The Kopanoar mud volcano on the Mackenzie Shelf, Beaufort Sea: Implications for Methane release on Arctic shelves

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Abstract

Fifty sites on the Mackenzie Shelf were sampled for foraminifera as part of the 2004 (Leg 8) Canadian Shelf Exchange Study (CASES). Part of this study sampled the Kopanoar mud volcano. A group of species observed on the Kopanoar mud volcano are described, along with the possibility of using the foraminifera to detect methane gas on the shelf and the implications (if any) this may have on the atmosphere.

Two cores, 805A from the top of the mud volcano and 805C from the moat of the mud volcano, had samples taken every centimeter. Another core, 609A, from a non-mud volcano control site in the pingo area of the shelf, was sampled every 5 centimeters. The foraminifera in the core samples are typical for the Arctic shelf marine environment and include species such as *Islandiella teretis* and *Elphidium exc.* f. *clavatum*. The presence of *Ammotium cassis* in parts of the cores may be an indicator that thermogenic methane is being released from the mud volcano area, along with the possibility of oxidation of biogenic methane in the non mud volcano area. The presence of *Trochammina macrescens* implies ice transport from salt marshes on the Mackenzie Delta. *Elphidiella hannai* has been found for the first time north of Vancouver Island, and seems only to occur with methane related areas.

The three cores contain 37 species. The > 63 μ samples had the highest diversity of formaminifera and the > 45 μ < 63 μ samples had large numbers but relatively few species; some of these species were deep water Arctic species. The species that were found in the small fraction were normally not found in the >63μ size fraction. The 805A sample had formaminifera in the top three centimeters followed by a dead zone with no formaminifera until the 14 centimeter level. A second dead zone occurred in the lower half of the 805A core. These dead zones could be interpreted as a sign of higher than normal methane activity. No such zone was found in the 805C which is at the base of the mud volcano, although there is a good presence of *Ammotium cassis*. This suggests, that at least during two periods of time, that there were much higher concentrations of methane seepage at the summit of the volcano, than there were at the areas of the other two cores.

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I would like to dedicate this paper to my fiancée Stacey Frail who had the patience and understanding that allowed me so much time to spend on this paper, and helped me to stay sane.

ACKNOWLEDGEMENTS

There were many people who helped and guided me in my long study. Special thanks to my advisor, Dr. Dave Scott, who provided me with the topic of my thesis as well as the never ending guidance and support. Thank you to the scientists and crew of the *NGCC Amundsen,* on the 2004 CASES mission (Leg 8) who collected the samples. Thank you to Chlöe Younger for the help with the lab work and sorting, Dr Trecia Schell for her expertise and guidance, P. Stoffyn of the Dalhousie University Electron MicroProbe unit for her time, Kate Jarrett and Frank Thomas of the Bedford Institute of Oceanography for their expertise, and to Dr. Patrick Ryall for the coordination of the honours program which strived to make things better. I would like to thank all the professors of Dalhousie who managed to put up with me over all the years which made me a better student. And last but not least, a thank you to my friends and family who understood the reason I was not around.

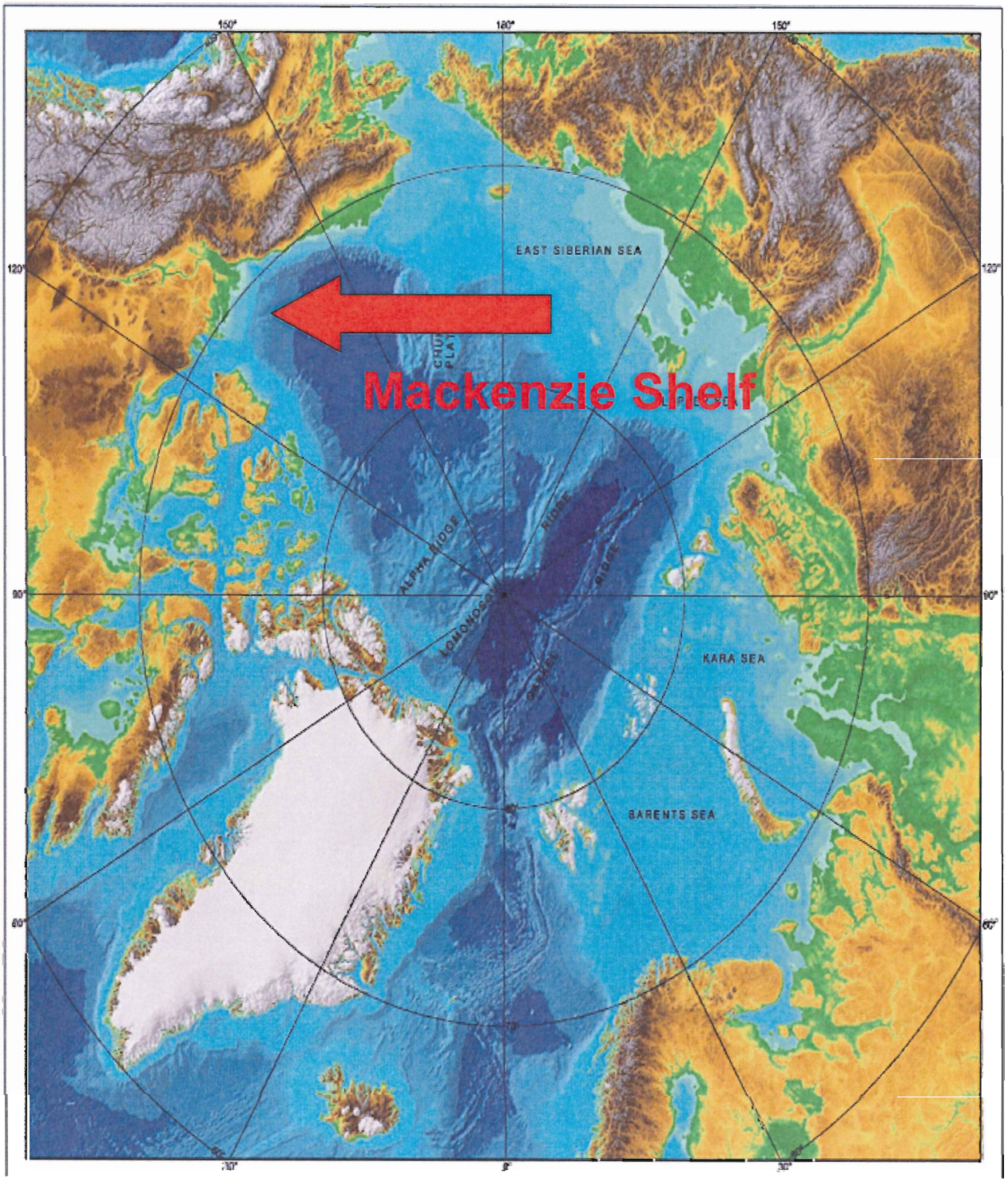
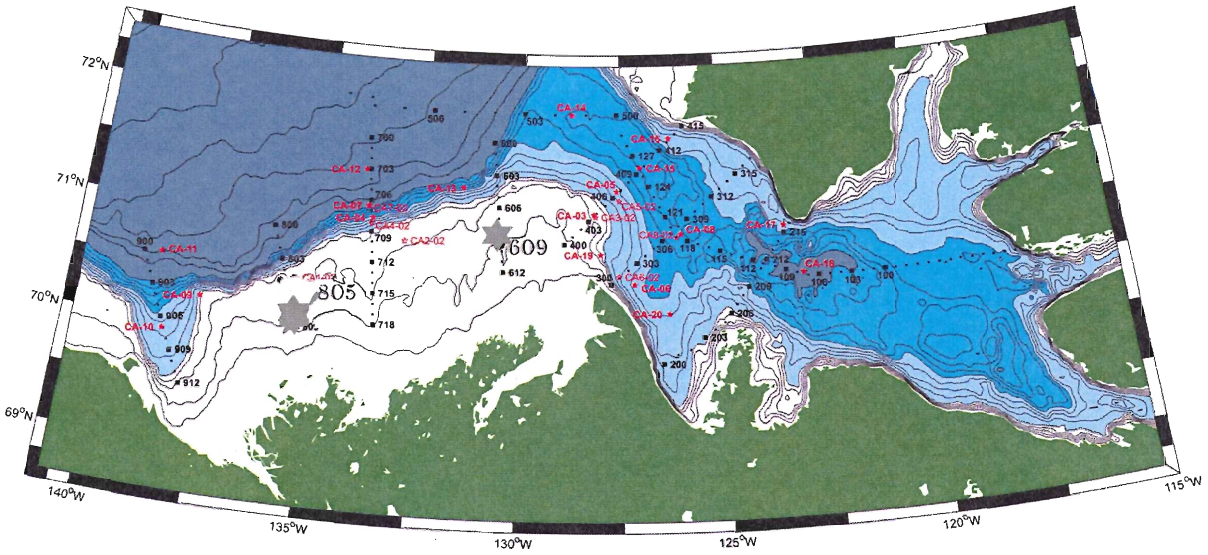


Figure 1 Location of study

Chapter 1

1.1 Introduction

The purpose of this thesis is to determine if there is now, or ever was, methane seeping through the sediments on the Mackenzie Shelf of the Beaufort Sea, in the Canadian Arctic, and if so, is there foraminifera that might be proxy for methane. To accomplish this, foraminifera were examined from three box cores: 805A and 805C from the Kopanoar mud volcano, and 609A for a comparison site, which is in a pingo-like area. These were collected on the CASES mission (Leg 8June 26-Aug. 4, 2004) onboard the *NGCC Amundsen.* The locations of the cores are shown in figure 1.1, with details of the location given in table 1.1.



Core	Latitude	Longitude	Water depth
805A	70° 23.405'N	135° 25.178'W	33 meters
805C	70° 23.571'N	135° 25.214'W	66 meters
609A	70° 56.58'N	130° 31.38'W	44 meters

Figure 1.1, location of cores on the shelf (CASES, 2003, 2004)

1.2 Environment, Seafloor Morphology

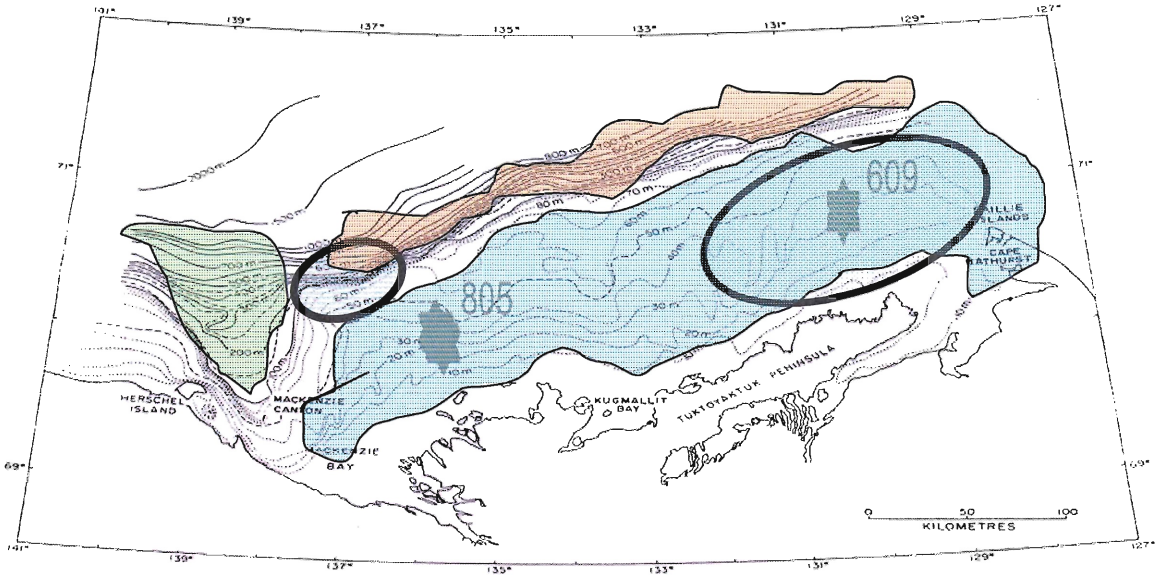


Figure 1.2, Bathymetry of the Mackenzie shelf and slope of the southeastern Beaufort Sea (Vilks, 1989).

Three major physiographic features are present on the seabed of the Beaufort Sea (figure,1.2): 1) the moderately wide gently sloping continental shelf (light blue), which extends approximately 100 km off the Yukon coast to a depth of 100 m; 2) the continental slope (light brown) which falls steeply at the 100 meter isobath to a depth of 2000 m in the Canada Basin approximately 500 km offshore; and 3) the Mackenzie Canyon (light green), which dissects the continental shelf and upper slope in a pronounced V-shaped pattern, with a headward portion lying immediately adjacent to the Mackenzie River delta. From the mouth of the delta the Mackenzie Canyon extends about 120 km along a northwest axis to a depth of some 500 m, and thence to the upper slopes of the Canada Basin (Vilks, et al., 1977).

From bathymetric maps of the area (Canadian Hydrographic Service Charts 23092A, 23096A, 26508A, 26602A, and 26606A), the possible routes of old drainage systems may be inferred, particularly in areas lying off Kugmallit Bay and regions to the east. At lease one of these routes has been confirmed by seismic reflection profiling (Shearer 1970). One submarine feature lying at the edge of the continental shelf directly northeast of Mackenzie Bay (in figure 1.2, small oval) may represent an area where mass wastage of the subsoil occurred (Vilks, et al., 1977).

Figure, 1.3 shows a vertical profile of the slump described by Vilks (1977) and figure 1.4 shows a multi-beam image of the slump feature.

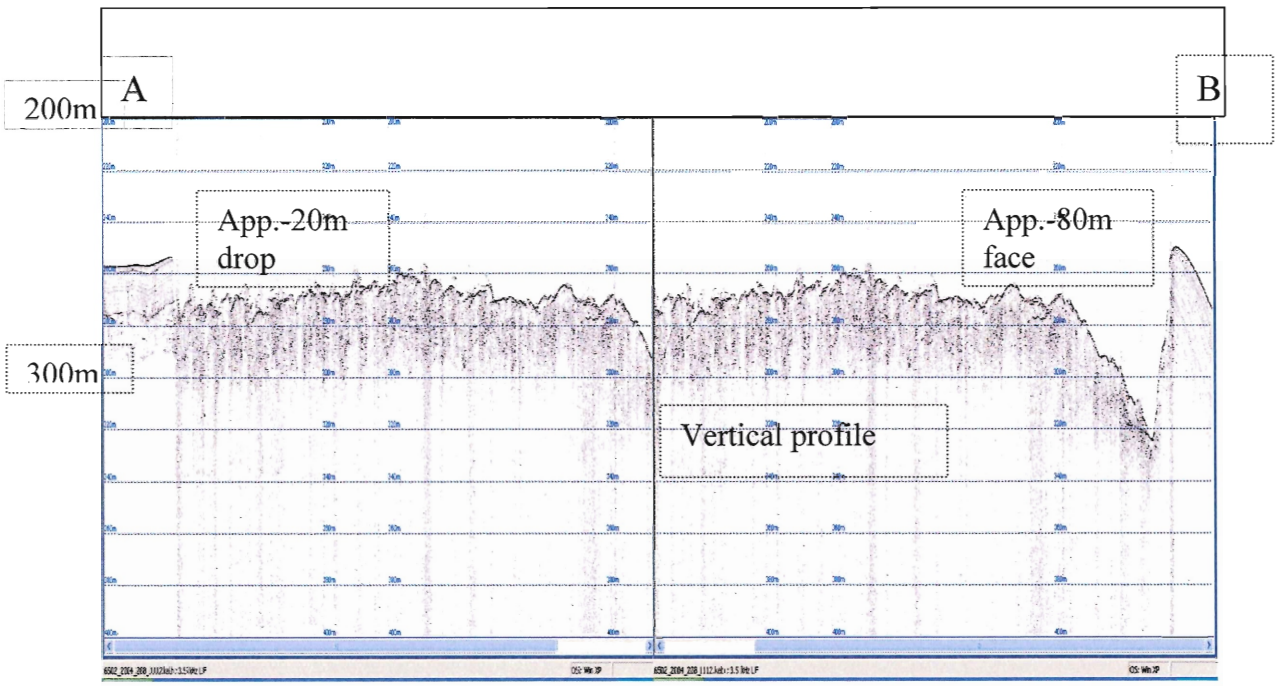
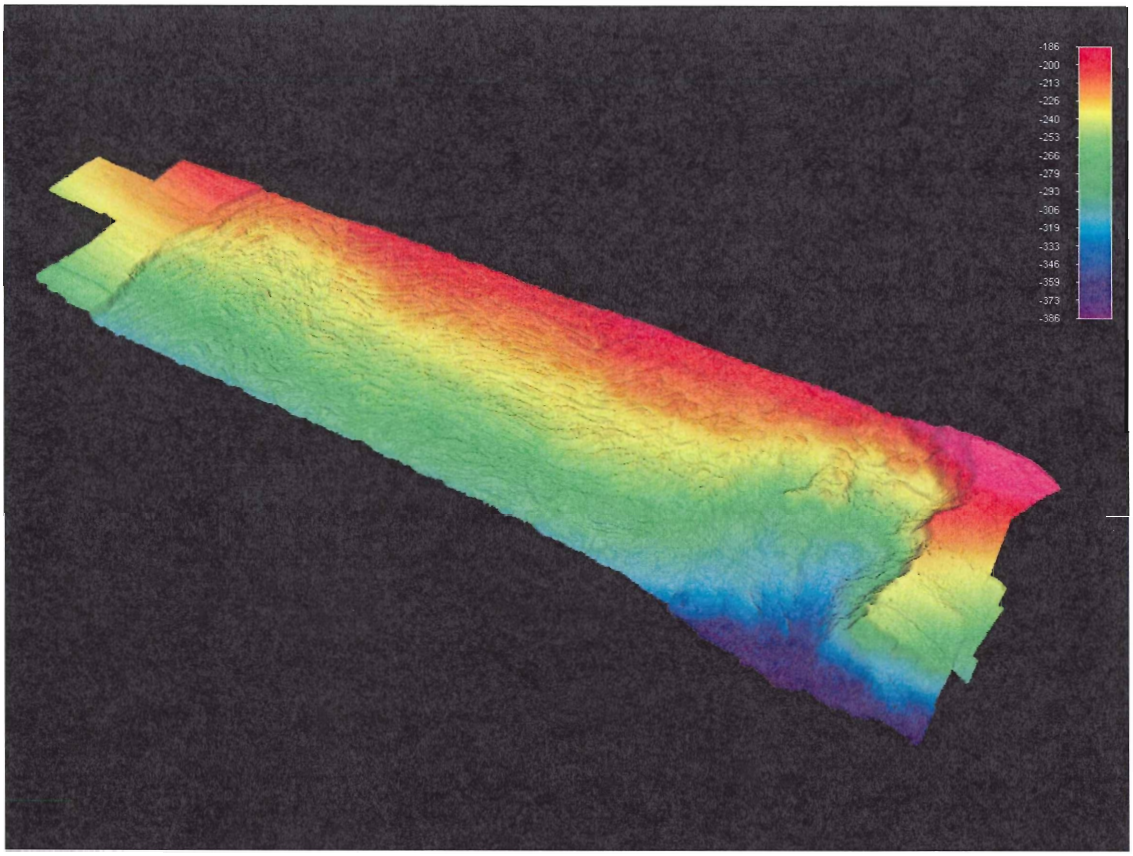


Figure 1.3, Vertical profile taken with a 3.5 kHz Sub bottom profiler, of the slump, which illustrates the sharp relief of the edge walls, particularly the one on the left which looks like a knife cut it (Bartlett, et al. 2004).

A



B

Figure1.4, multi-beam image of the slump feature which is approximately 10km across

Other morphological features shown on the Canadian Hydrographic charts are submarine hills (shown in figure 1.2, large oval) that resemble the pingos described by Mackay (1976) on the Tuktoyaktuk Peninsula. The so-called submarine pingos (Shearer, et al., 1971) have summits that reach to within 11 m of the surface. These pingos are ice cored conical mounds up to 300 m in diameter at their base and rise to 20 to 50 m peaks which commonly have been breached by expansion within the pingo. Generally the submarine pingos occur on the outer shelf east of Mackenzie Canyon, and also found

during lower sea levels. Those located in the inshore areas may have formed on land and subsequently may have been partly eroded and drowned recently by a rising sea level (Shearer et al., 1971). As on land, the submarine pingos occur singly and in clusters. Some conical mounds resembling pingos lie along the eastern edge of Mackenzie Canyon, but these appear to have been formed by the localized thixotropic movement of fine sediments. An acoustical cross-section of one such feature revealed a body of sediment that originated from an adjacent layer and was extruded through a vent in the core. These features also occur singly and in clusters, and are shallow in origin (Vilks, et al., 1977).

Grooves or furrows are abundant on the sea floor. They are generally steep walled linear features approximately 0.5 to 10 m deep, up to several tens of meters wide, and several hundred meters long. These features are produced by keels of drifting ice dragging along the sea floor. Although their orientation varies, the general direction of the grooving is southeasterly (Pelletier and Shearer, 1972) in response to the prevailing wind direction which drives the ice from the west and northwest. Most of the scours occur at water depths between 10 and 50 m. At the shallower depths the scouring is more frequent and the scours shallower; in deeper waters the scours are fewer but deeper. Grooves at depths exceeding 50 m are thought to be mainly relics (Lewis, 1975).

Along the low-lying coast of the mainland, spits and bars are present and are associated with numerous headlands and offshore islands. These features are growing eastward in the direction of sediment transport, except where local gyres create counter currents along the shore that transport the sediments to the west. Further aspects of the

deltas and coasts, including their geography, erosion, aggradation, and sediments, are discussed by Lewis and Forbes (1975), and Vilks, et al. (1977).

1.3 Oceanography

The waters of the Beaufort shelf and the Canadian Arctic Archipelago consist of locally modified Arctic Ocean water, which consists of three layers (Vilks, 1989).

1. The cold and relatively dilute Arctic surface layer approximately 200 m thick.
2. The warmer and more saline water mostly of Atlantic origin between 200 m and 400 m.
3. The Arctic bottom water (some of which flows onto the shelf)

A mixed seasonal surface layer to a depth of about 10-50 m is also present in the Canada Basin adjacent to the Canadian Archipelago (Melling et al., 1984). In the Beaufort Sea the Atlantic layer is slightly cooler and the Arctic surface water contains a layer of warm water entering from the Bering Strait in addition to the Colville River and Mackenzie River effluents.

In summary, the water mass properties on the Beaufort shelf are influenced by the Bering Sea water and river runoff. Within the Canadian Arctic Archipelago the water mass characteristics are similar to the Arctic Ocean to the west and north of the shallow sills in the Barrow Strait area. East of the sills the water is a mixture of Baffin Bay and Arctic surface water (Vilks, 1989).

Figure 1.5 (Miller, 2004) shows the salinity and the temperature in the water around the areas of 805A and 805C. This figure also shows the transmissometer reading, which is a measure of the amount of sediment in the water column. The figure also shows the fluorometer reading which shows the concentration of algae present, figure 1.6 (Miller, 2004) shows all the same parameters for the area around core 609A.

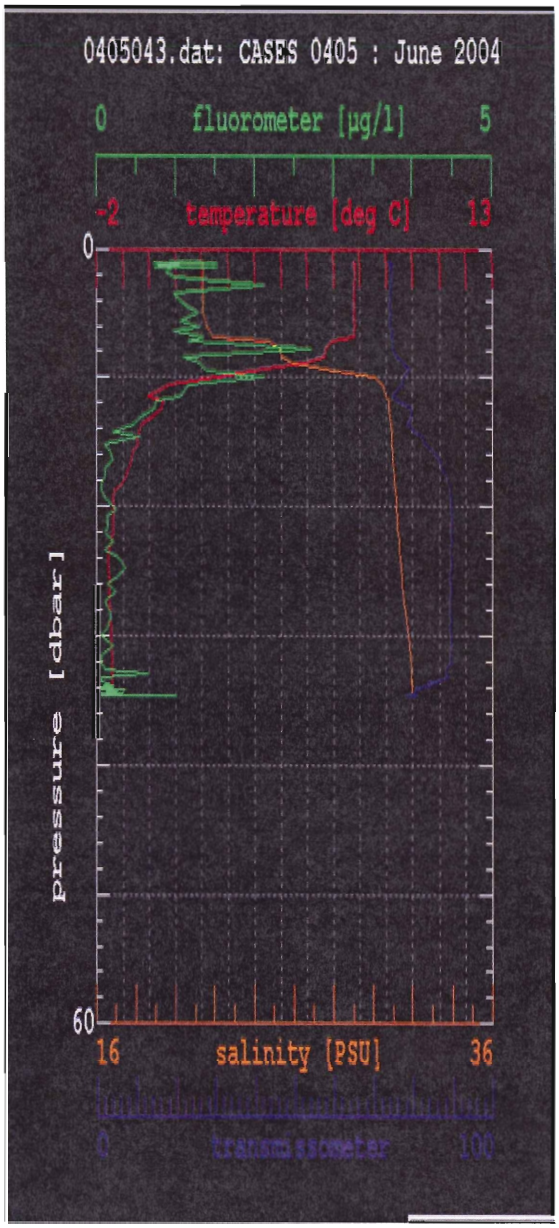


Figure 1.5 Water properties near 805A and 805C (Miller, 2004)

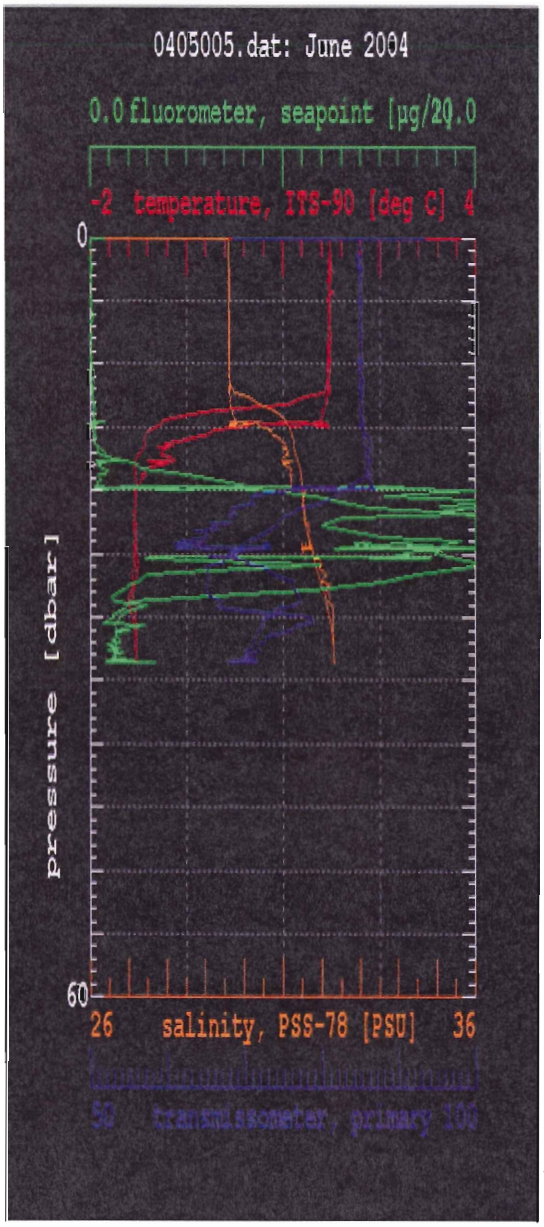


Figure 1.6 Water properties near 609A (Miller, 2004)

Chapter 2
Methods used

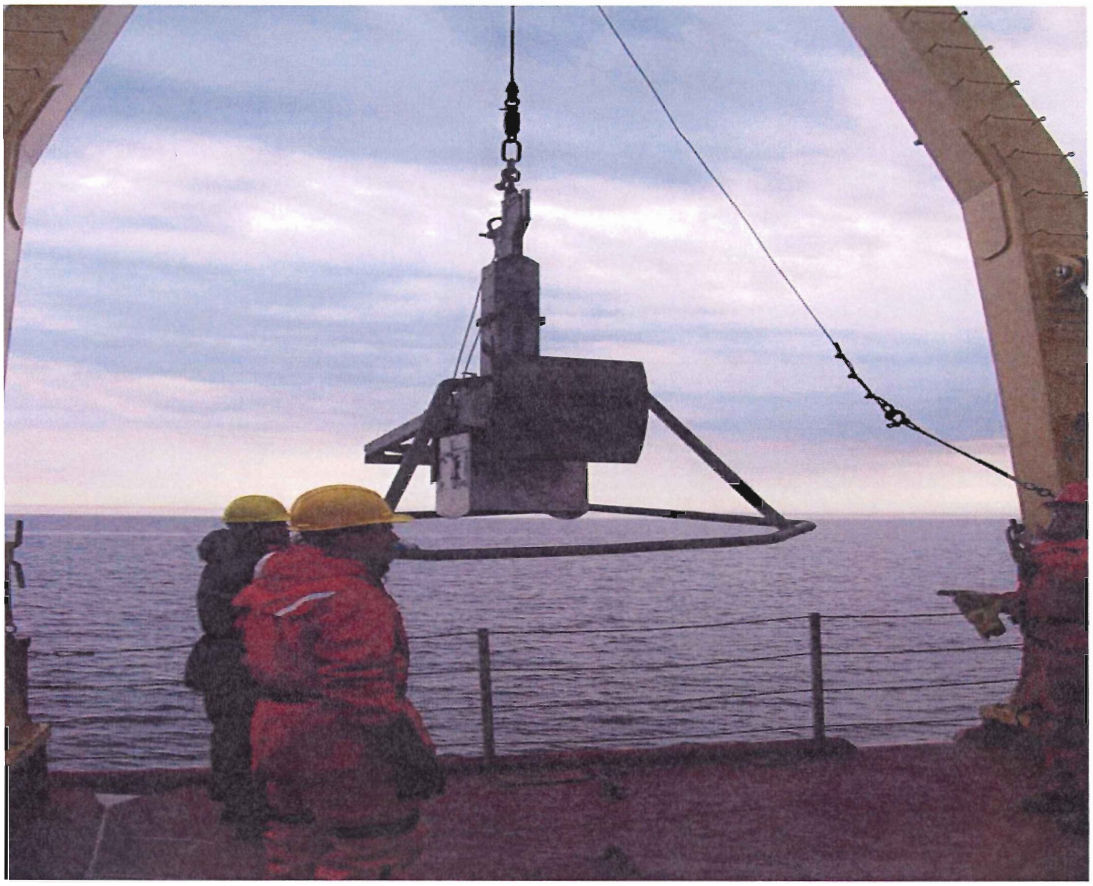


Figure 2.1 Boxcore (CASES Photo, 2004)

The box core samples studied were taken on the 2004 CASES mission (Leg 8) onboard the *NGCC Amundsen.* The boxcore (figure. 2.1) was used to retrieve samples from the ocean bottom, and the push cores (figure. 2.2) taken from the boxcore. The push cores were refrigerated at 4° C to keep the samples from deteriorating. The cores were taken to the Bedford Institute of Oceanography and kept refrigerated until removed for sampling. For sampling, the cores were cut in half; one half was wrapped and set aside in the refrigerator as an archive, and the other half was photographed, (figure 2.3 is

an example photo). Bottom photos were also taken of the area (figure 2.3a is an example photo).

Figure 2.2 Push cores taken from Boxcore (CASES Photo, 2004)

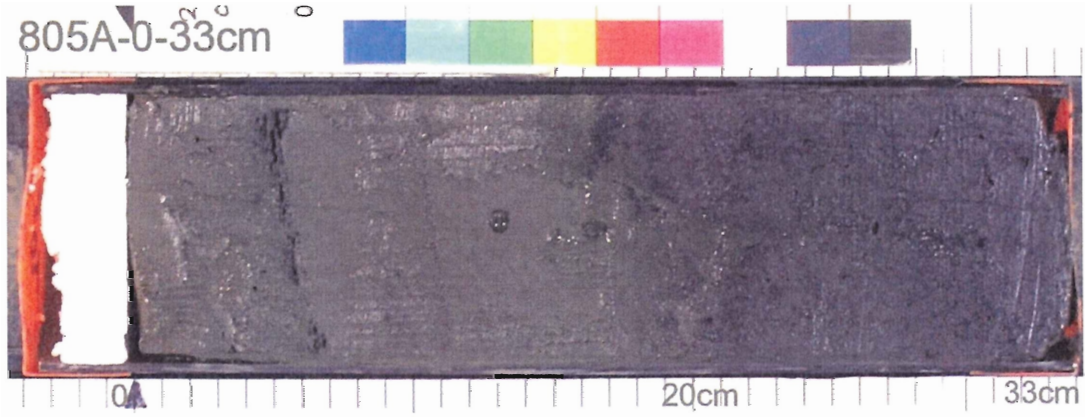


Figure 2.3 Photo of 805A, 0-33cm (Photo, K. Jarrett)

The core was then described, (example of core description shown in figure 2.4) wrapped and sent to Dalhousie University to be refrigerated. At Dalhousie, the X-Rays were taken of cores 805A, 805C and 609A (example shown in figure 2.5).

04-Amundsen-Bx core 805A.

GEOLOGICAL SURVEY OF CANADA (Atlantic) CORE DESCRIPTION

Cruise Number: **2004804 CASES** Sample Number: **32A (805A)**	Geographic Location: **Beaufort Sea Contintental Shelf**	Water Depth: **36 m** Total Length: **cm**
Core Barrel Type: **Push Core in Box Core**	Date: **December 2, 2004**	Project Number: **CASES**
Latitude: **70° 23.405** Longitude: **135° 25.178**	SYMBOL LEGEND clay silt worm burrows	
Described by: **T. Lawrence** at BIO.	Page 1 of 1	

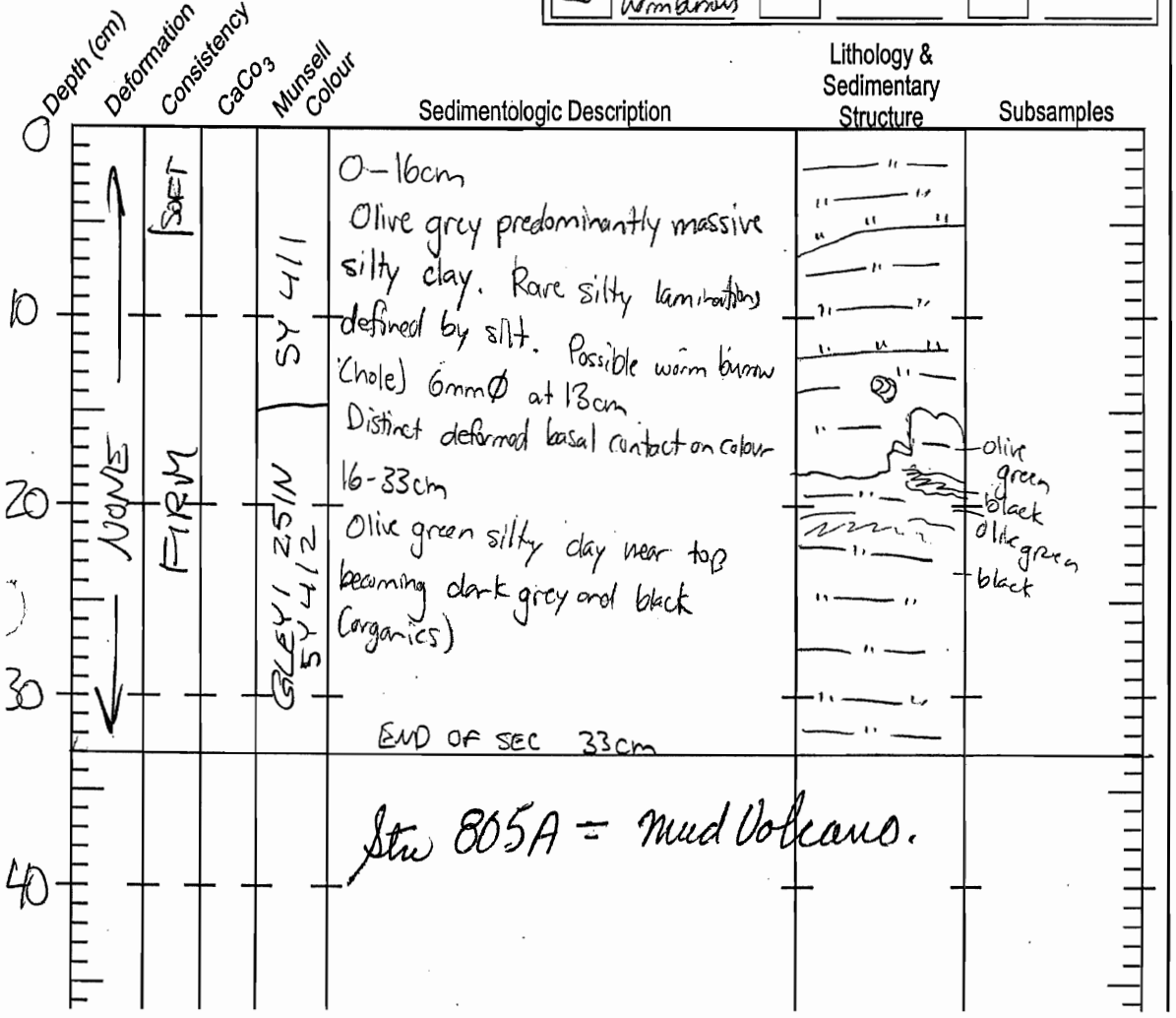


Figure 2.4 Core description of 805 A

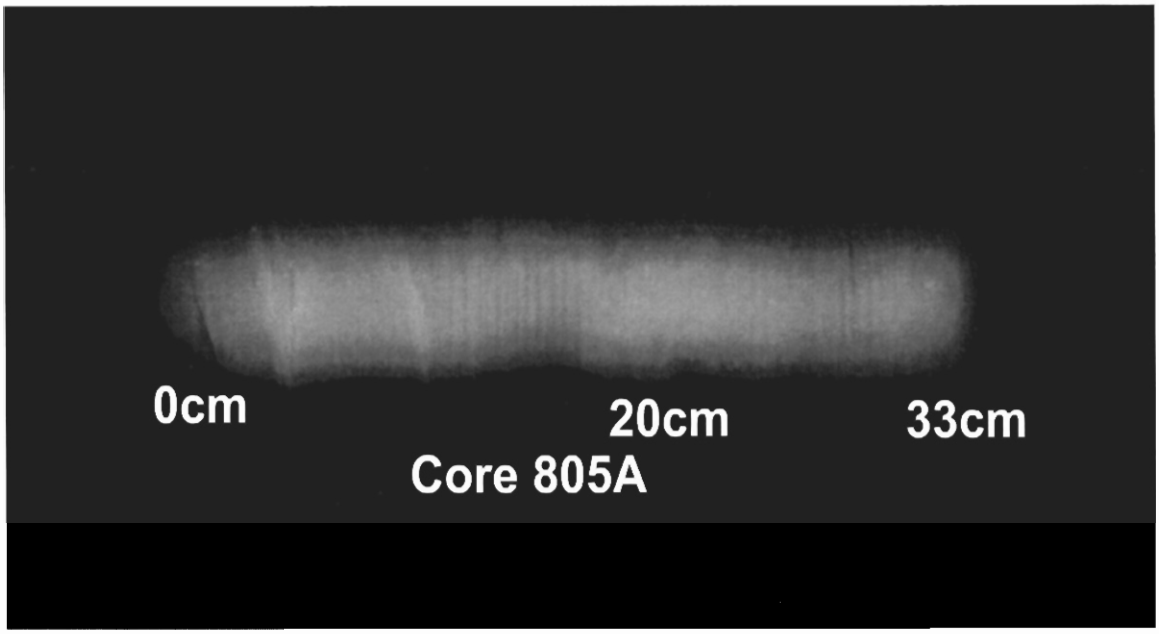


Figure 2.5 X-Ray for core 805A 0-33cm (Photo, C Younger)

The cores were then cut into one centimeter slices and logged on sediment sampling forms (example show in figure. 2.6) and from these slices 10cc samples were taken and washed through two sieves. First they were put through the >63μ sieve and then through the >45<63 μ sieve. Then they were examined under the microscope and preliminary observations were recorded. The cleaned material was then put into containers, alcohol was added and they were set aside for further study. For this study each sample was examined very closely under a binocular microscope to count and identify the foraminifera at 20 to 40 xs. Charts were then made up of the foraminifera and interpreted. Also this is the first time on the Mackenzie Shelf where the smaller size fraction (45<<63μ) has been examined (Schell NAPC et al., 2005) and (Scottet al., 2005).

SEDIMENT SAMPLING FORM — DALHOUSIE, CENTRE FOR MARINE GEOLOGY

PURPOSE: FORAM Studies. — MATERIAL: 04-Amundsen) Core 805A (Mud Volcano.) (Box core)

VOL: FORAMS 10cc *DINOS 10cc — BY: F. WALSH — DATE: DEC02/04

PROCESSING: 763µ, 745-63µ washed, in alcohol (Dec. 29/04). — FOR: DR. OB SCOTT & Andre Rochon (dino.)

INTERVALS/STN: F (DINOS)

1. 0-1 cm	10		25-26		
2. 1-2	1		26-27		
3. 2-3			27-28		
4. 3-4			28-29		
5. 4-5			29-30		
6. 5-6			30-31		
7. 6-7			31-32		
8. 7-8			32-33		
9. 8-9			"	"	"
10. 9-10			"	"	"
11. 10-11					
12. 11-12		Stn 805A - Mud Volcano. (AGC #27)			
13. 12-13					
14. 13-14					
15. 14-15					
16. 15-16					
17. 16-17					
18. 17-18					
19. 18-19					
20. 19-20					
21. 20-21					
22. 21-22					
23. 22-23					
24. 23-24					
25. 24-25					

Remarks:

* ① 10cc. removed from core for A. Rochon's dino studies
② Water depth 836 metres.

Storage:

Figure 2.6 805A core sampling form

Selected foraminifera specimens were placed on a special mount and taken over to the Bedford Institute of Oceanography for photographing with the Scanning Electron Microscope. The foraminifera were captured digitally and put on a CD.

Chapter 3
Previous work

The first descriptions of recent benthic foraminifera of the sub Arctic seas and Arctic Ocean were those published by Parker and Jones (1865), Brady (1878, 1881a), and Goës (1894) (quoted in Schröder-Adams et al. 1990).

Cushman (1948) described species collected, and summarized the results of early Arctic expeditions from the Bering Sea to Greenland, including Hudson Bay. Altogether 175 species are mentioned as occurring in Arctic waters (Vilks, 1989).

Vilks et al, (1977) discussed Holocene foraminifera from 49 piston cores of the Canadian Beaufort shelf facing the Mackenzie River delta. Despite an extensive redistribution of sediments due to ice scouring of the seafloor, two prominent foraminiferal zones were distinguished. The inner shelf zone is characterized by the dominance of *Elphidium excavatum* f. *clavatum* and delineates the area on the shelf that is most commonly covered by the sediment and freshwater plume of the Mackenzie River runoff. The outer shelf zone is dominated by a group of forms identified as *Islandiella teretis* which was described by Vilks et al, (1977) as *Islandiella helenae* and *Cassidulina laevigata*. The concentration of the planktonic foraminifer *Neogloboquadrina pachyderma* is reduced by several orders of magnitude in plankton tows taken through the ice in winter and is absent from the waters of the inner shelf year-round (Vilks, 1989).

The distribution of foraminiferal tests on the Beaufort shelf is patchy, with large areas of depleted faunas that cannot be explained in terms of the environment. It is possible that postmortem destruction of tests takes place. From 45 core top samples, in the Vilks study, 31 contained a sufficient number of specimens to be examined. Twenty-five benthic species are major and dominated by calcareous assemblages; cumulative arenaceous percentage is only 6 % (Vilks, 1989).

Elphidium excavatum f. *clavatum* is the most common species on the inner shelf facing the delta. Associated with *E. excavatum* is *Cassidulina reniforme* along the outer margin of the *E. excavatum* zone. *Cassidulina laevigata* occurs as the dominant species along the continental slope and in the Canada Basin, presumably outside the influence of the Mackenzie River runoff plume. *Islandiella helenae* occurs on the inner shelf but along the outer margins of the delta area (Vilks, 1989).

Spiroplectammina biformis only dominates at two stations at the shelf break. The specific depth of *S. biformis* on Beaufort shelf is 51 m but it is basically a shallow-water species elsewhere in the Arctic; therefore, according to the table in this report, its mean depth is only 16 m. Three minor Arctic species dominate one assemblage each on the Beaufort Shelf: *Fursenkoina fusiformis* in the fine sediments of the Mackenzie Canyon, *Haynesina orbiculare* at the nearshore station, and *Haynesina* associated with the high-diversity faunas toward the Amundsen Gulf (Vilks, 1989).

On the Cruise MR02-K05, on board the RV *Mirai* (Rochon, et al. 2003), used a multibeam system to get an image of the Kopanoar mud volcano at 3 meter resolution.

Several passes had to be made to obtain 100% coverage. Gas emissions were observed above the mud volcano crest during the survey. As a safety precaution and to avoid sudden degassing and a possible explosion of the cores, water samples were collected above and near the mud volcano and analyzed for methane content prior to coring. The water samples above the crest contained 20-30 nM of methane, which is 3-5 times the amount usually measured in sea water. However, no alarmingly high concentrations were measured so coring proceeded as planned. In the core from the volcano crest, the sediment reacted to hydrochloric acid, while sediment from the reference seabed did not. The formation of methane-related carbonate cement has been observed in pockmarks from the North Sea (Hovland and Judd, 1988) and is possibly due to oxidation of biogenic methane, with traces of thermogenic methane. We can assume that the carbonate content of the mud volcano crest sediments possibly have a similar origin. The only difference between our site and the North Sea pockmarks is that the surface sediments were not indurated and no crust or cementation was observed.

The seasonal ice cover, increased input of meltwater, high seasonal temperature change, lowered salinity, and higher sedimentation rate are prime controlling factors in the distribution of benthic foraminifera on the Mackenzie Shelf.

Chapter 4
Results
4.1-805A, photograph and x-ray

In the photograph of the core 805A (figure 4.1) the color change can be noted going from the gray to the dark gray to the black showing the organic rich zone. There is a distinct deformed basal contact of the color. The x-ray of 805A (figure, 4.2) shows some continuity; and lines showing laminations. There are also small white circular structures from the middle to the end of the core. Figure 4.2a the bottom photo shows little life.

The core description in 805A (appendix C, C.1) at the crest of the mud volcano, shows the first 5 cm as being soft and the rest of the core as being firm. The 0-16cm level is olive gray in color and predominantly massive silty clay. There are rare silty laminates defined by the silt. There is a possible worm burrow that is 6mm long at the 13cm level. There is a distinct deformed basal contact of the color. The 16-33cm area shows olive green silty clay near the top becoming dark gray and black which shows an organic rich zone.

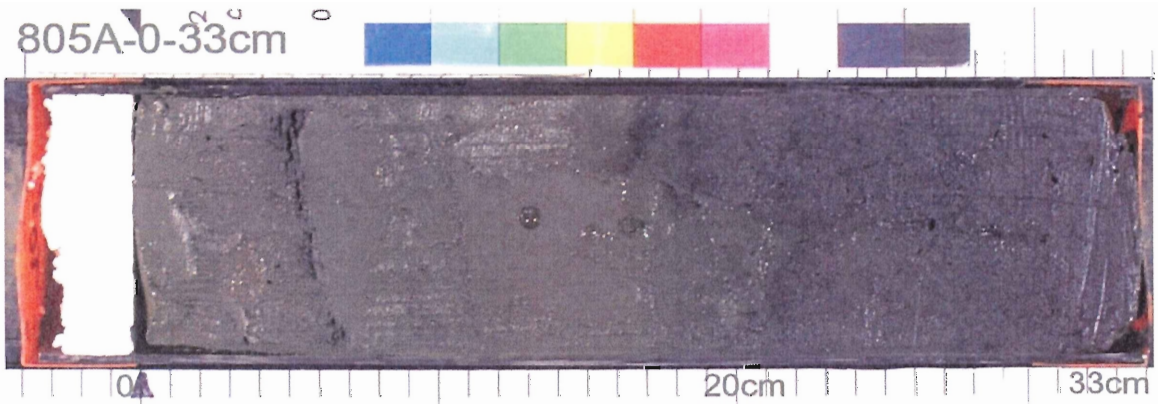


Figure 4.1 core photograph- 805A (Photo, K. Jarrett)

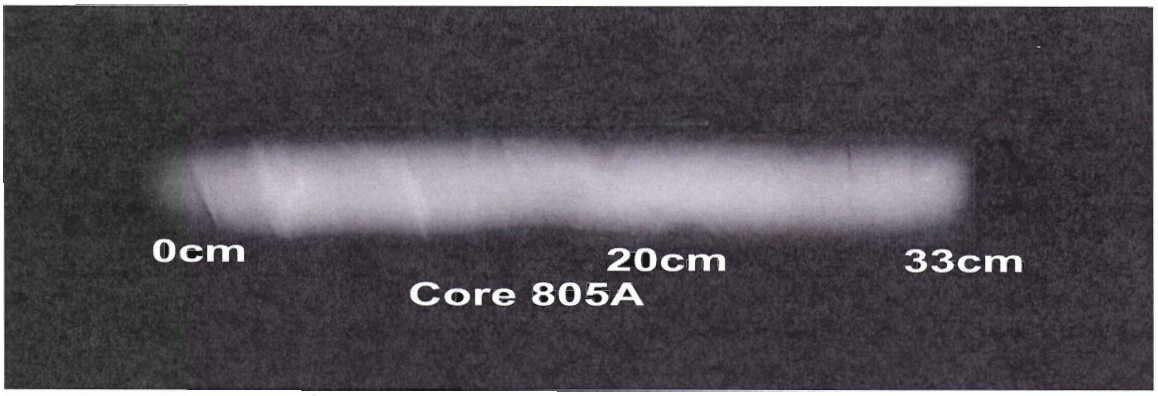


Figure 4.2, X-Ray 805A 0-33 (Photo, C Younger)


Figure 4.2a Bottom photo- 805A (CASES Photo, 2004)

4.2- 805C, photograph and x-ray

The photograph of the core 805C (figure 4.3) shows a disturbance in the top; however the rest of the core seems to remain undisturbed. The holes observed appear to show the bioturbation from worm tubes. Figure 4.3a shows no sign of life in this bottom photo. The x-ray of 805C (figure 4.4) shows good continuity and the lines indicate steady sedimentation. Again there are areas of bioturbation to be seen in this x-ray.

The 805C core (appendix C, C.2) in the moat of the volcano has a consistency that is soft for the whole core. The top 2cm is gray brown silty clay and is disturbed. The

2-41cm area shows dark grayish black silty clay with possible worm burrows, based on holes seen. This area is rich in organics.

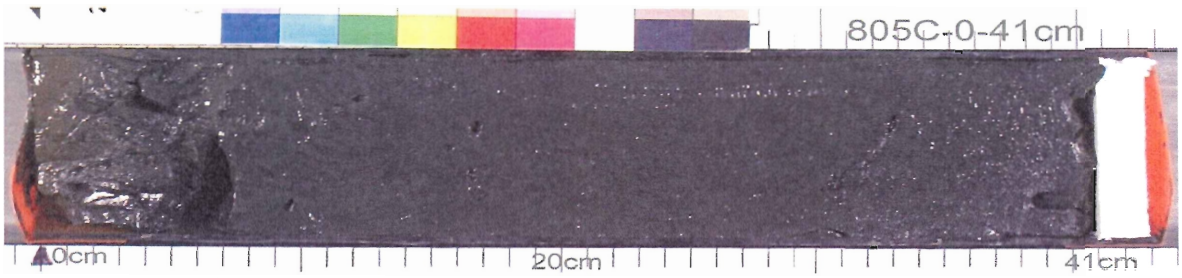


Figure 4.3 core photograph- 805C (Photo, K. Jarrett)


Figure 4.3a bottom photo 805C (CASES Photo, 2004)

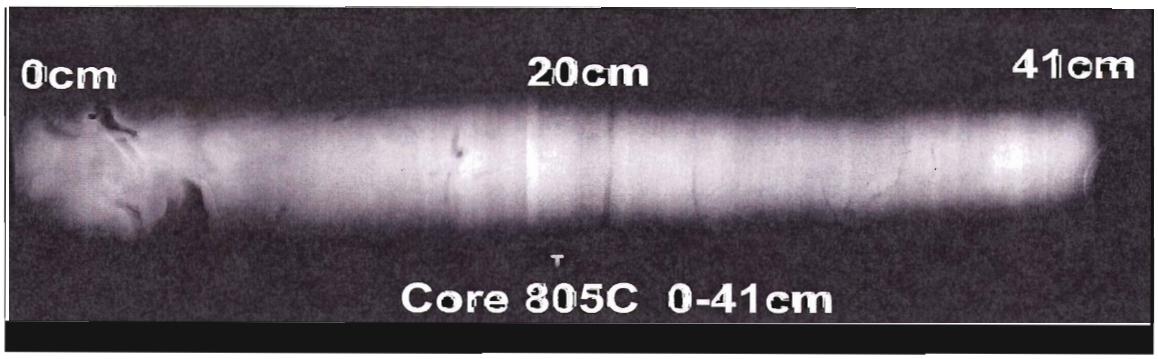


Figure 4.4, X-Ray 805C 0-41(Photo, C Younger)

4.3- 609A, photograph and x-ray

The photograph of core 609A (figure 4.5) shows the slight change in color, and the bioturbation from worms and other organic forms. The bottom photo near 609A

shows lots of life present. The x-ray shown in figure 4.6 has a high amount of bioturbation; so much, that the lines of layering cannot really be seen, except near the bottom.

The 609A core (appendix C, C.3) goes from a very soft consistency on the top to, slightly more consolidated but still soft consistency for the rest of the core. The 0-6cm area of the core is olive color silty clay with high water content. This area has disseminated medium grained sand throughout. There is a worm burrow tube at the 8cm that is 1.2 cm long. The 6-31cm area is a darker olive gray with more clay than silt. The contact with the above interval is gradational over 3cm. This area is highly bioturbated throughout with worm tubes of sizes that range from 1mm-2cm. There was dissociated medium grained sand throughout this area. The core had oxidization at the base which had changed the color there to a rusty color.

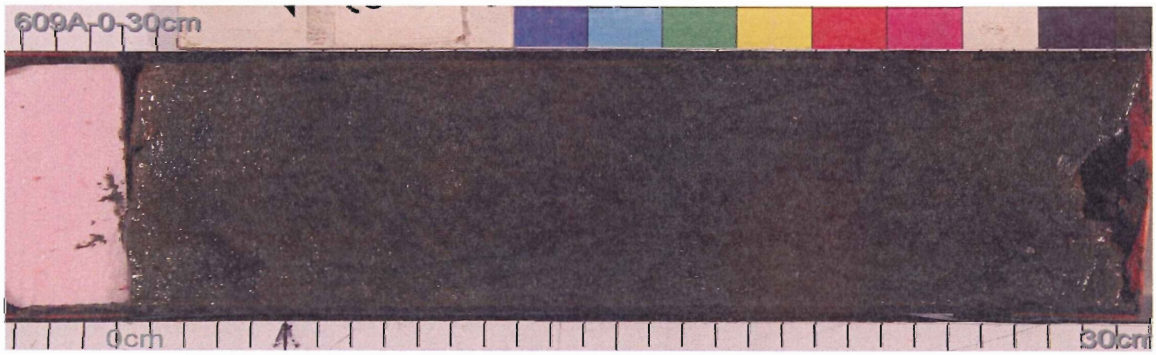


Figure 4.5 core photograph- 609A (Photo, K. Jarrett)

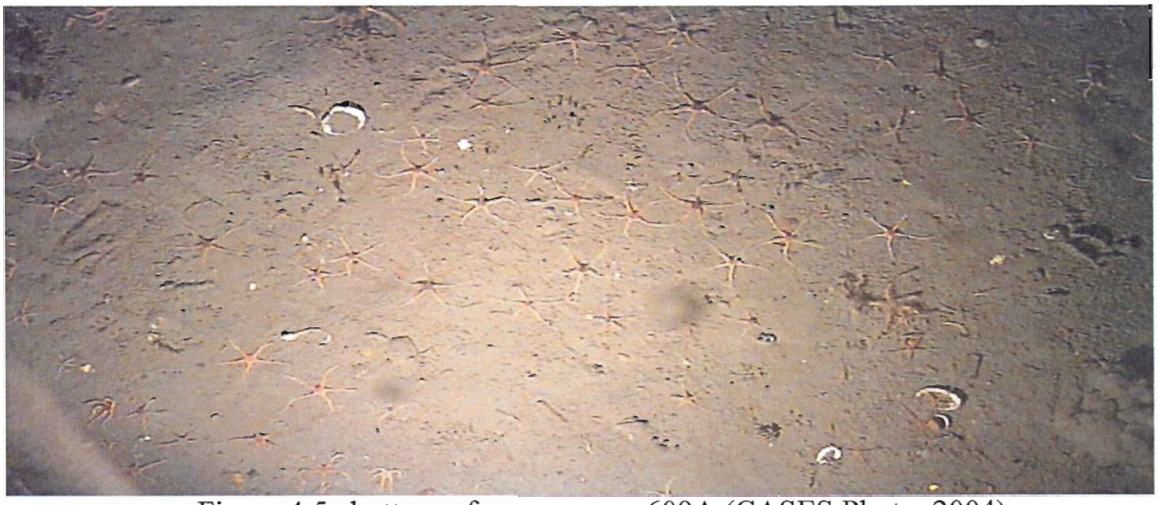


Figure 4.5a bottom of an area near 609A (CASES Photo, 2004)

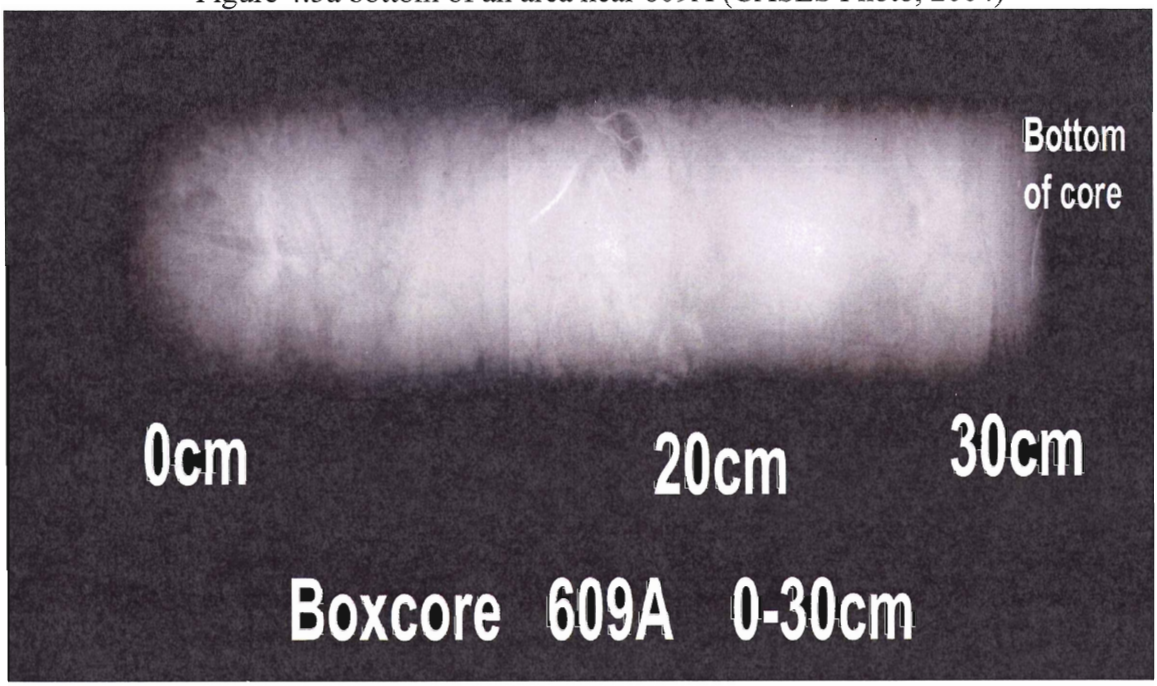


Figure 4.6, X-Ray 609A 0-30cm (Photo, C Younger)

4.4 Mineral found with Foraminifera

During the course of looking at the foraminifera in 805A an unusual mineral showed up that required identification. This mineral was in the shape of a spheroid and blue green in color. It was taken to the Dalhousie University Electron MicroProbe unit, where it was found to be a FeSiP type mineral (analyses shown in figure 4.7).

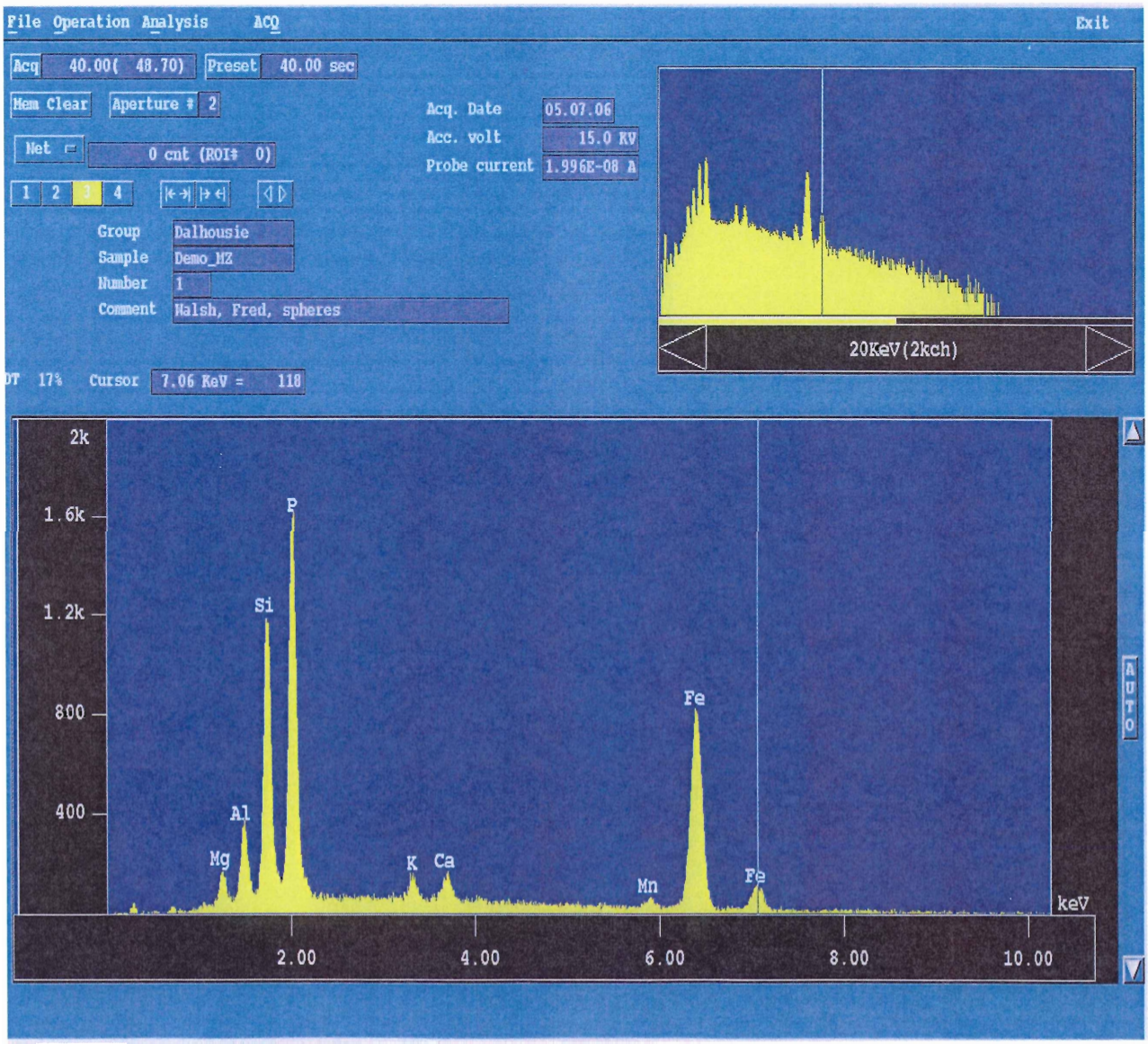


Figure 4.7 microprobe analyses (Stoffyn. P., 2005)

Figure 4.8 shows a photo taken by the microprobe. The colored circle was added to show the color of the mineral itself. The centre portion is white and shows the chambers of the foraminifera.

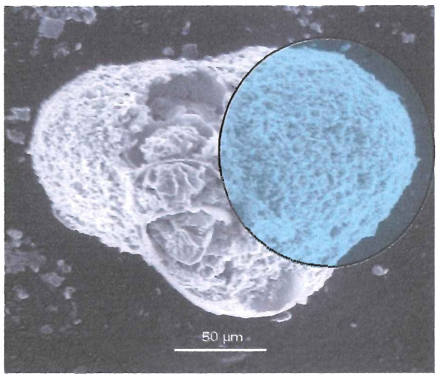


Figure 4.8, microprobe photo of foraminifera encrusted with mineral (Stoffyn. P., 2005).

4.5 Foraminifera Distribution

4.5.1 CORE 805A >63µ

Selected foraminifera of core 805A, the >63 micron fraction are shown in figure 4.9. The graph of the total number of species shows foraminifera distributed throughout the core; however as seen in the graph of the total number of individuals the numbers of foraminifera are very small, usually counts of 1. In general the foraminifera are only in the first few centimeters and at the 15-25 centimeter level. The graphs of the *Islandiella teretis, Cassidulina reniforme,* and the *Haynesina orbiculare* also show that in general; that there are two barren zones. The graph of the *Spiroplectammina biformis* shows them only near the surface and at the 16-26 centimeter levels. The graph presenting the *Ammotium cassis,* show that they are the last one to disappear at the 14-17 centimeter level. The graph of the *Elphidiella hannai* shows that it is only at the 17-25 centimeter level. In general, the graphs show that the main areas of the core the foraminifera occupy are at the surface and at the 15-25 centimeter levels.

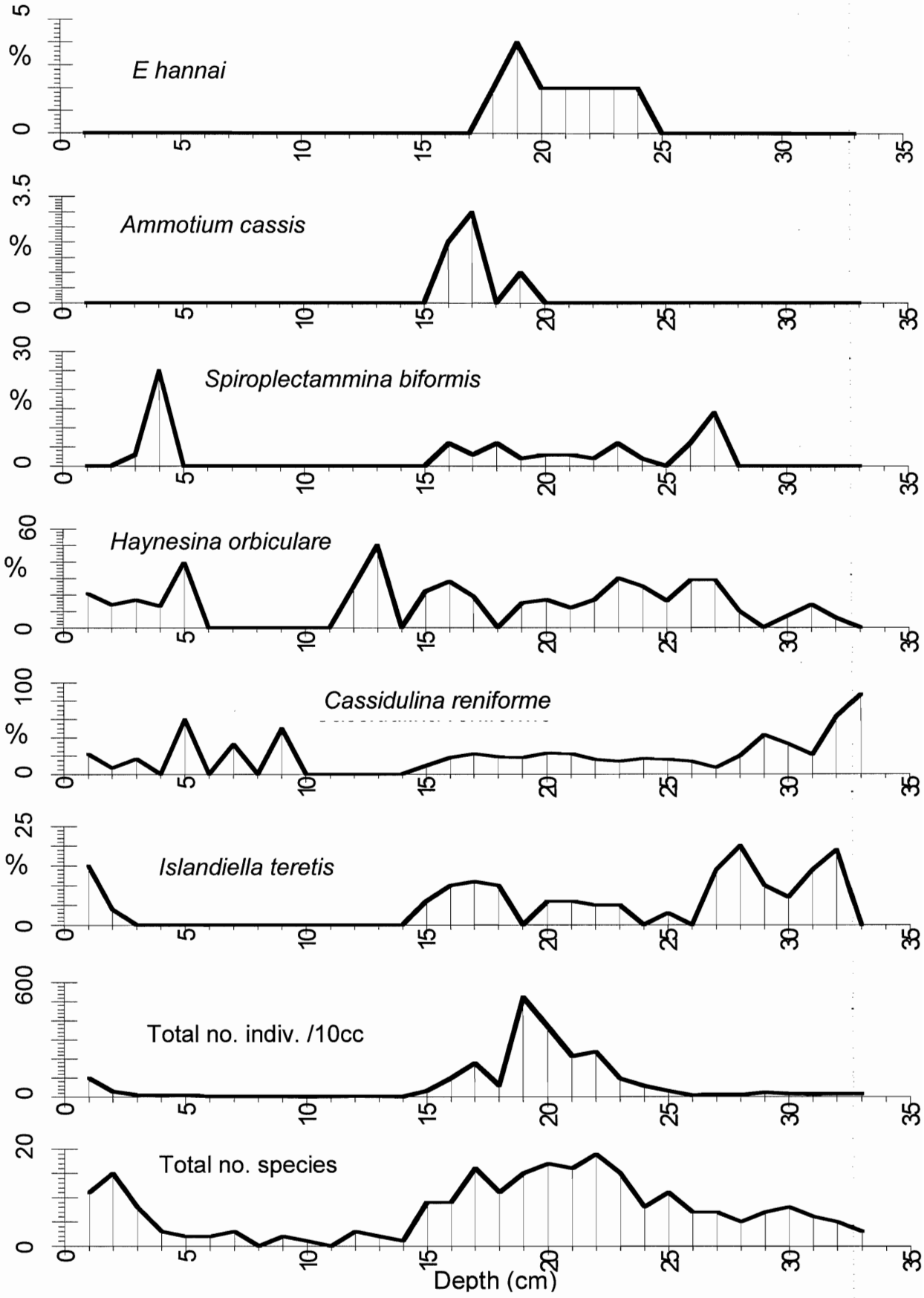


Figure 4.9 Graphs- 805A >63

4.5.2 CORE 805A 45<<63μ

Selected foraminifera of core 805A the 45<63 micron fraction are shown in figure 4.10. The graph of the Total number of species and the total number of individuals shows the foraminifera as only being in the first 2cm and between the 20-24cm levels. The graph of the *Islandiella teretis* shows them as only in the first 2cm, while the graph of the *Reophax scottii* shows them as in the first 2cm, and at the 20-23 centimeter levels. The graph of the *Buliminella hensoni* shows that they are at the surface, the 11 centimeter, and the 24 centimeter levels. The graphs of the *Cassidulina reniforme* and the *Textularia earlandi* show they are only at the 21 centimeter level. The graph showing the Tintinnids are only in the first 2cm, and at the 21 centimeter level. In general these graphs show that almost all of the foraminifera are in the first 2cm and the 20-24 centimeter level.

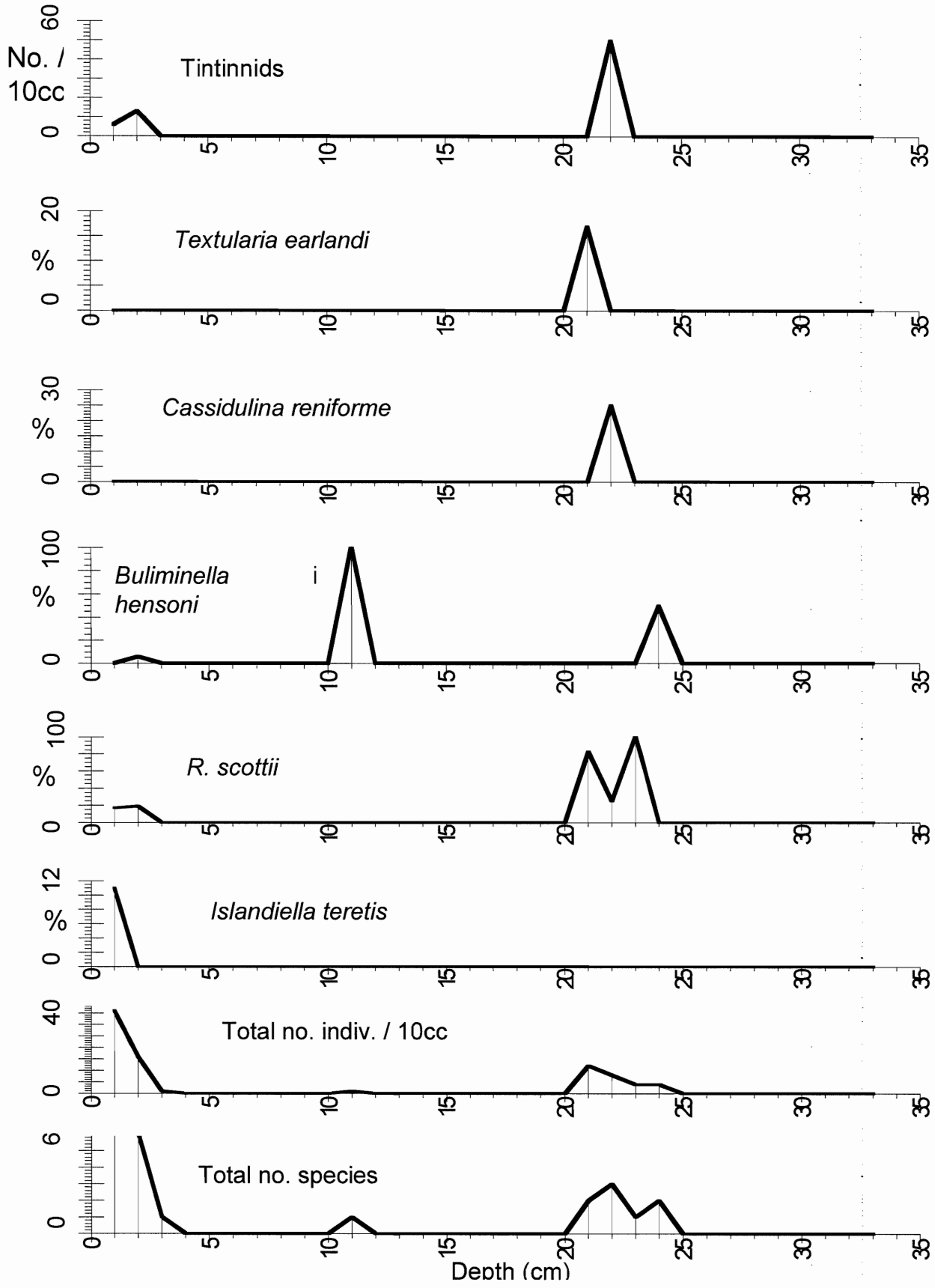


Figure 4.10 Graphs-805A 45<<63

4.5.3 CORE 805C >63μ

Selected foraminifera of core 805C the >63 micron fraction are shown in figure 4.11. The graph of the total number species and the graph of the total number of individuals show the number of foraminifera has increased significantly compared to 805A, and that the numbers of foraminifera are fairly steady throughout the whole core. The *Islandiella teretis* in the next graph shows them higher on the surface and generally going down towards the centre and increasing near the bottom. The graph of the *Spiroplectammina biformis* shows that there are greater numbers on the surface, decreasing slightly in the centre of the core and then increasing in numbers again towards the bottom. The *Ammotium cassis* graph shows that they appear in small amounts at the 28-22cm levels, and increase from the 8 centimeter level to the surface. The graph of the *Cassidulina reniforme* shows them increasing in numbers at the 3 centimeter level and staying fairly sterdy throughout the core. The graph of the *Haynesina orbiculare* shows them as steady throughout the core and then phasing out at the 4 centimeter level. The *Buliminella hensoni* graph shows more towards the bottom then staying steady until the 11 centimeter level and showing nothing from there to the surface. The graphs in general show that the abundance of the foraminifera are steady throughout the core with the exception of the *Ammotium casis* that seem to come in briefly three quarters down in the core and then increases in numbers nearing the surface. There seemed to be no *Elphidiella hannai* to be found in this core.

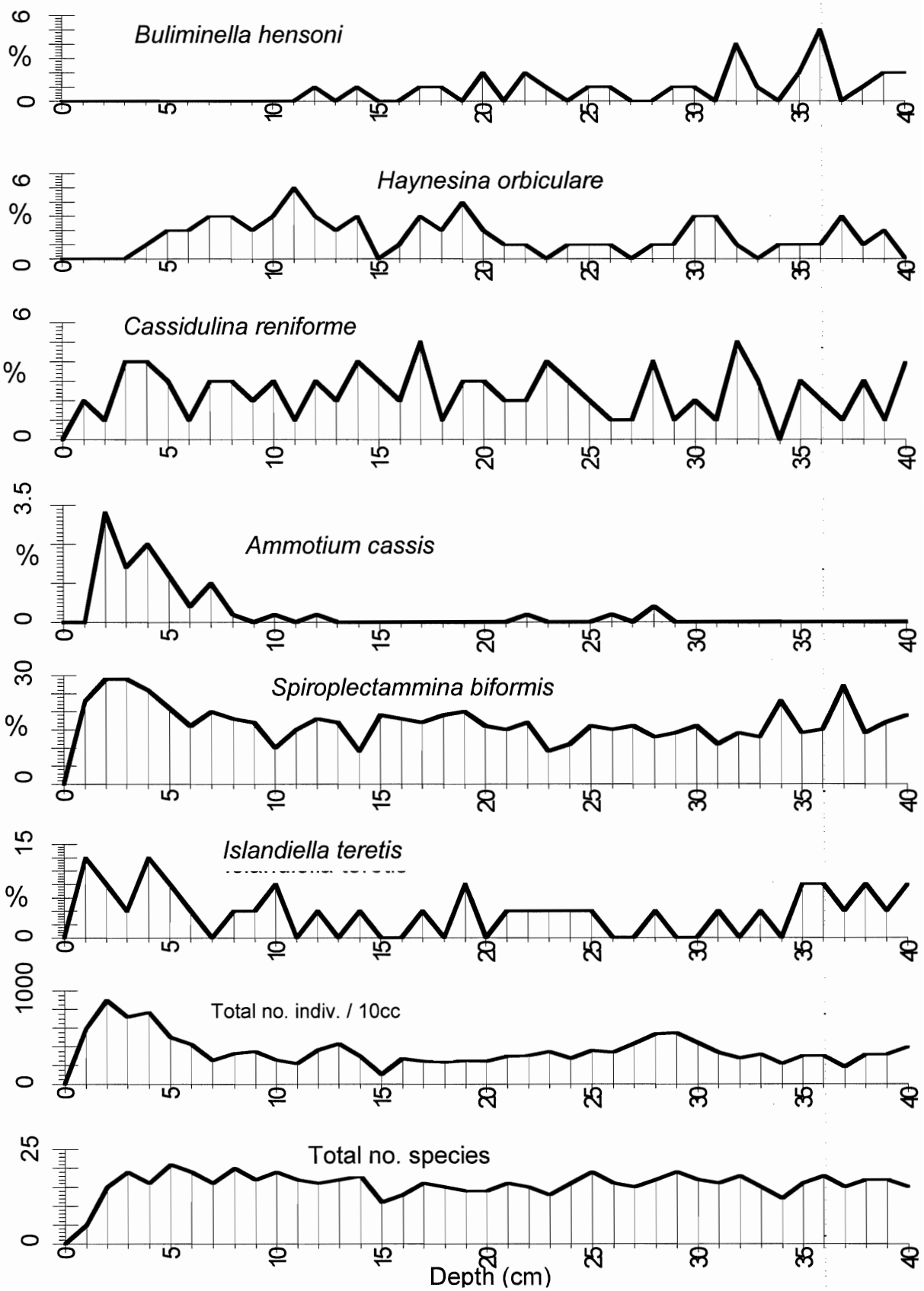


Figure 4.11 Graphs-805C >63

4.5.4 CORE 805C 45<<63μ

Selected foraminifera from core 805C the 45<<63μ fraction are shown in (figure 4.12). The graph of the total number of species, shows them increasing from the 1-2 centimeter levels and from then on remaining fairly constant throughout the core. The total number of individuals shows that the foraminifera increase in numbers at the 2 centimeter level and then dropping in numbers at the 7 cm level, staying fairly steady throughout the whole core. The *Spiroplectammina biformis* graph shows them from the 8 cm level to the surface only. The percentage of the *Reophax scottii* increases from the surface, then drops a little and stays fairly steady throughout the whole core. The *Cassidulina reniforme* stays fairly steady throughout the core. The graph shows the *Buliminella hensoni* stays fairly steady for the whole core. The graph of the *Islandiella teretis* has them phasing out towards the surface. The graph of the Tintinnids shows the same sort of steadiness as that of the total number of individuals, with greater numbers at the surface, then after losing some numbers; they stay fairly steady throughout the rest of the core.

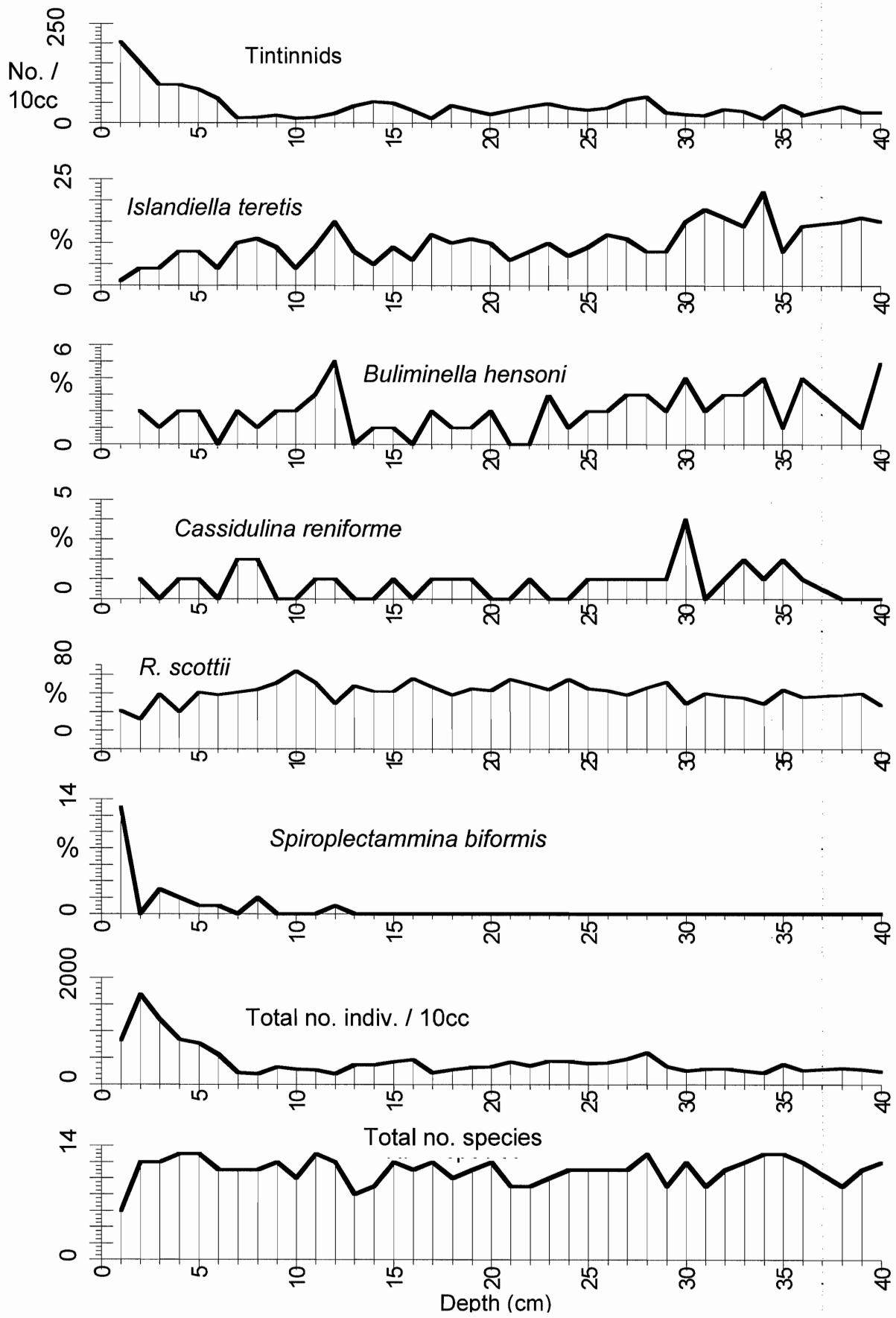


Figure 4.12 Graphs-805C 45<<63

4.5.5 CORE 609A >63μ

Selected foraminifera of core 609A, the >63 micron fraction are shown in figure 4.13. The graphs of the total number of species and the total number of individuals, show that both the species and the foraminifera stay fairly constant throughout the core, with a spike in numbers at the 10 centimeter level. The graph of the *Spiroplectammina biformis* shows them constant throughout most of the core and then increasing in percentage towards the surface. The graph of the *Ammotium cassis* shows an unusual trend different from most of the species. As shown in the graph the *Ammotium cassis* only comes in at the 14cm level and increases in percentage towards the surface. The graph of the *Elphidium exc.* f. ex*cavatum* shows them as coming in slowly for the first 7 centimeters, staying fairly steady throughout most of the core and then fading out towards the end. The graphs of the *Islandiella teretis* and the *Cassidulina reniforme* are somewhat similar in that they have higher percentages and the bottom of the core, then, in general, decreasing percentages towards the surface, going down to nothing at the 1 centimeter level. The graph of the *Elphidiella hannai* shows that they were only found at the 25 centimeter level, towards the end of the core.

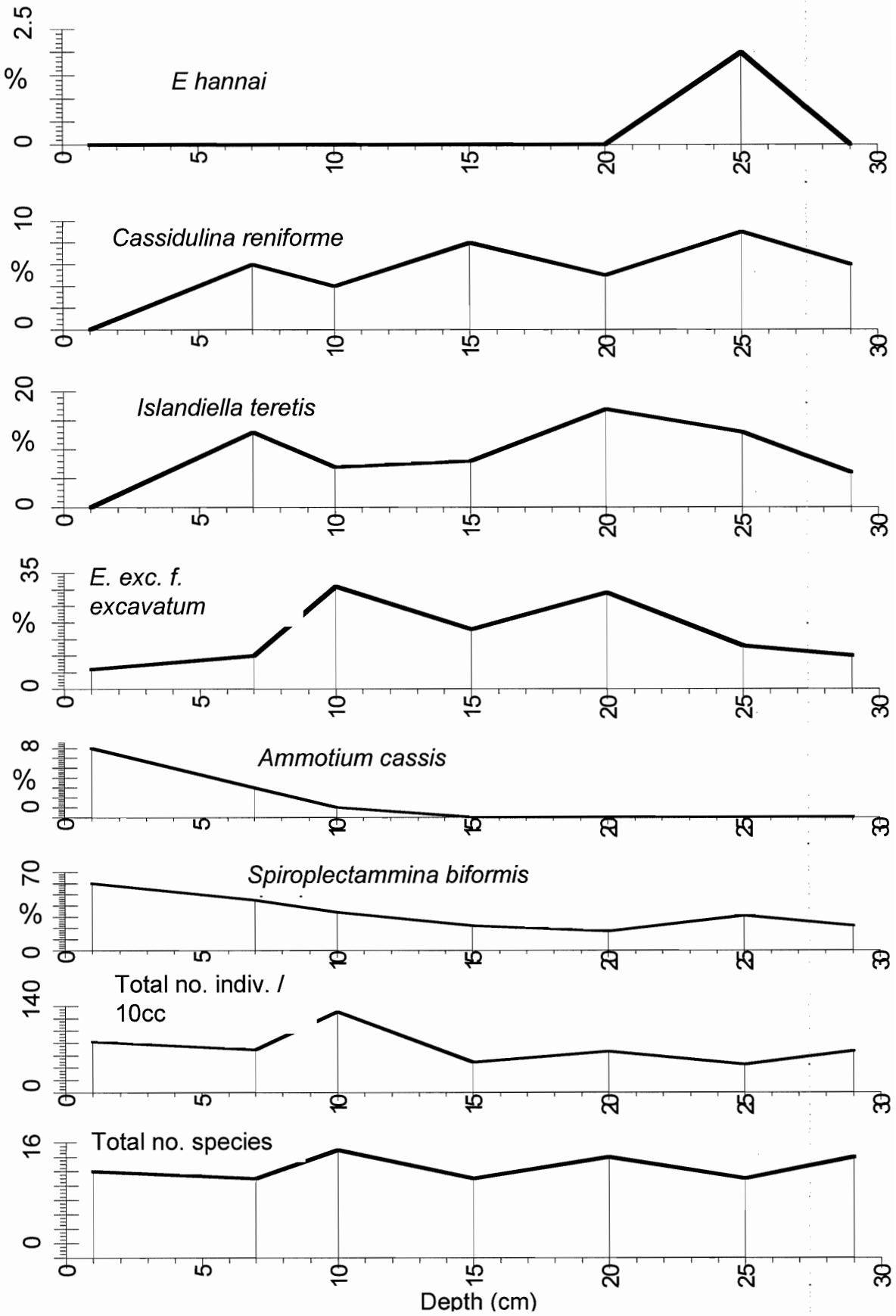


Figure 4.13 Graphs-609-A >63

4.5.6 CORE 609A 45<<63μ

Selected foraminifera at these final set of graphs of the core 609A the 45<<63 micron fraction are shown in figure 4.14. The graph of the total number of species shows the number of species staying fairly steady, with a spike in species at the 15 centimeter level. The graph of the total number of individuals shows that the numbers are fairly steady throughout the core, with increasing numbers towards the surface. The *Spiroplectammina biformis* graph shows them only around the 7 centimeter level. The graph of the *Textularia earlandi* shows that they come in at the 7 centimeter level and then phase out and in, throughout the core, showing up in greater percentage at the surface. The *Buliminella hensoni* graph shows them as coming in at the 11 centimeter level, decreasing to the 21 centimeter level, increasing and staying steady to the end of the core. The graph of the *Reophax scottii* shows them fairly steady with two spikes at the 11 and 21 centimeter levels. The graph of the *Cassidulina reniforme* shows them only at the 16 centimeter level. The graph of the Tintinnids starts off with a higher number at the surface and then decreases and remains steady for the rest of the core, increasing slightly towards the end.

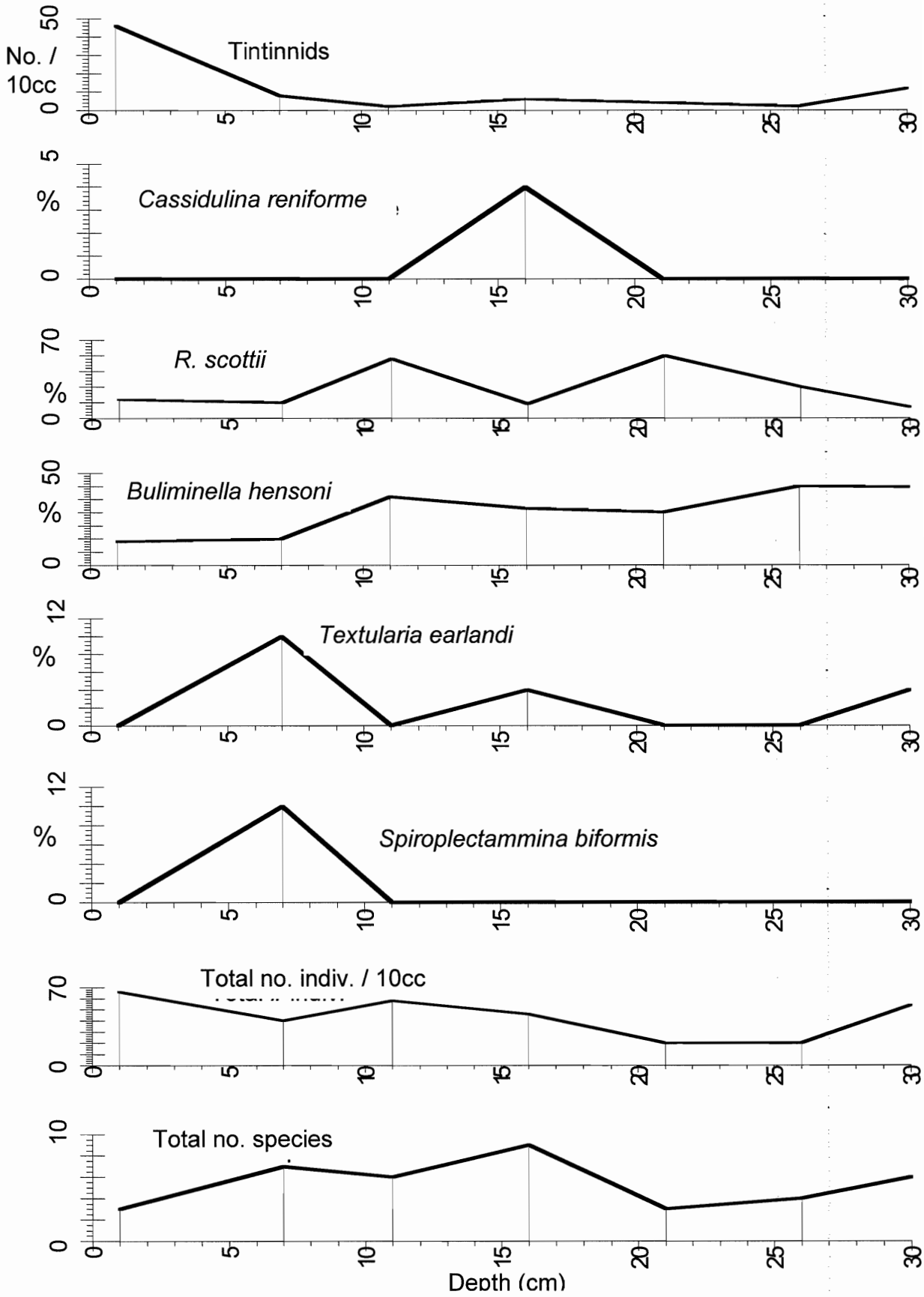


Figure 4.14 Graphs-609A 45<<63

Chapter 5
Discussion

The sediment around 805A, 805C, 609A is Holocene. The sedimentation rate in this area is not well known; however there have been some Cesium date testing on the 805A core (Smith, 2006.) The sediment that was tested had no Cesium present; this suggests that sediment on the Kopanoar mud volcano is very recently deposited but is actually older sediment coming up from within the mud volcano.

The *Ammotium cassis* in 805A, the >63 fraction (figure 4.9), was the last species present when the second barren zone started. (The *Ammotium cassis* is an estuarine species that is indicative of increased levels of suspended particulate matter (Scott et al., 1977). Estuarine areas have mud and silt and give off biogenic methane. The *Ammotium cassis* appears in greater numbers on the surface, which could be a good indictor of methane. The fact that there are two almost complete barren zones in this core, could mean this area had fast sedimentation, or an increase in methane release, or both of these things during two periods of time. On the Cruise MR02-K05 on board the RV *Mirai* Rochon et al. (2003), found that the water samples above the crest (in the 805A area) contained 20-30 nM of methane, which is 3-5 times the amount usually measured in sea water. The species that did survive, although only in numbers of one or two like the *Elphidium exc.* f. *excavatum,* are reported to live in extreme environments (Polyak et al. 2002). The fact that they are there, may show that the rate of sedimentation and methane made the environment too extreme for most foraminifera to survive. Heinz et al. (2005) reported that the *Spiroplectammina biformis* was the only species that was restricted to the seep environment. The *Spiroplectammina biformis* did well in the same two areas as

the *Ammotium cassis* in 805A, as well as showing up in higher percentages in the same depths of 805C and 609A as the higher percentages of the *Ammotium cassis*. There may in fact be a dual effect here possibly due to oxidation of biogenic methane, with belches of thermogenic methane during the sedimentation. For the first time *Elphidiella hannai* was found north of Vancouver (Scott, 1974, Scott, et al. 2005). The *Elphidiella hannai* have been considered an indicator of pollution (Jones and Ross, 1979). If this is so then it may be that the areas around 805A and 609A are becoming more polluted or the methane itself may be the natural pollutant that the *Elphidiella hannai* is attracted to. The tintinnids are also thought to like organic suspended particulate matter, which is another sign of pollution (Scott et al., 1995).

In 805A, in the 45<<63 fraction (figure 4.10), the tintinnids, *Reophax scottii* and the *Textularia earlandi* all have the same distributions as in the total number of individuals graph. The *Buliminella hensoni*, which until lately was thought to only be a Arctic deep water species, also appear in the same areas, with one appearing at the 11 centimeter level. This suggests that the deep arctic water is pentrating even to the shallow shelf area.

In 805C core, in the >63 micron fraction (figure 4.11), the total numbers show generally the same trend as the *Islandiella teretis*; this fraction is more abundant with higher percentages. The graphs in figure 4.11 show an increase of foraminifera at the surface which suggests better conditions. In 805C the *Ammotium cassis* and the *Spiroplectammina biformis* show up in increasing percentages towards the surface. This

is a good sign that there may be oxidation of biogenic methane, with traces of thermogenic methane.

In the 805C core, in the 45<<63 micron fraction (figure 4.12), the increase near the surface with *Spiroplectammina biformis* and the Tintinnids may suggest an increase in turbidly of the area. The *Buliminella hensoni* also appear in strong, steady numbers again suggesting that those deeper, colder waters continue to be present in the shallow water area.

The 609A core, in the >63 micron fraction (figure 4.13), the graph of the total number of individuals corresponds with the precentage for the *Elphidium exc.*f. *excavatum*, that are the foraminifera which are fairly constant throughout the core. In the 609A core, which is an area of slower, steadier sedimentation, the *Ammotium cassis* is only observed coming in at the 15 centimeter level with increasing percentage towards the surface. Again the *Spiroplectammina biformis* show up in greater numbers at the surface. This may suggest that there may be oxidation of biogenic methane, with traces of thermogenic methane, as the core is in a known pingo-like feature area that contains methane seeps.

In the 45<<63micron fraction of the 609A core (figure 4.14), the graphs show that the foraminifera are steady throughout the entire core. Again the *Buliminella hensoni* are present in good percentages showing that the colder deeper water is coming into the area.

These data may be showing that the *Ammotium cassis* have more tolerance for methane than other foraminifera, which could make it an indictor, in cores of paleo-methane release. If this is so, then there is a possibility that methane is being released more now than in the past. This possibility could contribute to the greenhouse effect.

Chapter 6: Conclusions

6.1 conclusions

The *Ammotium cassis* was the last to be present when the second barren zone started in 805A on the top of the mud volcano. If there was a larger than normal release of methane the *Ammotium cassis* persisted the longest. This indicates that they can stand higher amounts of methane as well as suspended particulate matter.In cores 805C and 609A the *Ammotium cassis* can be seen coming in strong on the surface. In all areas of this study there are known seepages of methane gas. The *Elphidiella hannai* have never been found this far north. They were thought to like the warmer waters; however they were found at the mud volcano and at the 25 centimeter level of 609A. Because they were found together with the *Ammotium cassis*, they may have similar tolerances. Tintinnids have been shown in other places to indicate both brackish water as well as high suspended particulates and it appears that is true on the Mackenzie Shelf. This is important since they live in the water column.

These data along with papers written by Rochon et al. (2003), Heinz et al. (2005) and Hovland et al., (1988) show that there is a good possibility that methane is being released, more now than in the past, and the *Ammotium cassis* may be a foraminifera that can successfully survive the effect of methane.

The *Buliminella hensoni* are abundant in the 45<<63 micron fraction of these cores. These foraminifera are a deep water species, so their presence suggests that the cold water gets onto the shelf as shown in the CTD charts, or conductivity, temperature and depth charts, (figures 1.5, 1.6).

6.2 Future Work

With regards to the sedimentation rate, dating the sediment using cesium as well as lead 210 dating should get some accurate dates for the sediment. This area should be looked at in the future for more testing, to see how much more methane seepage is occurring. More cores from around the areas talked about should be checked to look at the distribution of the *Ammotium cassis.*

TAXONOMY

Ammotium cassis (Parker)

Plate 1, figure 1

Lituola cassis Parker in Dawson, 1870, p. 177, 180, **Fig.** 3
Haplophragmium cassis (Parker). Brady, 1884, p. 304, pl.33
Ammobaculites cassis (Parker). Cushman, 1920, p. 63, pl. 12, **Fig.** 5
Ammotium cassis (Parker). Loeblich and Tappan, 1953, p. 33, pl. 2, figs 12-16; Scott et al, 1977, p. 1578, pl. 2, figs. 1,2; Miller et al., 1982a, p. 2362, pl. 1, **Fig.** 8. VILKS, 1989, Plate 21-II, Figure 4.

Buliminella hensoni Lagoe.

No photo

Buliminella elegantissima D'Orbigny var. *hensoni* Lagoe, 1977, p. 125, 126, figs. 6C, 6F, pl. 3, figs. 20-22;
Buliminella hensoni, Scott and Vilks, 1991, pl. 2, Fig. 7.

Cassidulina reniforme Nørvang

Plate 1, figures 2 and 3

Cassidulina crassa var. *reniforme* Nørvang, 1945, p. 41, text figs. 6c-h.
Cassidulina reniforme (Nørvang), Scott, 1987, p. 327, pl. 2, figs. 11,12. VILKS, 1989, Plate 21-VI, Figures 3 and 4.

Cyclogyra involvens (Reuss)

Plate 1, figure 4

Operculina involvens REUSS, 1850, p. 370, pl. 46, fig. 30.
Cornuspira involvens (Reuss). – BRADY, 1884, p. 200, pl. 11, fig. 1-3.
Cyclogyra involvens (Reuss). – Schroeder-adams and others, 1990, p. 24, pl. 6, fig. 1

Elphidium bartletti (Cushman)

Plate 1, figure 5.

Elphidium bartletti (Cushman), 1933, p. 4, pl. 1. **Fig.** 9; Schafer and Cole, 1978, p. 27, pl. 10, **Fig.** 4. *Crbrononion bartletti* (Cushman). Scott et al., 1980, p. 226, pl. 2, **Fig.** 7.
Crbrononion bartletti (Cushman), Vilks, 1989, Plate 21-V, Figures 6 and 7.

Elphidium exc.* f. *excavatum (Terquem)

Plate 1, figure 6

Polystomella excavata Terquem, 1876, p. 429, pl. 2, **Fig.** 2.
Elphidium excavatum (Terquem) formae Miller et al, 1982b, (all).
Elphidium excavatum forma *clavatum* (Cushman): VILKS, 1989, Plate 21-V, Figures 8 and 9, p. 557.

Elphidiella hannai (Cushman and Grant)
Plate 1, figures 7, 8 and 9
Elphidium hannai Cushman and Grant, 1927, v. no. 6, p. 77, pl. 8, fig. 1,2.
Elphidiella hanni (Cushman and Grant), Cushman 1939, Paper 191, p. 66, pl. 19, fig. 1,2.

Foraminifera **encrusted with mineral**
Plate 1 figure 10

Haynesina orbiculare (Brady)
Plate 1, figure. 11
Nonionina orbiculare Brady, 1881b, p. 415, pl. 21, **Fig.** 5.
Elphidium orbiculare (Brady). Hessland, 1943, p. 262; Gregory, 1970, p. 228, pl. 14, Figs. 5,6.
Protelphidium orbiculare (Brady). Todd and Low, 1961, p. 20, pl 2, **Fig.** 11; Scott et al., 1977, p. 1579, pl. 5, figs. 5,6; Schafer and Cole, 1978, p. 28, pl. 10, **Fig.** 5; Scott et al., 1980, p. 43, pl. 5, **Fig.** 7. *Haynesina orbiculare* (Brady): Vilks, 1989, Plate 21-V, Figures 12 and 13.

Islandiella teretis (Tappan)
Plate 1, figures 12 and 13
Cassidulina teretis Tappan, 1951, p. 7, pl. 1, figs. 30a-c
Islandiella helenae Feyling-Hanssen and Buzas: Vilks, 1989, Plate 21-IV, figure 3 and 4.
Islandiella norcrossi (Cushman): Vilks, 1989, Plate 21-IV, Figure 5 and 6.
Islandiella teretis (Tappan). Scott, 1987, p. 328, pl. 2, **Fig.** 13; Scott and Vilks, 1991, pl. 3, Fig. 1, 2; pl. 4, Figs. 1, 2.

Lagena spp.
Plate 1, figures 14 and 15

Planktonic
Plate 1, figures 16 and 17

Pseudopolymorphina novangliae (Cushman)
Plate 1, figures 18 and 19
Polymorphina lacteal (Walker and Jacob) var. *novangliae* Cushman, 1923, p. 146, pl. 39, figs. 6-8.
Pseudopolymorphina novangliae (Cushman). – Parker, 1952a, p. 410, pl. 5, fig. 1.,
Pseudopolymorphina novangliae (Cushman): Vilks, 1989, Plate 21-IV, Figures 1 and 2.

Quinqueloculina seminulum (Linne)

Plate 2, figure 13

Serpula seminulum Linne, 1758, p. 786, pl. 2, fig. 1.
Quinqueloculina seminulum (Linne).-Cushman, 1929, p. 24, pl. 2 figs. 1,2.-Schroeder and otrers, 1990, p. 35, pl. 4, fig. 2.

Recurvoides turbinatus (Brady)

Plate 2, figures 1 and 2

Haplophragmium turbinatum Brady, 1881c, p. 50.
Recurvoides turbinatus (Brady).-Parker, 1952a, p. 402, pl. 2, figs. 23, 24.; Vilks, 1989, Plate 21-II, figure 3

Reophax scottii Chaster

Plate 2, figures 3, 4 and 5

Reophax scottii Chaster, 1892, p. 57, pl. 1, **Fig.** 1; Miller et al., 1982a, p. 2362, pl. 1., **Fig.** 7.
Reophax gracilis (Kiaer), VILKS, 1989, Plate 21-1, Figure 10.

Spiroplectammina biformis (Parker and Jones)

Plate 2, figures 6 and 7

Textularia agglutinans D'Orbigny var. *biformis* Parker and Jones, 1865, p. 370, pl. 15, figs. 23, 24.
Spiroplectammina biformis (Parker and Jones). Cushman, 1927, p. 23, pl. 5, **Fig.** 1; Schafer and Cole, 1978, p. 19, pl. 3, **Fig.** 2; Scott et al., 1980, p. 231, pl. 2, **Fig.** 2.; VILKS, 1989, Plate 21-II, Figures 5 and 6.

Saccammina difflugiformis (Brady)

Plate 2, figure 8

Reophax difflugiformis Brady, 1879, p. 51, pl. 4, **Fig.** 3a, b.
Saccammina difflugiformis (Brady). Thomas et al, 1990, p. 234, pl. 2, figs. 10-12 ; Scott and Vilks, 1991, pl. 1, Figs. 8, 9.

TINTINNIDS

Plate 2, figure 9

Although in some cases Tintinnids may occur together with foraminifera and thecamoebians they are ciliate protozoans. Their exact taxonomic position is: Subphylum Ciliophora, class Ciliata, while thecamoebians and foraminifera belong to the Phylum sarcodaria, Superclass Rhizopoda.

Tintinnids are the only Ciliates with a long fossil record.

Textularia earlandi (Parker)

Plate 2, figure 10

Textularia earlandi Parker, 1952b, p. 458 (footnote); Vilks, 1989, Plate 21-II, Figure7.

Trochammina globigeriniformis (Parker and Jones).
Plate 1 figure 20

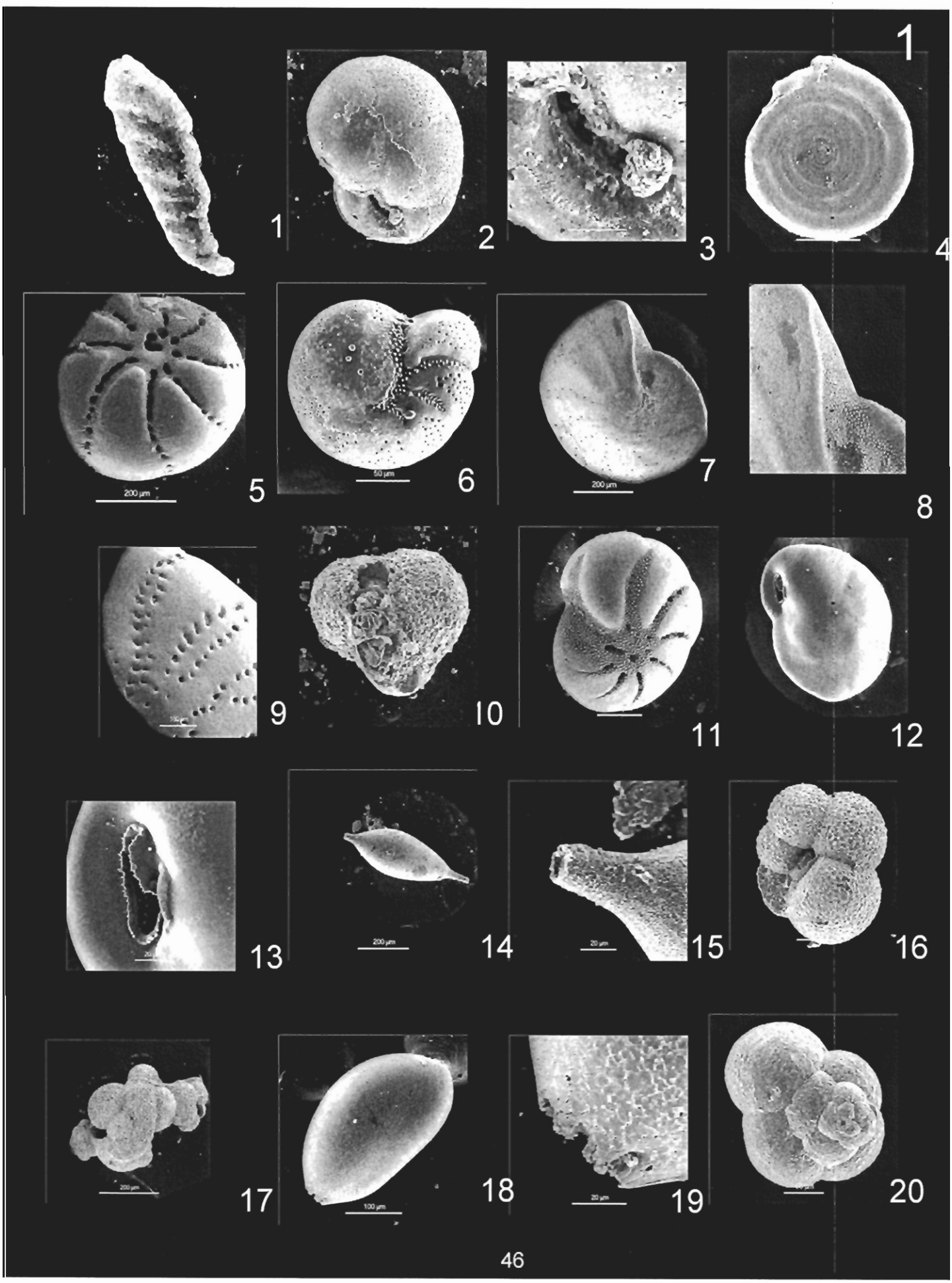
Lituola nautiloidea Lamarck var. globigeriniformis Parker and Jones, 1865, p. 407, pl. 17, fig. 96.
Trochammina globigeriniformis (Parker and Jones).-Cushman-, 1910, p. 124, text figs. 193-195.-Schroeder and others, 1990, p. 36, pl. 9, figs. 12-14.

Trochammina nana (Brady)
Plate 2, figures 11 and 12

Haplophragmium nana Brady, 1881b, p. 50.
Trochammina nana (Brady).—Loeblich and Tappan, 1953, p. 50, pl. 8, fig. 5a-c.; Vilks, 1989 Plate 21-III, figures 1 and 3.

PLATE- 1- some of the foraminifera found in the cores.

1/ scanning light microscope photo D. B. Scott, *Ammotium cassis*-400 µ.
All others were done on the Scanning Electron Microscope at BIO.
2/ *Cassidulina reniforme*- 50 µ **3/** Aperture of *Cassidulina reniforme*- 20µ **4/** *Cyclogyra involvens*-50µ **5/** *Elphidium bartletti*-200µ **6/** *Elphidium exc.* f. ex*cavatum*-50µ **7/** *Elphidiella hanni*-200µ **8/** *Elphidiella hanni*- aperture-20µ **9/** *Elphidiella hanni*- double row of pores-100µ **10/** *Foraminifera* encrusted with mineral-50µ **11/** *Haynesina orbiculare*-100µ **12/** *Islandiella teretis*-100µ **13/** *Islandiella teretis*- aperture-20µ **14/** *Lagena spp.*-200µ **15/** *Lagena spp.*- aperture-20µ **16/** *Planktonic*- normal-80µ **17/** *Planktonic*- deformed-200µ **18/** *Pseudopolymorphina novangliae*-100µ **19/** *Pseudopolymorphina novangliae*- aperture-20µ **20/** *Trochammina globigeriniformis*-60µ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20 µm
15
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200 µm
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100 µm
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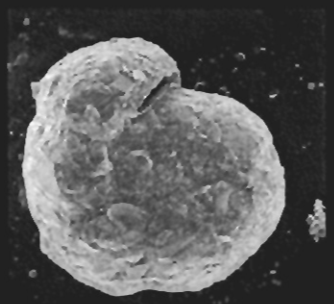
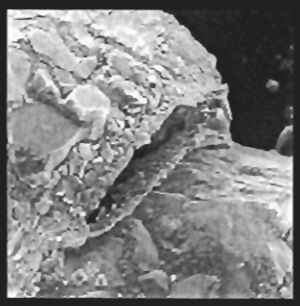
20 µm
19
20

PLATE 2- more foraminifera found in cores

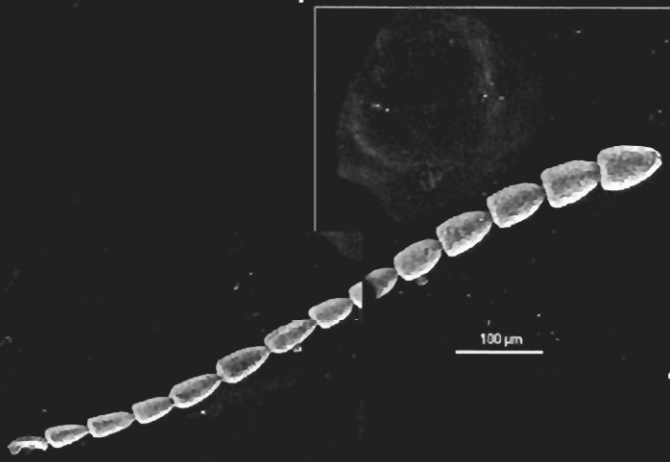
1/ *Recurvoides turbinatus*-50μ **2/** *Recurvoides turbinatus*-aperture-60μ **3and 4/** *Reophax scottii*-100μ **5/** *Reophax scottii*- aperture-20μ **6/** *Spiroplectammina biformis*-100μ **7/** *Spiroplectammina biformis*- aperture-60μ **8/** *Saccammina difflugiformis*-100μ **9/** TINTINNID-20μ **10/** *Textularia earlandi*-50μ **11/** *Trochammina nana*-50μ **12/** *Trochammina nana*- aperture-20μ **13/** *Quinqueloculina secinulum*-200μ



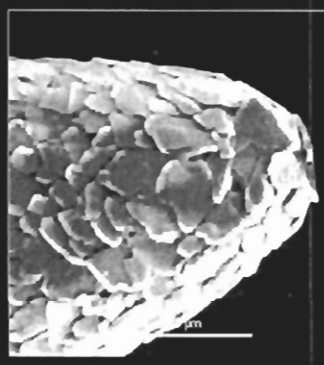
1



2



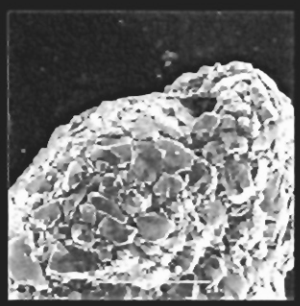
3



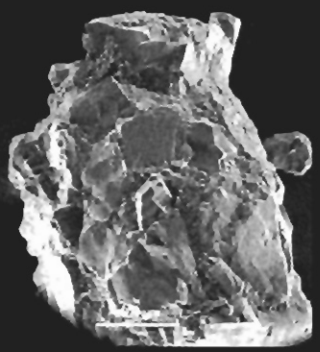
4

5

6

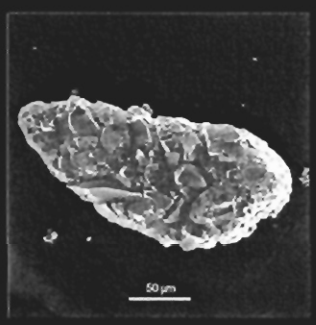


7



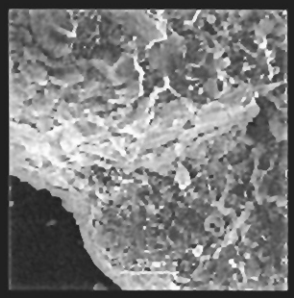
8

9



10

11



12

13

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APPENDIX A

1.1 Count numbers for foraminifer >63 and 45<<63 microns, 805A
Percent numbers for foraminifer >63 and 45<<63 microns, 805A

Numbers of foraminifera->63-805A																				
CASES2004 surface foraminiferal samples(>63microns)					**805A**															
Total #species	11	15	8	3	2	2	3		2	1		3	2	1	9	9	16	11	15	17
Total # indiv.	101	28	12	8	10	3	3		2	1		4	2	1	32	97	176	59	522	368
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ammotium cassis																2	6		3	
Buccella frigida		1																		
Cassidulina reniforme	22	2	2		6		1		1						3	17	39	11	96	86
Cyclogyra involvens																				
E. exc.f. excavatum	8	1	1			1	1			1		2			9	25	35	15	104	62
E. poeyanum																				
E. subarcticum	19	2	1	5														3	10	4
E. hannai																		1	20	7
Fursenkoina fusiformis	2	1	1			2	1					1	1		1		2		4	5
Haynesina orbiculare	21	4	2	1	4							1	1		7	27	33		76	63
Islandiella teretis	15	1													2	10	20	6		21
Lagena spp.	3															1	1	1		1
Pseudopolymorphina novangliae	6	1	1													5	7		14	15
Q. seminulum		2															4		18	1
Recurvoides turbinatus																		1		1
R. arctica	1														1		4			
R. scorpiurus																				
R. scottii																	5			
Saccammina difflugiformis		1																		
Spiroplectammina biformis		1	3												2	3	10	1	16	11
Textularia earlandi		2													1		3	2	8	8
Trochammina globigeriformis	1	1														2	1			
Valvulinaria arctica																		7	78	35
Planktonics		5		2																10
Tintinnids																	1			
Inner linings	1														1					
ostracods	2	3	1						1					1	5	7	9		36	35

Numbers of foraminifera->63-805A													
CASES2004 surface foraminiferal samples(>63microns)					**805A**								
Total #species	16	19	15	8	11	7	7	5	7	8	6	5	3
Total # indiv.	213	238	96	57	31	7	14	10	21	15	14	16	15
805A centrimetre	21	22	23	24	25	26	27	28	29	30	31	32	33
Ammotium cassis													
Buccella frigida													
Cassidulina reniforme	46	39	13	10	5	1	1	2	9	5	3	10	13
Cyclogyra involvens		1											
E. exc. F. excavatum	48	44	16	21	8	1	1		3	1	1	1	1
E. poeyanum													
E. subarcticum	5	4	4	1	1			1	2	1		1	
E. hannai	4	4	2	1									
Fursenkoina fusiformis	3	5	2		1		1		2				
Haynesina orbiculare	26	40	29	14	5	2	4	1		1	2	1	
Islandiella teretis	12	11	5		1		2	2	2	1	2	3	
Lagena spp.	2	1	2		1								
Pseudopolymorphina novangliae	7	5	2		1	1				1			
Q. seminulum	5	4											
Recurvoides turbinatus			1										
R. arctica													
R. scorpiurus			1										
R. scottii	2	1											
Saccammina difflugiformis													
Spiroplectammina biformis	4	13	2		2	1							
Textularia earlandi	1	8	5	2									
Trochammina globigeriformis													
Valvulinaria arctica	18	22	6	5	5		4		2	3	4	1	
Planktonics	6	10				1							
Tintinnids													
Inner linings													
ostracods	24	21	6	3			1	4	2	2	2		

Numbers of foraminifera->63-805A													
CASES2004 surface foraminiferal samples(>63microns)					**805A**								
Total #species	16	19	15	8	11	7	7	5	7	8	6	5	3
Total # indiv.	213	238	96	57	31	7	14	10	21	15	14	16	15
805A centrimetre	21	22	23	24	25	26	27	28	29	30	31	32	33
Ammotium cassis													
Buccella frigida													
Cassidulina reniforme	46	39	13	10	5	1	1	2	9	5	3	10	13
Cyclogyra involvens		1											
E. exc. F. excavatum	48	44	16	21	8	1	1		3	1	1	1	1
E. poeyanum													
E. subarcticum	5	4	4	1	1			1	2	1		1	
E. hannai	4	4	2	1									
Fursenkoina fusiformis	3	5	2		1		1		2				
Haynesina orbiculare	26	40	29	14	5	2	4	1		1	2	1	
Islandiella teretis	12	11	5		1		2	2	2	1	2	3	
Lagena spp.	2	1	2		1								
Pseudopolymorphina novangliae	7	5	2		1	1				1			
Q. seminulum	5	4											
Recurvoides turbinatus			1										
R. arctica													
R. scorpiurus			1										
R. scottii	2	1											
Saccammina difflugiformis													
Spiroplectammina biformis	4	13	2		2	1							
Textularia earlandi	1	8	5	2									
Trochammina globigeriformis													
Valvulinaria arctica	18	22	6	5	5		4		2	3	4	1	
Planktonics	6	10				1							
Tintinnids													
Inner linings													
ostracods	24	21	6	3			1	4	2	2	2		

Numbers of foraminifera 45<<63 805A																							
CASES2004-Forams 45<<63microns		**805A**																					
Total #species	6	6	1								1											2	3
Total #individuals/c	45	16	1								1											12	8
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Buliminella hensoni		1.0									1.0												
Cassidulina reniforme																							2.0
Dentalina ittai																							
Islandiella teretis	4.0																						
Pesudopolymaphing novansttae		2.0																					
R. scottii	6	3.0																				10.0	2.0
Textularia earlandi																						2.0	
Trochammina spp.		1	1.0																				
Valvulinaria arctica	3.0																						
Planktonics	21.0	7.0																					
Tintinnids	2	2																					4

Numbers of foraminifera 45<<63 805A											
CASES2004-Forams 45<<63microns			**805A**								
Total #species	1	2									
Total #individuals/c	4	4									
805A centimeter	23	24	25	26	27	28	29	30	31	32	33
Buliminella hensoni		2.0									
Cassidulina reniforme											
Dentalina ittai		2.0									
Islandiella teretis											
Pesudopolymaphing novansttae											
R. scottii	4.0										
Textularia earlandi											
Trochammina spp.											
Valvulinaria arctica											
Planktonics											
Tintinnids											

% Percentage->63microns 805A																			
CASES2004 surface foraminiferal samples(>63microns) 805A Percent %																			
Total #species 805A	11	15	8	3	2	2	3	0	2	1	0	3	2	1	9	9	16	11	15
Total # individuals/c 805A	101	28	12	8	10	3	3		2	1		4	2	1	32	97	176	59	522
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ammotium cassis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	1
Buccella frigida	0	4		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	22	7	17	0	60	0	33	0	50	0	0	0	0	0	9	18	22	19	18
Cyclogyra involvens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E. exc. f. excavatum	8	4	8	0	0	33	33	0	0	100	0	50	0	0	28	26	20	25	20
E. poeyanum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E. subarcticum	19	7	8	63	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2
E. hannai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
Fursenkoina fusiformis	2	4	8	0	0	67	33	0	0	0	0	25	50	0	3	0	1	0	1
Haynesina orbiculare	21	14	17	13	40	0	0	0	0	0	0	25	50	0	22	28	19	0	15
Islandiella teretis	15	4	0	0	0	0	0	0	0	0	0	0	0	0	6	10	11	10	0
Lagena spp.	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0
Pseudopolymorphina novangliae	6	4	8	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	3
Q. seminulum	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3
Recurvoides turbinatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
R. arctica	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0
R. scorpiurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. scottii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Saccammina difflugiformis	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroplectammina biformis	0	4	25	0	0	0	0	0	0	0	0	0	0	0	6	3	6	2	3
Textularia earlandi	0	7	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	3	2
Trochammina globigeriformis	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
Valvulinaria arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	15
Planktonics	0	18	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tintinnids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Inner linings	1	0	0	0	0	0	0	0	0	0	0	0	0		3	0	0	0	0
ostracods	2	11	8	0	0	0	0	0	50	0	0	0	0	100	16	7	5	0	7

% Percentage->63microns 805A														
CASES2004 surface foraminiferal samples(>63microns) 805A Percent %														
Total #species 805A	17	16	19	15	8	11	7	7	5	7	8	6	5	3
Total # individuals/c 805A	368	213	238	96	57	31	7	14	10	21	15	14	16	15
Depth cm	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Ammotium cassis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buccella frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassidulina reniforme	23	22	16	14	17	16	14	7	20	43	33	21	63	87
Cyclogyra involvens		0	0	0	0	0	0	0	0	0	0	0	0	
E. exc. F. excavatum	17	23	18	17	37	26	14	7	0	14	7	7	6	7
E. poeyanum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E. subarcticum	1	2	2	4	2	3	0	0	10	10	7	0	6	0
E. hannai	2	2	2	2	2	0	0	0	0	0	0	0	0	0
Fursenkoina fusiformis	1	1	2	2	0	3	0	7	0	10	0	0	0	0
Haynesina orbiculare	17	12	17	30	25	16	29	29	10	0	7	14	6	0
Islandiella teretis	6	6	5	5	0	3	0	14	20	10	7	14	19	0
Lagena spp.	0	1	0	2	0	3	0	0	0	0	0	0	0	0
Pseudopolymorphina novangliae	4	3	2	2	0	3	14	0	0	0	7	0	0	0
Q. seminulum	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Recurvoides turbinatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0
R. arctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. scorpiurus	0	0	0	1	0	0	0	0	0	0	0	0	0	0
R. scottii	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Saccammina difflugiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiroplectammina biformis	3	2	5	2	0	6	14	0	0	0	0	0	0	0
Textularia earlandi	2	0	3	5	4	0	0	0	0	0	0	0	0	0
Trochammina globigeriformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvulinaria arctica	10	8	9	6	9	16	0	29	0	10	20	29	6	0
Planktonics	3	3	4	0	0	0	14	0	0	0	0	0	0	0
Tintinnids	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inner linings	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ostracods	10	11	9	6	5	0	0	7	40	10	13	14	0	0

Numbers of foraminifera >63-805C																									
CASES2004 surface foraminiferal samples(>63microns) 805C																									
Total #species	5	15	19	16	21	19	16	20	17	19	17	17	18	11	13	16	15	14	14	16	15	13	16	19	16
Total # individuals/c	590	896	718	770	501	424	252	325	347	259	218	432	294	103	268	244	234	246	245	293	300	344	271	356	338
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Ammotium cassis		126	52	74	29	10	12	3	1	2	1				1			1			4		1	1	2
Bolivina sp		6	46	52	36	29	19	21	31	26	23	62	21	17	44	21	30	41	33	36	56	48	20	52	29
Buliminella hensoni						2		1		1	1	1	2			2	2		5		5	2		3	3
Cassidulina reniforme	12	12	26	28	16	6	8	11	8	7	2	10	11	3	5	11	3	7	7	7	6	13	9	6	3
Cycloqyra involvens	4	3	6	4	8	1	2	5	1	4		2	2			1	2		2	1			1	1	1
Elphidium exc. f. clavata																									
E. exc. f. excavatum	15	21	24	22	34	14	9	9	7	12	7	24	14		3	4	1	3	9	11	1	8	9	10	10
Fissurina spp	6							3	14	17	19	19	3	1											
Fursenkoina fusiformis		54	80	100	32	48	34	73	56	38	27	69	64	2	19	25	16	39	31	62	40	75	57	49	52
Haynesina orbiculare				4	11	10	7	9	8	8	10	7	9		2	7	4	9	5	3	4		4	5	4
Islandiella teretis	20	18	4	22	8	3	1	4	3	4		2	2			3		5		3	2	2	2	2	
Lagena spp.								1								1									
Pseudopolymorphina novangliae					2	4														2				2	
Q. seminulum					2	3					2			1							1			1	
Recurvoides turbinatus	42	51	26	14	12	3	4	3	2	4	1						2			1					
R. arctica	82	45	38	42	24	18	9	16	14	7	13	20	4	4	17	4	7	11	12	8	12	8	6	8	11
R. scottii	40	51	46	68	108	128	55	66	103	51	50	101	108	42	96	92	92	53	70	80	81	112	104	104	131
Saccammina difflugiformis	27		14	4	2	1	1	3		1		1	1			2			3	3			1	1	1
Spiroplectammina biformis	135	261	206	198	104	68	51	59	60	26	33	72	27	20	49	42	44	49	40	44	52	30	30	56	50
Textularia earlandi	83	135	70	76	41	18	21	15	18	24	15	20	15	7	17	10	24	21	16	14	16	16	4	16	19
T. macrescens	1																								
Planktonics	15																					1			
Tintinnids		90	24	20	3	2	3	4	4	6	5	12	3	1	6	8	3	4	8	10	14	24	11	26	10
Inner linings	18				1	1	2	3	2	1	1	1	2		6		1	1					2	3	3
ostracods		15	40	42	27	36	17	16	15	20	8	9	5	3	3	11	3	2	4	8	6	5	10	10	9
Gastropod																									

Numbers of foraminifera >63-805C														
CASES2004 surface foraminiferal samples(>63microns) 805C														
Total #species	15	17	19	17	16	18	15	12	16	18	15	17	17	15
Total # individuals/c	433	535	542	438	334	275	316	216	296	297	181	317	315	394
805C centrimetre	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ammotium cassis		9	1			1							1	
Bolivina sp	69	49	79	46	31	22	32	56	24	40	29	29	36	48
Buliminella hensoni	1	2	5	4		11	3		6	15		4	6	9
Cassidulina reniforme	4	22	8	8	2	14	8	1	10	6	2	9	4	14
Cyclogyra involvens			2	1							1			
Elphidium exc. f. clavata														
E. exc. f. excavatum	8	15	8	6	6	4	9		3	9		5	8	4
Fissurina spp					1	3	3							
Fursenkoina fusiformis	62	145	88	89	84	53	48	3	39	46	4	60	46	68
Haynesina orbiculare	2	7	8	12	11	3	1	3	2	2	6	2	5	
Islandiella teretis		4	2	2	2	1	3		5	5	1	5	3	6
Lagena spp.														
Pseudopolymorphina novangliae					1					2		2	1	
Q. seminulum														
Recurvoides turbinatus	4	2	2			1			1		1			
R. arctica	19	21	17	15	12	9	10	10	4	17	10	11	13	14
R. scottii	101	141	157	114	104	78	109	65	134	62	36	72	78	81
Saccammina diffluqiformis	1	1	2	3	1	1								1
Spiroplectammina biformis	69	72	76	69	37	38	40	49	42	44	48	44	55	76
Textularia earlandi	28	23	14	24	15	12	19	15	9	15	25	32	22	20
T. macrescens														
Planktonics										1				
Tintinnids	55	12	60	20	18	10	18	6	7	25	8	11	17	24
Inner linings	4	2	1	1	1	8	6		2	3	1	6	10	10
ostracods	6	8	8	13	8	6	7	3	4	3	3	6	3	6
Gastropod												1		

Numbers of foraminifera-45<<63 805C																							
CASES2004-Forams 45<<63microns 805C																							
Total #species	6	12	12	13	13	11	11	11	12	10	13	12	8	9	12	11	12	10	11	12	9	9	10
Total #individuals	824	1692	1218	840	766	556	215	195	327	284	268	198	366	362	417	464	216	277	320	335	422	350	433
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bolivina sp.		126	72	84	62	28	8	7	12	2	11	9	20	23	28	13	5	12	11	27	14	12	22
Buliminella hensoni		30	9	20	12		4	1	8	5	7	9		5	4	2	4	3	4	6	2	1	11
Cassidulina reniforme		12	6	10	6		4	3	1	1	2	2		1	3	1	2	3	4			3	
Cyclogyra involvens	2								2		1	1											1
Elphidium exc. f. excavatum		6	9	10	8	2			2	2	1				1								
Fissurina spp															2								
Fursenkoina fusiformis		84	60	40	36	28								17		12	12	13	12	17	10	6	18
Haynesin orbiculare																							
Islandiella teretis	8	66	48	66	62	22	22	21	28	11	24	29	29	18	36	29	26	29	36	33	27	28	45
Pseudopolymarphing novausliae																	3	1	1	1			
Quinqueloculina seminulum					2																		
Reophax arctica	36	96	51	46	22	18	7	6	4	1	3	4	9	3	8	5	1		4	5	3		4
R. scottii	338	900	720	338	466	322	132	124	231	239	189	98	249	223	258	353	145	161	207	212	318	246	277
Saccammina diffligiformis		6	21	16	4	2	3	3	2		6	1	1		1	3	3	2	1	2	2		3
Spiroplectammina biformis	104	6	39	14	8	6	1	4				2	1		2								
Textularia earlandi	132	210	87	86	82	58	16	10	17	10	7	17	14	8	24	12	3	9	7	5	14	11	3
Trochammina globigeriformis																							
Planktonics																				1			
Tintinnids	204	150	96	96		62	12	14	19	11	14	24	43	54	50	32	11	44	33	22	32	42	49
Inner linings											2												
ostracods				14	2	6	6	2	1	2	1	2				2	1			4		1	

Numbers of foraminifera-45<<63 805C																							
CASES2004-Forams 45<<63microns	**805C**																						
Total #species	6	12	12	13	13	11	11	11	12	10	13	12	8	9	12	11	12	10	11	12	9	9	10
Total #individuals	824	1692	1218	840	766	556	215	195	327	284	268	198	366	362	417	464	216	277	320	335	422	350	433
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bolivina sp.		126	72	84	62	28	8	7	12	2	11	9	20	23	28	13	5	12	11	27	14	12	22
Buliminella hensoni		30	9	20	12		4	1	8	5	7	9		5	4	2	4	3	4	6	2	1	11
Cassidulina reniforme		12	6	10	6		4	3	1	1	2	2		1	3	1	2	3	4			3	
Cyclogyra involvens	2								2		1	1											1
Elphidium exc. f. excavatum		6	9	10	8	2			2	2	1				1								
Fissurina spp															2								
Fursenkoina fusiformis		84	60	40	36	28								17		12	12	13	12	17	10	6	18
Haynesin orbiculare																							
Islandiella teretis	8	66	48	66	62	22	22	21	28	11	24	29	29	18	36	29	26	29	36	33	27	28	45
Pseudopolymarphing novausliae																	3	1	1	1			
Quinqueloculina seminulum					2																		
Reophax arctica	36	96	51	46	22	18	7	6	4	1	3	4	9	3	8	5	1		4	5	3		4
R. scottii	338	900	720	338	466	322	132	124	231	239	189	98	249	223	258	353	145	161	207	212	318	246	277
Saccammina diffligiformis		6	21	16	4	2	3	3	2		6	1	1		1	3	3	2	1	2	2		3
Spiroplectammina biformis	104	6	39	14	8	6	1	4				2	1		2								
Textularia earlandi	132	210	87	86	82	58	16	10	17	10	7	17	14	8	24	12	3	9	7	5	14	11	3
Trochammina globigeriformis																							
Planktonics																				1			
Tintinnids	204	150	96	96		62	12	14	19	11	14	24	43	54	50	32	11	44	33	22	32	42	49
Inner linings											2												
ostracods				14	2	6	6	2	1	2	1	2				2	1			4		1	

% percentage->63 805C																					
CASES2004 surface foraminiferal samples(>63microns)					805C	Percent %															
Total #species	5	15	19	16	21	19	16	20	17	19	17	16	17	18	11	13	16	15	14	14	
Total # individuals/c	590	896	718	770	501	424	252	325	347	259	218	364	432	294	103	268	244	234	246	245	
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Ammotium cassis	0	14	7	10	6	2	5	1	0	1	0	1	0	0	0	0	0	0	0	0	
Bolivina sp	0	1	6	7	7	7	8	6	9	10	11	12	14	7	17	16	9	13	17	13	
Buliminella hensoni	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	2	
Cassidulina reniforme	2	1	4	4	3	1	3	3	2	3	1	3	2	4	3	2	5	1	3	3	
Cyclogyra involvens	1	0	1	1	2	0	1	2	0	2	0	0	0	1	0	0	0	1	0	1	
Elphidium exc. f. clavata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
E. exc. f. excavatum	3	2	3	3	7	3	4	3	2	5	3	3	6	5	0	1	2	0	1	4	
Fissurina spp	1	0	0	0	0	0	0	1	4	7	9	5	4	1	1	0	0	0	0	0	
Fursenkoina fusiformis	0	6	11	13	6	11	13	22	16	15	12	16	16	22	2	7	10	7	16	13	
Haynesina orbiculare	0	0	0	1	2	2	3	3	2	3	5	3	2	3	0	1	3	2	4	2	
Islandiella teretis	3	2	1	3	2	1	0	1	1	2	0	1	0	1	0	0	1	0	2	0	
Lagena spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Pseudopolymorphina novangliae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Q. seminulum	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	
Recurvoides turbinatus	7	6	4	2	2	1	2	1	1	2	0	0	0	0	0	0	0	1	0	0	
R. arctica	14	5	5	5	5	4	4	5	4	3	6	4	5	1	4	6	2	3	4	5	
R. scottii	7	6	6	9	22	30	22	20	30	20	23	24	23	37	41	36	38	39	22	29	
Saccammina difflugiformis	5	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	
Spiroplectammina biformis	23	29	29	26	21	16	20	18	17	10	15	18	17	9	19	18	17	19	20	16	
Textularia earlandi	14	15	10	10	8	4	8	5	5	9	7	6	5	5	7	6	4	10	9	7	
T. macrescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Planktonics	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Tintinnids	0	10	3	3	1	0	1	1	1	2	2	2	3	1	1	2	3	1	2	3	
Inner linings	3	0	0	0	0	0	1	1	1	0	0	0	0	1	0	2	0	0	0	0	
ostracods	0	2	6	5	5	8	7	5	4	8	4	1	2	2	3	1	5	1	1	2	
Gastropod																					

% percentage->63 805C																					
CASES2004 surface foraminiferal samples(>63micr					805(	Precent %															
Total #species	16	15	13	16	19	16	15	17	19	17	16	18	15	12	16	18	15	17	17	15	
Total # individuals/c	293	300	344	271	356	338	433	535	542	438	334	275	316	216	296	297	181	317	315	394	
Depth (cm)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
Ammotium cassis	0	1	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
Bolivina sp	12	19	14	7	15	9	16	9	15	11	9	8	10	26	8	13	16	9	11	12	
Buliminella hensoni	0	2	1	0	1	1	0	0	1	1	0	4	1	0	2	5	0	1	2	2	
Cassidulina reniforme	2	2	4	3	2	1	1	4	1	2	1	5	3	0	3	2	1	3	1	4	
Cyclogyra involvens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Elphidium exc. f. clavata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
E. exc. f. excavatum	4	0	2	3	3	3	2	3	1	1	2	1	3	0	1	3	0	2	3	1	
Fissurina spp	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	
Fursenkoina fusiformis	21	13	22	21	14	15	14	27	16	20	25	19	15	1	13	15	2	19	15	17	
Haynesina orbiculare	1	1	0	1	1	1	0	1	1	3	3	1	0	1	1	1	3	1	2	0	
Islandiella teretis	1	1	1	1	1	0	0	1	0	0	1	0	1	0	2	2	1	2	1	2	
Lagena spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Pseudopolymorphina novangliae	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	
Q. seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Recurvoides turbinatus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	
R. arctica	3	4	2	2	2	3	4	4	3	3	4	3	3	5	1	6	6	3	4	4	
R. scottii	27	27	33	38	29	39	23	26	29	26	31	28	34	30	45	21	20	23	25	21	
Saccammina difflugiformis	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Spiroplectammina biformis	15	17	9	11	16	15	16	13	14	16	11	14	13	23	14	15	27	14	17	19	
Textularia earlandi	5	5	5	1	4	6	6	4	3	5	4	4	6	7	3	5	14	10	7	5	
T. macrescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Planktonics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Tintinnids	3	5	7	4	7	3	13	2	11	5	5	4	6	3	2	8	4	3	5	6	
Inner linings	0	0	0	1	1	1	1	0	0	0	0	3	2	0	1	1	1	2	3	3	
ostracods	3	2	1	4	3	3	1	1	1	3	2	2	2	1	1	1	2	2	1	2	
Gastropod																		0			

% percent- 45<<63 805C																									
CASES2004-Forams 45<<63microns 805C Percent %																									
Total #species	6	12	12	13	13	11	11	11	12	10	13	12	8	9	12	11	12	10	11	12	9	9	10	11	11
Total #individuals	824	1692	1218	840	766	556	215	195	327	284	268	198	366	362	417	464	216	277	320	335	422	350	433	429	389
Depth (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Bolivina sp.		7	6	10	8	5	4	4	4	1	4	5	5	6	7	3	2	4	3	8	3	3	5	3	6
Buliminella hensoni		2	1	2	2	0	2	1	2	2	3	5	0	1	1	0	2	1	1	2	0	0	3	1	2
Cassidulina reniforme		1	0	1	1	0	2	2	0	0	1	1	0	0	1	0	1	1	1	0	0	1	0	0	1
Cyclogyra involvens	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Elphidium exc. f. excavatum	0	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fursenkoina fusiformis	0	5	5	5	5	5	0	0	0	0	0	0	0	5	0	3	6	5	4	5	2	2	4	3	6
Haynesin orbiculare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Islandiella teretis	1	4	4	8	8	4	10	11	9	4	9	15	8	5	9	6	12	10	11	10	6	8	10	7	9
Pseudopolymarphing novausliae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Quinqueloculina seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax arctica	4	6	4	5	3	3	3	3	1	0	1	2	2	1	2	1	0	0	1	1	1	0	1	0	2
R. scottii	41	32	59	40	61	58	61	64	71	84	71	49	68	62	62	76	67	58	65	63	75	70	64	75	65
Saccammina diffligiformis	0	0	2	2	1	0	1	2	1	0	2	1	0	0	0	1	1	1	0	1	0	0	1	0	0
Spiroplectammina biformis	13	0	3	2	1	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia earlandi	16	12	7	10	11	10	7	5	5	4	3	9	4	2	6	3	1	3	2	1	3	3	1	1	2
Trochammina globigeriformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planktonics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tintinnids	25	9	8	11	0	11	6	7	6	4	5	12	12	15	12	7	5	16	10	7	8	12	11	9	8
Inner linings	0		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ostracods	0		0	2	0	1	3	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0

			% percent- 45<<63 805C												
CASES2004-Forams 45<<63microns 805C Percent %															
Total #species	11	11	13	9	12	9	11	12	13	13	12	12	9	11	12
Total #individuals	408	476	598	345	253	291	301	258	215	381	263	263	302	281	233
depth(cm)	26	27	28	29	30	31	32	33	34	35	36	36	38	39	40
Bolivina sp.	7	6	4	4	4	2	4	5	6	4	5	5	3	3	5
Buliminella hensoni	2	3	3	2	4	2	3	3	4	1	4	4	2	1	5
Cassidulina reniforme	1	1	1	1	4	0	1	2	1	2	1	1	0	0	0
Cyclogyra involvens	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Elphidium exc.f. excavatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fursenkoina fusiformis	2	3	2	2	6	4	3	2	3	2	5	5	2	2	3
Haynesin orbiculare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Islandiella teretis	12	11	8	8	15	18	16	14	22	8	14	14	15	16	15
Pseudopolymarphing novausliae	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Quinqueloculina seminulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reophax arctica	1	1	2	0	2	1	0	0	1	0	1	1	0	1	1
R. scottii	63	58	66	72	49	60	57	55	49	64	56	56	58	60	47
Saccammina diffligiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Spiroplectammina biformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textularia earlandi	3	3	2	2	7	5	3	5	6	5	4	4	3	4	6
Trochammina globigeriformis	0	0	1	0	0	0	0	1	1	1	0	0	2	2	5
Planktonics	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
Tintinnids	9	12	11	8	9	7	12	12	5	12	9	9	14	10	11
Inner linings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ostracods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1.3 Count numbers for foraminifer >63 and 45<<63 microns, 609A
Percent numbers for foraminifer >63 and 45<<63 microns, 609A

Numbers of foraminifera->63- 609A							
CASES2004 surface foraminiferal samples >63microns 609A							
Total #species	12	11	15	11	14	11	14
Total # individuals	82	69	131	49	66	45	67
Depth (cm)	1	7	10	15	20	25	29
Ammotium cassis	6	2	1				
Bolivina sp.	2	3	6	5	1	1	9
Cassidulina reniforme		4	5	4	3	4	4
Elphidium exc. f. excavaum	5	7	40	9	19	6	7
E. subarcticum				1			1
Elphidium Groenlandicum	1						
E. hannai						1	
Fursenkoina fusiformis	5				4		1
Haynesina orbiculare		2	5	5	9	4	3
Islandiella teretis		9	9	4	11	6	4
Pseudopolymorphina novangliae			1		1		
Q. seminulum	1				1		
Recurvoides turbinatus	2		1				3
Reophax aduncus							
R. arctica	5	4	9	5	1	3	1
R. scottii			1	1			
Spiroplectammina biformis	49	31	45	11	11	14	15
Trochammina globigeriformis	3	5	3	1	1		9
Valvulinaria arctica					2		4
Planktonics						4	
Inner linings		2	1				2
brachiopods	2						
ostracods	1	2	2		1	1	4

% percentage- >63 609A							
CASES2004 surface foraminiferal samples(>63microns)							
Total #species	12	11	15	11	14	11	14
Total # individuals/c	82	69	131	49	66	45	67
Depth (cm)	1	7	10	15	20	25	29
Ammotium cassis	7	3	1	0	0	0	0
Bolivina sp.	2	4	5	10	2	2	13
Cassidulina reniforme	0	6	4	8	5	9	6
Elphidium exc. f. excavatum	6	10	31	18	29	13	10
E. subarcticum	0	0	0	2	0	0	1
Elphidium Groenlandicum	1	0	0	0	0	0	0
E. hannai	0	0	0	0	0	2	0
Fursenkoina fusiformis	6	0	0	0	6	0	1
Haynesina orbiculare	0	3	4	10	14	9	4
Islandiella teretis	0	13	7	8	17	13	6
Pseudopolymorphina novangliae	0	0	1	0	2	0	0
Q. seminulum	1	0	0	0	2	0	0
Recurvoides turbinatus	2	0	1	0	0	0	4
Reophax aduncus	0	0	0	0	0	0	0
R. arctica	6	6	7	10	2	7	1
R. scottii	0	0	1	2	0	0	0
Spiroplectammina biformis	60	45	34	22	17	31	22
Trochammina globigeriformis	4	7	2	2	2	0	13
Valvulinaria arctica	0	0	0	0	3	0	6
Planktonics	0	0	0	0	0	9	0
Inner linings	0	3	1	0	0	0	3
brachiopods	2	0	0	0	0	0	0
ostracods	1	3	2	0	2	2	6

CASES2004-Forams 45<<63microns 609A							
Total #species	3	7	6	9	3	4	6
Total #individuals	66	40	58	46	20	20	54
Depth (cm)	1	7	10	15	20	25	29
Bolivina hensoni	12	8	30	20	8	12	32
Cassidulina reniforme				2			
Centropyxis aculeata							
Eoeponides pulchella		4	2	4	4		2
Reophax arctica		8		4		2	2
R. scottii	8	4	22	4	8	4	4
Spiroplectammina biformis		4					
Textularia earlandi		4		2			2
Trochammina globigeriformis			2	2			
Planktonics							
Tintinnids	46	8	2	6		2	12
Inner linings				2			

CASES2004-Forams 45<<63microns 609A Pr	Precent %						
Total #species	3	7	6	9	3	4	6
Total #individuals	66	40	58	46	20	20	54
Depth (cm))	1	7	10	15	20	25	29
Bolivina hensoni	18	20	52	43	40	60	59
Cassidulina reniforme	0	0	0	4	0	0	0
Centropyxis aculeata	0	0	0	0	0	0	0
Eoeponides pulchella	0	10	3	9	20	0	4
Reophax arctica	0	20	0	9	0	10	4
R. scottii	12	10	38	9	40	20	7
Spiroplectammina biformis	0	10	0	0	0	0	0
Textularia earlandi	0	10	0	4	0	0	4
Trochammina globigeriformis	0	0	3	4	0	0	0
Planktonics	0	0	0	0	0	0	0
Tintinnids	70	20	3	13	0	10	22
Inner linings	0	0	0	4	0		

APPENDIX B

Sampling forms

SEDIMENT SAMPLING FORM — DALHOUSIE, CENTRE FOR MARINE GEOLOGY

PURPOSE: FORAM Studies

MATERIAL: 04-Amundsen) Core 805A (Mud Volcano.) (Box core)

VOL: FORAMS 10cc *DINOS 10 cc

BY: F. WALSH DATE: DEC02/04

PROCESSING: 63µ, 45-63µ washed, in alcohol (Dec. 29/04)

FOR: DR. OB SCOTT & Andre Rochon (desc.)

INTERVALS/STN: F

1. 0-1 cm	10		25-26		
2. 1-2			26-27		
3. 2-3			27-28		
4. 3-4			28-29		
5. 4-5			29-30		
6. 5-6			30-31		
7. 6-7			31-32		
8. 7-8			32-33		
9. 8-9			"	"	"
10. 9-10			"	"	"
11. 10-11					
12. 11-12		Stn 805A - Mud Volcano. (AGC #27)			
13. 12-13					
14. 13-14					
15. 14-15					
16. 15-16					
17. 16-17					
18. 17-18					
19. 18-19					
20. 19-20					
21. 20-21					
22. 21-22					
23. 22-23					
24. 23-24					
25. 24-25					

Remarks:

* ① 10cc. removed from core for A. Rochon's dino studies
② Water depth 3 Canethes.

Storage:

Figure B.1 sampling form 805A

SEDIMENT SAMPLING FORM — DALHOUSIE, CENTRE FOR MARINE GEOLOGY

PURPOSE: FORAM STUDIES — MATERIAL: 04-Amundsen "Mud Volcano" By core 805

VOL: FORAMS 10 cc *DINOS 10 cc — BY: F WALSH — DATE: JAN 11

PROCESSING: >63μ, >45<63μ. WASHED, IN ALCOHOL (01/11/05 AND — FOR: DR. D.B. SCOTT & ANDRE ROCHON (DINOS)

INTERVALS/STN:

1. 0-1 cm			25-26 cm		
2. 1-2			26-27		
3. 2-3			27-28		
4. 3-4			28-29		
5. 4-5			29-30		
6. 5-6			30-31		
7. 6-7			31-32		
8. 7-8			32-33		
9. 8-9			33-34		
10. 9-10			34-35		
11. 10-11			35-36		
12. 11-12			36-37		
13. 12-13			37-38		
14. 13-14			38-39		
15. 14-15			39-40		
16. 15-16					
17. 16-17			STN 805C - MUD VOLCANO.		
18. 17-18			AGC # 32A		
19. 18-19					
20. 19-20					
21. 20-21					
22. 21-22					
23. 22-23					
24. 23-24					
25. 24-25					

Remarks: * ① 10 cc REMOVED FROM CORE FOR A. ROCHON'S DINO STUDIES
② WATER DEPTH 66 METERS

Figure B.2 805C sampling form

GEOLOGICAL SURVEY of CANADA { ATLANTIC }

SEDIMENT SUBSAMPLE DATA

CRUISE NUMBER: 2004804	SAMPLE NUMBER: 609A (AGC 2A)	SECTION LENGTH: 31 cm
SAMPLE TYPE: PUSH CORE FROM BOX CORE	CALENDAR DATE: NOV 4 2005	SECTION NAME (ie. A/B): A/B
GEOGRAPHIC LOCATION: BEAUFORT SEA CONTINENTAL SHELF		PROJECT NUMBER: CASIS
SUBSAMPLED FOR: DAVE SCOTT		SUBSAMPLED BY: FRED/WALSH

INTERVALS (cm)										WEIGHTS (grams)	
FROM	TO	POLLEN	FORAMS	GRAIN SIZE	DIATOMS					BEFORE	AFTER
0	1		✓								
6	7		✓								
10	11		✓								
15	16		✓								
20	21		✓								
25	26		✓								
29	30		✓								

Figure B.3 609A sampling form

APPENDIX C- core descriptions

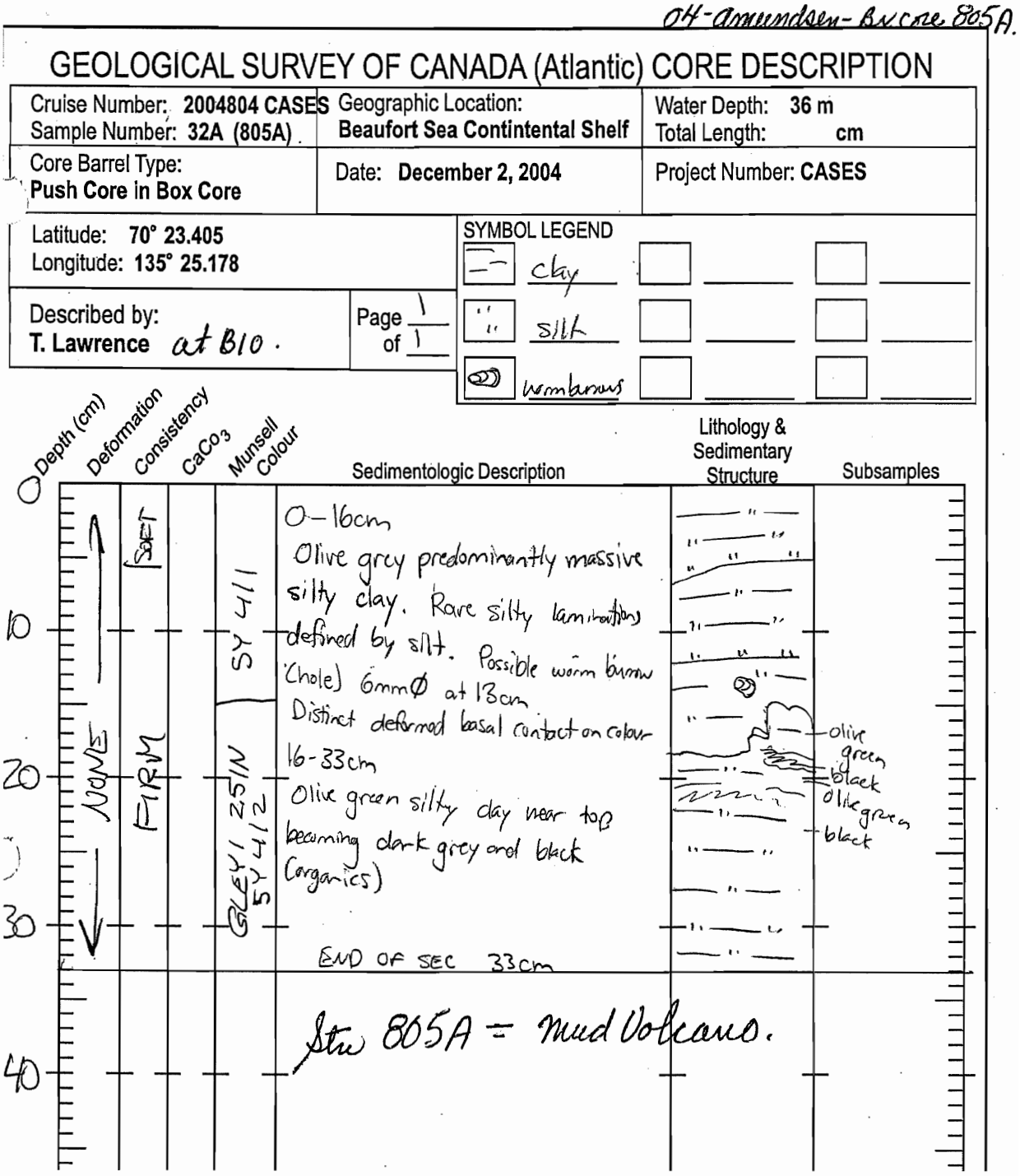

Figure C.1 805A core descriptions

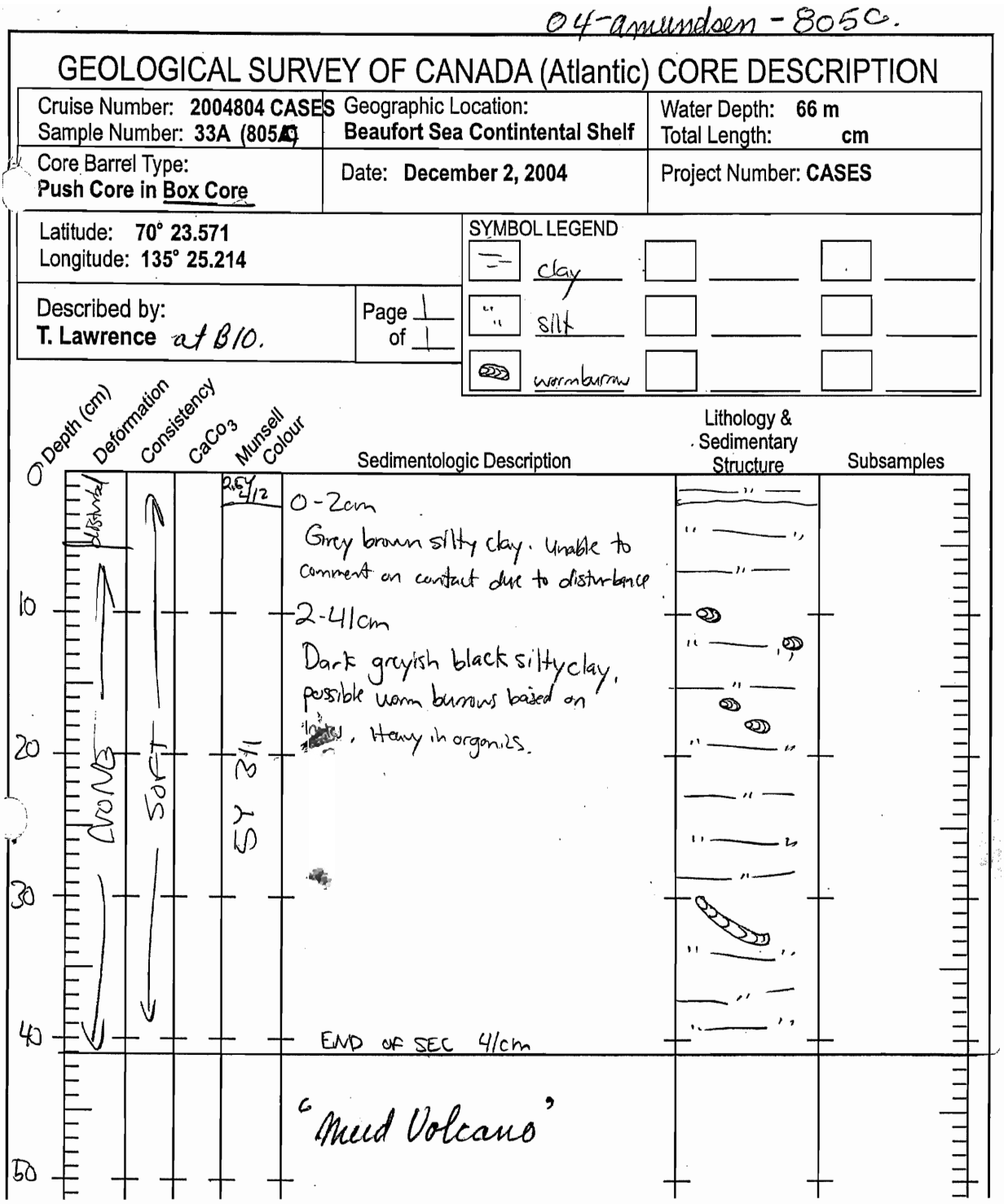

Figure C.2 805C core descriptions

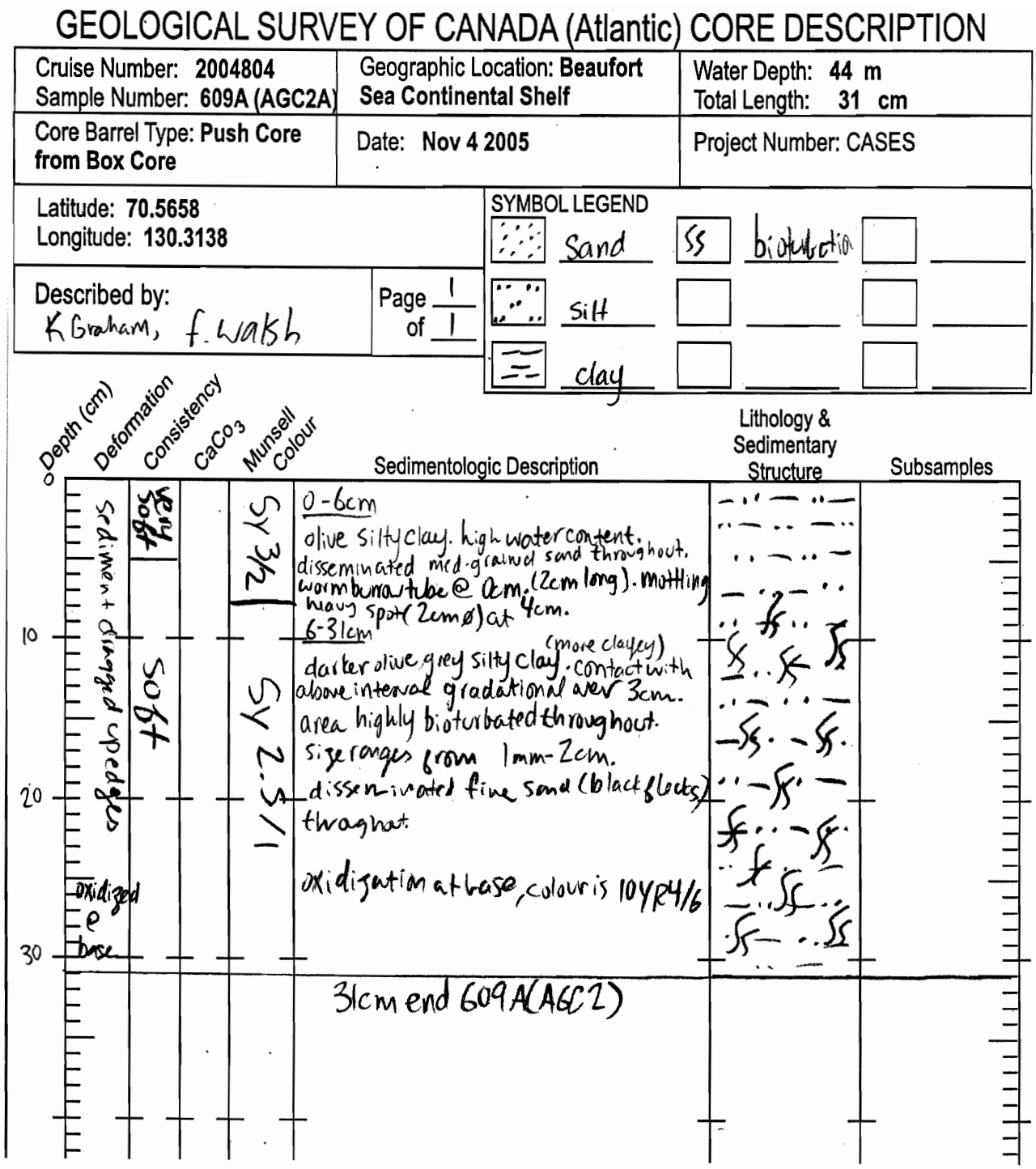

Figure C.3 609A core descriptions