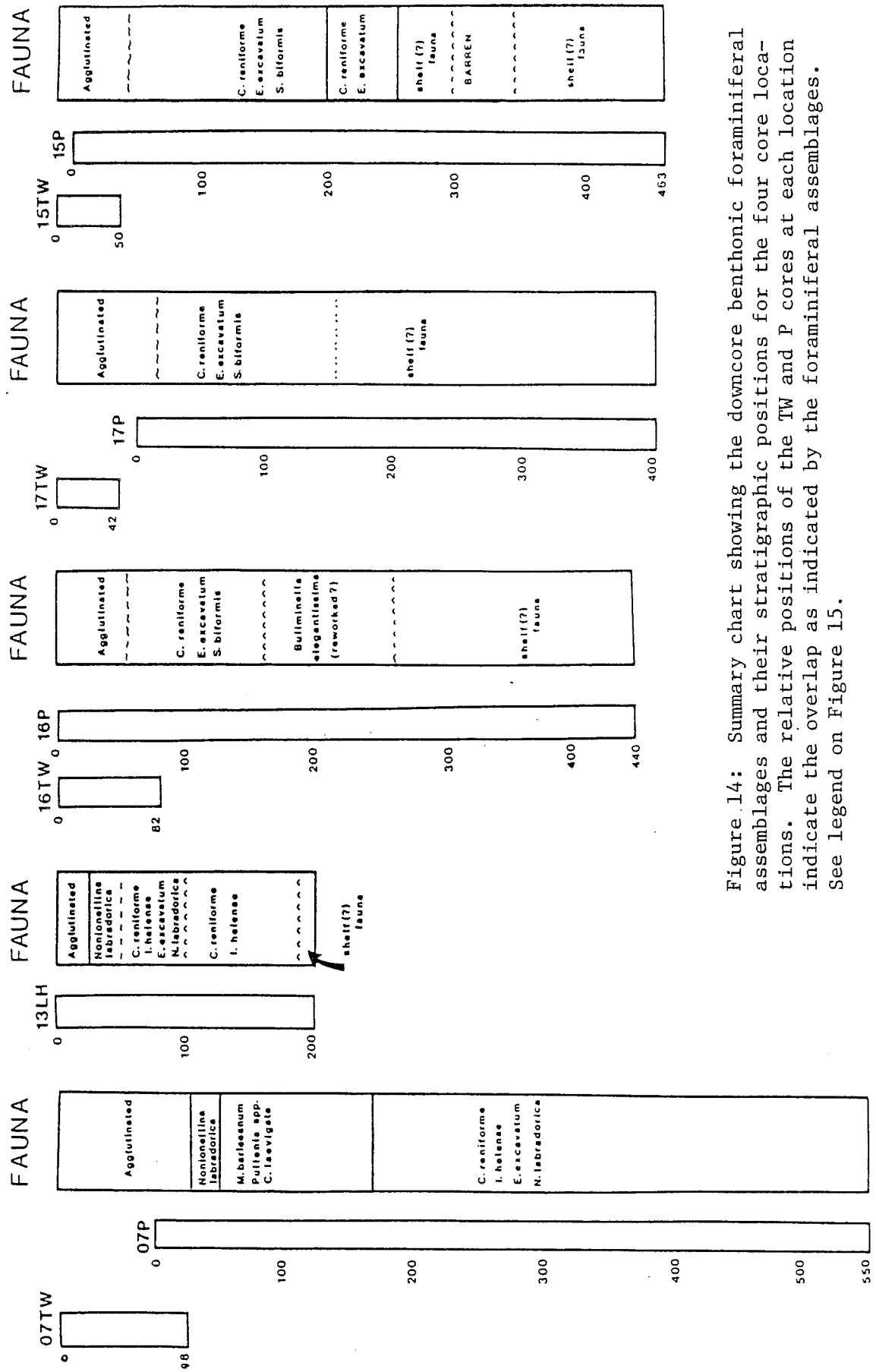

Figure 14: Summary chart showing the downcore benthonic foraminiferal assemblages and their stratigraphic positions for the four core locations. The relative positions of the TW and P cores at each location indicate the overlap as indicated by the foraminiferal assemblages. See legend on Figure 15.

surface of one piston core (78-023-20TW:0-25 cm, and 80-030-26TW:0-20 cm, 26P:0-10 cm) from Notre Dame Bay and Notre Dame Channel, respectively. It also corresponds well to the fauna found in the surface of box cores taken at the same sites (MacKinnon and Scott, unpub. data; Vilks et al., 1984). The Inner Labrador Current waters have a temperature of 0-3^{o} C and a salinity of 31-34 $^{o/oo}$ (Scott et al., 1984)

The N. labradorica fauna in Cores 07P and 13LH is similar to what has been found in the surficial sediments of Cartwright and Hawke Saddles, and Notre Dame Bay and Channel (Vilks et al. 1982, 1984; Scott et al., 1984; MacNeil, 1986). This fauna in Core 07P and in the Notre Dame Channel cores is interpreted as being deposited in conditions similar to areas now under the influence of the present day Outer Labrador Current (i.e. Cartwright Saddle), areas in deep water basins on the outer Labrador Shelf where there is mixing of arctic and subarctic water (Mudie et al., 1984; Vilks, 1980, 1981).

The third faunal unit, which appears only in Core 07P, is dominated by E. excavatum - C. reniforme - I. helenae (which comprise approximately 60% of the fauna) but it is the presence of Melonis barleeanum - Pullenia spp. - C. laevigata on which the fauna is defined. The consistent presence of these three species is more difficult to explain, (1) because there is no present day equivalent on the Newfoundland or the Labrador shelves, and (2) there is no similar Quaternary faunal unit in any of the Labrador - Newfoundland areas that have been subject to any detailed study. Vilks (1981) finds comparable numbers of M. zaandamae (= M. barleeanum) as common in specific zones of the Quaternary in northern Europe, but the two genera (Melonis and Pullenia) are not reported as occurring concurrently.

These two genera are currently found in an area offshore of this Core 07P site, on the Newfoundland Slope (southeast of the Core 07 site, northeast of Core 15), and area studied by Cole (1981) and Schafer et al. (1981). Cole (1981)

reports P. bulloides as common from 390-3210 m, and abundant from 600-1380 m; P. osloensis as scattered from 400-3000 m; and M. zaandamae (= M. barleeanum) as scattered from 390-3210 m and common from 500-1600 m. However, Schafer et al. (1981) place these genera in their thanatotope 1A, an area confined to water depths of < 2000 m and containing a diverse arenaceous - calcareous fauna with many deep water calcareous forms which are absent in Core 07P faunal unit 3. Their thanatotope does show minor occurrences of Oolina, Lenticulina and Dentalina, genera found in this unit 3, too. These are common arctic water (shelf) genera (Loeblich and Tappan, 1953). Schafer et al. (1981) are of the opinion that this fauna is governed by the Outer Labrador Current. This is an area of upwelling and mixing (Cole, 1985 pers. comm.), also indicated by the presence of diatoms in the samples (Appendix B). The presence of C. laevigata in conjunction with C. reniforme is somewhat similar to the middle unit found in cores from Emerald Basin (Scott et al., 1984). Scott et al. (1984) report an absence of I. helenae and E. excavatum where numbers of C. laevigata are high, but they also report Globobulimina auriculata, Cibicides sp. and scattered occurrences of various shelf species in conjunction with this fauna. Vilks (1985, pers. comm.) suggests that this represents an "offshore" Labrador Current water mass, cold and more saline than the present day Outer Labrador Current.

Faunal unit 4 is the E. excavatum - C. reniforme fauna, well documented and discussed (Mudie et al., 1984; Scott and Medioli, 1980a; Scott et al., 1984; Vilks, 1980, 1981) and for which there is no modern analogue.

Cores 07P and 13LH contain this fauna accompanied by I. helenae and N. labradorica, very similar to that found by Vilks (1981) and Scott et al. (1984) at Cartwright and Hawke Saddles. Vilks and Mudie (1978), Mudie et al. (1984) and Scott et al. (1984) interpret this fauna as influenced by Outer rather than Inner Labrador Current waters. It also appears in faunal units in the Notre Dame Bay and Channel cores, though N. labradorica is not a dominant species in the

assemblages. This may be due to the shallow water depth and inshore location of these two cores; N. labradorica prefers offshore basin environments over 300 m deep. This may explain the presence of N. labradorica in Cores 07P and 13LH, and it's absence at the Core 15, 16 and 17 sites, as well as the two inshore cores from Notre Dame Bay and Channel.

What is found in Cores 15, 16 and 17 is a C. reniforme - E. excavatum - S. biformis fauna. This is very similar to units found by both Scott et al. (1984) and MacNeil (1986) downcore at the two Notre Dame Bay and Channel sites. This is also very comparable to faunas observed off Baffin Island Fjords today (Schafer and Cole, 1986). These fjords are covered with sea ice most of the year; have bottom salinities of 33.0 - 34.5 $^{o/oo}$ and temperatures in the range of 1.3 - 1.5^{o} C. There are high SPM concentrations and moderate to high sedimentation rates.

The sediments in which this fauna is found show evidence of reworking in Cores 15, 16 and 17. Sediment is coarse, angular and poorly sorted; low foraminiferal numbers probably indicate a high sedimentation rate. There is a section in Core 16 underlying this fauna that appears to be reworked and there is a zone barren of foraminifera in Core 15P, underlying a C. reniforme - E. excavatum fauna from which the agglutinated fauna is absent. These barren / reworked zones were probably the result of till or till- like material being deposited in almost glacial fluvial conditions.

The contact between the Inner Labrador Current (agglutinated) fauna and the "warm" ice margin fauna is sharp (at 40-60 cm) in all three cores and must contain an unconformity.

Scott et al. (1984) and MacNeil (1986) report a similar fauna in both of their core sites and Scott et al. (1984) interpret this as indicating a slight warming period (Outer Labrador Current event) at approximately 21,000 YBP.

At the base of Cores 13LH, 15P, 16P and 17P is a diverse fauna dominated by C. reniforme - E. excavatum and accompanied by many shelf species. It compares very

well with the Arctic shelf fauna seen by Loeblich and Tappan (1953) and by Schafer et al. (1981). Schafer et al. (1981) are of the opinion that this fauna is governed by the Outer Labrador Current. This fauna, particularily in Core 13LH, is accompanied by a abundant and diverse planktonic fauna. This diverse fauna would not be present under ice cover and probably indicates a mixing of water masses.

Both of the areas where this fauna is currently found are ice free for a portion of the year. This fauna was probably deposited in an environment offshore of the ice sheet before the ice entered a recessional state, and the C. reniforme - E. excavatum - S. biformis fauna was deposited during the recession. The shelf fauna would have been deposited in a quiet, open marine environment with near normal salinities and not a high terrigenous sediment input. Loeblich and Tappan (1953) report this fauna from sandy and gravelly substrates and well oxygenated waters less than 300 m deep.

Regional Correlation and Framework

Though there is little direct chronological control (i.e. C^{14} dates) on these cores, dates are available from some of the other material discussed and the corresponding oceanographic events extrapolated to these core sites. In addition there is detailed pollen stratigraphy for Cores 07TW and P and 15P; in addition to both the Notre Dame Bay and Channel Cores.

These events will be discussed here in chronological order, (i.e. oldest to youngest) and are shown on Figures 14 and 15.

Scott et al. (1984) have a C^{14} date on Core 20P from Notre Dame Channel, dating material containing the C. reniforme - E. excavatum - S. biformis fauna at 21, 000 YBP. Scott et al. (1984) are of the opinion that this may be indicative of an interstade, a slight warming event when the ice was in a recessional state that may be correlateable with isotope stage 3. The underlying shelf fauna would

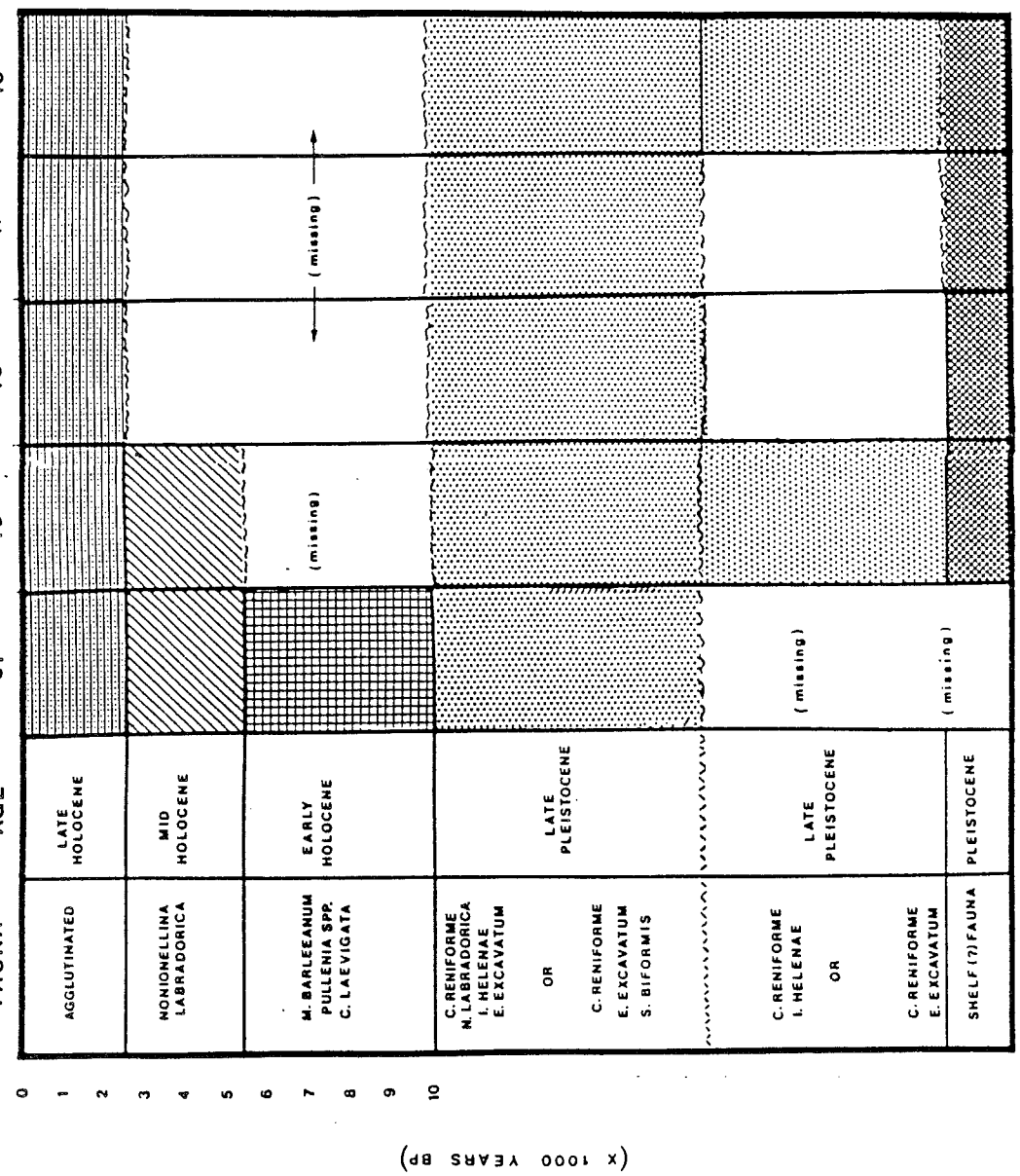

Figure 15: A summary of the history of the bottom water mass distribution at the five core locations.

have been deposited when conditions were static, a cold open marine shelf environment, free of continuous ice cover, with a low influx of melt water and sediment. This shelf fauna must have been deposited at least 25,000 YBP.

The C. reniforme - E. excavatum - I. helenae - N. labradorica assemblage underlying the N. labradorica assemblage in Core 13LH and at the base in Core 07P is observed in all marine shelf sediments and is dated at 16,000 - 12,000 YBP, from the Labrador Shelf to the Gulf of Maine (Schnitker, 1976) and the Bay of Fundy (Scott and Medioli, 1980b). This is a late glacial ice-margin fauna. The presence of this fauna on the Inner Labrador Shelf and on Cartwright Saddle suggests tha these areas were not glaciated during the Late Wisconsinan (Vilks and Mudie, 1978; Vilks, 1980, 1981; Vilks et al., 1984) though the same fauna at the Notre Dame Channel site is interpreted as reflecting glacial meltwater/a permanent ice shelf during the Late Wisconsinan (Scott et al., 1984). The E. excavatum - C. reniforme - S. biformis assemblage may be the shallow water/ice margin equivalent of the floating ice shelf/deeper water of the "calcareous" assemblage.

Overlying this unit in Core 07P (absent from all others) is an "offshore" Labrador Current fauna (I. helenae - C. reniforme - C. laevigata dominated), accompanied by Melonis barleeanum and Pullenia spp. It represents a water mass more saline than the two underlying faunas. This M. barleeanum - Pullenia spp. fauna is similar to the present day Newfoundland slope fauna occurring with the Outer Labrador Current and may indicate the early development of the Labrador Current. The boundary between this fauna and the underlying C. reniforme - E. excavatum fauna is considered to mark the glacial - post glacial boundary but there is not enough control to determine if this is the Holocene - Pleistocene boundary. This fauna could be very late Pleistocene or early Holocene; it is unlikely that it is older than 12,000 years.

The Nonionellina labradorica fauna occurred on the inner shelf during the

early to mid-Holocene (Scott et al., 1984) and occurs in outer shelf basins today (Vilks, 1980, 1981; Scott et al., 1984); if indicative of present Outer Labrador Current conditions then it probably represents a drop in salinity and approximately the same water temperature as the M. barleeanum - Pullenia spp. - C. laevigata fauna as the Labrador Current continued to develop (7,000 - 5,000 YBP). The N. labradorica fauna is abruptly replaced by a late Holocene agglutinated fauna in all cores, which appeared with the development of the Inner Labrador Current 2,500 YBP. This Inner Labrador Current is colder and less saline than the Outer Labrador Current waters.

Pollen stratigraphies confirm the glacial - post glacial boundaries as determined by the foraminifera. Smith (Figures 4, 5 and 6, Miller et al., 1985) places the glacial - post glacial boundary in Core 07P at 200 cm and in Core 15P at 80 cm. MacPherson (1986, pers. comm.) has completed a pollen stratigraphy for the Notre Dame Bay Cores 26TW and P and places the Holocene - pre-Holocene boundary at 26P:10 cm, at the base of the N. labradorica foraminiferal assemblage. Mudie (in Scott et al., 1984) has completed pollen analysis for the Notre Dame Channel Core and places the glacial - post glacial boundary at 20P:200 cm. At all four sites the change in foraminiferal assemblage occurs after the change in pollen which may indicate a lag in bottom water changes.

Due to the similarities in the sequences in Cores 15, 16 and 17, the boundary in Core 15 can be extrapolated to both Cores 16 and 17 at the base of the agglutinated assemblage. Similarily the glacial - post glacial boundary in Core 13LH has been extrapolated to the base of the C. reniforme - E. excavatum - I. helenae - N. labradorica assemblage.

In summary, the cores from sites 13, 15, 16 and 17 show a shelf fauna, probably indicative of static ice margin conditions 20,000 - 25,000 YBP. The barren zone in Core 15P and reworked zone in Core 16P probably indicate an influx of sediment and hyposaline waters compatible with the possibility of a warming

period or interstade with ice in a recessional state. The C. reniforme - E. excavatum fauna overlies this in Core 15P and C. reniforme - I. helenae overlies it in Core 13LH. This unit in Core 15P is included with the C. reniforme - S. biformis assemblage, which may have been deposited in glacial marine or almost fluvial conditions during this warming (?) period, or the period immediately following (a cooling period ? 20,000 - 16,000 YBP) but it is still interpreted as not being deposited under continuous ice cover. This fauna is truncated by an unconformity in all three cores.

Both of these faunas (units 6 and 7) would have been under the influence of the Outer Labrador Current.

In Core 13LH is the C. reniforme - I. helenae assemblage overlain by C. reniforme - I. helenae - E. excavatum - N. labradorica, the late glacial ice shelf fauna, late Pleistocene in age. This fauna is the oldest found in Core 07P. In Core 13LH this fauna is truncated by an unconformity, in Core 07P it is overlain by an offshore, normal marine, post glacial (late Pleistocene - early Holocene) shelf fauna. During the early and mid Holocene there was a cooling and an increase in salinity as indicated by the M. barleeanum - Pullenia spp. - C. laevigata fauna, and then the N. labradorica fauna. Cooling has continued and the salinity has decreased steadily since the mid Holocene; the present day conditions are the coldest and least saline since the last glacial. The planktonic foraminifera occurring with the agglutinated fauna in Cores 15, 16 and 17 indicate that the Inner Labrador Current surface waters are being mixed with Gulf Stream waters.

The stratigraphic sequence in Core 07P appears to be complete and the benthonic foraminifera show no evidence of reworking. If this Core 07P sequence is complete then Core 13LH contains at least one unconformity and most of the early Holocene is missing; and Cores 15P, 16P and 17P contain at least one unconformity and most of the Holocene is missing; there is part (or all) of the late Holocene

overlying late Pleistocene glacial or early post glacial sediments. Consequently there is no sedimentary record here for the period 10,000 - 2,500 YBP, perhaps longer. The total numbers, lack of planktonic forms and condition of the glacial fauna do not rule out the possiblitiy of grounded ice/reworking in this section of the cores.

CONCLUSIONS

1. Core 07TW and P appear to contain a continuous though not necessarily complete post glacial record. Core 13LH contains late Pleistocene faunas overlain by mid and late Holocene faunas; some of the early Holocene record appears to be missing. Cores at sites 15, 16 and 17 contain only a late Holocene fauna overlying a glacial fauna and a late glacial/early post glacial fauna; consequently most of the Holocene sedimentary record is absent at these three sites.

2. There are four distinct benthonic foraminiferal faunas in Cores 07TW anf P: an agglutinated (Inner Labrador Current - Late Holocene) assemblage; a N. labradorica (Outer Labrador Current - early to mid Holocene) assemblage; a M. barleeanum - Pullenia spp. - C. laeviqata ("cold" more saline offshore Labrador Current - post glacial; early Holocene) assemblage; and a C. reniforme - E. excavatum - I. helenae - N. labradorica ("warm" ice margin - glacial/early post glacial; late Pleistocene) assemblage.

3. Core 13LH contains a condensed sequence, probably containing two unconformities, the late and mid Holocene agglutinated and N. labradorica assemblages unconformibly overlying the "warm" ice margin fauna in turn unconformibly overlying a cold shelf fauna. The planktonic foraminifera accompanying this shelf fauna indicate an area free of continuous ice cover and a mixing of water masses.

4. Cores at sites 15, 16 and 17 contain the late Holocene agglutinated assemblage unconformably overlying a late Pleistocene sequence consisting of an ice shelf/ice margin fauna and barren/reworked zones. All three piston cores contain the shelf fauna at the base.

5. The post glacial record in Cores 07TW and P indicates a "warm" interval of low salinity immediately following deglaciation, followed by cooling (which has continued to the present day) and an early Holocene increase in salinity. Salinity has continued to decrease since early Holocene times, to present day conditions.

6. The planktonic foraminifera in the surface sediments at sites 15, 16 and 17 indicate a mixing of Inner Labrador Current - Gulf Stream surface waters during the late Holocene at this site.

ACKNOWLEDGEMENTS

This work was completed under D.S.S. contract (09SC.23420-6-M840) to the Centre for Marine Geology (CMG), Dalhousie University (principal investigator R. Boyd). I thank Dr. G. Vilks and Dr. C. F. M. Lewis (Atlantic Geoscience Centre) for making this award possible and Dr. R. Boyd and Dr. D.B. Scott (CMG) for providing facilities to complete the work at the Centre for Marine Geology. I also thank Dr. Vilks and Mr. B. Deonarine (AGC) for participating in core sampling; Mrs. I. Hardy and the core repository staff (AGC) for supplying exact core locations, water depths and sampling information; Mrs. D. C. Younger (CMG) for sample processing; Mr. V. Baki (CMG) for patiently producing the data tables and Ms. F. Bulca for drafting some of the figures. I also thank Dr. Vilks, Mrs. F. Cole (AGC), Dr. Scott and Dr. C. J. Schroder (CMG) for assisting with some of the species identifications and taxonomy. I also thank Drs. Vilks and Scott for helpful discussions concerning the paleo-environmental interpretation.

Technical Report No. 4, Part II, Centre for Marine Geology, Dalhousie University.

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APPENDIX C

(supercedes APPENDIX A)

Faunal List of Foraminifera

This is not a taxonomic report and synonymies will not be given here. However, it is important that an unambiguous concept of each species be conveyed to the reader, to that end the following references are given, with illustrations / synonymies of each species cited in this report. Where the name of the species in this report is not the same as the one cited in the given reference, the name immediately following in brackets [] is the one used in the reference given.

The generic classification is in accordance with Loeblich and Tappan (1964) except for Atlantiella (Saidova, 1981; see Loeblich and Tappan, 1985) and Haynesina (Banner and Culver, 1978).

References are listed in reverse chronological order (starting with the most recent). First agglutinated, then calcareous species are listed; within each group the listing is alphabetic. Planktonic foraminifera are listed at the end.

Benthic Foraminifera

Schröder, 1986

Adercotryma glomerata (Brady)
Ammodiscus incertus (d'Orbigny)
Astrammina sphaerica (Heron-Allen and Earland)
Haplophragmoides bradyi (Robertson)
Recurvoides scitulum (Brady)
Reophax fusiformis (Williamson)
Reophax scorpiurus (de Montfort)
Saccammina sphaerica Brady

Kaminski, 1983

Hyperammina cylindrica (Parr)
Saccammina tubulata (Sars)

Miller et al., 1982a

Elphidium excavatum (Terquem) - mostly specimens of E. excavatum forma clavata, with some specimens of forma magna.

Miller et al., 1982b

Ammotium cassis (Parker)
Cribrostomoides crassimargo (Norman)
Reophax arctica Brady
Reophax scottii Chaster
Saccammina atlantica Cushman
Spiroplectammina biformis (Parker and Jones)
Textularia torquata Parker
Trochrammina ochracea (Williamson)

Brizalina pseudopunctata (Höglund)
Buccella frigida (Cushman)
Buliminella elegantissima (d'Orbigny)
Cassidulina reniforme (Nørvang)
Elphidium bartletti Cushman
Elphidium subarcticum Cushman
Epistominella takayanagii Iwasa
Fissurina marginata (Montagu)
Fursenkoina fusiformis (Williamson)
Glabratella wrightii (Brady)
Haynesina orbiculare (Brady)
Nonionellina labradorica (Dawson)
Quinqueloculina seminula (Linné)

Vilks et al., 1982

Atlantiella atlantica (Parker) [Trochamminella atlantica]
Cibicides lobatalus (Walker and Jacob)
Islandiella helenae (Feyling-Hanssen and Buzas)
Nonionella auricula (Heron-Allen and Earland)

Cole, 1981

Textularia earlandi Phleger

Cycloqyra involvens (Reuss)
Gyroidina soldanii (d'Orbigny)
Pullenia bulloides (d'Orgigny)
Pullenia osloensis Feyling-Hanssen
Stainforthia concava (Höglund)

Scott and Medioli, 1980a

Hemisphaerammina bradyi Loeblich and Tappan

Lagoe, 1977

Stetsonia horvathi Green [Stetsonia horvathi and Epistominella arctica]

Knudsen, 1971

Eggerella scabra (Williamson)
Bulimina marginata d'Orbigny
Cassidulina laevigata d'Orbigny
Elphidium groenlandicum Cushman
Guttulina lactea (d'Orbigny)
Islandiella islandica (Nørvang)
Islandiella norcrossi (Cushman)
Oolina striatopunctata (Parker and Jones)
Trifarina angulosa (Williamson) [Trifarina fluens]

Barker, 1960

Tholosina bulla (Brady)
Tritaxis conica (d'Orbigny) [Textularia conica]

Astacolus crepidulus (Fichtel and Moll)
Cibicides pseudoungerianus (Cushman)
Lagena distoma Parker and Jones
Lagena striata (d'Orbigny)
Lenticulina gibba (d'Orbigny)
Nonionella turgida (Williamson)
Oolina globosa (Montagu)
Pullenia subcarinata (d'Orbigny)
Sigmoidella pacifica (Cushman and Ozawa)

Loeblich and Tappan, 1953

Cribrostomoides jeffreysi (Williamson) [Alveophragmium jeffreysi]
Silicosigmoilina groenlandica (Cushman)
Trochammina nana (Brady)

Astacolus hyalacrulus Loeblich and Tappan
Astrononion gallowayi Loeblich and Tappan
Dentalina baggi Galloway and Wissler
Dentalina frobisherensis Loeblich and Tappan
Dentalina ittai Loeblich and Tappan
Dentalina pauperata d'Orbigny
Fissurina cucurbitasema Loeblich and Tappan
Globobulimina auriculata (Bailey)
Lagena laevis (Montagu)
Lagena semilineata Wright
Laryngosigma hyalacrulus Loeblich and Tappan
Laryngosigma williamsoni (Terquem)
Melonis barleeanum (Williamson) [Nonion zaandamae]
Miliolinella chukchiensis Loeblich and Tappan
Oolina costata (Williamson)
Oolina lineata (Williamson)
Oolina melo d'Orbigny

Oolina squamosa (Montagu)
Oolina striatopunctata (Parker and Jones)
Parafissurina himatiostoma Loeblich and Tappan
Parafissurina tectulostoma Loeblich and Tappan
Quinqueloculina arctica Cushman
Quinqueloculina stalkeri Loeblich and Tappan
Robertinoides charlottensis (Cushman)
Scutuloris tegminus Loeblich and Tappan
Triloculina trihedra Loeblich and Tappan

Parker, 1952

Reophax gracilis (Kiar)

Discorbis squamata Parker
Eoeponidella pulchella (Parker) [Pninaella (?) pulchella]
Nonionella turgida (Williamson) var. digitata Nørvang

Parker and Phleger, 1952

Gavelinopsis transluscens Phleger and Parker ['Rotalia' transluscens]
Höglundina elegans (d'Orbigny)
Valvulineria laevigata Phleger and Parker

Planktonic Foraminifera

Saito et al., 1981

Globigerina bulloides (d'Orbigny)
Globigerina quinqueloba - left and right coiled Natland
Globigerinita glutinata (Egger)
Globigerinita uvula (Natland)
Globigerinoides ruber (d'Orbigny)
Globorotalia scitula (Brady)
Neogloboquadrina dutertri (d'Orbigny)
Neogloboquadrina pachyderma - left and right coiled (Ehrenberg)
Orbulina universa(d'Orbigny)