HOLOCENE RELATIVE SEA-LEVEL CHANGE

IN NOVA SCOTIA

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Submitted in Partial Fulfilment of the Requirements
for the Degree of Bachelor of Science, Honours
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March 1993

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DATE April 23, 1993

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TITLE Holocene Relative Sea-level Change in Nova Scotia

Degree BSc. Convocation May Year 1993

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ABSTRACT

Core samples collected around Atlantic Canada, specifically from the West Head salt marsh, Chezzetcook Inlet, enable temporal and spatial examination of benthic foraminiferal assemblages. Benthic foraminiferal zonations, representing specific environments above mean sea level, occur in salt marshes. *Trochammina macrescens* and *Tiphotrocha comprimata* indicate the higher high water (HHW) level, the maximum tidal extent during any time period and the most accurate former sea-level marker. Collected core samples yielded nine accurate sea-level points and one additional point was extrapolated from Baie Verte. Carbon-14 dating (corrected to sidereal years) permits the construction of a Holocene relative sea-level (RSL) curve by plotting corrected ^{14}C dates (temporal) against corresponding sample depths (spatial). The curve produced for the Atlantic coast of Nova Scotia shows a rise in RSL for the last 7859 years and, more specifically, a RSL rise in Chezzetcook for 4247 years. RSL curves are variable across Atlantic Canada and local isostatic adjustment associated with peripheral forebulge migration following deglaciation is probably the source of the overall variation. However, an acceleration observed between 5295-3819 ybp in this curve and a previous curve from Northern Nova Scotia is hypothesised to be a eustatic response, possibly correlated with an oscillation reported in South Carolina.

Key Words: foraminifera, salt marsh, Chezzetcook Inlet, Holocene, relative sea level, peripheral forebulge, eustatic

This work is dedicated to my Grandparents
Dr. and Mrs. John Hunter

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ACKNOWLEDGEMENTS

The author thanks his supervisor Dr. D.B. Scott for suggesting the research topic and for his time, thoughts, encouragement, and constructive evaluations; Dr. D.B. Clarke for his many suggestions and writing assistance; Dr. P. Robinson for allowing use of his resources; Eric Collins and Cecily Honig for their technical assistance and many suggestions; and to all others in the department who contributed their time and effort.

CHAPTER 1 INTRODUCTION

1.1 Introduction

Foraminifera are heterotrophic marine organisms belonging to the Phylum Protozoa, Class Sarcodina (Loeblich and Tappan 1964). Single or multi-chambered tests composed of chitinous, agglutinated, or calcareous material enclose living foraminifera (Boltovskoy and Wright 1976). Chitinous foraminifera use polysaccharides formed from N-acetyl-glucosamine in test formation. Agglutinated foraminifera cement particles onto tectin, an organic membrane, during test formation. Calcareous foraminifera, however, secrete a calcium carbonate test of either granular or hyaline character (Haq and Boersma 1978).

Foraminiferal habitats include all marine environments from tidal marshes to the deepest abyssal plains. Factors which determine habitat for individual species include temperature, salinity, feeding rates, pH, water depth, turbidity, and inter- and intraspecific competition (Murray 1991; Boltovskoy and Wright 1976). Planktonic foraminifera, for example, occupy the photic zone in the open ocean, whereas benthic foraminifera live on the ocean bottom.

Foraminiferal associations in the stratigraphic record can indicate specific paleoenvironments. For example, foraminiferal zones, ranging vertically from lowest low marsh at mean sea level (MSL) to highest marsh at higher high water (HHW), exist in salt marshes. These zones, which occur in conjunction with floral assemblages and appear to be controlled by elevation relative to MSL (Scott 1977; Scott and

Medioli 1978; Scott and Medioli 1980; Scott et al. 1981), aid in constructing relative sea-level (RSL) curves.

1.2 Purpose

The purpose of this project is to measure the frequency distribution of populations of salt marsh foraminifera from cores collected in the West Head of Chezzetcook Inlet, Nova Scotia (Fig. 1.1), to qualitatively evaluate the frequencies obtained, and to determine the age by carbon-14 (^{14}C) dating of selected samples. These analyses, coupled with selected samples from elsewhere in Atlantic Canada, permit construction of a Holocene RSL curve, using benthic foraminiferal assemblages indicative of HHW environments for elevation and ^{14}C dates for timing.

1.3 Scope

The scope of this investigation includes cores containing HHW intervals collected within the West Head salt marsh; published data from Nova Scotia including Bedford Basin (Miller et al. 1982), Lunenburg (Scott and Medioli 1982), and Baie Verte (Scott et al. 1987a); and ^{14}C dates. Previous work provides the basis for interpretation of foraminiferal zones (Scott and Medioli 1980).

1.4 Physical Setting

Chezzetcook Inlet is situated on the Eastern Shore of Nova Scotia 45 km ENE of Halifax at 44° 80'N and 63° 30'W. Spits and sand bars anchored in glacial

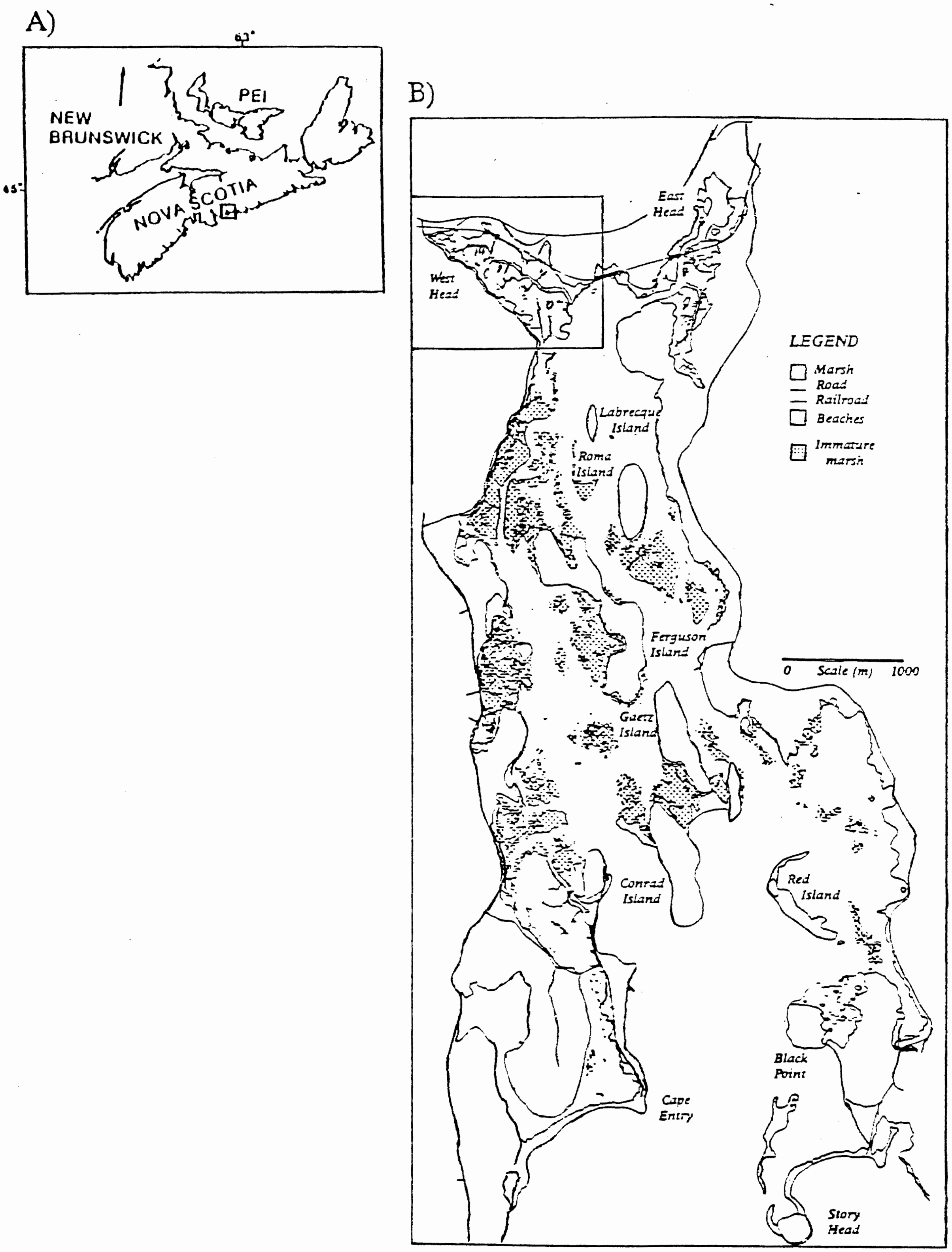

Figure 1.1. A) A regional location map showing the location (box) of Chezzetcook Inlet (after Honig, 1987), B) A map of Chezzetcook Inlet showing the relative location of the West Head salt marsh (box) and some physical characteristics (after Scott and Medioli 1980).

C)

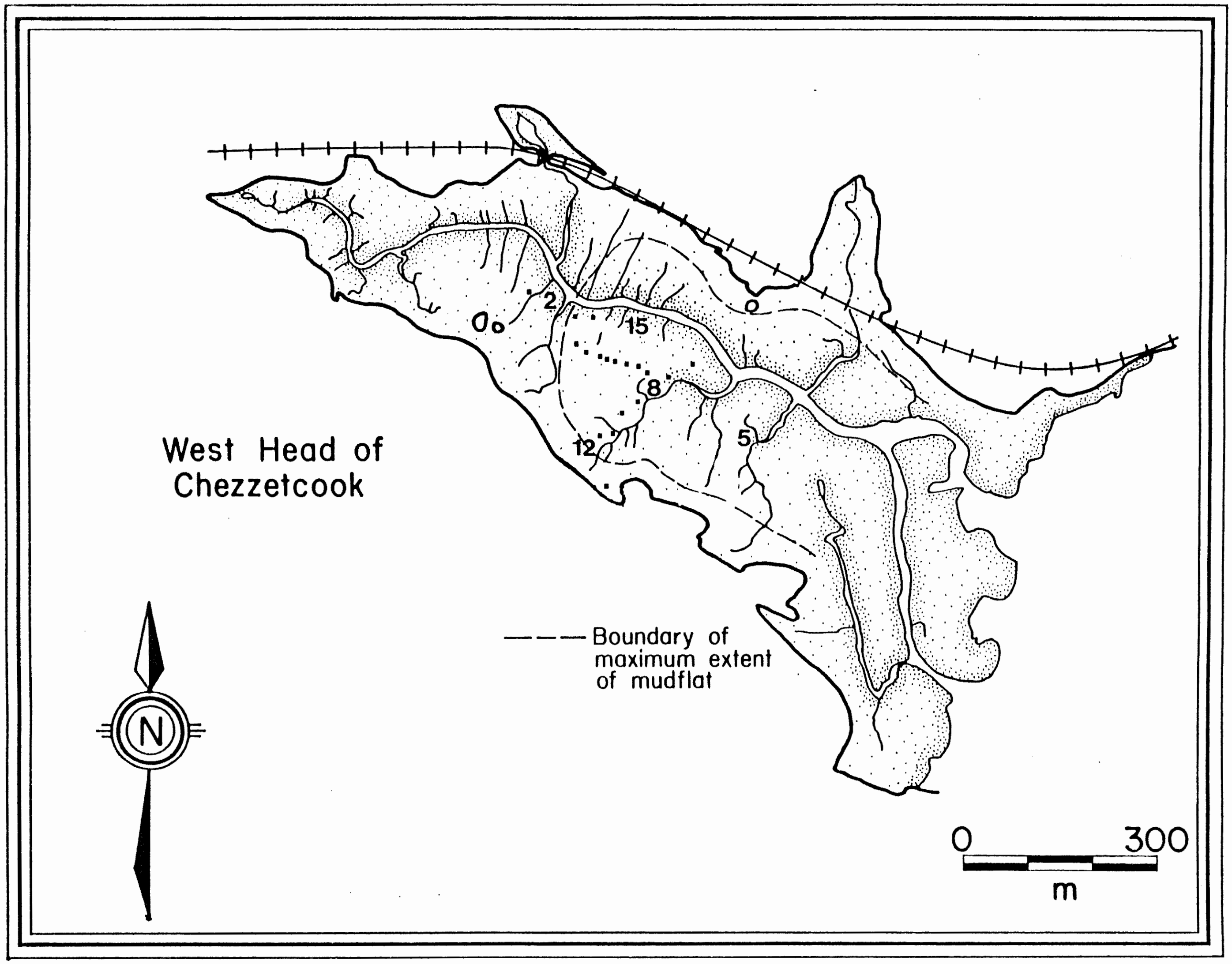

Figure 1.1. C) West Head salt marsh showing vibracore sites (numbers) and Davis corer sites (·) (after Scott et al. 1988).

drumlins characterize the estuary at its mouth. In the inlet itself, intertidal mudflats, salt marshes, and tidal channels are the dominant environments.

Vertical vegetative zonations (Fig 1.2) characterize salt marshes globally (Chapman 1960, as cited by Scott 1977; Scott and Medioli 1980), including Atlantic Canada, particularly Chezzetcook (Scott 1977; Scott and Medioli 1980; Scott et al. 1981; Scott et al. 1988). The plant species *Spartina alterniflora* and *Spartina patens* typically characterize low marsh environments, *Spartina patens* indicates middle marsh, and *Juncus gerardii, Solidago sempervirens, Potentilla anserina* and Cyperaceae represent high marsh.

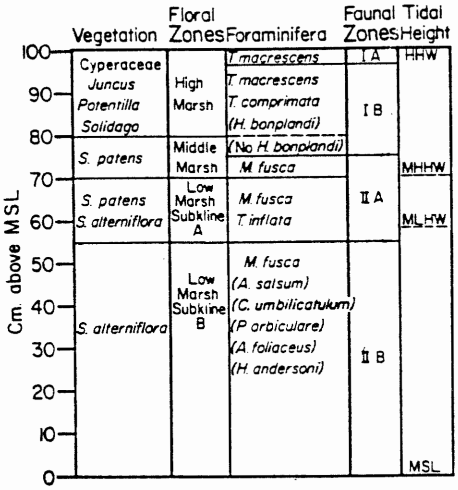

Figure 1.2. Chezzetcook salt marsh vegetation, floral zones, foraminifera, faunal zones, and tidal heights defined by elevation above MSL (from Scott and Medioli 1978).

1.5 Previous Investigations

Scott and Medioli (1978) showed two vertical foraminiferal zonations (Fig. 1.2) in the Chezzetcook salt marshes. The lower zone (Zone II) ranges from 0 to +75 cm above MSL and contains *Ammobaculites dilatatus, Ammotium salsum, Miliammina* *fusca*, and *Trochammina inflata*. *Tiphotrocha comprimata*, *Trochammina macrescens*, and *Haplophragmoides manilaensis* characterize Zone I which ranges from +75 cm to +101 cm above MSL. The +75 cm boundary marks a compositional change in foraminiferal assemblages, whereas the +110 cm boundary marks the end of the foraminiferal range and the HHW level. Subzone IA occurs from 100 to +110 cm above MSL, marks the highest tidal levels, and consists primarily of high numbers of *T. macrescens*. Application of these faunal zones in the stratigraphic record can locate former sea-level positions.

Several investigators have determined Nova Scotian Holocene RSLs. Scott et al. (1987b) used marsh foraminiferal zonations to produce local Holocene RSL curves (Fig. 1.3). Honig (1987) used estuarine sedimentation, coupled with microfaunal assemblages, along the Eastern Shore of Nova Scotia to show a transgressive sequence during the Holocene. Facies characteristics, microfaunal assemblages, stratigraphic relationships, and modern estuarine sedimentary processes show transgressive conditions in local areas (Boyd and Honig 1992).

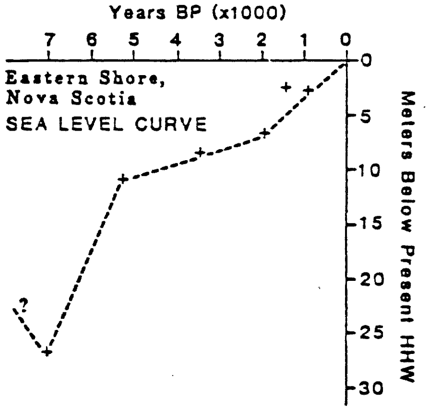

Figure 1.3. RSL curve of Eastern Shore, Nova Scotia. C^{14} dates are not corrected for sidereal years (after Scott et al. 1987b).

Combinations of local RSL curves established other local trends of Holocene RSL. Belknap et al. (1987) showed that the Maine coastline is transgressing in response to eustatic sea-level changes and isostatic subsidence (Fig. 1.4). Scott and Greenberg (1983) showed evidence for RSL increments in the Bay of Fundy using microfaunal data obtained from salt marsh peat (Smith et al. 1984). Studies using foraminiferal zonations in Prince Edward Island show an increasing trend of RSL rise, with the rate of rise greater in the east than the west (Scott et al. 1981). Scott et al. (1987b) compiled data from all of the Maritimes, showed regional trends, and compared them to theoretical models.

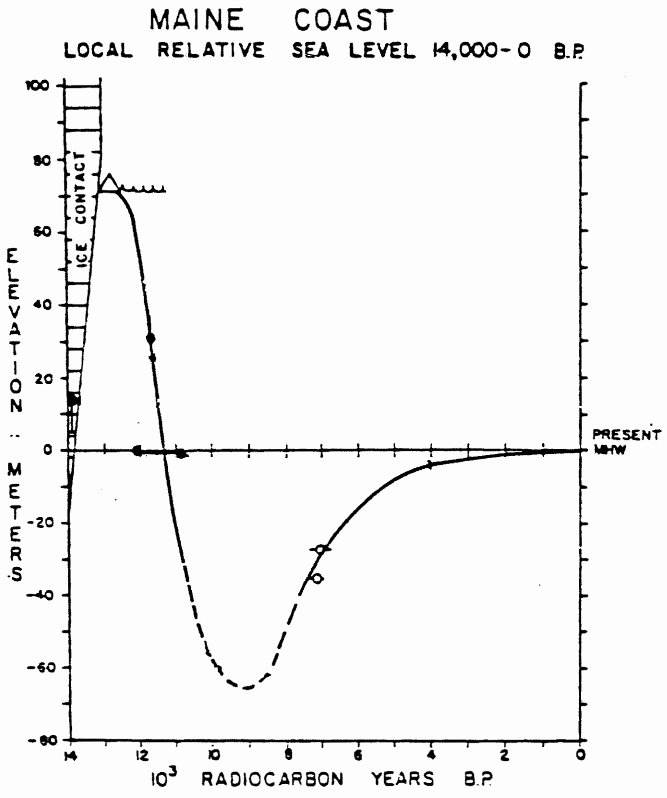

Figure 1.4. Regional RSL curve based on data from Maine (after Belknap et al. 1987).

Whereas local RSL curves can produce similar results, they cannot be extrapolated on a world-wide scale (Ota et al. 1988, Pirazzoli and Montaggioni 1988, Katupotha and Fujiwara 1988, Kayan 1988). Newman et al. (1989) plotted all known sea-level points against time, and found that no global trend for RSL existed in the Holocene (Fig. 1.5).

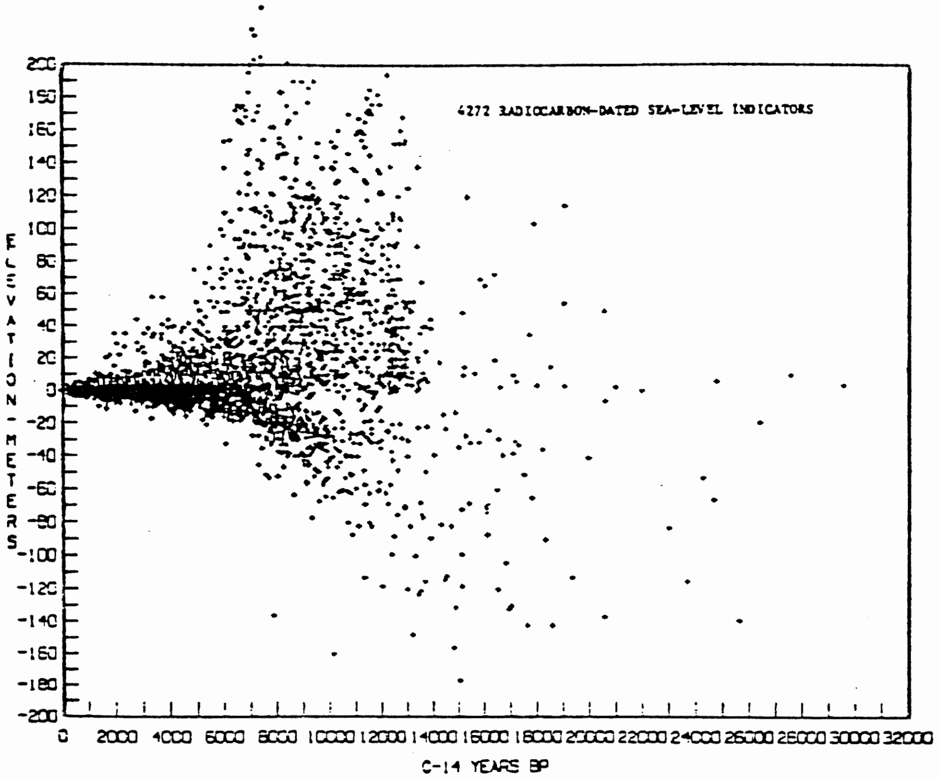

Figure 1.5. Scatter diagram representing global sea-level indicators (from Newman et al. 1989).

1.6 Organization

Chapter 1 introduces foraminiferal research and discusses the purpose, scope, and physical setting of the current Holocene RSL investigation. Chapter 2 outlines the methodology of this research, including data collection methods, sampling techniques, foraminiferal analysis, and ^{14}C dating procedures. Chapters 3 and 4 deal explicitly with results of foraminiferal analysis and ^{14}C dating, and with discussion of results regarding Holocene RSL change in Nova Scotia. Finally, Chapter 5 concludes the investigation and summarizes main points of interest.

CHAPTER 2 METHODS

2.1 Introduction

Cores were retrieved from Chezzetcook Inlet using a vibracore and Davis peat corer. Analysis of foraminifera and ^{14}C dating of samples from the cores provided the essential data to construct a Holocene RSL curve.

2.2 Vibracoring

Subsurface samples were obtained using a Wink vibracore fitted with aluminum tubing (Honig 1987). A Honda 5 hp gasoline motor provided sufficient vibration for ground penetration. The vibrations generated by the motor were conducted through a 369 cm flexible rotating shaft plugged into the vibracore head attached firmly to the aluminum tubing. The vibrations produced along the outside edges of the aluminum tubing allowed the tube to penetrate through the soft sediments.

When the vibracore reached its maximum penetration, the motor was switched off. The ground level was marked on the aluminum tubing. If the core did not fill the aluminum tube, water was poured into the tubing until it reached a level of 10-15 cm below the top, then the aluminum tubing was capped with a rubber stopper. An aluminum tripod was erected above the aluminum tubing. The core was then pulled out using a hand winch and a chain wrapped around the exposed tubing. The rubber stopper produced a suction vacuum preventing loss of material during extraction of the core.

Cores were protected with a plastic cap and sealed using electrical tape. Cores were labelled to indicate top, site number, depth intervals, location names, and dates. Each tube was cut at the ground level marker and the core measured to give total penetration depth. By measuring the distance between the top (ground level) and the sediment within the tubing, the degree of compaction caused by coring and friction in the tube was determined by comparing the distance the tube penetrated with the actual length of the sediment in the core tube. The top of the core was marked and the tubing was cut 15 cm above the mark. The core tube was cut in 1.5 m intervals, labelled, and the ends capped. All measurements and labelling were recorded in a field notebook.

2.3 Splitting

The aluminum tubing was split into two longitudinal sections using a radial arm saw and a U-shaped tray to house the tube as it was pushed past the saw. Ideally, splitting procedures resulted in shaving the aluminum tubing so that all but a few millimetres of aluminum were removed, thus preventing the core sections from falling apart before processing.

During processing, any thin aluminum threads produced by the saw were peeled away. A thin wire was placed between the sawn halves and pulled along the section length, severing the cores into two portions. Each core half was relabelled, one half for analysis and the other half for archiving. Split core sections were wrapped in plastic wrap, placed in plastic layflat (D-tubes) tubing, taped shut, and relabelled. Core sections are stored in a cold room at temperatures between 2-4°C in the Centre for Marine Geology, Dalhousie University.

2.4 Davis Coring

Davis coring allowed sampling at specific depths. A 1-m Davis core steel section was pushed into the ground until approximately 30 cm of the section remained above ground. Additional 1-m sections were attached if greater penetration was desired. The Davis core was triggered at the desired depth by activating a locking mechanism on an open core barrel by pulling upwards and a "snapshot" sample was retrieved thereafter by pushing downwards. After obtaining the sample, the Davis core was withdrawn and dismantled. The samples were labelled and stored in plastic containers.

2.5 Sampling

Vibracore sections were photographed and described to identify intervals used for foraminiferal and ^{14}C analysis. Designated areas were removed from the cores with two spatulas. Typically, 20 cc of core material was removed for foraminiferal analysis, and 10 cc removed for ^{14}C dating. Samples were taken above, at, and below textural boundary changes, and in 20-cm intervals if the core section was homogeneous. Material removed from the cores during sampling was replaced with plastic wrap. Specific Davis core samples were chosen for foraminiferal analysis and ^{14}C dating.

Samples for foraminiferal analysis were processed through a >63 µm sieve which retained foraminifera and a 500 µm sieve which retained coarse organic material. Material not passing through the >63 µm sieve was collected in plastic containers, while material in the >500 µm sieve was discarded. Light organic material was removed by decantation from the 63-500 µm fraction and collected in plastic containers. All samples were stored in alcohol.

Samples weighing 10 g were collected from peat and oyster shell layers within the vibra- and Davis cores for ^{14}C dating. These samples were oven dried at 55°C for several hours, weighed, and stored in sealed plastic containers.

2.6 Foraminiferal Examination

Foraminifera were rinsed in water through a >63 µm sieve and placed in a liquid medium in a petri dish. Samples containing abundant foraminifera were split using a wet splitter to retrieve a statistically correct sample of at least 300 individuals (Scott and Hermelin 1993). All samples were examined under a dissecting microscope at 20x and 40x magnification.

2.7 Carbon-14 Dating

According to Ogden (1975), radiocarbon is produced when cosmic rays, in the form of neutrons, bombard atmospheric nitrogen (Eqn. 2.1). Atmospheric radioactive

$$7N^{14} + {}_0n^1 \text{ --> } {}_6C^{14} + {}_1H^1 \qquad (2.1)$$

carbon is quickly converted into carbon dioxide. Photosynthetic plants fix carbon dioxide, and other organisms obtain this radioactive carbon by consuming the plants. After death, equilibrium with atmospheric radiocarbon no longer exists and natural radioactive decay begins.

Selected peat and oyster shell samples were sent to Krueger Enterprises, Inc., Geochron Laboratories Division, Cambridge, Massachusetts. According to Krueger Enterprises, the peat samples were treated as follows: The entire sample was dispersed in a large volume of water and the clays and organic matter were eluted away from any sand and silt by sedimentation and decantation. The clay/organic fraction was then treated with hot dilute HCl to remove any carbonates. It was then filtered, washed, dried, and roasted in oxygen to recover carbon dioxide from the organic matter for the analysis. Oyster shell fragments, however, were treated as follows: The shells were cleaned thoroughly in an ultrasonic cleaner. They were then leached thoroughly with dilute HCl to remove additional surficial material which may have been altered, and ensure that only fresh carbonate material was used. The cleaned shells were then hydrolyzed with HCl, under vacuum and the carbon dioxide was recovered for analysis.

All ^{14}C dates obtained were based on the Libby half life of 5570 years and referenced to 1950. All dates were then converted to sidereal years using a microcomputer program supplied by M. Stuiver (Stuiver and Reimer 1987).

2.8 Summary

Field cores from the West Head salt marsh provide stratigraphic data. Foraminiferal sample analyses locate former HHW zones spatially and ^{14}C dating provides the temporal values necessary for the construction of a Holocene RSL curve.

CHAPTER 3 RESULTS

3.1 Introduction

Vibracores and Davis cores were taken in two transects from the West Head salt marsh, Chezzetcook Inlet. Transect 1 includes Cores 2, 5, 8, and 15 (Fig. 3.1) whereas Transect 2 includes Cores 8 and 12 and Davis core 13 (Fig. 3.2). Results of foraminiferal analyses and ^{14}C dating of selected samples provide the necessary information for constructing a Holocene RSL curve.

3.2 Core 2 Lithology

Core 2 is 244 cm long with a compaction measurement of 108 cm (Fig. 3.1). The entire core is composed of salt marsh peat of varying composition. The upper 75 cm of the core contains rootlets, grass, and wood fragments dispersed in brown mud. Olive grey salt marsh occurs from 75-157 cm depth. Salt marsh dispersed in brown mud forms the remaining core from 157 to 244 cm.

3.3 Core 2 Foraminiferal Assemblages

Ten foraminiferal species occur in Core 2 (Table 3.1). Numbers of foraminifera ranged from 603-30976 per 10 cc of core, with an increase in abundance with depth. *Cribrostomoides crassimargo* is present only within the upper 2 cm, whereas *Miliammina fusca, Tiphotrocha comprimata, Trochammina inflata, and Trochammina macrescens* occur in most samples from Core 2. *Ammobaculites exigus,*

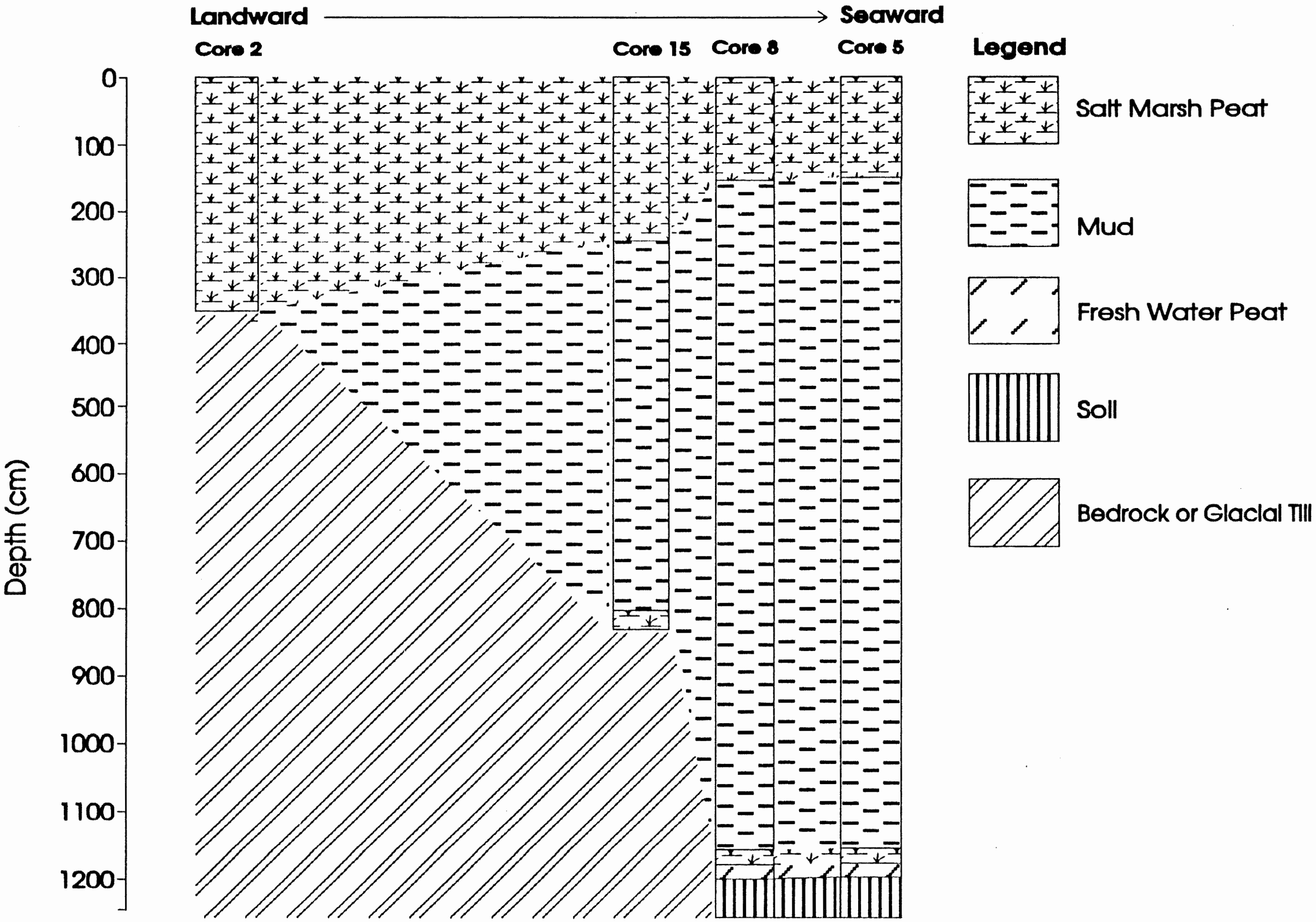

FIGURE 3.1. Lithological cross section of Transect 1, including Cores 2, 15, 8, and 5. Horizontal discontinuity prevented correlation between basal salt marsh peat units. Core locations shown on Fig. 1.1c.

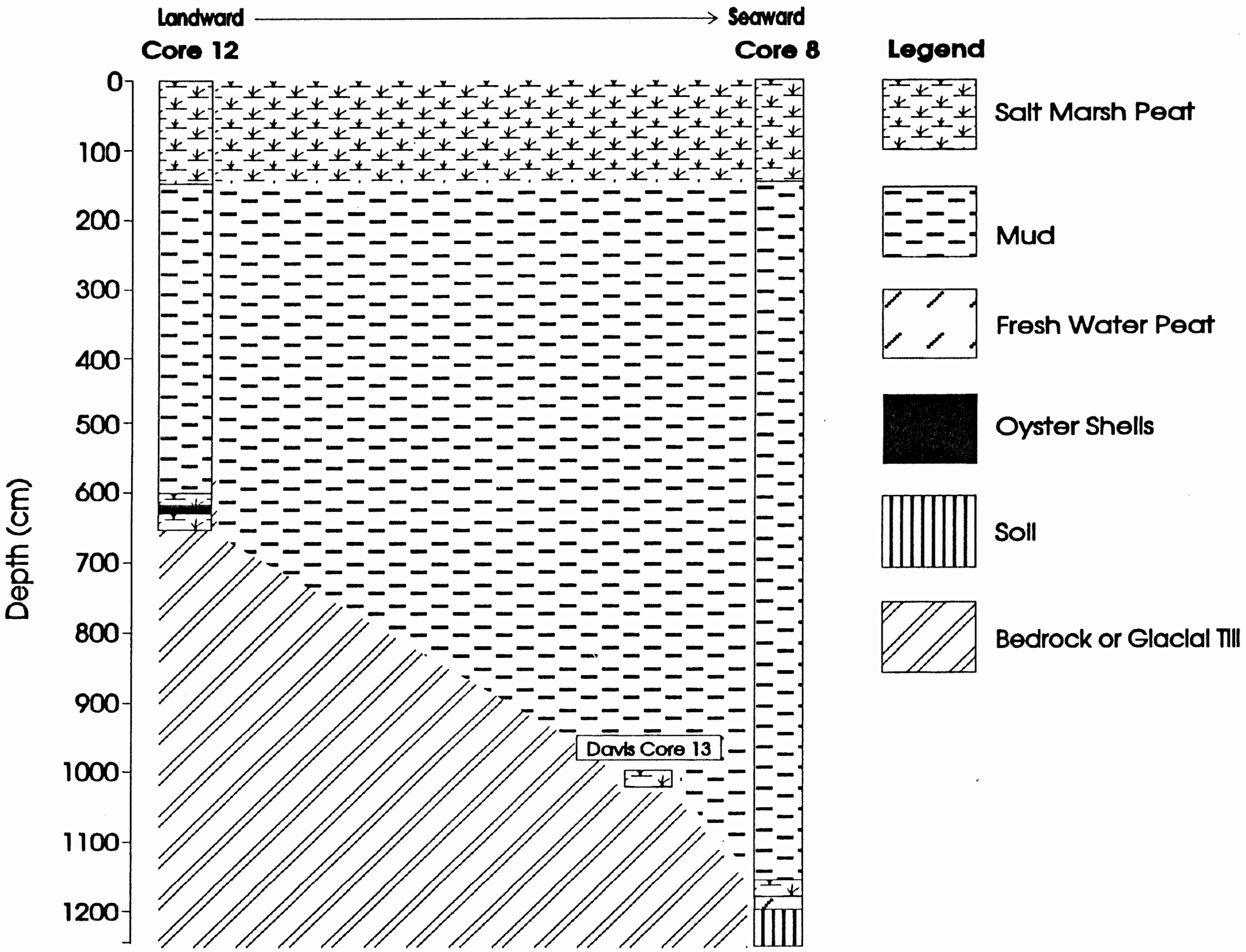

Figure 3.2. Lithological cross section representating transect 2, including Core 12, Davis Core 13, and Core 8. Horizontal discontinuity prevented correlation between basal salt marsh peat units. Core locations shown on Fig. 1.1c.

Depth in core (cm)	0-2	15-17	25-27	40-42	60-62	70-72	75-77	85-87	95-97	101-103	120-122	135-137	141-143
Total number of species	7	4	5	5	3	4	4	6	4	6	6	5	5
Total number of individuals/10cc	1112	3528	603	2644	14088	6456	5616	6144	2372	926	3387	4296	2906
Ammobaculites exigus													0.1
Ammotium salsum										0.1	0.1		
Cribrostomoides crassimargo	0.4												
Haplophragmoides manilaensis	0.2							0.1					
Miliammina fusca	3.6	3.9	1.5	16.6	0.2	0.9	1.3	0.4	1	9.6	4.5	2.6	0.8
Polysaccammina ipohalina							0.3	0.1					
Tiphotrocha comprimata	5.8	16.3	6.6	12.9	0.9	1.1	4.4	1.6	2.1	1.8	1.2	1.5	4.7
Trochammina inflata	3.4	2	1.5	0.5		0.1		2	0.1	0.6	3.8	2.8	1.7
T. macrescens	86.5	77.8	90.2	69.9	98.9	97.9	94	95.8	96.8	86.9	90.2	92.9	92.6
T. squamata	0.2		0.2	0.2						0.9	0.3	0.2	
Agglutinated foraminiferal fragments												16	8

Depth in core (cm)	161-163	169-171	175-177	185-187	195-197	202-204	210-212	217-219	224-226	231-233	238-240
Total number of species	6	5	4	4	5	5	5	4	4	4	5
Total number of individuals/10cc	9496	12384	2912	11536	6096	23208	30976	19776	15072	6188	10296
Ammobaculites exigus	0.1										
Ammotium salsum	0.1										
Cribrostomoides crassimargo											
Haplophragmoides manilaensis											
Miliammina fusca	2.6	0.8	1.5	1	0.8	1.8	1.8	1.3	1.8	0.4	1.9
Polysaccammina ipohalina		0.3			0.3	0.3	0.5				0.1
Tiphotrocha comprimata	13.3	4.8	23.2	29.3	36.1	21.8	23.7	32.5	29.1	31.1	21
Trochammina inflata	4.1	2.3	5.5	5.7	3.5	7.4	5.2	4.1	1.9		3
T. macrescens	79.8	91.9	68.9	64.1	59.3	68.6	68.8	62.2	67.3	68.4	74.1
T. squamata										0.1	
Agglutinated foraminiferal fragments	56		4		8						

Table 3.1. Core 2 total species, population density, foraminiferal species percentage, agglutinated foraminiferal fragment distributions versus depth.

Ammotium salsum, *Haplophragmoides manilaensis*, *Polysaccammina ipohalina*, *Trochammina squamata*, and unidentifiable agglutinated foraminiferal fragments are rare.

T. macrescens is the most abundant species throughout the core, while *M. fusca*, *T. comprimata*, and *T. inflata* are less common (Fig. 3.3). All other species form insignificant proportions of the total. With depth, however, *T. macrescens* abundance decreases and *T. comprimata* abundance increases. *M. fusca* and *T. inflata* abundances fluctuate throughout the core but remain generally lower than *T. macrescens* and *T. comprimata.*

3.4 Cores 5 and 8 Lithologies

Core 5 (from Scott 1977) and Core 8 are lithologically comparable (Fig. 3.1). Core 5 is 1200 cm long and has no compaction because it was drilled, not cored. The upper 155 cm is salt marsh dispersed in brown mud. Mud replaces salt marsh at 155 cm and is present to a depth of 1150 cm. Below this interval, salt marsh peat, present to 1170 cm, is replaced by fresh water peat. A soil horizon occurs after 1200 cm.

Core 8 is 992 cm long with a compaction measurement of 228 cm. The upper 10 cm of the core is salt marsh dispersed in dark brown mud. During vibracoring, however, 100-150 cm of salt marsh material in Core 8 was lost from plugging of the vibracore head and was replaced lithologically with the upper 155 cm of Core 5 salt marsh. At 155 cm, therefore, dark olive grey mud containing shells and organic begins and continues to a depth of 534 cm. Surface salt marsh occurs between 534-

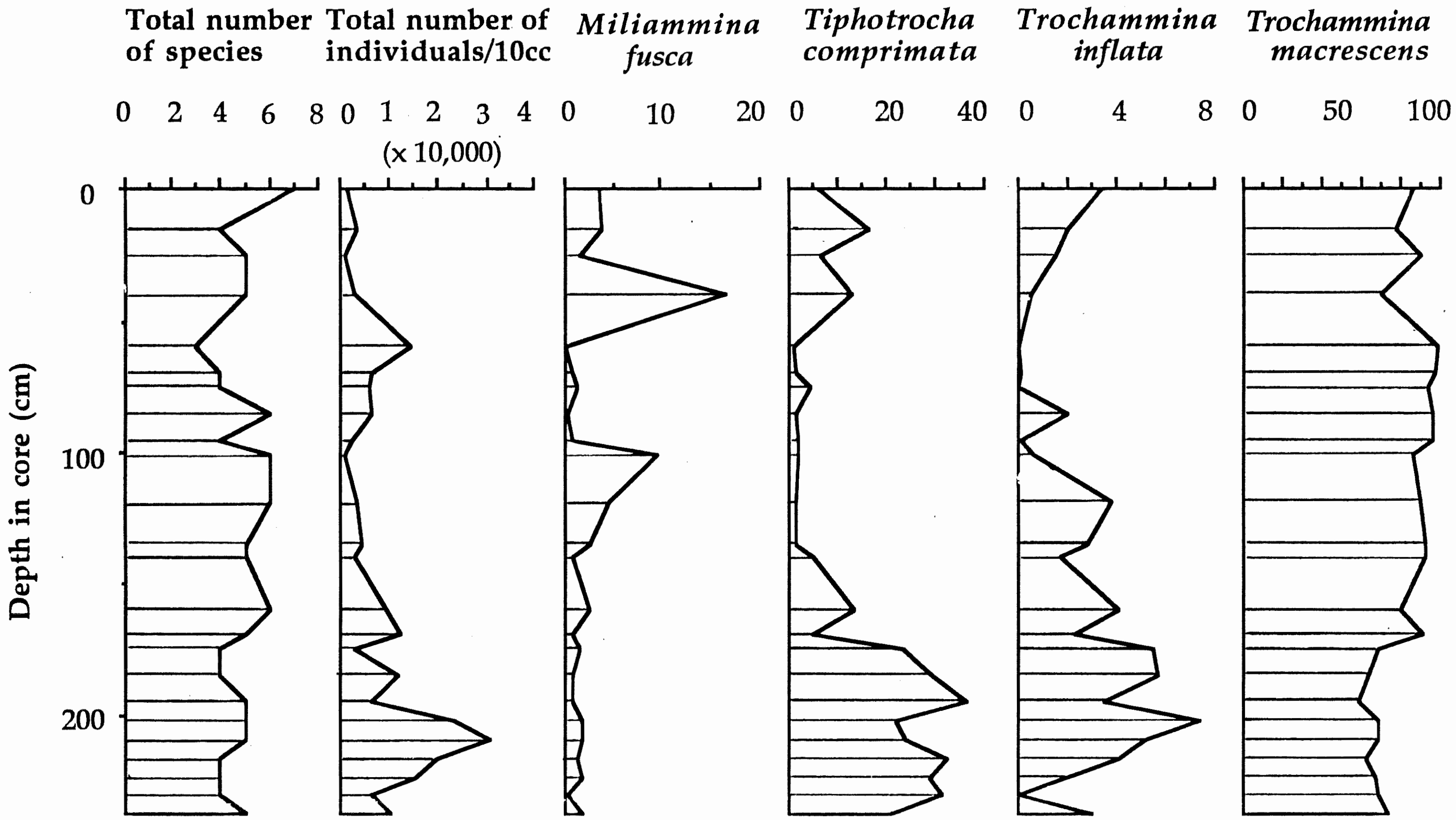

Figure 3.3. Core 2 species diversity, species density, and foraminiferal percentages plotted against core depth (without compaction added).

666 cm as a result of switching aluminium tubes during vibracoring to achieve greater depths. Wood fragments are visible at 835 cm. Olive grey mud occurs to the bottom of the core at 992 cm. The salt marsh peat, fresh water peat, and soil horizon visible in Core 5 are known to exist in the Core 8 locality from deep penetrating Davis cores taken in the same position as Core 8.

3.5 Cores 5 and 8 Foraminiferal Assemblages

Faunal assemblages of Cores 5 and 8 are comparable. The number of individuals ranges between 20-1918 per 10 cc (from Scott 1977). *Miliammina fusca, Tiphotrocha comprimata, Trochammina inflata,* and *Trochammina macrescens* are present throughout the cores, and dominate the upper 180 cm. *Ammonia beccarii, Ammotium salsum, Elphidium excavatum, Haynesina orbiculare,* and *Reophax nana* are common at greater depths. *Ammobaculites exigus, Ammobaculites dilatatus, Arenoparella mexicana, Buccella frigida, Elphidium excavatum, Elphidium excavatum selseynesis, Eggerella advena, Polysaccammina ipohalina, Rosalina columbiensis, Textularia earlandi,* and *Trochammina squamata* are rare. Other fossils present include gastropods, ostracods, and bivalves. Davis core 8 sampled the salt marsh and fresh water marsh sequences present at depth.

3.6 Core 12 Lithology

Core 12 is 567 cm long (Fig 3.2) with a compaction measurement of 83 cm. The upper 15 cm contains salt marsh dispersed in brown mud. Again, during vibracoring, 100-150 cm of salt marsh material was lost from plugging of the vibracore head and was substituted with data from the upper 155 cm of Core 5 (from Scott 1977). At 155 cm, therefore, faintly laminated dark olive grey mud containing shells and organic materials abruptly replaces salt marsh. Dark brown peat occurs at 537 cm, after which, an oyster layer abruptly occurs between 549-551 cm. Peat recurs to the end of the core at 567 cm.

3.7 Core 12 Foraminiferal Assemblages

Sixteen foraminiferal species occur in Core 12 (Table 3.2). Abundances range from 28-9200 foraminifera per 10 cc with the lowest abundances occurring around 445 cm. *Trochammina macrescens* is present in most of the core whereas *Tiphotrocha comprimata*, *Trochammina inflata*, and *Trochammina squamata* are present at various intervals throughout the core. *Ammobaculites exigus*, *Ammobaculites dilatatus*, *Ammotium salsum*, and *Reophax nana* are present in the upper portion of the core, but disappear with depth. Large numbers of unidentifiable fragmented foraminifera occur in the mud portion of the core. *Haplophragmoides manilaensis* is rare within the basal peats. Calcareous foraminiferal species, such as *Elphidium excavatum*, *Elphidium subarcticum*, *Haynesina orbiculare*, and *Helenina andersoni* are present in, and adjacent to, the oyster deposit.

Other microfossils present include ostracods, planktonic foraminifera, and a thecamoebian. Few ostracods occur in the upper portion of Core 12. Planktonic

Depth in core (cm)	0	20	29	45	63	92	110	130	141	155	185-187	205-207	225-227	245-247	265-267
Total number of species	4	5	5	4	5	5	5	7	7	7	6	5	9	8	8
Total number of individuals/10cc	555	630	1424	1835	1918	600	778	823	1409	888	164	145	442	447	620
Ammobaculites dilatatus								x			3.7	3.4	7.7	7.6	3.5
A. exigus								x	1	3	0.6		1.6	1.8	0.5
Ammotium salsum		x	x		x		x	4	5	4	18.3	11.7	23.5	19.9	7.3
Arenopareaal mexicana						x									
Eggerella advena									x						
Elphidium excavatum															
E. subarcticum															
Haplophragmoides manilaensis															
Haynesina orbiculare															
Helenina andersoni															
Miliammina fusca	27	34	13	5	2	24	43	81	81	84	62.8	11	2.9	15.4	1.3
Reophax nana										x			0.7	1.1	1.6
Tiphotrocha comprimata	5	8	33	24	21	13	7	2	1	1	9.8		1.1	0.2	0.2
Trochammina inflata	2	25	4	19	9	12	6	3	2	1			0.7		
T. macrescens	66	33	50	53	68	50	44	11	10	6	4.9	4.1	11.8	8.3	30.2
T. squamata												69.7	50	46.1	55.5
Agglutinated foraminiferal fragments											16	14	94	74	49
Ostracods											5			1	
Planktonic foraminifera											5				
Thecamoebians															1

Table 3.2. Core 12 total species, population density, foraminiferal species percentage, agglutinated foraminiferal fragments, ostracod, planktonic foraminifera, and thecamoebian distributions versus depth. x representes values less than 1%.

Depth in core (cm)	285-287	305-307	325-327	345-347	365-367	385-387	405-407	425-427	445-447	465-467	485-487
Total number of species	8	9	8	6	9	7	7	8	3	2	6
Total number of individuals/10cc	544	1145	924	353	1140	1710	250	271	28	63	590
Ammobaculites dilatatus	7.7	2.8	1.7	1.7	0.7	0.5	1.2	1.1			
A. exigus	3.1	4.4	3.7	2.8	3.8	0.8	2	3.3			
Ammotium salsum	20.6	51.7	72.4	40.8	45.9	28.3	40	39.9			
Arenopareaal mexicana											
Eggerella advena											
Elphidium excavatum											
E. subarcticum											
Haplophragmoides manilaensis											
Haynesina orbiculare											
Helenina andersoni											
Miliammina fusca	9.7	5	5.5	13.3	25.5	35.1	22.8	6.6	3.6		0.2
Reophax nana	8.3	13.7	0.3		6.3	20.1	7.2	16.2			0.2
Tiphotrocha comprimata	0.2	0.1			0.3						0.7
Trochammina inflata		1.4	1.7		0.7			2.2		4.8	3.6
T. macrescens	8.8	19.6	10.4	21.8	14.5	12.9	19.2	29.9	92.8	95.2	89.5
T. squamata	41.5	1.4	4.2	19.5	2.4	2.3	7.6	0.7	3.6		5.9
Agglutinated foraminiferal fragments	111	557	496	81	307	268	34	22		2	
Ostracods											
Planktonic foraminifera											
Thecamoebians											

Table 3.2. Continued

Depth in core (cm)	505-507	525-527	530-532	535-537	540-542	545-547	549-551	552-554	558-560	564-566
Total number of species	3	4	3	4	3	4	3	8	3	4
Total number of individuals/10cc	120	266	261	557	632	1063	269	1137	5616	9200
Ammobaculites dilatatus										
A. exigus										
Ammotium salsum										
Arenopareaal mexicana										
Eggerella advena										
Elphidium excavatum							6.3	0.7		
E. subarcticum								0.1		
Haplophragmoides manilaensis			1.1			0.3				
Haynesina orbiculare								0.6		
Helenina andersoni								0.1		
Miliammina fusca		1.5								
Reophax nana										
Tiphotrocha comprimata			0.4	0.2				0.1		0.3
Trochammina inflata	0.8	1.1		2	0.3	0.2		0.2	1.1	0.9
T. macrescens	96.7	97	98.5	96.9	97.8	99.2	89.2	98	98.9	98
T. squamata	2.5	0.4		0.9	1.9	0.2	4.5	0.3	0.1	0.9
Agglutinated foraminiferal fragments										
Ostracods										
Planktonic foraminifera							96			
Thecamoebians										

Table 3.2. Continued

foraminifera are present in salt marsh deposits at the surface and within the oyster layer. One thecamoebian occurred at 265-267 cm.

T. macrescens is the most abundant species between 0-110 cm and below 445 cm, whereas *T. comprimata* and *T. squamata* are less common in the salt marsh and basal peats (Fig 3.4). *A. salsum*, *M. fusca*, and T. *squamata* are common in the mud between 110-445 cm, where fewer *A. exigus* and A. *dilatatus* occur. Low numbers of calcareous foraminifera occur within the oyster layer interval.

3.8 Core 15 Lithology

Core 15 is 823 cm long with no compaction (Scott unpublished data) (Fig 3.1). The upper 227 cm is salt marsh dispersed in brown peaty mud. At 227 cm, grey mud, containing rare organic matter, shells, and sand, replaces salt marsh. Salt marsh, containing wood fragments and coarse clasts, forms the basal portion of the core from 804 to 823 cm.

3.9 Core 15 Foraminiferal Assemblages

Twenty-three foraminiferal species occur in Core 15 (from Scott unpublished data) (Table 3.3). Abundances range between 6-4058 foraminifera per 20 cc with a general decrease in abundance with depth. *Ammotium salsum*, *Miliammina fusca*, *Tiphotrocha comprimata*, *Trochammina inflata*, and *Trochammina macrescens* are present in most of the core. *Ammobaculites exigus* and *Reophax nana* are present in the upper portion of the core, but disappear below 630 cm. *Trochammina squamata*

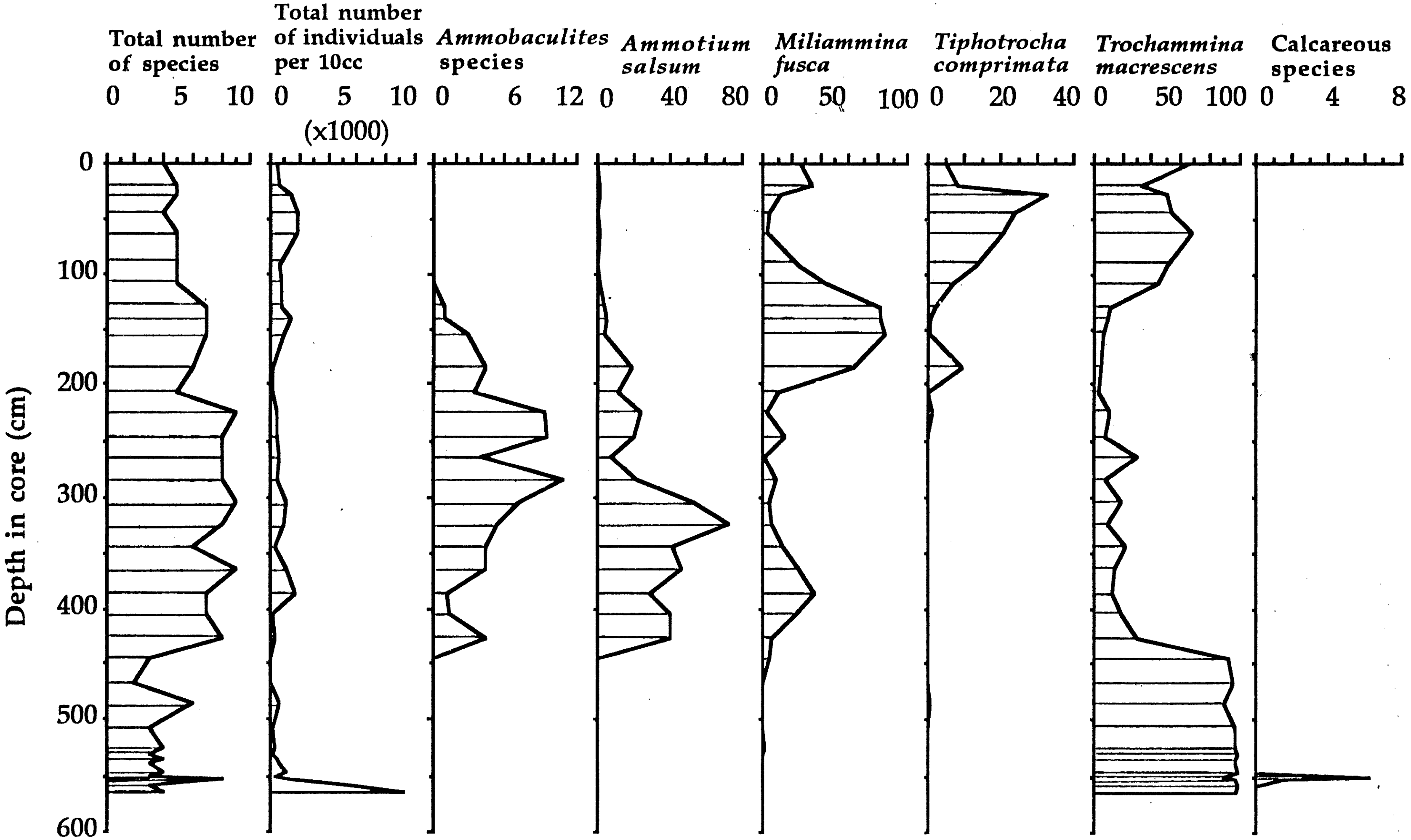

Figure 3.4. Core 12 species diversity, species density, and foraminiferal percentages plotted against core depth (without compaction added).

Depth in core (cm)	0	28	50	72	90	128	151	180	200	227	250	279	300	321	350	377	395	412	427	446	469	482
Total number of species	5	7	7	8	8	5	8	8	11	10	10	8	9	9	11	12	12	13	13	13	13	11
Total number of individuals/20cc	459	1620	4058	726	1140	1264	1358	132	300	594	778	722	928	555	820	634	409	664	772	514	794	364
Ammonia beccarii											0.3			0.2	0.7	0.6	0.2		0.3	0.6	0.1	0.8
Ammobaculites dilatatus																			0.3			
A. exigus		0.1			0.4				1	0.7	0.3	1.1	0.9	0.2	0.2		0.5	0.5	0.8	0.8	0.6	0.8
Ammotium salsum		0.2	0.2	1.1	6.2		3.1	25.8	38	27.3	69.7	57.1	65.1	67.2	60	57.1	69.4	77.6	81.3	75.1	70	62.6
Arenoparella mexicana																	0.2	0.2	0.3			
Buccella frigida																						
Elphidium excavatum f. clavatium																		0.2	0.5	0.2	0.3	1.4
E. excavatum f. excavatum																		0.3	3.1	0.4	0.1	0.8
E. excavatum f. gunteri																0.3	0.2					
Eggerella advena							0.1			0.2						0.9						
Haplophragmoides manilaensis									0.3								0.2	0.2			0.1	
Haynesina orbiculare													0.2					0.2	0.3	0.6	0.3	0.3
Miliammina fusca	26.6	10.1	2.7	13.8	62.3	18.5	70.3	9.1	18.3	20.7	12.3	16.1	13.6	12.8	11.5	17	12.5	10.7	7	10.3	14	19.2
Polysaccammina ipohalina				0.3		0.2			0.3							0.3						
Pseudothurammina limnetis	9.6	1.9	0.3	0.3	0.8		1.2	6.1	2	0.5						0.2						
Reophax nana				0.6	0.6		0.3	0.8	1.3	2.7	2.6	5.5	8	5.9	9.8	9.5	9.5	5	3.6	3.5	4.7	4.9
R. scottii											0.3											
Rosalina columbiensis															0.2							
Textularia earlandi																		0.3				
Tiphotrocha comprimata	2.2	23.7	15.2	37.5	8.3	17.6	3.7	8.3	4.7	7.2	1	2.2	1.1	1.4	1.5	0.9	0.5	1.2	0.5	0.4	1.4	1.1
Trochammina inflata	1.5	1.5	2.3	1.4	0.6	1.3	0.9	12.9	3	4.9	0.8	0.6	0.2	0.2	0.5	0.3	1	0.5	0.3	0.6	1.1	0.5
T. macrescens	60.1	62.5	79.3	45.2	21	62.5	20.2	34.1	28.7	32.7	11.3	15.8	9.3	9.6	11.5	7.6	4.4	3.5	1.8	6.8	7.1	7.4
T. squamata								3.1	2.3	3.2	1.5	1.7	1.7	2.6	3.9	5.3	1.2			0.8	0.3	
Planktonic foraminifera																						
Thecamoebians										1							1					

Table 3.3. Core 15 total species, population density, foraminiferal species percentage, planktonic foraminifera, and thecamoebian distributions versus depth.

Depth in core (cm)	492	504	530	560	589	610	630	651	670	692	710	720	730	750	765	775	787	796	804	815	823
Total number of species	14	14	16	11	13	12	9	8	7	8	7	7	6	8	3	2	3	6	8	6	7
Total number of individuals/20cc	386	468	426	277	286	187	148	103	103	122	323	201	796	659	23	9	6	31	67	45	82
Ammonia beccarii	1.8	1.5	8.7	0.4	1.7	4.1				0.8											
Ammobaculites dilatatus		0.2	0.2																		
A. exigus	2.1	1.1	0.5		0.3		0.7														
Ammotium salsum	50.8	57.3	39.4	58.8	36.1	26.4	17.6	8.7	1	4.1	0.9	1	0.3	1.1	4.3			9.7	14.9		
Arenoparella mexicana																					
Buccella sp.														0.5							
Elphidium excavatum f. clavatium	0.3	2.1	7.3	2.9	4.2	8.1	6.1	1.9	3.9	5.7	16.1	25.4	29.9	28.1	4.3		16.7	6.5	1.5		
E. excavatum f. excavatum	0.8	1.1	0.5	0.7	0.7	0.5		1													
E. excavatum f. gunteri			0.7																		
Eggerella advena	0.3	0.2																			
Haplophragmoides manilaensis	0.3	0.2		0.4		0.5															
Haynesina orbiculare	0.5	0.9	1.9	2.2	13.7	15.2	40.5	70.9	76.7	71.3	74.9	65.7	68.6	66.8	91.3	22.2	16.7	16.1	6	2.2	1.2
Miliammina fusca	15.5	12.4	13.4	13.4	10.5	11.2	8.8	1.9	2.9	3.3	0.6	2.5	0.8	0.6				6.5	14.9	13.3	34.1
Polysaccammina ipohalina																					1.2
Pseudothurammina limnetis																					
Reophax nana	4.7	13.2	7.3	4.3	6.3	1	0.7												1.5		
R. scottii																					
Rosalina columbiensis																					
Textularia earlandi			0.2																		
Tiphotrocha comprimata	5.2	1.7	0.9	2.9	4.2	3.6	6.1	1	6.8	1.6	0.9	0.5	0.3	0.5				22.6	10.4	37.8	20.7
Trochammina inflata	0.8		0.2	1.8	1.7	7.1		1	2.9	1.6	0.6	0.5		0.6					3	31.1	20.7
T. macrescens	16.6	7.3	15.5	12.3	18.6	21.8	16.9	13.6	5.8	11.5	5.9	4.5	0.3	2		77.8	66.7	38.7	47.8	13.3	20.7
T. squamata	0.5	0.9	3.1		1.7	0.5	2.7													2.2	1.2
Planktonic foraminifera																			1		
Thecamoebians										1											

Table 3.3. Continued

occurs between 180-630 cm and below 815 cm. Calcareous species, including *Ammonia beccarii*, *Buccella frigida*, *Elphidium excavatum* forme *clavatium*, *Elphidium excavatum* forme *excavatum*, *Elphidium excavatum* forme *gunteri*, and *Haynesina orbiculare*, are present only at depth. *Ammobaculites dilatatus*, *Arenoparella mexicana*, *Eggerella advena*, *Haplophragmoides manilaensis*, *Polysaccammina ipohalina*, *Pseudothurammina limnetis*, *Rosalina columbiensis*, *Reophax scottii*, and *Textularia earlandi* are rare. Other microfossils present include planktonic foraminifera and thecamoebians.

M. fusca, *T. macrescens*, and *T. comprimata* are the most abundant species in the salt marsh, whereas *T. inflata* is less common (Fig 3.5). *A. salsum* is common in the upper mud, whereas the calcareous species are common in the lower mud.

3.10 Davis Core Samples

Davis cores 8 and 13 consist of salt marsh and fresh water peat used for ^{14}C analysis (Table 3.4). *Haplophragmoides manilaensis*, *Miliammina fusca*, *Trochammina Inflata*, *T. macrescens*, *T. squamata*, and occur between 1020-1030 cm. At 1150-1160 cm only *M. fusca*, *T. Inflata*, and *T. macrescens* are present. The 1170-1180 cm interval is a fresh-water sample with no mature foraminifera, although some juvenile individuals may be present.

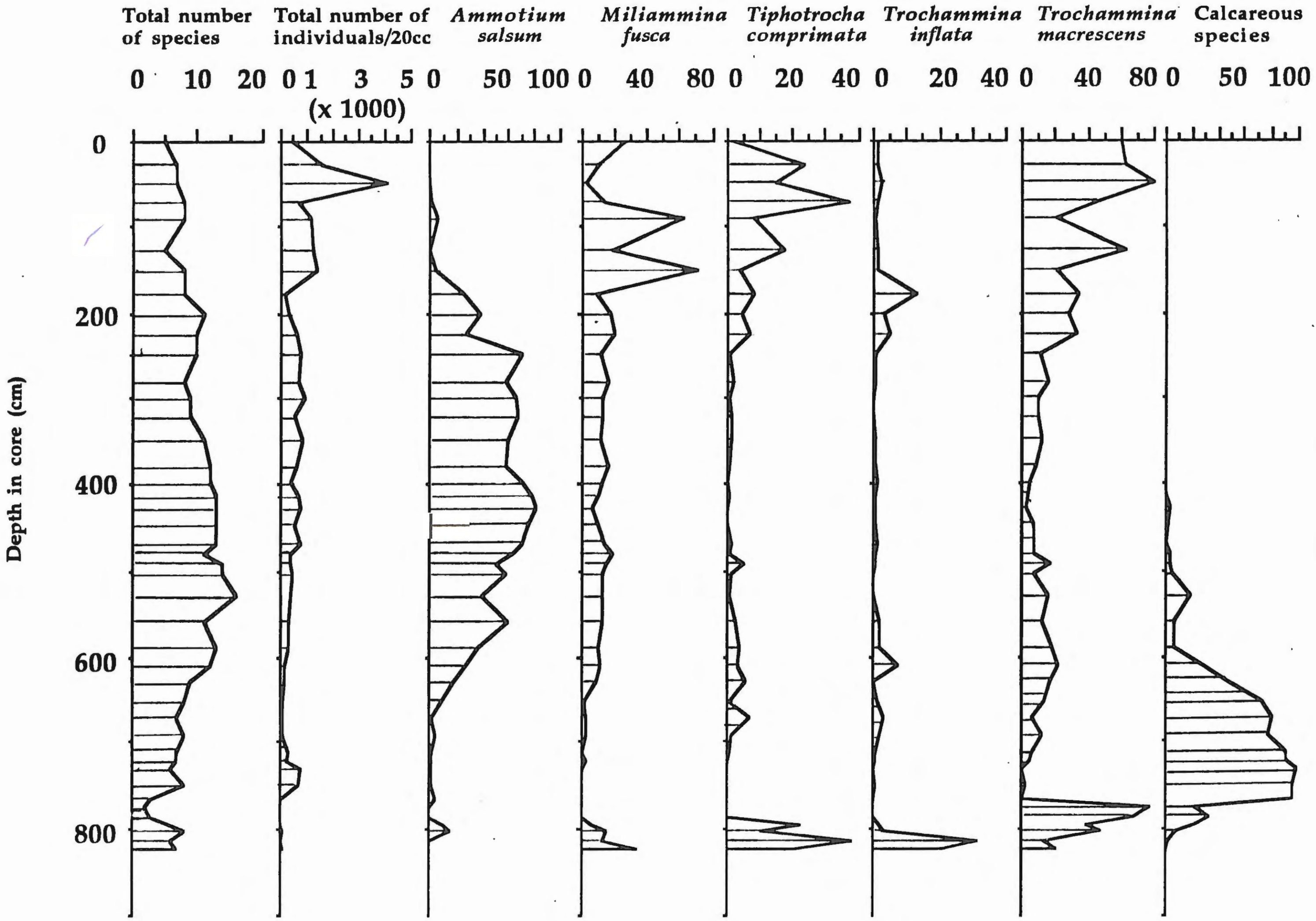

Figure 3.5. Core 15 species diversity, species density, and foraminiferal percentages plotted against core depth (without compaction added).

3.11 Carbon-14 Dates

Carbon-14 dates were determined for six samples taken from both vibracores and Davis cores (Table 3.5). The depths of the samples ranged from 343-1160 cm. Older dates occurred with increasing sample depth, varying from 1670 ybp in the shallowest sample to 7859 ybp in one of the deepest samples. The 1160 cm date is from the same interval previously dated by Scott (1977) and reported by Scott (1987b). The discrepancy between the Scott (1977) date and the present date is attributed to contamination of the Scott sample by reworked older material. In addition, Dr. D.B. Scott supplied one ^{14}C date from Chezzetcook and two published dates (from Miller et al. 1992; Scott and Medioli 1982) (Table 3.6). These varied in depth from 840-2800 cm and in age from 3819-7859 ybp.

3.12 Summary

Examination of vibracores and Davis cores collected from the West Head salt marsh revealed several patterns of foraminiferal distributions, which can be used to locate former sea-level points (HHW zonations), and aid in constructing RSL curves. All sea-level points were determined at or near a basal bedrock or glacial till sequence to avoid post-depositional compaction problems (Kaye and Barghoorn 1964, as cited in Scott 1977). Only non-contaminated samples are useful as former sea-level markers. These markers, coupled with ^{14}C dating in sidereal years, permit the construction of a Holocene RSL curve.

Sample	Davis Core 13	Davis Core 8	Davis Core 8
Depth (cm)	1020-1030	1150-1160	1170-1180
H. manilaensis	1	0	0
M. fusca	1	1	0
T. inflata	14	4	0
T. macrescens	1053	208	18*
T. squamata	1	0	0

Table 3.4. Numbers of foraminifera individuals/10cc from ^{14}C Davis core samples. * These individuals could be juvenile forms.

Sample	Core 2	Core 12	Core 12	Core 12	Davis core 13	Davis core 8
Sample Number	GX18458	GX18452	GX18453	GX18454	GX18459	GX18455
Description	peat	peat	oyster shell	peat	peat	peat
Depth (cm)	235-237	545-547	549-551	564-566	1020-1030	1150-1160
C^{14} Dates (ybp)	1735+-120	2495+-125	2495+-115	2710+-155	3820+-165	3830+-150
Corrected Sidereal Dates (ybp)	1670	2554	2554	2879	4247	4247

Table 3.5. Carbon-14 sample numbers, descriptions, depths, C^{14} dates, and corrected sidereal dates.

Sample Locations	West Head salt marsh (Core 15)	Bedford Basin (piston core)	Lunenburg (piston core)
Sample Number	GX5708	Bedford Basin	GX6490
Description	salt marsh	peat	peat
Depth (cm)	823	2100	2800
C^{14} Dates (ybp)	3525+-230	5830+-230	7070+-300
Corrected Sidereal Dates (ybp)	3819	6676	7859

Table 3.6 Locations, numbers, descriptions, depths, ^{14}C dates, and corrected sidereal dates of ^{14}C samples supplied by Dr. D.B. Scott, Miller et al. (1982), and Scott and Medioli (1982).

CHAPTER 4 DISCUSSION

4.1 Introduction

Marsh foraminiferal zones accurately locate former sea-level points (Scott and Medioli 1980). Increased elevation towards the HHW level provide the most accurate sea-level points because this elevation represents the maximum tidal limit above MSL during any time period. Several different hypotheses can explain RSL changes on global and local scales. In Nova Scotia, the dominant factors contributing to RSL change is hypothesised to be migration and collapse of the peripheral forebulge following deglaciation (Quinlan and Beaumont 1981) and a mid-Holocene warm period.

4.2 Sea-level Points

The presence of *Miliammina fusca*, *Tiphotrocha comprimata*, *Trochammina inflata*, and *Trochammina macrescens* throughout most of Core 2 represents low-middle salt marsh (Zone IIA-B) environments based on foraminiferal salt marsh zonations (Scott and Medioli 1980) (Fig. 3.3). At 343-347 cm depth (corrected for compaction), however, a faunal change to *T. macrescens* and *T. comprimata* signifies a former high salt marsh environment (Zone IB) (Scott and Medioli 1980) representing former sea level. A ^{14}C date indicates this level occurred 1670 ybp.

A low-middle salt marsh fauna occurs in the upper 155 cm of cores 5 and 8, whereas the remaining core contains *Ammobaculites dilatatus*, *Ammotium salsum*, *Haynesina orbiculare*, and *M. fusca*, representing low marsh fauna (Scott 1977). High marsh foraminiferal zonations exist only in the lower 30-40 cm of Core 5 and *Ammonia beccarii* occurs at depth, indicating warmer water conditions than present.

A low-middle salt marsh fauna occurs in the upper 155 cm of vibracore 12 representing low-middle salt marsh (Fig. 3.4). Typical low marsh mudflat fauna occur to a depth of 508 cm (corrected for compaction). The remainder of the core contains a high marsh fauna representing an accurate sea-level interval, except for the oyster bed located at depths between 632-634 cm (corrected for compaction) which, if *in situ*, could represent a former elevated MSL. Carbon-14 dates above, in, and below the oyster layer are 2554, 2554, and 2879 ybp, respectively.

Typical low-middle salt marsh faunas are present in the upper 227 cm of core 15 (Fig. 3.5). Low marsh mudflat faunas grading into a shallow subtidal fauna occur to a depth of 804 cm, below which a low-middle salt marsh fauna is present. At 815 cm a high marsh fauna is present and provides a sea-level point dated at 3819 ybp. The remaining core contains low-middle marsh fauna. The presence of *A. beccarii* at depth indicates former warmer water conditions.

The high percentage of *T. macrescens* in Davis cores 8 and 13, both dated at 4247 ybp, represents high salt marsh (Zone IA) (Scott and Medioli 1980) which is the most accurate former sea-level marker. Other published points from nearby include 2100 cm depth from Bedford Basin (Miller et al. 1982) and 2800 cm depth from Lunenburg (Scott and Medioli 1982). Associated ^{14}C dates are 6676 and 7859 ybp, respectively. A final sea-level point includes a date of 5295 ybp, where the curve from Chezzetcook was extrapolated to this date based on a break in rate observed at this time from Baie Verte, Nova Scotia (Scott et al. 1987a).

4.3 Causes of RSL Change

Raised marine features provide evidence that sea level is not constant (Stea 1987). According to Pirazzoli (1991), possible causes of RSL change include modifications to ocean basin volumes, resulting from plate interactions and crustal deformation. A second possible mechanism includes fluctuations in sea water mass. Addition to or removal of water from the oceans would change the volume of the oceans and result in a corresponding change in sea level. For example, greenhouse warming may cause polar melting that would raise sea level several metres. Additionally, changes in ice volume during glacial and interglacial periods may alter sea level. Eustatic changes are observable on a global scale. Nova Scotia, however, is experiencing different RSL changes from nearby areas and, therefore, eustatic sea level change cannot be the complete explanation.

Local variables influencing RSL include local tectonics, glacial isostatic adjustment, and sedimentation rates (Plint et al. 1992). In addition, changes in atmospheric pressure, winds, and currents can influence water masses and cause upward swelling in specific localities (Pirazzoli 1991).

4.4 Peripheral Forebulge Concept

Wisconsinan glaciation reached its maximum advance 18 kybp (Fig. 4.1). At least part of the Atlantic region was covered by an ice mass more than 1 km thick, the edges of which extended offshore for approximately 100 km. Early offshore studies suggested a RSL at 15 kybp 120 m below present-day MSL (King 1976, as cited by Scott and Medioli 1982). The absence of post-Wisconsinan raised marine features in Nova Scotia implies that present MSL is a highstand (Scott and Medioli 1982). Examination of foraminiferal samples collected in the West Head salt marsh, Chezzetcook Inlet, permits the construction of a late Holocene RSL curve that is not possible using data from offshore deposits.

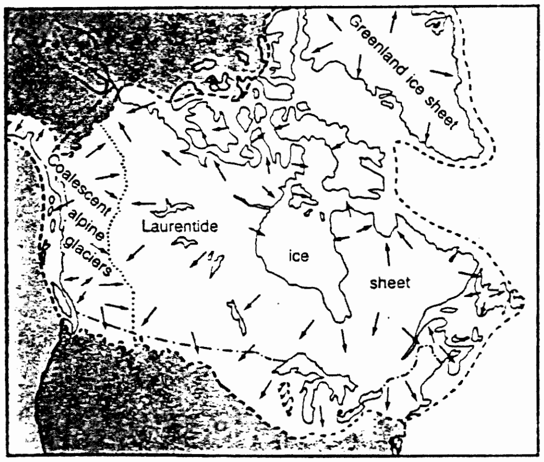

Figure 4.1. Maximum advance of Wisconsinan Glaciation 18 kybp (from Tarbuck and Lutgens 1982).

According to Quinlan and Beaumont (1982) and Scott et al. (1987b), isostatic adjustment following deglaciation explains RSL variation in the Atlantic region. Glacial loading caused isostatic depression of the earth's crust and the formation of a peripheral forebulge around the ice margin. As the ice ablated, the displaced mantle material and the peripheral forebulge migrated slowly towards the former ice centre. Relative sea levels vary in accordance with the position of the peripheral forebulge (Fig. 4.2). Areas seaward of the peripheral forebulge, such as Sable Island, experience only submergence as the ice retreats, whereas areas landward, such as Nova Scotia, experience emergence followed by submergence. Prolonged emergence occurs with proximity to the former ice centre.

Scott et al. (1987b) observed sea-level forebulge zonations which correspond closely with the maximum ice zonation model (Quinlan and Beaumont 1982) (Fig 4.3). The similarities between the final zonation positions, as determined by all authors, suggests that the Quinlan-Beaumont model best explains the RSL record for the Maritimes.

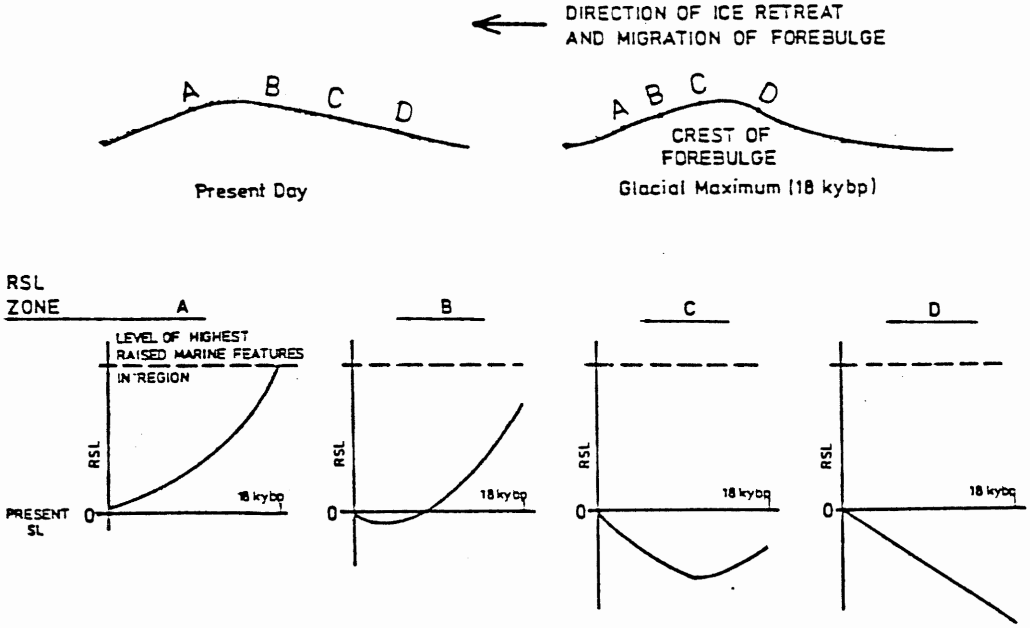

Figure 4.2. Forebulge migration following deglaciation and various sea level responses associated with location relative to the forebulge. Point D experiences only submergence; point C experiences emergence followed by submergence; point B experiences prolonged emergence followed by submergence; and point A experiences only emergence (from Scott et al. 1986).

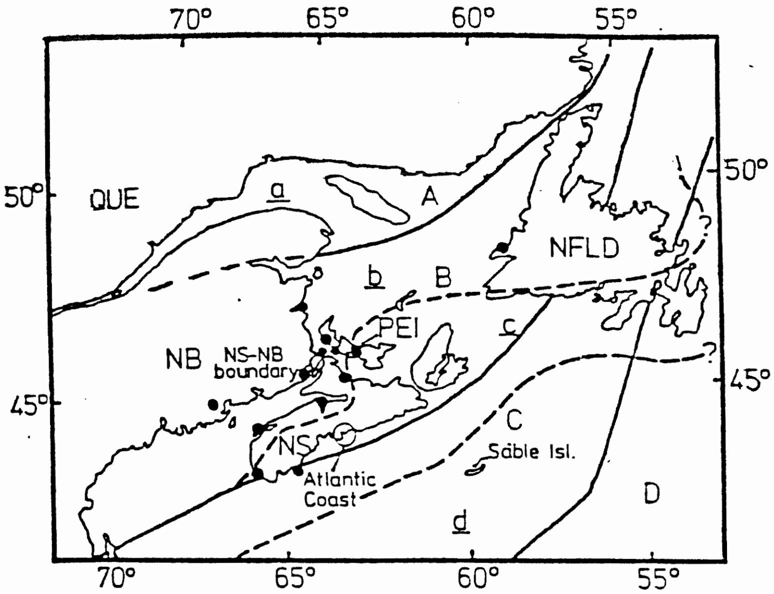

Figure 4.3. Observed versus theoretical RSL response in Maritime Canada following deglaciation. Observed zones are represented by dashed lines and small letters, whereas, theoretical zones are represented by capital letters and solid lines. Letters indicate type of response as outlined in Figure 4.2 (from Scott et al. 1987b).

4.5 Sea-level Implications

Each marsh point described above, representing a former sea-level position, aided in constructing a Holocene RSL curve (Fig. 4.4) for Nova Scotia by plotting sample depth representing elevation against ^{14}C (sidereal) dates for timing. According to the curve, Atlantic Canada has experienced overall RSL rise for at least 7859 years. Other authors (Carter et al. 1989; Quinlan and Beaumont 1982; Scott and Greenberg 1983; Scott et al. 1987b) showed similar trends of RSL rise. Prior to thissubmergence period, however, the Atlantic region emerged (Quinlan and Beaumont 1982; Scott and Medioli 1982; Scott et al. 1986; Scott et al. 1987b).

This curve corresponds to Zone C (Fig. 4.3) in the observed zonations of Scott 1987b), located landward of the peripheral forebulge. As the ice ablated and the forebulge migrated towards the ice center, the Atlantic region emerged. After the

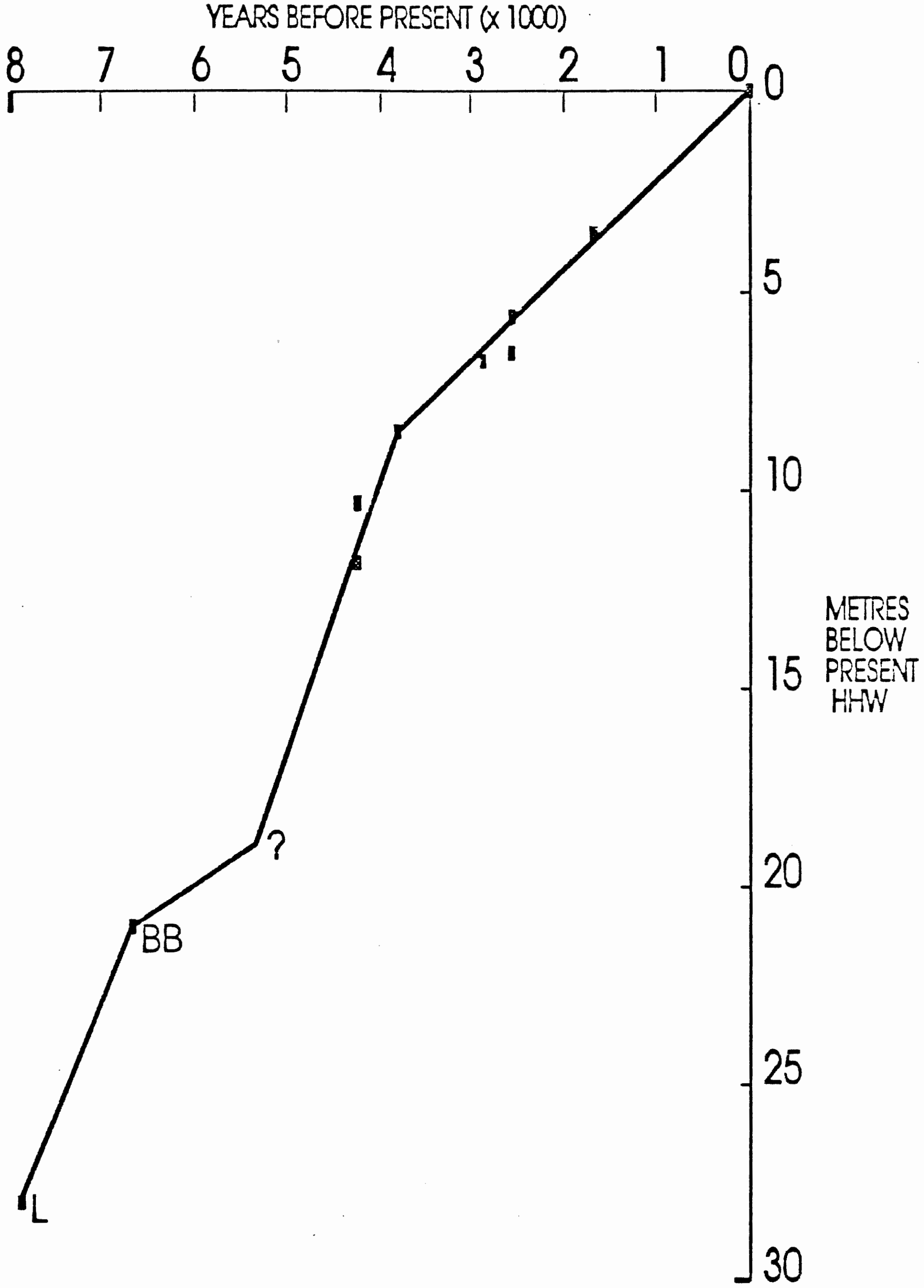

Figure 4.4. RSL curve of Atlantic Canada, based on foraminiferal assemblages collected from Chezzetcook cores, points from Lunenburg (L), Bedford Basin (BB), and an extrapolated point from Baie Verte (?).

forebulge crest passed through the Atlantic region, the area submerged more than the previous emergence, and eliminated all formerly emerged marine features.

Figure 4.4 suggests that a RSL rise of 59.2 cm/century occurred during 7859-6676 ybp. Rates then slowed to 13.8 cm/century during 6676-5295 ybp. Extrapolation from another curve showing similar acceration rates produced the 5295 ybp date. Rapid submergence rates of 72.5 cm/century recurred between 5295-3819 ybp. Eustatic response to climatic warming may have resulted in this acceleration of RSL rise (Houghton et al. 1990). An average RSL rise of 21.3 cm/century occurred from 3819 ybp to the present.

Isostatic adjustment following deglaciation explains the overall trend of rising RSLs, but the accelerated sea-level response between 5295-3819 ybp may be a eustatic response to the mid-Holocene warm period. Higher sea levels are observed in the southern hemisphere for this period (Dominquez et al. 1987) and at least one verification of a highstand from the southeastern United States exists (Gayes et al. 1992). Figure 4.4 contrasts earlier results from the Atlantic region, where no rapid acceleration was observed during the mid-Holocene (Scott 1977; Scott et al. 1987b), but supports Northumberland Strait data for the same time period (Scott et al. 1987a).

4.6 Summary

Isostatic response following deglaciation explains major variations in sea level in Atlantic Canada. Migration and collapse of the peripheral forebulge through the Atlantic coastal zone resulted in early regression (Scott and Medioli 1982) , followed by transgression. The Atlantic coast of Nova Scotia has transgressed for at least 7859 years and, specifically, Chezzetcook for the last 4247 years. Although glacio-isostatic adjustment explains most sea-level variation, it appears that eustatic response associated with global warming occurred during the mid-Holocene.

CHAPTER 5 CONCLUSIONS

5.1 Conclusions

Floral and faunal zonations in salt marshes are characteristic of specific environments. Floral preservation in the stratigraphic record is poor, whereas foraminiferal test preservation is excellent. Therefore, foraminiferal assemblages permit relocating paleoenvironments, such as high marsh, indicative of former RSL highstands.

Foraminiferal examination of samples taken from the West Head salt marsh, Chezzetcook Inlet, produced accurate markers of former sea levels. *Tiphotrocha comprimata* and *Trochammina macrescens* represent high marsh environments and the HHW point, the most accurate sea-level marker. *Ammobaculites dilatatus*, *Ammotium salsum*, *Miliammina fusca*, and *Trochammina inflata* represent middle-low marsh environments. Carbon-14 dating corrected to sidereal years of former sea-level points permitted the construction of a Holocene RSL curve (Stuiver and Reimer 1987).

Glacio-isostacy resulting in migration of the peripheral forebulge following Wisconsinan deglaciation explains the various sea-level curves observed in Atlantic Canada. In addition, a mid-Holocene warm interval resulted in a eustatic RSL change detectable in Chezzetcook Inlet. Various rates of sea-level rise occurred in Atlantic Canada within the last 7859 year interval. Average rates of present sea-level rise are 21.3 cm/century.

SYSTEMATIC TAXONOMY

Ammobaculites dilatatus **Cushman and Brönnimann**
Ammobaculites dilatatus CUSHMAN and BRÖNNIMANN 1948b, p. 39, pl. 7, figs. 3, 4.
Ammobaculites foliaceus (H.B. Brady).- SCOTT and MEDIOLI 1980a, p. 39, pl. 1, figs. 6-8.

Ammobaculites exigus **(Cushman and Brönnimann)**
Ammobaculites exigus CUSHMAN and BRÖNNIMANN 1948b, p. 38, pl. 7, figs. 7, 8.
Ammobaculites dilatatus Cushman and Brönnimann.- SCOTT and MEDIOLI 1980a, p. 39, pl. 1, figs. 6-8.

Ammonia beccarii **(LINNÉ)**
Nautilis beccerii LINNÉ, 1758, p. 710.
Ammonia beccerii (Linné).- BRUNNICH 1772, p. 232.

Ammotium salsum **(Cushman and Brönnimann)**
Ammobaculites salsus CUSHMAN and BRÖNNIMANN 1948a, p. 16, pl.3, fig. 7-9.
Ammotium salsum (Cushman and Brönnimann).- PARKER and ATHEARN 1959, p. 340, pl. 50, figs. 6, 13.- BOLTOVSKOY and VIDARTE 1977, p. 38, pl. 1, fig. 14-19.- ZANINETTI ET AL. 1977, pl.2, figs. 4, 5.- BOLTOVSKOY and HINCAPIÉ DE MARTNÍNEZ 1983, p. 212, pl.1, figs. 14-25.- SCOTT and MEDIOLI 1980a, p.37, pl.1, figs. 11-13.

Arenoparella Mexicana **(Kornfeld)**
Trochammina Inflata (Montagu) var. mexicana KORNFELD 1931, p. 86, pl. 13, fig. 5.
Arenoparella Mexicana (Kornfeld).- ANDERSON 1951, p. 31, fig. 1.- BOLTOVSKOY and VIDARTE 1977, p. 38, pl. 2, fig. 1-3.- ZANINETTI ET AL. 1977, pl.2, figs. 3,7.- BOLTOVSKOY and HINCAPIÉ DE MARTNÍNEZ 1983, p. 212, pl.1, figs. 26-30.- SCOTT and MEDIOLI 1980a, p. 41, pl. 4, figs. 8-11.

Buccella frigida **(Cushman)**
Pulvinulina frigida CUSHMAN 1921 (1922), p. 144.
Eponides frigida (Cushman) var *calida* Cushman and Cole, 1930, p. 98/ pl. 13, fig. 13a-c.- Phleger and Walton 1950, p. 277, pl. 2, fig. 21.- Parker 1952b, p. 449, pl. 5, fig. 3a, b.
Eponides frigidus (Cushman) Cushman 1941, p. 37, pl. 9, figs. 16, 17.- Parker 1952b, p. 449, pl. 5, fig. 2a, b.
Buccella frigida (Cushman).- Andersen 1952, p. 144, figs. 4a-c, 5, 6a-c.- Gregory 1970, p. 220, pl. 12, figs. 1-3.- Cole and Ferguson 1975, p. 33, pl. 8, fig. 8, 9.

Cribrostomoides crassimargo (Norman)
Haplophragmium crassimargo NORMAN 1892, p. 17.
Labrospira crassimargo (Norman).- HOEGLUND 1947, p. 11, fig. 1, text figs. 121-125.
Cribrostomoides crassimargo (Norman).- LESLIE 1965, p. 158, pl. 2, fig. 2a,b.- WILLIAMSON 1983, p. 209, pl. 1, figs. 6-7

Eggerella advena (Cushman)
Verneuilina advena CUSHMAN 1921, p. 141.
Eggerella advena (Cushman).- CUSHMAN 1937, p. 51, pl. 5, figs. 12-15.- SCOTT and MEDIOLI 1980a, p. 38, pl. 2, fig. 7.

Elphidium excavatum (Terquem)
Polystomella excavata TERQUEM 1876, p. 429, pl. 2, fig. 2a-d.
Elphidium excavatum (Terquem).- CUSHMAN 1944, p. 26, pl. 2, fig. 40.

Elphidium subarcticum Cushman
Elphidium subarcticium CUSHMAN 1944, p. 27, pl. 3, fig. 34, 35.- Schnitker 1971, p. 198, pl. 7, fig 3.- Cole 1981, p. 101, pl. 20, fig. 4.

Haplophragmoides manilaensis Anderson
Haplophragmoides manilaensis ANDERSON 1953, p. 22, pl. 4, fig. 8.
Haplophragmoides bonplandi TODD and BRÖNNIMANN 1957, p. 23, pl. 2, fig. 2.- SCOTT and MEDIOLI 1980a, p. 40, pl. 2, figs. 4, 5.

Haynesina orbiculare (Brady)
Nonionina orbicularis BRADY 1881, p. 414, pl. 21, fig. 5.
Haynesina orbiculare (Brady).- Banner and Culver 1978, p. 188.

Helenina andersoni (Warren)
Valvulinera sp. PHLEGER and WALTON 1950, p. 281, pl. 2, figs. 22a, b.
Pseudoeponides andersoni Warren, 1957, p. 39, pl. 4, figs. 12-15.- Parker and Athearn, 1959, p. 341, pl. 50, figs. 28-31.
Helenina andersoni (Warren). SAUNDERS, 1961, p. 148.- SCOTT, 1977, p. 173, pl. 6, figs. 12, 13.

Miliammina fusca (Brady)
Quinquelouilina fusca BRADY 1870, p.47, pl. 11, figs. 2,3.
Miliammina fusca (Brady).- PHLEGER and WALTON 1950, p. 280, pl. 1, figs 19a,b.- BOLTOVSKOY and VIDARTE 1977, p. 39, pl. 3, figs. 7-9.

Polysaccammina ipohalina Scott
Polysaccammina ipohalina SCOTT 1976, p. 318, pl. 2, figs. 1-4, text figs. 4a-c.-

ZANINETTI ET AL. 1977, pl. 1, fig. 7.- BRÖNNIMANN ET AL. 1979, pp. 33, 34, pl. 3, fig. 1-14; pl. 4, fig. 4, 6; pl. 5, figs. 1, 7.

Pseudothurammina limnetis (Scott and Medioli)
Astrammina sphaerica (Heron-Allen and Earland).- ZANINETTI ET AL. 1977, pl. 1, fig. 9.
Tholsina sp. BOLTOVSKOY and VIDARTE 1977, p. 39, pl. 4, fig. 8.
Thurammina ? limnetis SCOTT and MEDIOLI 1980a, pp. 43, 44, pl. 1, figs. 1-3.
Pseudothurammina limnetis (Scott and Medioli).- SCOTT, MEDIOLI, and WILLIAMSON 1981, pp. 126, 127.

Reophax nana Rhumbler
Reophax nana RHUMBLER 1911, p. 182, pl. 8, figs 6-12.- SCOTT and MEDIOLI 1980a, p. 38, pl. 2, fig. 6.

Reophax scottii Chaster
Reophax scottii CHASTER 1982, p. 57, pl. 1, fig. 1.- WILLIAMSON 1983, p.207, pl. 1, fig. 11.

Rosalina columbiensis (Cushman)
Discorbis columbiensis CUSHMAN 1925, p. 43, pl. 6, fig. 13.
Rosalina columbiensis (Cushman).- LANKFORD AND PHLEGER 1973, pp. 127-128, pl. 5, figs. 10-12.

Textularia earlandi Parker
Textularia earlandi PARKER 1952, p. 458 (footnote).-BOLTOVSKOY and VIDARTE 1977, p. 39, pl. 4, figs.6,7.- BOLTOVSKOY and HINCAPIÉ DE MARTNÍNEZ 1983, p. 218, pl. 3, figs. 24, 25.

Tiphotrocha comprimata (Cushman and Brönnimann)
Trochammina comprimata CUSHMAN and BRÖNNIMANN 1948b, p. 41, pl. 8, figs. 1-3.
Tiphotrocha comprimata (Cushman and Brönnimann).- SAUNDERS 1957, p. 11.- BOLTOVSKOY and VIDARTE 1977, p. 39, pl. 4, figs. 9, 10.- ZANINETTI ET AL. 1977, pl. 1, figs. 4, 6.- SCOTT and MEDIOLI 1980a, p. 42, pl. 5, figs. 1-3.

Trochammina inflata (Montagu)
Nautilus inflata MONTAGU 1808, p. 81, pl. 18, fig 3.
Trochammina inflata (Montagu).- PARKER and JONES 1859, p.347.- BOLTOVSKOY and VIDARTE 1977, p. 39, pl. 4, figs. 11, 14.- ZANINETTI ET AL. 1977, pl. 1, figs. 1, 2.- SCOTT and MEDIOLI 1980a, p. 39, pl. 3, figs. 12-14.
Siphotrochammina elegans ZANINETTI ET AL. 1977, pl. 2, fig. 8, 10, 11.

Trochammina macrescens Brady
Trochammina inflata (Montagu) var. macrescens BRADY 1970, p. 290, pl. 11, figs. 5a-c.
Jadammina polystoma BARTENSTEIN and BRAND 1938, p. 381, figs. 1a-c, 2a-1.
Trochammina macrescens Brady.-PHLEGER and WALTON 1950, p. 281, pl. 2, figs. 6, 7.- BOLTOVSKOY and VIDARTE 1977, p. 39, pl. 4, figs. 12, 13.- SCOTT and MEDIOLI 1980a, p. 39, pl. 3, figs. 1-8.

Trochammina squamata Parker and Jones
Trochammina squamata PARKER and JONES, 1865, p. 407, pl. 15, figs. 30, 31a-c.- SCOTT and MEDIOLI 1980a, p. 41, pl. 4, figs. 6, 7.

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PLATE 1

PLATE 1

Plate 1 includes eight agglutinated species which can be observed in the West Head salt marsh, Chezzetcook Inlet.

1 *Ammobaculites dilatatus.* 1. Side view (uniserial chambers missing).

2-3 *Ammobaculites exigus.* 2. Side view. 3. Apertural view .

4-5 Ammotium salsum. 4. Side view. 5. Apertural view.

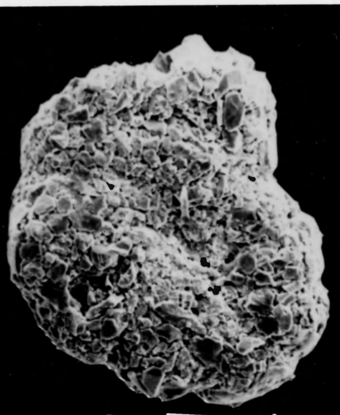
6 *Miliammina fusca.* 6. Side view of four-chamber side.

7-8 *Tiphotrocha comprimata.* 7. Dorsal view. 8. Ventral view .

9-10 *Trochammina inflata.* 9. Dorsal view. 10. Ventral view .

11-12 *Trochammina macrescens.* 11. Dorsal view. 12 . Ventral view.

13-14 *Trochammina squamata.* 13. Dorsal view. 13. Ventral view.



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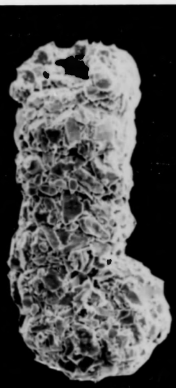

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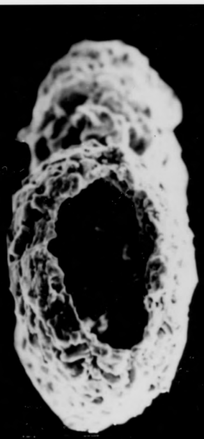

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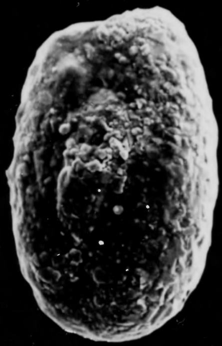

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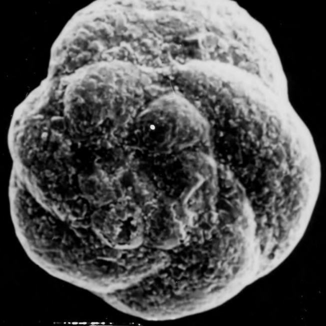

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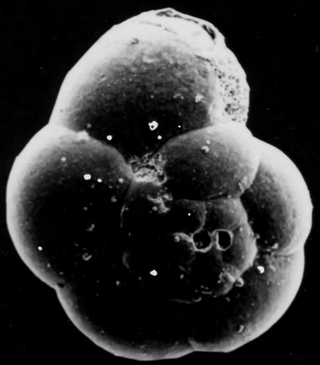

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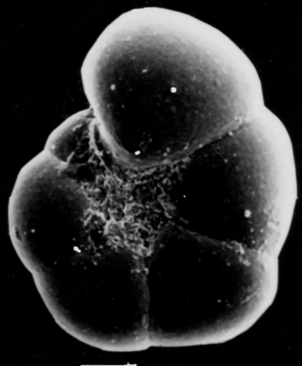

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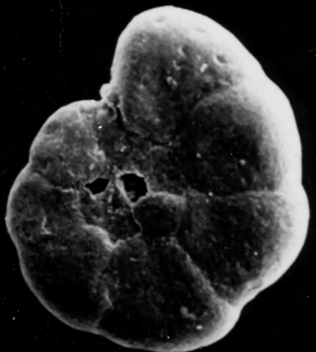

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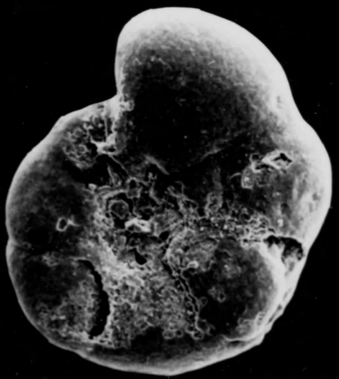

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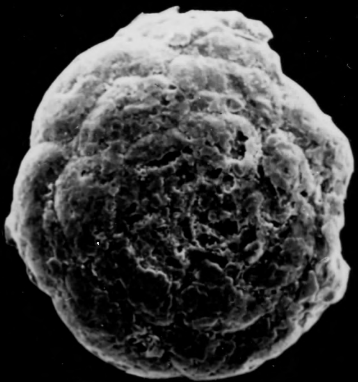

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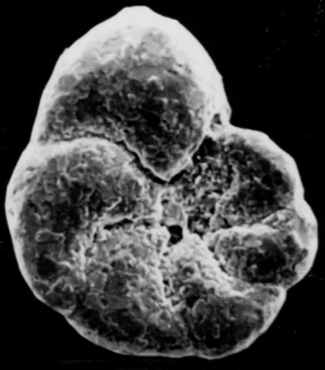


14

APPENDIX A
CORE LOGS

Appendix A contains reproduced core logs for Cores 2, 8A, 8B, and 12. Original core data, including cores, site locations, core logs, core sample intervals, and ^{14}C dating sample intervals are stored in the Centre for Marine Geology Core Room, Dalhousie University.

DALHOUSIE UNIVERSITY CENTRE FOR MARINE GEOLOGY
CORE LOGGING SHEET

CORE IDENTIFICATION: '92
DESCRIBED BY: Kendrick Brown
LOCATION: CHEZZETCOOK 2
DATE: May 6/92.

0-170cm

SEDIMENTARY TEXTURE & STRUCTURES: G, CS, MS, FS, ST, C | INTERVAL (cm) | DEFORMATION | SED. TYPE | BED THICKNESS: < 1 cm, 1-10 cm, 10-30 cm, > 30 cm | COLOR | AV. GRAIN SIZE | BURROWING | SHELL CONTENT | % ORGANIC | STRATIFICATION TYPE: LAMINATED, WAVY, LENTICULAR, SM X BEDS, LG X BEDS, MASSIVE | SAMPLE: GRAIN-SIZE, PEEL, RADIOMETRIC, RADIOGRAPH, PHOTOGRAPH | COMMENTS

INTERVAL (cm)	SED. TYPE	COLOR	AV. GRAIN SIZE	COMMENTS
10	marsh Peat	dark brown	3ϕ	- marsh (dark brown mud 10YR 3/3 and organics (rootlets)) peat
20				- sharp boundary (20cm)
20-30	marsh Peat	very dark greyish brown		- marsh (very dark greyish brown mud 2.5Y 3/2 and organics (rootlets, grass and wood fragments)) peat
30-40	Marsh Peat			- sharp boundary (35cm) peat (very dark greyish brown mud 2.5Y 3/2 and organics - (rootlets, grass, wood fragments) - increased wood fragments
40-50	Marsh Peat	dark brown	3ϕ	- sharp boundary (45cm) - dark brown mud and rootlets
60	Marsh Peat	dark brown		- boundary (50cm) - peat (slightly darker brown mud), rootlets and wood fragments at lower section)
70-90	mud	very dark greyish brown		- gradational boundary (75cm) - increased mud proportion - very dark greyish mud 10YR 3/2 - wood fragments only (common at 35cm)
100-120	mud	olive	5ϕ	- gradational boundary (99cm) - olive grey mud 5Y 4/2 with - common rootlets and grass - wood fragments rare
130-150	mud	very dark grey		- rootlets and grass abruptly stop (135cm) - dark olive grey mud 5Y 3/2 - rare wood fragments
160-170	mud		8ϕ	- gradational boundary (157cm) - very dark greyish mud 5Y 3/1 - rootlets and wood fragments common - abrupt boundary (170cm)

170

DALHOUSIE UNIVERSITY CENTRE FOR MARINE GEOLOGY
CORE LOGGING SHEET

CORE IDENTIFICATION: '92

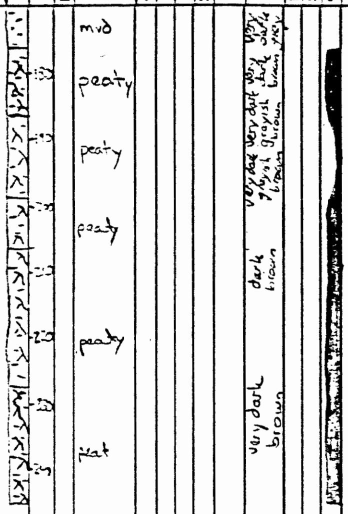
DESCRIBED BY: Kendrick Brown

LOCATION: Chezzetcook 2

DATE:

170-244

SEDIMENTARY TEXTURE & STRUCTURES	INTERVAL (cm)	DEFORMATION	SED. TYPE	BED THICKNESS				COLOR		BURROWING	SHELL CONTENT	% ORGANIC	STRATIFICATION TYPE						SAMPLE					COMMENTS
G CS MS FS ST C				< 1 cm	1-10 cm	10-30 cm	> 30 cm						LAMINATED	WAVY	LENTICULAR	SM X BEDS	LG X BEDS	MASSIVE	GRAIN-SIZE	PEEL	RADIOMETRIC	RADIOGRAPH	PHOTOGRAPH	

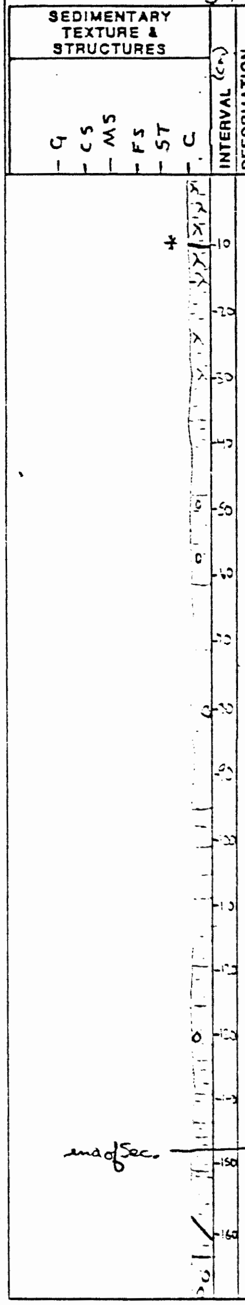


very dark grey mud 2.5Y N3/0
- gradational boundary (177cm
- very dark brown mud, rootlets and grasses
- boundary (137cm)
- rare rootlets
- very dark greyish brown mud 2.5Y 3/2
- gradational boundary (197 cm)
- very dark greyish brown mud 2.5Y 4/2
- common rootlets and grasses
- gradational boundary (205 cm)
- various shades of very dark brown mud 10YR 3/3
- rootlets and grasses very common
- gradational boundary (227cm)
- very dark brown mud 10YR 2/2
- very common rootlets and grasses

DALHOUSIE UNIVERSITY CENTRE FOR MARINE GEOLOGY
CORE LOGGING SHEET

CORE IDENTIFICATION: '92
DESCRIBED BY: Kendrick Brown
LOCATION: Chezzetcook 12
DATE: May 6/92

0-170



DEFORMATION

SED. TYPE: Organics and mud; mud; mud; mud

BED THICKNESS: < 1 cm; 1-10 cm; 10-30 cm; > 30 cm

COLOR: brown; dark olive grey (5Y 3/2); dark olive grey (5Y 3/2); very dark greyish brown

AV. GRAIN SIZE: 8ϕ; 8ϕ

BURROWING

SHELL CONTENT

% ORGANIC

STRATIFICATION TYPE: LAMINATED; WAVY; LENTICULAR; SM X BEDS; LG X BEDS; MASSIVE

SAMPLE: GRAIN-SIZE; PEEL; RADIOMETRIC; RADIOGRAPH; PHOTOGRAPH

COMMENTS

- organics (salt marsh grass and rootlets)
- intermixed with brown mud
- sharp boundary

dark olive grey mud
5Y 3/2

- organ[illegible] at top [illegible] common
- faint laminae throughout (alternating [illegible] and [illegible])
- rare [illegible]
- large [illegible] (2cm [illegible])
- increased lamination
- gradational boundary
- increased shell fragments [illegible] shells rare
- lamination
- very dark greyish brown
2.5Y 3/2

*Note - May have lost 1-1½ [illegible] Peat

DALHOUSIE UNIVERSITY CENTRE FOR MARINE GEOLOGY
CORE LOGGING SHEET

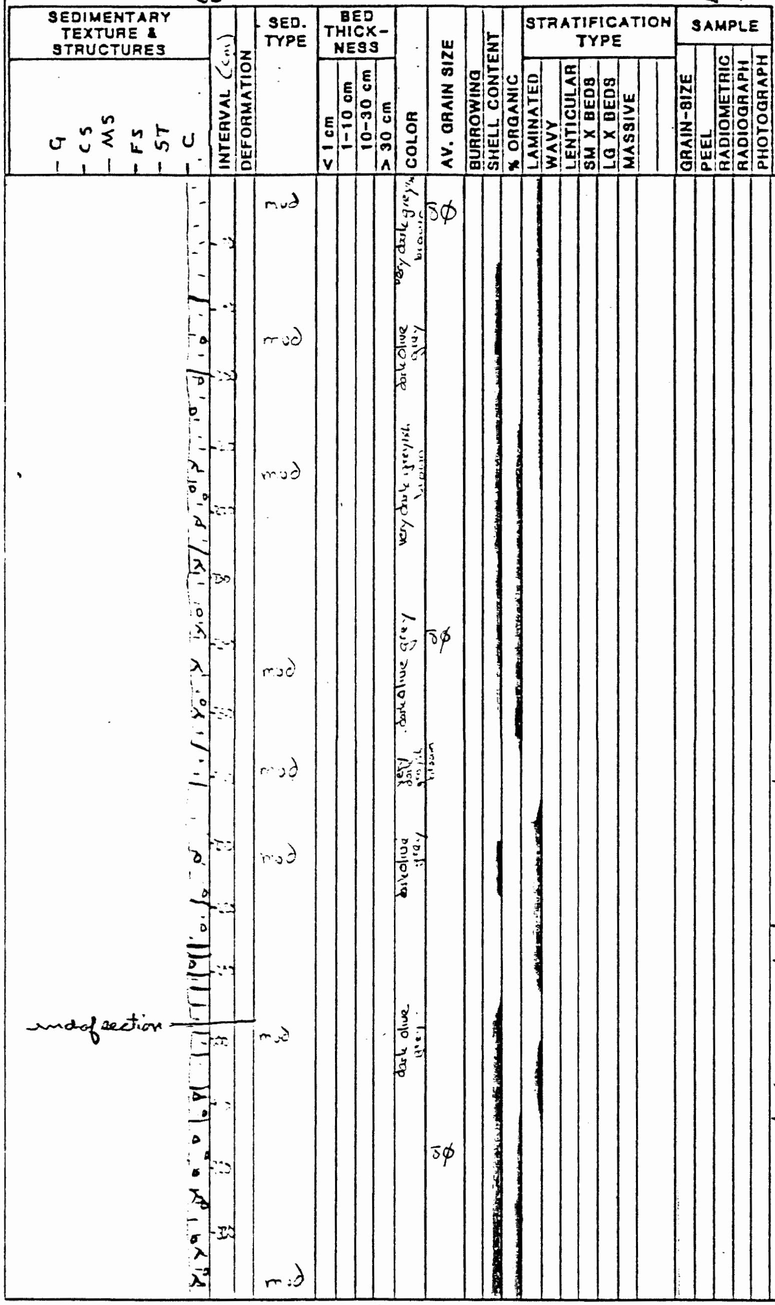
CORE IDENTIFICATION: '92

DESCRIBED BY: K[illegible] Crown

LOCATION: Ch[illegible] 12

DATE: May 6/92

170-340



COMMENTS

- sharp boundary
- dark olive grey mud 5Y 3/2
- extremely rare shell fragments
- sharp boundary
- faint laminations
- rare shell fragments
- very dark greyish brown mud 2.5Y 3/2
- increased organics (rare)
- sharp boundary
- dark olive grey mud 5Y 3/2
- rare shell fragments
- sharp boundary
- very dark greyish brown mud 2.5Y 3/2
- sharp boundary
- dark olive grey mud 5Y 3/2
- increased shell fragments
- increased laminations
- dark olive grey mud 5Y 3/2
- laminations
- common shell fragments

DALHOUSIE UNIVERSITY CENTRE FOR MARINE GEOLOGY
CORE LOGGING SHEET

CORE IDENTIFICATION: 192

DESCRIBED BY: Kendall Brown

LOCATION: Chezzetcook 12

DATE: May 6 '92

340 — 412

SEDIMENTARY TEXTURE & STRUCTURES: G CS MS FS ST C | **INTERVAL (cm)** | **DEFORMATION** | **SED. TYPE** | **BED THICKNESS:** < 1 cm, 1-10 cm, 10-30 cm, > 30 cm | **COLOR** | **AV. GRAIN SIZE** | **BURROWING** | **SHELL CONTENT** | **% ORGANIC** | **STRATIFICATION TYPE:** LAMINATED, WAVY, LENTICULAR, SM X BEDS, LG X BEDS, MASSIVE | **SAMPLE:** GRAIN-SIZE, PEEL, RADIOMETRIC, RADIOGRAPH, PHOTOGRAPH | **COMMENTS**

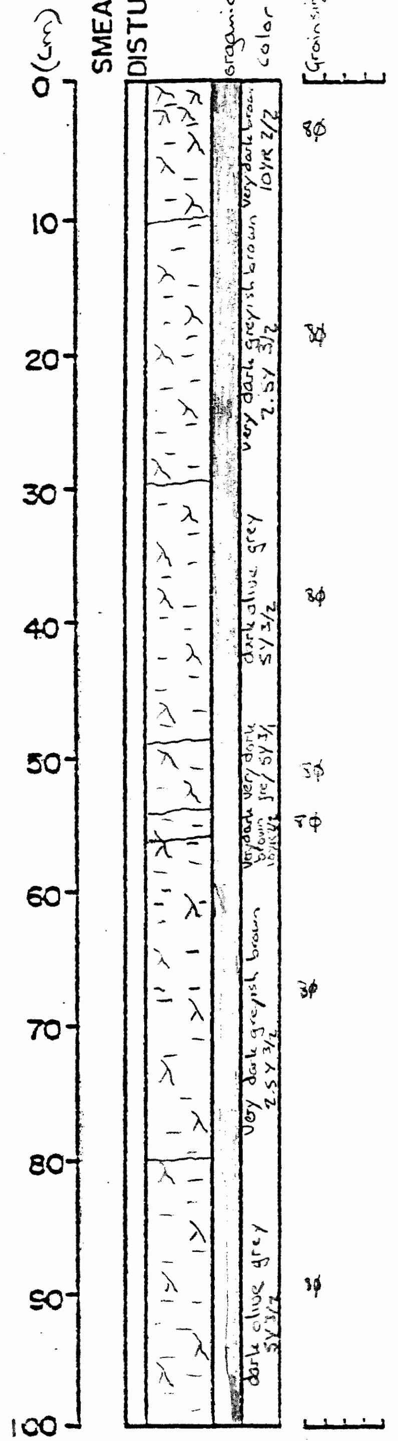
SED. TYPE	COLOR	AV. GRAIN SIZE	COMMENTS
		8φ	- increased organics - dark olive gray mud 5Y 3/2
mud			
			- gradational boundary
peat	very dark brown		- very dark brown peat 10 YR 2/2
shell fragments			- abrupt oyster shell layer
peat	very dark brown		- very dark brown peat 10 YR 2/2

500

CORE 5A
LOCATION Chezzetcook
WATER DEPTH

DEPTH IN CORE 0-100 cm
Described by: Kendrick Brown

VII



DESCRIPTION

- marsh peat
- organics (salt marsh grasses and rootlets)
- intermixed with very dark brown mud (10YR 2/2)
- gradational boundary (10cm)
- organics (rootlets)
- intermixed with very dark greyish brown mud

- gradational boundary (29cm)
- organics (rootlets) intermixed with dark olive grey (2.5Y 3/2) mud

- sharp boundary (49 cm)
- organics (rootlets intermixed) with very dark grey (10YR 2/2)
- sharp boundary (53cm)
- organics (rootlets) inter-
- mixed with very dark brown mud (10YR 2/2)
- gradation boundary (55 cm)
- organics (rootlets intermixed with very dary greyish brown mud (2.5Y 3/2)
- organics less common (75%)

- gradational boundary (80cm)
- organics less common
- organics intermixed with dark olive grey mud (5Y 3/2)

SAMPLE RECORD

General comments:

VIII

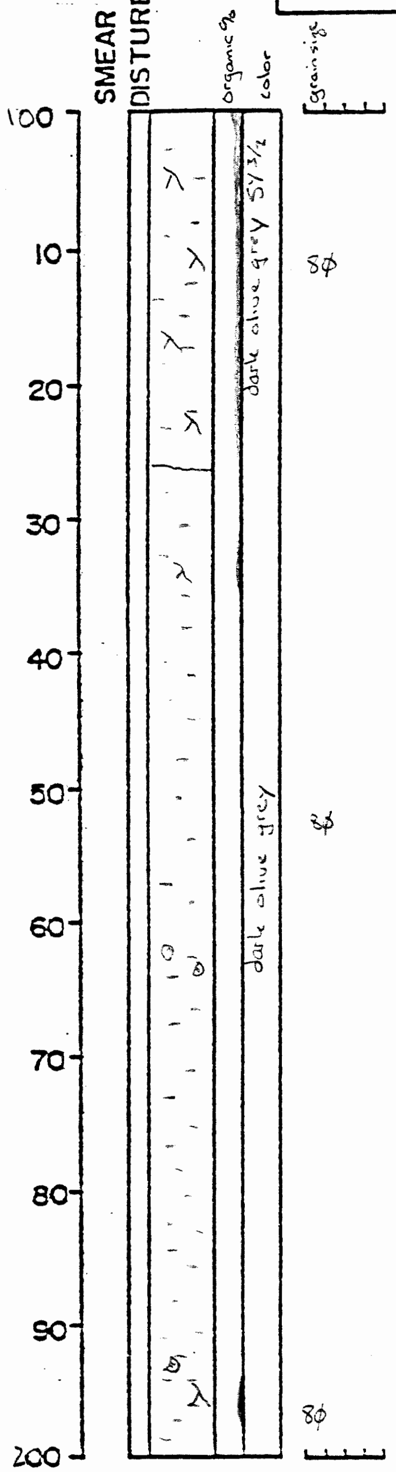
CORE 8A

LOCATION Chezzetcook

WATER DEPTH

DEPTH IN CORE 100 - 200 cm

Described by: K. Brown



DESCRIPTION

SAMPLE RECORD

- organics (rootlets) less common

-organics rare
-dark olive grey mud 5Y3/2

- shells very rare

- organics rare

General comments:

IX

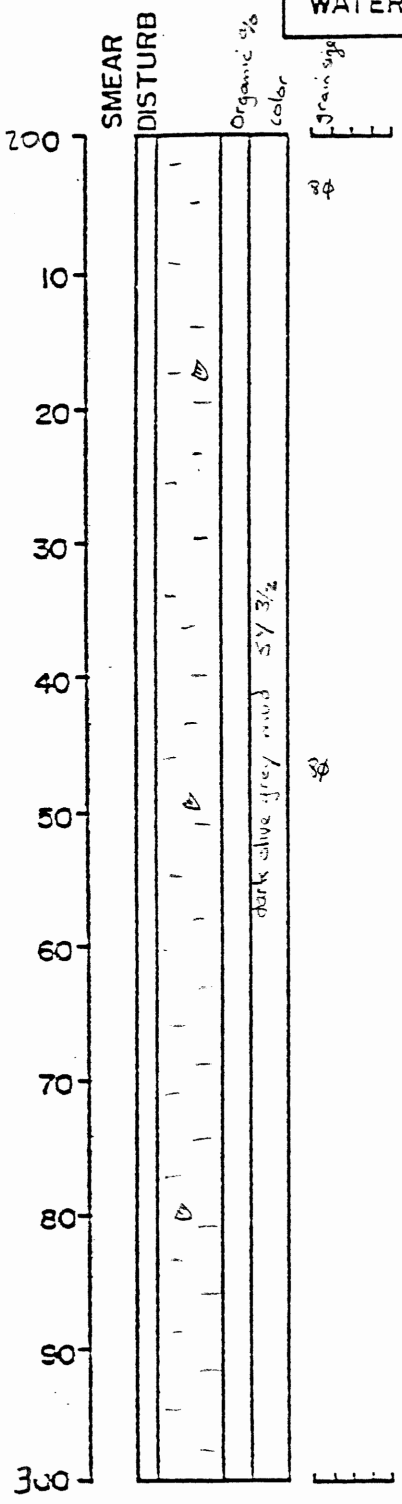
CORE 8A

LOCATION Chezzetcook

WATER DEPTH

DEPTH IN CORE 200-300 cm

Described by: K. Brown



DESCRIPTION

- dark olive grey mud 5Y 3/2
- shell fragments very rare

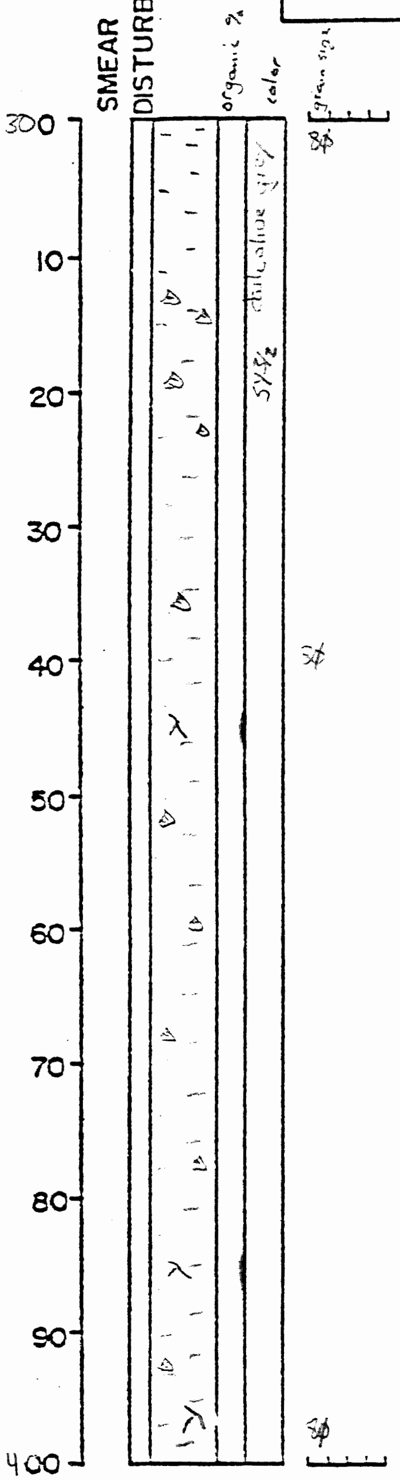
SAMPLE RECORD

General comments:

CORE 8A
LOCATION Chezzetcook
WATER DEPTH

DEPTH IN CORE 300-400 X cm

Described by: K Brown



DESCRIPTION

- dark olive grey mud
  5Y3/2

- rare shell fragments
- very rare organics

SAMPLE RECORD

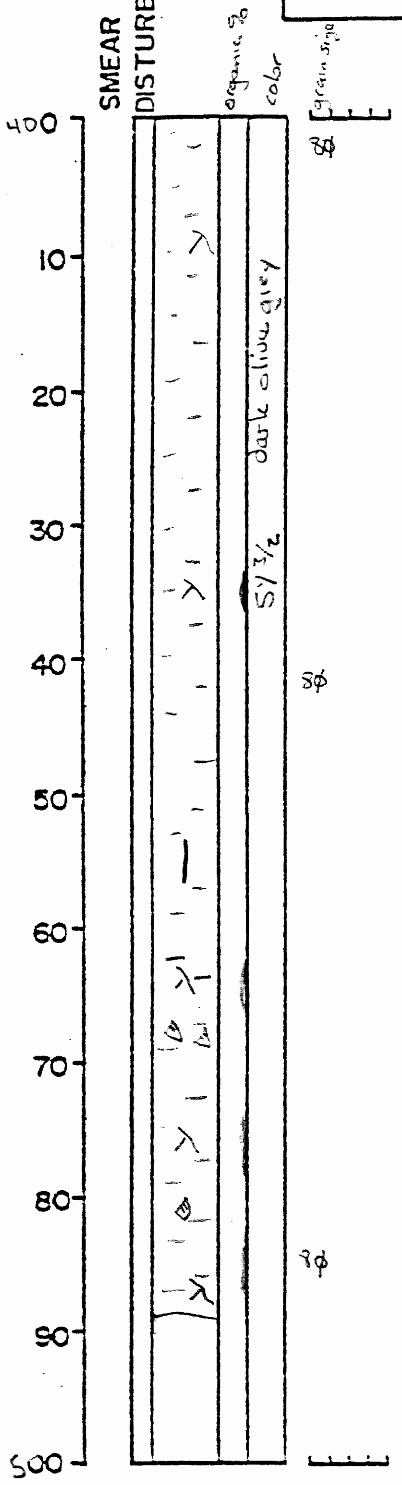
General comments:

XI

CORE 8A
LOCATION Chezzetcook
WATER DEPTH

DEPTH IN CORE 400 - 500 cm

Described by: K. Brown



DESCRIPTION

dark olive grey mud
5Y 3/2

- organics rare

- wood fragment

- organics rare
- shell fragments rare

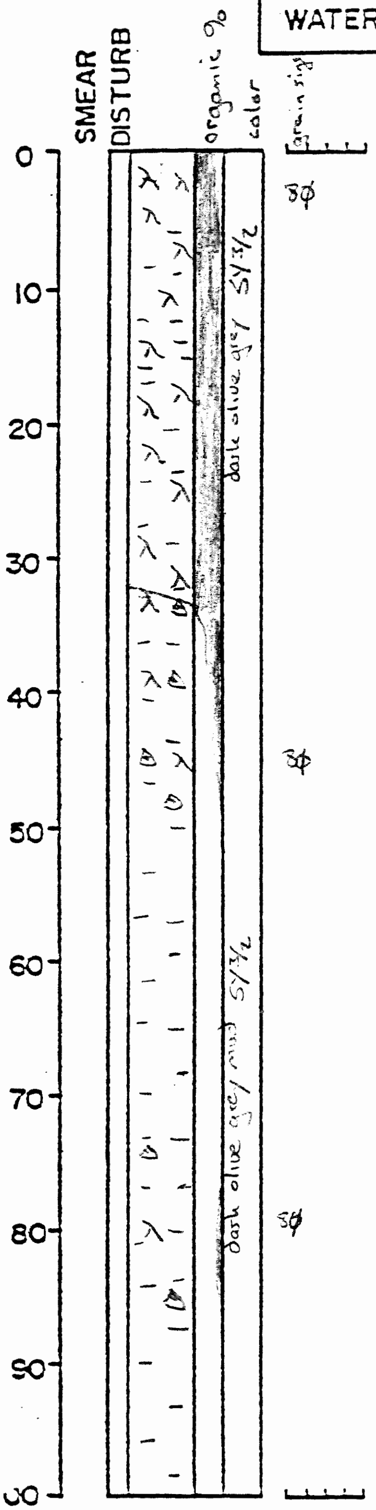
SAMPLE RECORD

General comments:

XII

CORE 8B
LOCATION Chezzetcook
WATER DEPTH

DEPTH IN CORE 0-100 cm
Described by: K. Brown



DESCRIPTION

- marsh peat
- organics (rootlets) intermixed with dark olive grey mud 5Y3/2

- organics common
- shell fragments rare

- dark olive grey mud 5Y3/2

SAMPLE RECORD

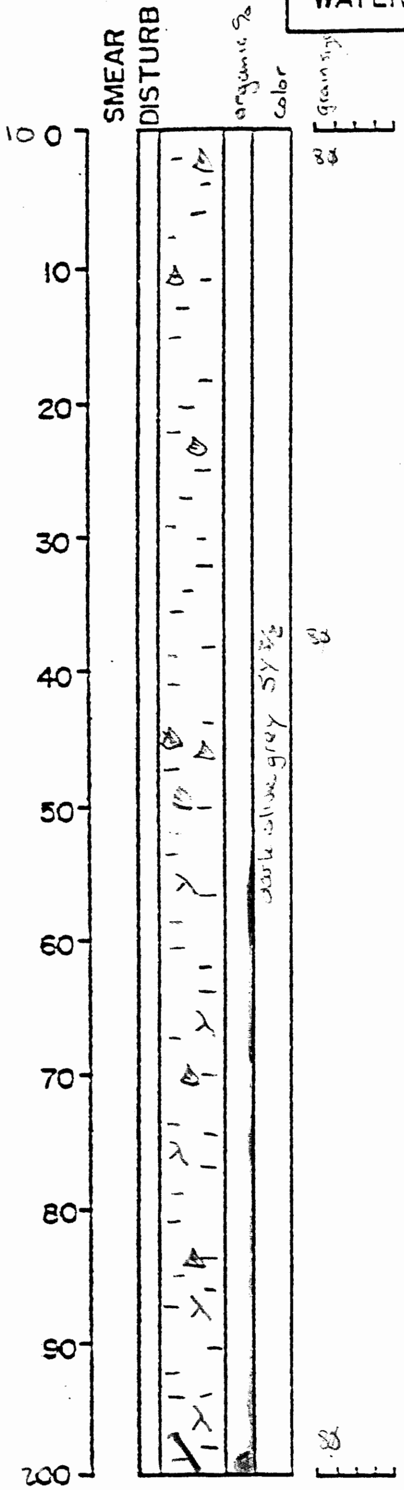
General comments:

XIII

CORE 8B
LOCATION Chezzetcook
WATER DEPTH

DEPTH IN CORE 100-200

Described by: K Brown



DESCRIPTION

- dark olive grey mud 5Y3/2
- rare shell fragments
- rare shell fragments (oyster)
- organics rare
- wood fragment

SAMPLE RECORD

General comments:

XIV

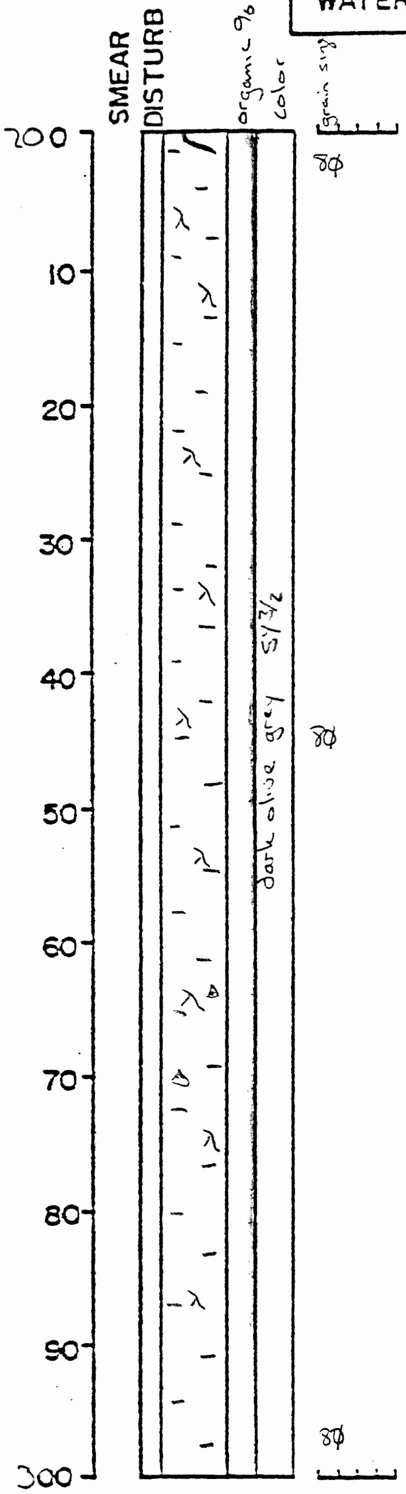
CORE 3B

LOCATION Chezzetcook

WATER DEPTH

DEPTH IN CORE 200-300

Described by: K. Brown



DESCRIPTION

- wood fragment
- rare organics
- dark olive grey mud 5Y3/2

- very rare shell fragments

SAMPLE RECORD

General comments:

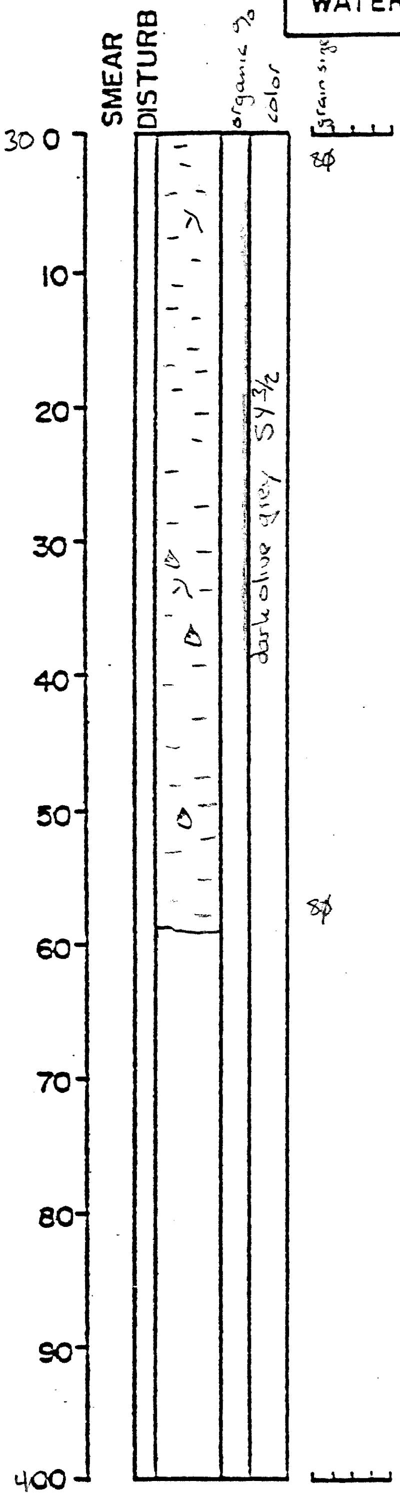
CORE 8B

LOCATION Chezzetcook

WATER DEPTH

DEPTH IN CORE 300-358

Described by: K. Brown



DESCRIPTION

- dark olive grey mud 5Y 3/2
- rare organics
- rare shell fragments

SAMPLE RECORD

General comments: